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MERENJE I ANALIZA DINAMIKE PROFITABILNOSTI BANKARSKOG SEKTORA U SRBIJI NA BAZI FLMAW-MARCOS METODA

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Rezime: Istraživanje dinamike profitabilnosti bankarskog sektora je kontinuirano aktuelno, značajno i složeno. Imajući to u vidu, u ovom radu se vrši merenje i analiza dinamike profitabilnosti bankarskog sektora u Srbiji sa primenom FLMAW-MARCOS metoda. Dobijeni empirijski rezultati primenom date metodologije pokazuju da su pet najboljih godina ostvarene profitabilnosti u bankarskom sektoru u Srbiji u periodu 2008 – 2022. god. po redosledu: 2018, 2017, 2008, 2019. i 2022. god. U 2013. god. ostvarena je najlošija profitabilnost. U poslednje vreme poboljšala se profitabilnost bankarskog sektora u Srbiji. Na to su uticali ekonomska klima, upravljanje ljudskim resursima, aktivom, kapitalom, prodajom bankarskog proizvoda, troškovima i profitom. U tome značajnu ulogu ima i digitalizacija celokupnog poslovanja. Značajan je uticaj i pandemije korona virusa Covid-19, kao i svetske energetske krize. U cilju poboljšanja profitabilnosti bankarskog sektora u Srbiji neophodno je što efikasnije upravljati ljudskim resursima, aktivom, kapitalom, prodajom, troškovima i profitom i prilagođavati se promenama ekonomske klime.

Ključne reči: bankarski sektor, FLMAW-MARCOS metoda, profitabilnost, Srbija

JEL klasifikacija: D40, G21

Uvod

Problematika merenja i analize faktora dinamike profitabilnosti bankarskog sektora vrlo je aktuelna, značajna i složena. U ovom radu se, s obzirom na to, kao predmet istraživanja, analizira dinamika profitabilnosti bankarskog sektora u Srbiji na bazi FLMAW-MARCOS metoda. Cilj i svrha toga je da se što bolje sagleda dinamika profitabilnosti bankarskog sektora u Srbiji u cilju unapređenja u budućnosti primenom adekvatnih mera.

Literatura posvećena razvoju i značaju primene DEA modela vrlo je bogata (Andersen, 1993; Banker, 1984; Chen, 2021; Chang, 2020; Guo, 2020; Lee, 2011; Lin, 2020; Pendharkar, 2021; Tone, 2002; Podinovski, 2021; Rostamzadeh, 2021; Fenyves, 2020; Tsai, 2021). Oni se vrlo uspešno primenjuju i u analizi efikasnosti banaka i osiguravajućih kompanija (Savić, 2012; Maletić, 2013; Radojičić, 2018; Cvetkoska, 2017, 2020, 2021; Lukić, 2017; 2018a,b, 2021). Isto tako, prilikom analize finansijskih performansi (profitabilnost, likvidnost) i efikasnosti banaka sve više se primenjuju, integralno ili pojedinačno, i različiti metodi višekriterijumskog odlučivanja (Ünlü, 2022; Ali,2022, Lukić, 2022a,b; Demir, 2022). Sva relevantna literatura u ovom[1] radu se koristi kao teorijsko-metodološka i empirijska osnova za analizu dinamike profitabilnosti bankarskog sektora u Srbiji pomoću FLMAW-MARCOS metoda.

Poznato je da samo kontinuirano praćenje finansijskih performansi (profitabilnost, likvidnost) i efikasnosti bankarskog sektora u Srbiji omogućuje unapređenje u budućnosti primenom adekvatnih mera. U tome se manifestuje osnovna istraživačka hipoteza u ovom radu.

U metodološkom smislu te reči, značajnu ulogu u tome ima primena FLMAW-MARCOS metoda. U radu se u izvesnoj meri koristi i statistička analiza.

Potrebni empirijski podaci za istraživanje tretiranog problema u ovom radu su prikupljeni od Narodne banke Srbije, koji su usklađeni sa relevantnim međunarodnim standardima, tako da u pogledu komparacije ne postoje nikakva ograničenja.

Metodologija

Logaritamska metodologija aditivnih težina koristi se za utvrđivanje težinskih koeficijenata i rangiranje alternativa. **Fuzzy logaritamska metodologija aditivnih težina** (Fuzzy Logarithm Methodology of Additive Weights – FLMAW) je zasnovana na primeni trouglastih fuzzy brojeva (Božanić et al., 2022; Pamučar, 2021; Puška, 2022). FLMAW metoda odvija se kroz šest koraka (Božanić et al., 2022).

Korak 1. Formiranje inicijalne (ekspertske) matrice odlučivanja $(\tilde{X}^e)$

U ovom koraku svaki ekspet (e) iz grupe k eksperata ($1 \leq e \leq k$) definiše jednu matricu odlučivanja evaluacijom m alternativa $A = \{A_1, A_2, \dots, A_m\}$ u odnosu na n kriterijum $C = \{C_1, C_2, \dots, C_n\}$ Dakle, za svakog eksperta dobijena matrica $\tilde{X}^e = [\tilde{\vartheta}^e_{ij}]_{mxn}$, gde $\tilde{\vartheta}^e_{ij}$ predstavlja fuzzy vrednost baziranu na ekspertskoj e vrednosti i-te alternative u odnosu na j-ti kriterijum. Evaluacija je bazirana na kvantitativnim indikatorima ili fuzzy lingvističkih deskriptora u zavisnosti od vrste kriterijuma.

Korak 2. Formiranje inicijalne (agregatne) matrice odlučivanja $(\tilde{X})$

Agregacija početnih (ekspertskih) matrica u jednu agregiranu matricu se vrši primenom Bonferroni agregatora na sledeći način:

$$\tilde{\vartheta}_{ij} = \left(\frac{1}{k(k-1)}\right) \sum_{\substack{i,j=1 \\ i \neq j}}^{k} \tilde{\vartheta}_i^{(e)p} \, \tilde{\vartheta}_j^{(e)q} = \left\{ \left(\frac{k}{k(k-1)} \sum_{\substack{i,j=1 \\ i \neq j}}^{k} \vartheta_i^{(l_e)p} \, \vartheta_j^{(l_e)q} \right)^{\frac{1}{p+q}}, \left(\frac{k}{k(k-1)} \sum_{\substack{i,j=1 \\ i \neq j}}^{k} \vartheta_i^{(m_e)p} \, \vartheta_j^{(m_e)q} \right)^{\frac{1}{p+q}}, \left(\frac{k}{k(k-1)} \sum_{\substack{i,j=1 \\ i \neq j}}^{k} \vartheta_i^{(r_e)p} \, \vartheta_j^{(r_e)q} \right)^{\frac{1}{p+q}} \right\} \quad (1)$$

gde $\tilde{\vartheta}_{ij}$ dpredstavlja agregiranu vrednost dobijenu primenom Bonferroni agregatora; $p, q \geq 0$ stabilizacione parametre Bonferroni agregatora, e - e-tog eksperta $1 \leq e \leq k$, l – leva distribucija fuzzy broja, r – desna distribucija fuzzy broja, i m – vrednost pri kojoj je funkcija pripadnosti fuzzy broju jednaka jedan. Pre agregacije vrši se kvantifikacija lingvističkih kriterijuma.

Korak 3. Normalizacija elemenata inicijalne matrice

Normalizovana matrica $\sim = [\tilde{\vartheta}_{ij}]_{mxn}$ dobija se na sledeći način:

$$\tilde{\vartheta}_{ij} = \begin{cases} 1 + \dfrac{\widetilde{\vartheta_{ij}}}{\vartheta_j^{(+)}} = \left(1 + \dfrac{\vartheta_{ij}^{(l)}}{\vartheta_j^{(+)}}, 1 + \dfrac{\vartheta_{ij}^{(m)}}{\vartheta_j^{(+)}}, 1 + \dfrac{\vartheta_{ij}^{(r)}}{\vartheta_j^{(+)}}\right) if \in B, \\ 1 + \dfrac{\tilde{\vartheta}_j^{-}}{\widetilde{\vartheta_{ij}}} = \left(1 + \dfrac{\vartheta_j^{-}}{\vartheta_{ij}^{(r)}}, 1 + \dfrac{\vartheta_j^{-}}{\vartheta_{ij}^{(m)}}, 1 + \dfrac{\vartheta_j^{-}}{\vartheta_{ij}^{(l)}}\right) \quad if \in C \end{cases} \quad (2)$$

gde $\tilde{\vartheta}_{ij}$predstavlja normalizovanu vrednost inicijalne matrice odlučivanja, pri čemu je $\vartheta_j^{+} = max\left(\tilde{\vartheta}_j^{(r)}\right)$, i $\vartheta_j^{-} = min\left(\vartheta_j^{(l)}\right)$, l - levu distribuciju fuzzy broja, r - desnu distribuciju fuzzy broja, i m - vrednost pri kojoj je funkcija pripadnosti fuzzy broja jednaka jedan.

Korak 4. Determinisanje težinskih koeficijenata kriterijuma

U cilju određivanja težinskih koeficijenata kriterijumima treba da budu angažovani određeni eksperti $E = \{E1, E2, \dots, Ek\}$.

Korak 4.1 Određivanje prioriteta kriterijuma

Na osnovu vrednosti unapred definisanoj fuzzy lingvističkoj skali eksperti određuju prioritete kriterijumima $C = \{C1, C2, \dots, Cn\}$. Pri tom se kriterijumu visokog značaja pripisuje veća vrednost iz fuzzy lingvističke skale, i obrnuto. Na ovaj način definisani su vektori prioriteta $\tilde{P}^e = (\tilde{\gamma}_{C1}^e, \tilde{\gamma}_{C2}^e, \dots, \tilde{\gamma}_{Cn}^e)$, posebno za svakog ekspeta, gde $\tilde{\gamma}_{Cn}^e$ predstavlja vrednost iz fuzzy lingvističke skale koju ekspert e ($1 \le e \le k$) označi za kriterijum n.

Korak 4.2 Definisanje apsolutne fuzzy anti-idealne tačke $(\tilde{\gamma}AIP)$

Ovu vrednost definiše donosilac odluke, i predstavlja fuzzy broj koji je manji od najmanje vrednosti iz skupa svih vektora prioriteta.

Korak 4.3 Definisanje fuzzy relacionog vektora $\tilde{R}^e$

Relacija između elemenata vektora proriteta i apsolutne anti-idealne tačke (γAIP) se determiniše primenom sledeće jednačine:

$$\tilde{n}_{Cn}^e = \left(\frac{\tilde{\gamma}_{Cn}^e}{\tilde{\gamma}_{AIP}}\right) = \left(\frac{\gamma_{Cn}^{(l)e}}{\gamma_{AIP}^{(r)}}, \frac{\gamma_{Cn}^{(m)e}}{\gamma_{AIp}^{(m)}}, \frac{\gamma_{Cn}^{(r)\,e}}{\gamma_{AIP}^{(l)}}\right) \tag{3}$$

Primenom ove jednačine, relacioni vektor eksperta e($1 \le e \le k$) dobijen je: $R^e = (\tilde{n}_{C1}^e, \tilde{n}_{C2}^e, \dots, \tilde{n}_{Cn}^e)$.

Korak 4.4 Determinisanje težinskih koeficijenata vektora $\omega_j^e = (\widetilde{\omega}_1^e, \widetilde{\omega}_2^e, \dots, \widetilde{\omega}_n^e)^T$, posebno za svakog eksperta

Fuzzy vrednost težinskih koeficijenat kriterijuma za e ($1 \le e \le k$) dobija se primenom sledeće jednačine:

$$\widetilde{\omega}_j^e = \left(\frac{ln(\tilde{n}_{Cn}^e)}{ln\left(\prod_{j=1}^n \tilde{n}_{Cn}^e\right)}\right) = \left(\frac{ln\left(n_{Cn}^{(l)e}\right)}{ln\left(\prod_{j=1}^n n_{Cn}^{(r)e}\right)}, \frac{ln\left(n_{Cn}^{(m)e}\right)}{ln\left(\prod_{j=1}^n n_{Cn}^{(m)e}\right)}, \frac{ln\left(n_{Cn}^{(r)e}\right)}{ln\left(\prod_{j=1}^n n_{Cn}^{(l)e}\right)}\right) \tag{4}$$

gde $\tilde{n}^{e}_{Cn}$ predstavlja element relacionog vektora R^{e}, $n^{(l)e}_{Cn}$ levu distribuciju fuzzy vektora prioriteta, $n^{(r)e}_{Cn}$ desnu distribuciju fuzzy vektora prioriteta, i $n^{(m)e}_{Cn}m$ vrednost pri kojoj je funkcija pripadnosti fuzzy vektora prioriteta jednaka jedan.

Korak 4.5 Izračunavanje težinskih koeficijenata agregiranih fuzzy vektora $\omega_j = (\widetilde{\omega}_1, \widetilde{\omega}_2, \dots, \widetilde{\omega}_n)^T$

Težinski koeficijenti agregiranih fuzzy vektora $\omega_j = (\widetilde{\omega}_1, \widetilde{\omega}_2, \dots, \widetilde{\omega}_n)^T$ određuju se primenom Boneferroni agregatora (Yager, 2009) na sledeći način:

$$\widetilde{\omega}_j = \left(\frac{1}{k(k-1)}\sum_{\substack{i,j=1\\ i\neq j}}^{k} \widetilde{\omega}_i^{(e)p}\widetilde{\omega}_j^{(e)q}\right)^{\frac{1}{p+q}} = \left\{\left(\frac{1}{k(k-1)}\sum_{\substack{i,j=1\\ i\neq j}}^{k} \widetilde{\omega}_i^{(l_e)p}\widetilde{\omega}_j^{(l_e)q}\right)^{\frac{1}{p+q}}, \left(\frac{1}{k(k-1)}\sum_{\substack{i,j=1\\ i\neq j}}^{k} \widetilde{\omega}_i^{(m_e)p}\widetilde{\omega}_j^{(m_e)q}\right)^{\frac{1}{p+q}}, \left(\frac{1}{k(k-1)}\sum_{\substack{i,j=1\\ i\neq j}}^{k} \widetilde{\omega}_i^{(r_e)p}\widetilde{\omega}_j^{(r_e)q}\right)^{\frac{1}{p+q}}\right\} \tag{5}$$

gde $p,q\geq 0$ predstavlja stabilizacione parametre Bonoferroni agregatora, $\widetilde{\omega}_j^{e}$ težinske koeficijente dobijene na bazi procene e-tog eksperta $1 \leq e \leq k$, $\omega_j^{(l_e)}$levu distribuciju fuzzy težinskih koeficijenata $\widetilde{\omega}_j^{e}$,$\omega_j^{(r_e)}$ desnu distribuciju fuzzy težinskih koeficijenata, $\widetilde{\omega}_j^{e}$, i $\omega_j^{(m_e)}$ pravu vrednost pri kojoj je funkcija fuzzy težinskog koeficijenta $\omega_j^{(l_e)}$ jednaka jedan.

Korak 4.6 Izračunavanje konačnih vrednosti težinskih koeficijenata $\omega_j = (\widetilde{\omega}_1, \widetilde{\omega}_2, \dots, \widetilde{\omega}_n)^T$

Izračunavanje finalne vrednosti težinskih koeficijenata kriterijuma vrši se defuzifikacijom na sledeći način:

$$\omega_j = \frac{l+4m+r}{6} \tag{6}$$

Korak 5. Izračunavanje težinske matrice (N)

Elementi težinske matrice $N = \left[\tilde{\xi}_{ij}\right]_{mxn}$ dobijeni su na sledeći način:

$$\tilde{\xi}_{ij} = \frac{2\widetilde{\varphi}_{ij}^{\omega_j}}{(2-\widetilde{\varphi}_{ij})^{w_j}+\widetilde{\varphi}_{ij}^{\omega_j}} = \left(\frac{2{\varphi_j^{(l)}}^{\omega_j}}{\left(2-\varphi_j^{(r)}\right)^{\omega_j}+{\phi_j^{(r)}}^{\omega_j}}, \frac{2{\varphi_j^{(m)}}^{\omega_j}}{\left(2-\varphi_j^{(m)}\right)^{\omega_j}+{\phi_j^{(m)}}^{\omega_j}}, \frac{2{\varphi_j^{(r)}}^{\omega_j}}{\left(2-\varphi_j^{(l)}\right)^{\omega_j}+{\phi_j^{(l)}}^{\omega_j}}\right) \tag{7}$$

gde je

$$\widetilde{\varphi}_{ij} = \frac{ln\left(\widetilde{\vartheta}'_{ij}\right)}{ln\left(\prod_{i=1}^{m}\widetilde{\vartheta}'_{ij}\right)} = \left(\frac{ln\left(\vartheta'^{(l)}_{ij}\right)}{ln\left(\prod_{i=1}^{m}\vartheta'^{(r)}_{ij}\right)}, \frac{ln\left(\vartheta'^{(m)}_{ij}\right)}{ln\left(\prod_{i=1}^{m}\vartheta'^{(m)}_{ij}\right)}, \frac{ln\left(\vartheta'^{(r)}_{ij}\right)}{ln\left(\prod_{i=1}^{m}\vartheta'^{(l)}_{ij}\right)}\right) \tag{8}$$

pri čemu $\tilde{\vartheta}_j$, predstavlja elemente normalizovane matrice ~ = $[\vartheta_{ij}]_{mxn}$, ω_j težinske elemente kriterijuma, l – levu distribuciju fauzzy broja, r – desnu distribuciju fuzzy broja, i m - vrednost pri kojoj je funkcija pripadnosti fuzzy broja jednaka jedan.

Korak 6. Izračunavanje finalnog indeksa rangiranosti alternativa (Q_i)

Finalni rang alternativa se definiše na bazi vrednosti Q_i , pri čemu je bolje rangirana alternativa sa većom vrednošću Q_i . Vrednost Q_i dobijena je sa defuzikacijom vrednosti $\tilde{Q}_i$, pomoću jednačine(6). Vrednost $\tilde{Q}_i$ izračunava se primenom sledeće jednačine:

$$\tilde{Q}_i = \sum_{j=1}^{n} \tilde{\xi}_{ij} = \left(\sum_{j=1}^{n} \xi_{ij}^{(l)}, \sum_{j=1}^{n} \xi_{ij}^{(m)}, \sum_{j=1}^{n} \xi_{ij}^{(r)}\right) \tag{9}$$

gde $\tilde{\xi}_{ij}$ predstavlja elemente težinske matrice $\tilde{N}$ = $[\tilde{\xi}_{ij}]_{mxn}$, l - levu distribuciju fuzzy broja, r - desnu distribuciju fuzzy broja, i m vrednost pri kojoj je vrednost pripadnosti fuzzy broju jednaka jedan.

MARCOS (measurement alternatives and ranking according to compromise solution) **metoda** je bazirana na definisanju odnosa između alternativa i referentnih vrednosti (idealna i anti-idealna alternativa). Na osnovu definisanih odnosa, funkcije korisnosti alternativa se određuju i vrši se kompromisno rangiranje u odnosu na idealne i anti-idealne solucije. Preferencije odlučivanja se definišu na osnovu funkcije korisnosti. Funkcije korisnosti predstavljaju poziciju alternative u odnosu na idealne i anti-idealne solucije. Najbolja alternativa je ona koja je najbliža idealnoj i istovremeno najdalja anti-idealnoj referentnoj tački. MARCOS metoda se procesno odvija kroz sledeće korake (Stević, 2020a, b):

Korak 1: Formiranje inicijalne matrice za donošenje odluka

Multi-kriterijumski model uključuje definisanje skupa n kriterijuma i m alternativa. U slučaju grupnog odlučivanja, formira se skup r eksperta koji procenjuju alternative u odnosu na kriterijume. U tom slučaju, matrice ekspertske evaluacije su agregirane u inicijalne matrice grupnog odlučivanja.

Korak 2: Formiranje proširene inicijalne matrice

U ovom koraku, proširenja inicijalna matrica je definisana sa idealnim (*AI*) i anti-idealnim (*AAI*) solucijama.

$$X = \begin{array}{c} \\ AAI \\ A_1 \\ A_2 \\ \cdots \\ A_m \\ AI \end{array} \begin{array}{c} \begin{array}{cccc} C_1 & C_2 & \cdots & C_n \end{array} \\ \begin{bmatrix} x_{aa1} & x_{aa2} & \cdots & x_{aan} \\ x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ x_{m1} & x_{m2} & \cdots & x_{mn} \\ x_{ai1} & x_{ai2} & \cdots & x_{ain} \end{bmatrix} \end{array} \tag{10}$$

Anti-idealna solucija (*AAI*) je najgora alternativa. Idealna solucija (*AI*) je, suprotno tome, alternativa sa najboljim karakteristikama. U zavisnosti od prirode kriterijuma, *AAI* i *AI* se definišu primenom sledećih jednačina:

$$AAI = \min_i x_{ij} \ \ if\ j \in B\ and\ \max_i x_{ij}\ \ if\ j \in C \tag{11}$$

$$AI = \max_i x_{ij}\ \ if\ j \in B\ and\ \min_i x_{ij}\ \ if\ j \in C \tag{12}$$

gde *B* predstavlja benefitnu, a *C* troškovnu grupu kriterijuma.

Korak 3: Normalizacija proširene inicijalne matrice (*X*)

Elementi normalizovane matrice $N = [n_{ij}]_{mxn}$ su dobijeni primenom sledećih jednačina:

$$n_{ij} = \frac{x_{ai}}{x_{ij}}\ if\ j \in C \tag{13}$$

$$n_{ij} = \frac{x_{ij}}{x_{ai}}\ if\ j \in B \tag{14}$$

gde elementi x_{ij} i x_{ai} predstavljaju elemente matrice *X*

Korak 4: Definisanje težinske matrice $V = [v_{ij}]_{mxn}$

Težinska matrica *V* se dobija množenjem normalizovane matrice *N* sa težinskim koeficijentima kriterijuma w_j primenom sledeće jednačine:

$$v_{ij} = n_{ij} x v_j \tag{15}$$

Korak 5: Utvrđivanje stepena korisnosti alternativa K_i

Stepen korisnosti alternativa u odnosu na anti-idealne i idealne solucije se utvrđuje sa primenom sledećih jednačina:

$$K_i^- = \frac{S_i}{S_{aai}} \tag{16}$$

$$K_i^+ = \frac{S_i}{S_{ai}}$$

gde S_i $(i=1,2,..,m)$ predstavlja sumu elemenata težinske matrice *V*, prikazano u sledećoj jednačini:

$$S_i = \sum_{i=1}^{n} v_{ij} \tag{18}$$

Korak 6: Utvrđivanje funkcije korisnosti alternativa $f(K_i)$

Funkcija korisnosti je kompromis posmatrane alternative u odnosu na idealne i anti-idealne solucije. Funkcija korisnosti alternativa se definiše sa sledećom jednačinom:

$$f(K_i) = \frac{K_i^+ + K_i^-}{1 + \frac{1-f(K_i^+)}{f(K_i^+)} + \frac{1-f(K_i^-)}{f(K_i^-)}}; \qquad (19)$$

gde $f(K_i^-)$ reprezentuje funkciju korisnosti u odnosu na anti-idealnu soluciju a $f(K_i^+)$ prezentuje funkciju korisnosti u odnosu na idealnu soluciju.

Funkcije korisnosti u odnosu na idealne i anti-idealne solucije se utvrđuju sa primenom sledećih jednačina:

$$f(K_i^-) = \frac{K_i^+}{K_i^+ + K_i^-} \qquad (20)$$

$$f(K_i^+) = \frac{K_i^-}{K_i^+ + K_i^-} \qquad (21)$$

Korak 7: Rangiranje alternativa

Rangiranje alternativa bazirano je na konačnoj vrednosti funkcije korisnosti. Poželjna je ona alternativa koja ima najveću moguću vrednost funkcije korisnosti.

1. Rezultati i diskusija

Izabrani kriterijumi za analizu dinamike efikasnosti bankarskog sektora u Srbiji su: C1 - prinos na aktivu, C2 - prinos na kapital, C3 - kamatna marža u odnosu na bruto dobitak, C4 - nekamatni rashodi u odnosu na bruto dobitak i C5 -troškovi zaposlenih u odnosu na nekamatne rashode. Alternative su posmatrane u periodu 2008 – 2022. godine. U Tabeli 1 su prikazani inicijalni podaci.

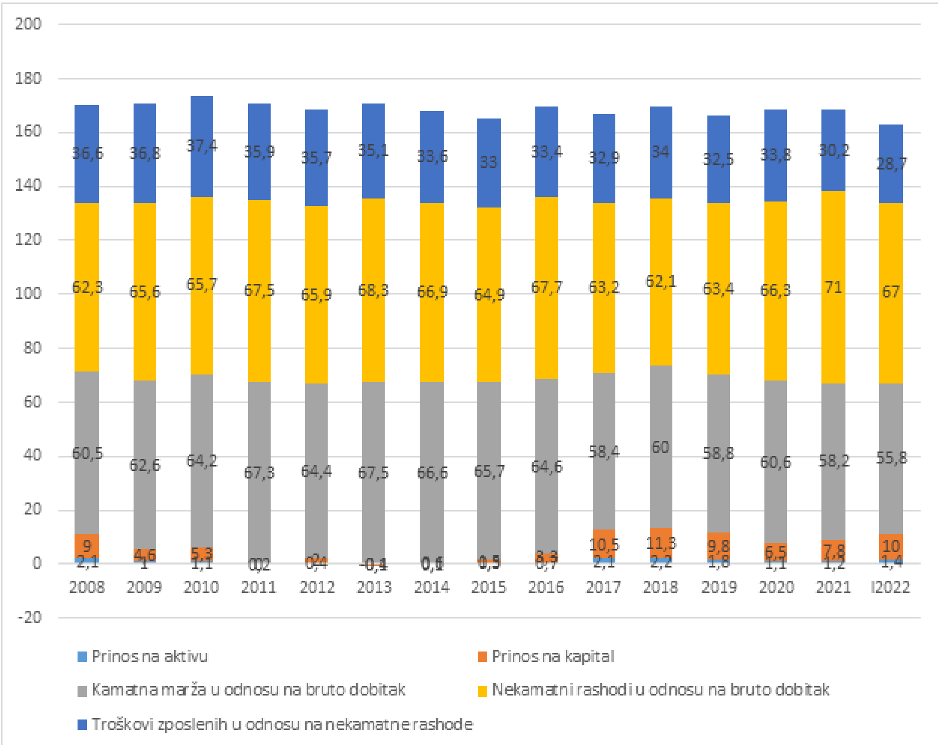
Tabela 1 - Inicijalni podaci – pokazatelji profitabilnosti bankarskog sektora u Srbiji

		Prinos na aktivu	Prinos na kapital	Kamatna marža u odnosu na bruto dobitak	Nekamatni rashodi u odnosu na bruto dobitak	Troškovi zaposlenih u odnosu na nekamatne rashode
		C1	C2	C3	C4	C5
A1	2008	2,1	9,0	60,5	62,3	36,6
A2	2009	1,0	4,6	62,6	65,6	36,8
A3	2010	1,1	5,3	64,2	65,7	37,4

A4	2011	0,0	0,2	67,3	67,5	35,9
A5	2012	0,4	2,0	64,4	65,9	35,7
A6	2013	-0,1	-0,4	67,5	68,3	35,1
A7	2014	0,1	0,6	66,6	66,9	33,6
A8	2015	0,3	1,5	65,7	64,9	33,0
A9	2016	0,7	3,3	64,6	67,7	33,4
A10	2017	2,1	10,5	58,4	63,2	32,9
A11	2018	2,2	11,3	60,0	62,1	34,0
A12	2019	1,8	9,8	58,8	63,4	32,5
A13	2020	1,1	6,5	60,6	66,3	33,8
A14	2021	1,2	7,8	58,2	71,0	30,2
A15	2022	1,4	10,0	55,8	67,0	28,7
	Statistika					
	Mean	1,0267	5,4667	62,3467	65,8533	33,9733
	Std. Error of Mean	,20318	1,06179	,95966	,62479	,62263
	Median	1,1000	5,3000	62,6000	65,9000	33,8000
	Std. Deviation	,78692	4,11229	3,71673	2,41982	2,41142
	Skewness	,108	-,023	-,133	,188	-,654
	Std. Error of Skewness	,580	,580	,580	,580	,580
	Kurtosis	-1,238	-1,582	-1,235	,089	,315
	Std. Error of Kurtosis	1,121	1,121	1,121	1,121	1,121
	Minimum	-,10	-,40	55,80	62,10	28,70
	Maximum	2,20	11,30	67,50	71,00	37,40
	NPar Tests **Friedman Test**					
	Ranks					
		Mean Rank				
	Prinos na aktivu	1,07				
	Prinos na kapital	1,93				
	Kamatna marža u odnosu na bruto dobitak	4,7				
	Nekamatni rashodi u odnosu na bruto dobitak	4,93				
	Troškovi zaposlenih u odnosu na nekamatne rashode	3,00				
	Test Statistic[a]					

	N	15				
	Chi-Square	58,507				
	df	4				
	Asymp. Sig.	,000				
	a. Friedman Test					

Napomena: Podatak za 2022. god. dat je za prvi kvartal. Autorova izračunata statistika
Izvor: Narodna banaka Srbije



Slika 1 - Indikatori profitabilnosti bankarskog sektora u Srbiji

Izvor: Autorova slika

Između posmatranih statističkih varijabli postoji značajna razlika, tako da se odbacuje nulta hipoteza. U Tabeli 2 je prikazana korelaciona matrica inicijalnih podataka.

Tabela 2 - Korelacija

Korelacija						
		1	2	3	4	5
1. Prinos na aktivu	Pearson Correlation	1	,968**	-,834**	-,637*	-,188
	Sig. (2-tailed)		,000	,000	,011	,503
	N	15	15	15	15	15

2. Prinos na kapital	Pearson Correlation	,968**	1	-,932**	-,495	-,390
	Sig. (2-tailed)	,000		,000	,060	,151
	N	15	15	15	15	15
3. Kamatna marža u odnosu na bruto dobitak	Pearson Correlation	-,834**	-,932**	1	,245	,596*
	Sig. (2-tailed)	,000	,000		,379	,019
	N	15	15	15	15	15
4. Nekamatni rashodi u odnosu na bruto dobitak	Pearson Correlation	-,637*	-,495	,245	1	-,297
	Sig. (2-tailed)	,011	,060	,379		,282
	N	15	15	15	15	15
5. Troškovi zaposlenih u odnosu na nekamatne rashode	Pearson Correlation	-,188	-,390	,596*	-,297	1
	Sig. (2-tailed)	,503	,151	,019	,282	
	N	15	15	15	15	15
** Korelacija je značajna na nivou 0,01 (2-tailed)						
* Korelacija je značajna na nivou 0,05 (2-tailed)						

Napomena: Autorovo izračunavanje

Korelaciona matrica pokazuje da postoji jaka korelaciona veza između kamatne marže u odnosu na bruto dobitak i prinosa na aktivu, prinosa na kapital i troškova zaposlenih u odnosu na nekamatne rashode u bankarskom sektoru Srbije na nivo statističke značajnosti. Između kamatne marže u odnosu na bruto dobitak i nekamatnih rashoda u odnosu na bruto dobitak je, međutim, slaba korelaciona veza. Između nekamatnih rashoda u odnosu na bruto dobitak i prinosa na aktivu je značajna korelaciona veza na nivou statističke značajnosti. Između nekamatnih rashoda u odnosu na bruto dobitak i prinosa na kapital, kamatne marže u odnosu na bruto dobitak i troškova zaposlenih u odnosu na nekamatne rashode je, nasuprot tome, slaba korelaciona veza. Između troškova zaposlenih u odnosu na nekamatne rashode i prinosa na aktivu, prinosa na kapital i nekamatnih rashoda u odnosu na bruto dobitak slaba je korelaciona veza. Dakle, u cilju poboljšanja profitabilnosti bankarskog sektora u Srbiji neophodno je što efikasnije upravljati prvenstveno sa troškovnim elementima.

Težinski koeficijenti kriterijuma su utvrđeni korišćenjem FLMAW metode. U Tabeli 3, za te svrhe, prikazana je fuzzy skala prioritizacije kriterijuma.

Table 3 - Fuzzy skala prioritizacije kriterijuma

Fuzzy skala prioritizacije kriterijuma				
Fuzzy Linguistic Descriptor	**Abbreviation**	Fuzzy Number		
Absolutely Low	**AL**	1	1	1
Very Low	**VL**	1	1,5	2
Low	**L**	1,5	2	2,5
Medium Low	**ML**	2	2,5	3
Equal	**E**	2,5	3	3,5

Medium High	**MH**	3	3,5	4
High	**H**	3,5	4	4,5
Very High	**VH**	4	4,5	5
Absolutely High	**AH**	4,5	5	5

Tabela 4 pokazuje ekspertsku evaluaciju kriterijuma

Tabela 4 - Evaluacija kriterijuma

VRSTA	**1**	**1**	**1**	**-1**	**-1**
	C1	**C2**	**C3**	**C4**	**C5**
P1	**AH**	**L**	**VL**	**E**	**VL**
P2	**AH**	**ML**	**AL**	**H**	**AL**
P3	**AH**	**ML**	**AL**	**MH**	**VL**
P4	**AH**	**E**	**AL**	**VH**	**AL**
P5	**AH**	**E**	**AL**	**VH**	**AL**

YAIP	**0.5**	**0.5**	**0.5**

	C1			**C2**			**C3**			**C4**			**C5**		
P1	9	10	10	3	4	5	2	3	4	5	6	7	2	3	4
P2	9	10	10	4	5	6	2	2	2	7	8	9	2	2	2
P3	9	10	10	4	5	6	2	2	2	6	7	8	2	3	4
P4	9	10	10	5	6	7	2	2	2	8	9	10	2	2	2
P5	9	10	10	5	6	7	2	2	2	8	9	10	2	2	2

Napomena: Autorovo izračunavanje

U Tabeli 5 prikazani su težinski koeficijenti vektora.

Tabela 5 - Težinski koeficijenti vektora

Težinski koeficijenti vektora	**C1**			**C2**			**C3**			**C4**			**C5**		
W1j	0,255	0,300	0,366	0,127	0,181	0,256	0,080	0,143	0,220	0,186	0,233	0,309	0,080	0,143	0,220
W2j	0,286	0,312	0,333	0,181	0,218	0,259	0,090	0,094	0,100	0,253	0,282	0,318	0,090	0,094	0,100
W3j	0,266	0,301	0,341	0,168	0,210	0,265	0,084	0,091	0,103	0,217	0,254	0,308	0,084	0,144	0,205
W4j	0,277	0,300	0,317	0,203	0,233	0,268	0,087	0,090	0,095	0,262	0,286	0,317	0,087	0,090	0,095
W5j	0,277	0,300	0,317	0,203	0,233	0,268	0,087	0,090	0,095	0,262	0,286	0,317	0,087	0,090	0,095

Napomena: Autorovo izračunavanje

Tabela 6 pokazuje agregirani fuzzy vektor, agregirani fuzzy težinski koeficijenti vektora i finalnu vrednost težinskih koeficijenata.

Tabela 6 - Agregirani fuzzy vektor, agregirani fuzzy težinski koeficijenti vektora i finalna vrednost težinskih koeficijenata

Agregirani fuzzy vector	C1			C2			C3			C4			C5		
W1j	0,014	0,018	0,024	0,005	0,008	0,014	0,001	0,003	0,004	0,009	0,013	0,019	0,001	0,003	0,005
W2j	0,015	0,019	0,022	0,006	0,009	0,014	0,002	0,002	0,003	0,012	0,015	0,020	0,002	0,002	0,003
W3j	0,015	0,018	0,023	0,006	0,009	0,014	0,001	0,002	0,003	0,010	0,014	0,019	0,001	0,003	0,005
W4j	0,015	0,018	0,021	0,007	0,010	0,014	0,001	0,002	0,002	0,012	0,015	0,020	0,001	0,002	0,003
W5j	0,015	0,018	0,021	0,007	0,010	0,014	0,001	0,002	0,002	0,012	0,015	0,020	0,001	0,002	0,003
SUM	0,074	0,092	0,112	0,031	0,046	0,069	0,007	0,010	0,014	0,056	0,072	0,098	0,007	0,012	0,020
Agregirani fuzzy težinski koeficijenti	0,272	0,303	0,334	0,176	0,215	0,263	0,086	0,101	0,120	0,236	0,268	0,314	0,086	0,112	0,140
Finalna vrednost težinskih koeficijenata	**0,303**			**0,216**			**0,102**			**0,270**			**0,112**		

Napomena: Autorovo izračunavanje

U Tabeli 7 je prikazana inicijalna matrica.

Tabela 7 - Inicijalna matrica

Inicijalna matrica					
težina kriterijuma	0,303	0,216	0,102	0,27	0,112
vrsta kriterijuma	1	1	1	-1	-1
	C1	**C2**	**C3**	**C4**	**C5**
A1	2,1	9	60,5	62,3	36,6
A2	1	4,6	62,6	65,6	36,8
A3	1,1	5,3	64,2	65,7	37,4
A4	0	0,2	67,3	67,5	35,9
A5	0,4	2	64,4	65,9	35,7
A6	-0,1	-0,4	67,5	68,3	35,1
A7	0,1	0,6	66,6	66,9	33,6
A8	0,3	1,5	65,7	64,9	33
A9	0,7	3,3	64,6	67,7	33,4

A10	2,1	10,5	58,4	63,2	32,9
A11	2,2	11,3	60	62,1	34
A12	1,8	9,8	58,8	63,4	32,5
A13	1,1	6,5	60,6	66,3	33,8
A14	1,2	7,8	58,2	71	30,2
A15	1,4	10	55,8	67	28,7
MAX	2,2	11,3	67,5	71	37,4
MIN	-0,1	-0,4	55,8	62,1	28,7

Napomena: Autorovo izračunavanje

Tabela 8 pokazuje proširenu inicijalnu matricu.

Tabela 8 - Proširena inicijalna matrica

Proširena inicijalna matrica					
težina kriterijuma	0,303	0,216	0,102	0,27	0,112
vrsta kriterijuma	1	1	1	-1	-1
	C1	**C2**	**C3**	**C4**	**C5**
AAI	-0,1	-0,4	55,8	71	37,4
A1	2,1	9	60,5	62,3	36,6
A2	1	4,6	62,6	65,6	36,8
A3	1,1	5,3	64,2	65,7	37,4
A4	0	0,2	67,3	67,5	35,9
A5	0,4	2	64,4	65,9	35,7
A6	-0,1	-0,4	67,5	68,3	35,1
A7	0,1	0,6	66,6	66,9	33,6
A8	0,3	1,5	65,7	64,9	33
A9	0,7	3,3	64,6	67,7	33,4
A10	2,1	10,5	58,4	63,2	32,9
A11	2,2	11,3	60	62,1	34
A12	1,8	9,8	58,8	63,4	32,5
A13	1,1	6,5	60,6	66,3	33,8
A14	1,2	7,8	58,2	71	30,2
A15	1,4	10	55,8	67	28,7
AI	2,2	11,3	67,5	62,1	28,7

Napomena: Autorovo izračunavanje

U Tabeli 9 je prikazana normalizovana matrica.

Tabela 9 - Normalizovana matrica

Normalizovana matrica					
težina kriterijuma	0,303	0,216	0,102	0,27	0,112
vrsta kriterijuma	1	1	1	-1	-1
	C1	C2	C3	C4	C5
AAI	-0,04545	-0,0354	0,826667	0,874648	0,76738
A1	0,9545	0,7965	0,8963	0,9968	0,7842
A2	0,4545	0,4071	0,9274	0,9466	0,7799
A3	0,5000	0,4690	0,9511	0,9452	0,7674
A4	0,0000	0,0177	0,9970	0,9200	0,7994
A5	0,1818	0,1770	0,9541	0,9423	0,8039
A6	0,0000	0,0000	1,0000	0,9092	0,8177
A7	0,0455	0,0531	0,9867	0,9283	0,8542
A8	0,1364	0,1327	0,9733	0,9569	0,8697
A9	0,3182	0,2920	0,9570	0,9173	0,8593
A10	0,9545	0,9292	0,8652	0,9826	0,8723
A11	1,0000	1,0000	0,8889	1,0000	0,8441
A12	0,8182	0,8673	0,8711	0,9795	0,8831
A13	0,5000	0,5752	0,8978	0,9367	0,8491
A14	0,5455	0,6903	0,8622	0,8746	0,9503
A15	0,6364	0,8850	0,8267	0,9269	1,0000
AI	1	1	1	1	1

Napomena: Autorovo izračunavanje

Tabela 10 pokazuje težinski normalizovanu matricu

Tabela 10 - Težinski normalizovana matrica

Težinski normalizovana matrica					
	C1	C2	C3	C4	C5
AAI	0	0	0,08432	0,236155	0,085947
A1	0,2892	0,1720	0,0914	0,2691	0,0878

A2	0,1377	0,0879	0,0946	0,2556	0,0873
A3	0,1515	0,1013	0,0970	0,2552	0,0859
A4	0,0000	0,0038	0,1017	0,2484	0,0895
A5	0,0551	0,0382	0,0973	0,2544	0,0900
A6	0,0000	0,0000	0,1020	0,2455	0,0916
A7	0,0138	0,0115	0,1006	0,2506	0,0957
A8	0,0413	0,0287	0,0993	0,2584	0,0974
A9	0,0964	0,0631	0,0976	0,2477	0,0962
A10	0,2892	0,2007	0,0882	0,2653	0,0977
A11	0,3030	0,2160	0,0907	0,2700	0,0945
A12	0,2479	0,1873	0,0889	0,2645	0,0989
A13	0,1515	0,1242	0,0916	0,2529	0,0951
A14	0,1653	0,1491	0,0879	0,2362	0,1064
A15	0,1928	0,1912	0,0843	0,2503	0,1120
AI	0,303	0,216	0,102	0,27	0,112

Napomena: Autorovo izračunavanje

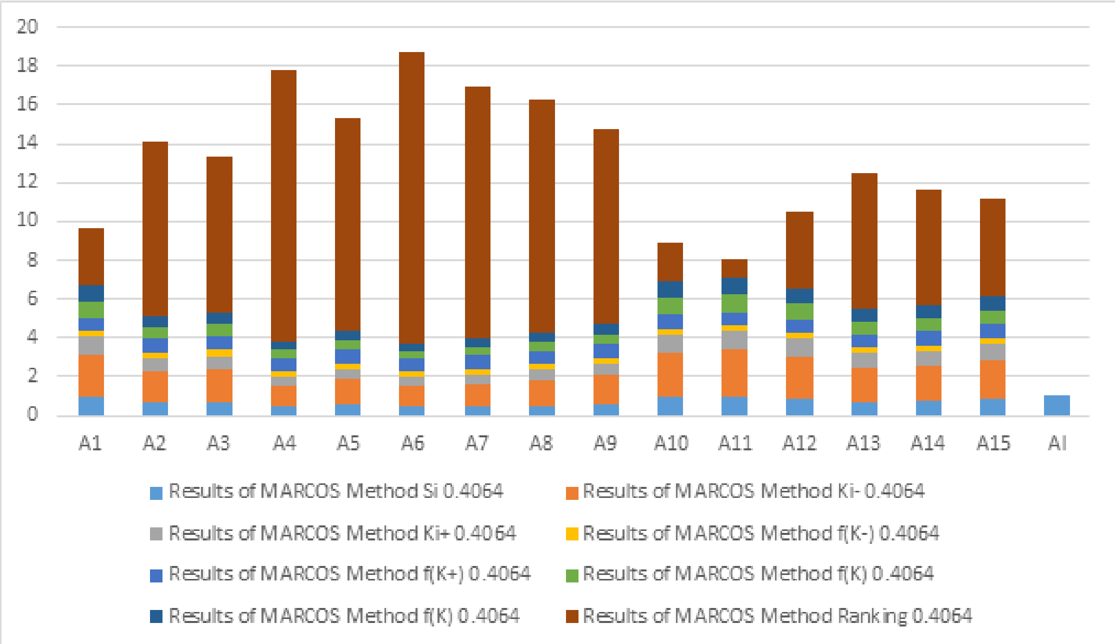
U Tabeli 11 i na Slici 2 su prikazani rezultati MARCOS metode

Tabela 11 - Rezultati MARCOS metode

	Rezultati MARCOS metode								
		Si	Ki-	Ki+	f(K-)	f(K+)	f(K)		Ranking
	AAI	0,4064							
2008	**A1**	0,9096	2,2382	0,9069	0,2884	0,7116	0,8120	0,8120	**3**
2009	**A2**	0,6632	1,6318	0,6612	0,2884	0,7116	0,5920	0,5920	**9**
2010	**A3**	0,6910	1,7001	0,6889	0,2884	0,7116	0,6168	0,6168	**8**
2011	**A4**	0,4435	1,0911	0,4421	0,2884	0,7116	0,3959	0,3959	**14**
2012	**A5**	0,5351	1,3166	0,5335	0,2884	0,7116	0,4777	0,4777	**11**
2013	**A6**	0,4391	1,0803	0,4378	0,2884	0,7116	0,3920	0,3920	**15**
2014	**A7**	0,4722	1,1618	0,4708	0,2884	0,7116	0,4215	0,4215	**13**
2015	**A8**	0,5250	1,2918	0,5235	0,2884	0,7116	0,4687	0,4687	**12**
2016	**A9**	0,6010	1,4788	0,5992	0,2884	0,7116	0,5365	0,5365	**10**
2017	**A10**	0,9412	2,3158	0,9384	0,2884	0,7116	0,8402	0,8402	**2**
2018	**A11**	0,9742	2,3970	0,9713	0,2884	0,7116	0,8697	0,8697	**1**

2019	**A12**	0,8875	2,1836	0,8848	0,2884	0,7116	0,7922	0,7922	**4**
2012	**A13**	0,7153	1,7600	0,7132	0,2884	0,7116	0,6386	0,6386	**7**
2021	**A14**	0,7449	1,8328	0,7427	0,2884	0,7116	0,6650	0,6650	**6**
2022	**A15**	0,8305	2,0435	0,8281	0,2884	0,7116	0,7414	0,7414	**5**
	AI	1,0030							

Napomena: Autorovo izračunavanje



Slika 2 - Rangiranje alternativa
Izvor: Autorova slika

Prema tome, pet najboljih godina ostvarene profitabilnosti u bankarskom sektoru u Srbiji u periodu 2008 – 2022. god. po redosledu su: 2018, 2017, 2008, 2019. i 2022. godina. Najlošija profitabilnost je ostvarena u 2013. god. Primetno je da se u poslednje vreme poboljšala profitabilnost bankarskog sektora u Srbiji. Na profitabilnost bankarskog sektora u Srbiji uticali su ekonomska klima, upravljanje ljudskim resursima, aktivom, kapitalom, prodajom bankarskog proizvoda, troškovima i profitom, digitalizacija celokupnog poslovanja, pandemije korona virusa Covid-19 i svetska energetska kriza.

U cilju poboljšanja profitabilnosti bankarskog sektora u Srbiji neophodno je što efikasnije upravljati ljudskim resursima, aktivom, kapitalom, prodajom, troškovima i profitom. Isto tako se blagovremeno prilagođavati promenama ekonomske klime.

Preporuka je da se prilikom analize dinamike profitabilnosti bankarskog sektora u Srbiji istovremeno komparativno koriste nekoliko metoda višekriterijumskog odlučivanja. Na taj način se dobija potpunija slika o dinamici profitabilnosti bankarskog sektora u Srbiji.

Zaključak

Na osnovu dobijenih empirijskih rezultata primenom date metodologije može se zaključiti sledeće:

1. Pet najboljih godina ostvarene profitabilnosti u bankarskom sektoru u Srbiji u periodu 2008 – 2022. god. po redosledu su: 2018, 2017, 2008, 2019. i 2022. god. Najlošija profitabilnost je zabeležena u 2013. godini. U poslednje vreme poboljšala se profitabilnost bankarskog sektora u Srbiji.

2. Faktori profitabilnosti bankarskog sektora u Srbiji su ekonomska klima, upravljanje ljudskim resursima, aktivom, kapitalom, prodajom bankarskog proizvoda, troškovima i profitom. Značajnu ulogu u tome ima i digitalizacija celokupnog poslovanja. Nije zanemarljiv i uticaj pandemije korona virusa Covid-19, ako i svetske energetske krize. Njihovom adekvatnom kontrolom može se znatno uticati na ostvarenje ciljne profitabilnosti bankarskog sektora u Srbiji.

U cilju poboljšanja profitabilnosti bankarskog sektora u Srbiji neophodno je što efikasnije upravljati ljudskim resursima, aktivom, kapitalom, prodajom, troškovima i profitom. Uz to se blagovremeno prilagođavati promenama ekonomske klime i globalnom okruženju.

Literatura

1. Ali, S.M., Hoq, S.M.N., Bari, A.B.M.M., Kabir, G., Paul, S.K. (2022). Evaluating factors contributing to the failure of information system in the banking industry. PLoS ONE, 17(3): e0265674. https://doi.org/10.1371/journal.pone.0265674
2. Andersen, P.; Petersen, N.C. (1993). A procedure for ranking efficient units in data envelopment analysis. Management Science, 39, 1261-1264.
3. Banker, R.D., Charnes, A. and Cooper, W.W. (1984). Some models for estimating technical and scale inefficiencies in data envelopment analysis. Management Science, 30(9), 1078–1092.
4. Božanić, D., Pamučar, D., Milić,A., Marinković, M.and Komazec, N. (2022). Modification of the Logarithm Methodology of Additive Weights (LMAW) by a Triangular Fuzzy Number and Its Application in Multi-Criteria Decision Making. Axioms, 11(3), 89. https://doi.org/10.3390/axioms11030089
5. Chang, X. and Wang, X. (2020). Research Performance Evaluation of University Based on Super DEA Model. 2020 IEEE 9th Joint International Information Technology and Artificial Intelligence Conference (ITAIC), 1252-1255. doi: 10.1109/ITAIC49862.2020.9339131
6. Chen, Chunhua, Liu, Haohua, Tang, Lijun and Ren, Jianwei. (2021). A Range Adjusted Measure of Super-Efficiency in Integer-Valued Data Envelopment Analysis with Undesirable Outputs. Journal of Systems Science and Information, 9(4), 378-398. https://doi.org/10.21078/JSSI-2021-378-21
7. Cvetkoska, V., and Savić, G. (2017). Efficiency of bank branches: Empirical evidence from a two-phase research approach. Economic Research-Ekonomska istrazivanja, 30(1), 318–333. doi: 10.1080/1331677X.2017.1305775
8. Cvetkoska, V. and Ciković, K.F.(2020). Assessing the relative efficiency of commercial banks in the Republic of North Macedonia: DEA window analysis. Croatian Operational Research Review 217 CRORR 11, 217-227.

9. Cvetkoska, V., Fotova Ciković, K. and Tasheva, M. (2021). Efficiency of Commercial Banking in Developing Countries. Mathematic , 9, 1597. https://doi.org/10.3390/math9141597
10. Demir, G. (2022). Analysis of the financial performance of the deposit banking sector inthe Covid-19 period with LMAW-DNMA methods. International Journal of Insurance and Finance, 2(2), 17-36.https://doi.org/10.52898/ijif.2022.7
11. Fenyves, V. and Tarnóczi, T. (2020). Data envelopment analysis for measuring performance in a competitive market. Problems and Perspectives in Management, 18(1), 315-325. doi:10.21511/ppm.18(1).2020.27
12. Guo, D. and Cai, Z.Q. (2020). Super-Efficiency Infeasibility in the Presence of Nonradial Measurement. Mathematical Problems in Engineering, 2020, Article ID 6264852, 7 pages. https://doi.org/10.1155/2020/6264852
13. Lee, H.S., Chu, C.W. and J. Zhu, J. (2011). Super-efficiency DEA in the presence of infeasibility. European Journal of Operational Research, 212(1), 141–147.
14. Lin, R. (2020). Cross-efficiency evaluation capable of dealing with negative data: A directional distance function based approach. Journal of the Operational Research Society, 71(3), 505-516.
15. Lukić, R., Sokić, M. & Vojteski Kljenak, D. (2017). Efficiency Analysis Of Banking Sector In Republic Of Serbia. Business Excellence and Management, 7(4), 5-17.
16. Lukić, R. (2018a). Bankarsko računovodstvo. Beograd: Ekonomski fakultet.
17. Lukić, R. (2018d). Analysis of the efficiency of insurance companies. In: Insurance in the post-crisis era, Belgrade: Faculty of Economics, University of Belgrade. ISBN:978-86-403-1548-7.
18. Lukić, R. and Hadrović Zekić, B. (2019). Evaluation of efficiency of trade companies in Serbia using the DEA approach. Proceedings of the 19 th International Scientific Conference Business logistics in modern management October 10-11, Osijek, Croatia, Josip Juraj Strossmaye, 145-162.
19. Lukić, R. (2021). Application of the EDAS method in the evaluation of bank efficiency in serbia. Bankarstvo - Banking, 50(2), 13-24. doi: 10.5937/bankarstvo2102064L
20. Maletić, R., Kreća, M., & Maletić, P. (2013). Application of dea methodology in measuring efficiency in the banking sector. Economics of Agriculture, 60(4), 843–855. https://www.ea.bg.ac.rs/index.php/EA/article/view/423
21. Lukić, R. (2022). Evaluation of the efficiency of banks in Serbia using the MABAC method. Bankarstvo - Banking, 2, 35-60. DOI: 10.5937/bankarstvo2202010L
22. Radojko Lukić, (2022b). Analysis of financial performance and efficiency of banks in serbia using fuzzy LMAW and MARCOS methods. Bankarstvo – Banking, 4, 130-169.
23. Milenković, N., Radovanov, B., Kalaš, B. and Horvat, A.M. (2022). External Two Stage DEA Analysis of Bank Efficiency in West Balkan Countries. Sustainability, 14, 978. https://doi.org/10.3390/su14020978
24. Pamučar, D., Žižović, M., Biswas, S., Božanić, D. (2021). A new logarithm methodology of additive weights (LMAW) for multi-criteria decision-making: Application in logistics. Facta Univ. Ser. Mech. Eng., 2021, 19, 361–380. https://doi.org/10.22190/FUME210214031P
25. Puška, A., Božanić, D., Nedeljković, M., Janošević, M. (2022). Green Supplier Selection in an Uncertain Environment in Agriculture Using a HybridMCDM Model: Z-Numbers–Fuzzy LMAW–Fuzzy CRADIS Model. Axioms, 11, 427. https://doi.org/ 10.3390/axioms1109042
26. Pendharkar, P.C. (2021). Hybrid radial basis function DEA and its applications to regression, segmentation and cluster analysis problems. Machine Learning with Applications, 6, 100092. https://doi.org/10.1016/j.mlwa.2021.100092.

27. Peykani, P., Seyed Esmaeili, F.S., Mirmozaffari, M., Jabbarzadeh, A. and Khamechian, M. (2022). Input/Output Variables Selection in Data Envelopment Analysis: A Shannon Entropy Approach. Mach. Learn. Knowl. Extr., 4, 688–699. https://doi.org/10.3390/ make4030032
28. Peykani, P., Gheidar-Kheljani, J., Farzipoor Saen, R., & Mohammadi, E. (2022a).Generalized Robust Window Data Envelopment Analysis Approach for DynamicPerformance Measurement under Uncertain Panel Data. Operational Research, 1-36.https://doi.org/10.1007/s12351-022-00729-7.
29. Podinovski, V.V. and Bouzdine-Chameeva, T. (2021). Optimal solutions of multiplier DEA models. J Prod Anal, 56, 45–68. https://doi.org/10.1007/s11123-021-00610-3
30. Radojičić, M., Savić, G., & Jeremić, V. (2018). Measuring the efficiency of banks: the bootstrapped I-distance GAR DEA approach. Technological and Economic Development of Economy, 24(4), 1581-1605. https://doi.org/10.3846/tede.2018.3699
31. Rostamzadeh, R., Akbarian, O., Banaitis, A., & Soltani, Z. (2021). Application of DEA in benchmarking: a systematic literature review from 2003–2020. Technological and Economic Development of Economy, 27(1), 175-222. https://doi.org/10.3846/tede.2021.13406
32. Savić, G., Radosavljević, M., & Ilievski, D. (2012). DEA Window analysis approach for measuring the efficiency of Serbian banks. Management - časopis za teoriju i praksu menadžmenta, 17(65), 5-14.
33. Stević, Ž., Pamučar, D., Puška, A. and Chatterjee, P. (2020a). Sustainable supplier selection in healthcare industries using a new MCDM method: Measurement of alternatives and ranking according to COmpromise solution (MARCOS). Computers & Industrial Engineering, 140, 106231. https://doi.org/10.1016/j.cie.2019.106231.
34. Stević, Ž. and Brković, N. A. (2020b). Novel Integrated FUCOM-MARCOS Model for Evaluation of Human Resources in a Transport Company. Logistics, 4, 4. https://doi.org/10.3390/logistics4010004
35. Tone, K. (2002). A slacks-based measure of super-efficiency in data envelopment analysis. European Journal of Operational Research, 143, 32-41.
36. Tsai, Chi-Mao; Lee, Hsuan-Shih; and Gan, Guo-Ya (2021). A New Fuzzy DEA Model for Solving the MCDM Problems in Supplier Selection. Journal of Marine Science and Technology: 29(1) , Article 7. DOI: 10.51400/2709-6998.1006
37. Ünlü, U., Yalçın, N. and Avşarlıgil, N. (2022). Analysis of Efficiency and Productivity of Commercial Banks in Turkey Pre- and during COVID-19 with an Integrated MCDM Approach. Mathematics, 10(13), 2300. https://doi.org/10.3390/math10132300

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MEASUREMENT AND ANALYSIS OF PROFITABILITY DYNAMICS OF THE BANKING SECTOR IN SERBIA BASED ON THE FLMAW-MARCOS METHOD

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Summary: Research into the profitability dynamics of the banking sector is continuously current, significant, and complex. Bearing that in mind, this paper measures and analyzes the profitability dynamics of the banking sector in Serbia using FLMAW-MARCOS methods. The empirical results obtained by applying the given methodology show that the five best years of achieved profitability in the banking sector in Serbia in the period 2008 - 2022 are in order: 2018, 2017, 2008, 2019 and 2022. The worst profitability was achieved in 2013. Recently, the profitability of the banking sector in Serbia has improved. It was influenced by the economic climate, management of human resources, assets, capital, sales of banking products, costs, and profits. The digitalization of the entire business plays a significant role in this. The impact of the Covid-19 corona virus pandemic, as well as the global energy crisis, is significant. In order to improve the profitability of the banking sector in Serbia, it is necessary to manage human resources, assets, capital, sales, costs and profits as efficiently as possible and adapt to changes in the economic climate.

Keywords: banking sector, FLMAW-MARCOS method, profitability, Serbia

JEL classification: D40, G21

Introduction

The issue of measuring and analyzing factors of banking profitability dynamics is very current, significant and complex. In this paper, considering that, as a subject of research, the profitability dynamics of the banking sector in Serbia is analyzed based on the FLMAW-MARCOS method. The aim and purpose of this is to better understand the profitability dynamics of the banking sector in Serbia with the aim of improving it in the future by applying adequate measures.

The literature devoted to the development and importance of the application of the DEA model is very rich (Andersen, 1993; Banker, 1984; Chen, 2021; Chang, 2020; Guo, 2020; Lee, 2011; Lin, 2020; Pendharkar, 2021; Tone, 2002; Podinovski , 2021; Rostamzadeh, 2021; Fenyves, 2020; Tsai, 2021). They are also very successfully applied in the analysis of the efficiency of banks and insurance companies (Savic, 2012; Maletić, 2013; Radojicic, 2018; Cvetkoska, 2017, 2020, 2021; Lukic, 2017; 2018a,b, 2021). Likewise, when analyzing financial performance (profitability, liquidity) and efficiency, banks are increasingly applying, integrally or individually, different methods of multi-criteria decision-making (Ünlü, 2022; Ali, 2022, Lukic, 2022a,b; Demir, 2022). All relevant literature in this work is used as a theoretical-methodological and empirical basis for the analysis of the profitability dynamics of the banking sector in Serbia using the FLMAW-MARCOS method.

It is known that only continuous monitoring of financial performance (profitability, liquidity) and efficiency of the banking sector in Serbia enables improvement in the future by applying adequate measures. This manifests the basic research hypothesis in this paper.

In the methodological sense of the word, the application of FLMAW-MARCOS methods plays a significant role in this. Statistical analysis is also used to some extent in the work.

The necessary empirical data for the research of the problem treated in this paper were collected from the National Bank of Serbia, which are aligned with the relevant international standards, so that there are no limitations in terms of comparison.

Methodology

The logarithmic methodology of additive weights is used to determine weight coefficients and rank alternatives. **Fuzzy Logarithm Methodology of Additive Weights** (FLMAW) is based on the application of triangular fuzzy numbers (Božanić et al., 2022; Pamučar, 2021; Puška, 2022). The FLMAW method takes place through six steps (Božanić et al., 2022).

Step 1. Formation of the initial (expert) decision-making matrix $(\tilde{X}^e)$

In this step, each expert (e) from the group of k experts ($1 \le e \le k$)defines a decision matrix by evaluating m alternatives A={$A = \{A_1, A_2, \dots, A_m\}$elation to n criteria C={C_$C = \{C_1, C_2, \dots, C_n\}$fore, for each expert, a matrix was obtained $\tilde{X}^e = [\tilde{\vartheta}_{ij}^e]_{mxn}$, where $\tilde{\vartheta}_{ij}^e$ it represents a fuzzy value based on the expert value of the i - th alternative in relation to the j -th criterion. The evaluation is based on quantitative indicators or fuzzy linguistic descriptors, depending on the type of criteria.

Step 2. Formation of the initial (aggregate) decision-making matrix $(\tilde{X})$

Aggregation of the initial (expert) matrices into one aggregated matrix is performed using the Bonferroni aggregator as follows:

$$\tilde{\vartheta}_{ij} = \left(\frac{1}{k(k-1)}\right) \sum_{\substack{i,j=1 \\ i \neq j}}^{k} \tilde{\vartheta}_i^{(e)p} \, \tilde{\vartheta}_j^{(e)q} = \tag{1}$$

$$\left\{ \left(\frac{k}{k(k-1)} \sum_{\substack{i,j=1 \\ i \neq j}}^{k} \vartheta_i^{(l_e)p} \, \vartheta_j^{(l_e)q} \right)^{\frac{1}{p+q}}, \left(\frac{k}{k(k-1)} \sum_{\substack{i,j=1 \\ i \neq j}}^{k} \vartheta_i^{(m_e)p} \, \vartheta_j^{(m_e)q} \right)^{\frac{1}{p+q}}, \left(\frac{k}{k(k-1)} \sum_{\substack{i,j=1 \\ i \neq j}}^{k} \vartheta_i^{(r_e)p} \, \vartheta_j^{(r_e)q} \right)^{\frac{1}{p+q}} \right\}$$

where $\tilde{\vartheta}_{ij}^e$ represents the aggregated value obtained by applying the Bonferroni aggregator; $p,q \ge 0$ stabilization parameters of the Bonferroni aggregator, e e -th expert $1 \le e \le k$, l – left distribution of fuzzy number, r – right distribution of fuzzy number, and m – value at which the membership function of the fuzzy number is equal to one. Linguistic criteria are quantified before aggregation.

Step 3. Normalization of elements of the initial matrix

The normalized matrix $\sim = [\tilde{\vartheta}_{ij}]_{mxn}$ is obtained as follows:

$$\tilde{\vartheta}_{ij} = \begin{cases} 1 + \dfrac{\widetilde{\vartheta_{ij}}}{\widetilde{\vartheta_j^{(+)}}} = \left(1 + \dfrac{\vartheta_{ij}^{(l)}}{\vartheta_j^{(+)}}, 1 + \dfrac{\vartheta_{ij}^{(m)}}{\vartheta_j^{(+)}}, 1 + \dfrac{\vartheta_{ij}^{(r)}}{\vartheta_j^{(+)}} \right) if \in B, \\ 1 + \dfrac{\tilde{\vartheta}_j^{-}}{\widetilde{\vartheta_{ij}}} = \left(1 + \dfrac{\vartheta_j^{-}}{\vartheta_{ij}^{(r)}}, 1 + \dfrac{\vartheta_j^{-}}{\vartheta_{ij}^{(m)}}, 1 + \dfrac{\vartheta_j^{-}}{\vartheta_{ij}^{(l)}} \right) \quad if \in C \end{cases} \tag{2}$$

where {$\tilde{\vartheta}_{ij}^e$ represents the normalized value of the initial decision matrix, where $\vartheta_j^{+} = max\,,(\tilde{\vartheta}_j^{(r)})$,.), i $\vartheta_j^{-} = min(\vartheta_j^{(l)})$, l is the left distribution of the fuzzy number, r is the right distribution of the fuzzy number, and m is the value at which the membership function of the fuzzy number is equal to one.

Step 4. Determining the weighting coefficients of the criteria

In order to determine the weighting coefficients of the criteria, certain experts should be engaged $E = \{E1, E2, \ldots, Ek\}$.

Step 4.1 Prioritization of criteria

Based on the value of the predefined fuzzy linguistic scale, the experts determine the priorities of the criteria. $C = \{C1, C2, \ldots, Cn\}$. In that criterion of high importance, a higher value from the fuzzy linguistic scale is assigned, and vice versa. In this way, the priority vectors are defined $\tilde{P}^e = (\tilde{\gamma}^e_{C1}, \tilde{\gamma}^e_{C2}, \ldots, \tilde{\gamma}^e_{Cn})$ especially for each expert, where $\tilde{\gamma}^e_{Cn}$ it represents the value from the fuzzy linguistic scale that the expert e (1≤*e*≤*k*) mark for criterion *n* .

Step 4.2 Defining the absolute fuzzy anti-ideal point $(\tilde{\gamma}AIP)$

This value is defined by the decision maker, and is a fuzzy number that is smaller than the smallest value from the set of all priority vectors.

Step 4.3 Defining the fuzzy relational vector $\tilde{R}^e$

The relationship between the elements of the priority vector and the absolute anti-ideal point $(\tilde{\gamma}AIP)$ is determined by applying the following equation:

$$\tilde{n}^e_{Cn} = \left(\frac{\tilde{\gamma}^e_{Cn}}{\tilde{\gamma}_{AIP}}\right) = \left(\frac{\gamma^{(l)e}_{Cn}}{\gamma^{(r)}_{AIP}}, \frac{\gamma^{(m)e}_{Cn}}{\gamma^{(m)}_{AIp}}, \frac{\gamma^{(r)\,e}_{Cn}}{\gamma^{(l)}_{AIP}}\right) \tag{3}$$

By applying this equation, the expert's relational vector e(1≤e≤k)is obtained: $R^e = (\tilde{n}^e_{C1}, \tilde{n}^e_{C2}, \ldots, \tilde{n}^e_{Cn})$.

Step 4.4 Determining vector weight coefficients $\omega^e_j = (\tilde{\omega}^e_1, \tilde{\omega}^e_2, \ldots, \tilde{\omega}^e_n)^T$ especially for each expert

Fuzzy value of weighting coefficients criteria for e (1≤e≤k)is obtained by applying the following equation:

$$\tilde{\omega}^e_j = \left(\frac{ln(\tilde{n}^e_{Cn})}{ln\left(\prod_{j=1}^n \tilde{n}^e_{Cn}\right)}\right) = \left(\frac{ln\left(n^{(l)e}_{Cn}\right)}{ln\left(\prod_{j=1}^n n^{(r)e}_{Cn}\right)}, \frac{ln\left(n^{(m)e}_{Cn}\right)}{ln\left(\prod_{j=1}^n n^{(m)e}_{Cn}\right)}, \frac{ln\left(n^{(r)e}_{Cn}\right)}{ln\left(\prod_{j=1}^n n^{(l)e}_{Cn}\right)}\right) \tag{4}$$

where $\tilde{n}^{e}_{Cn}$ erepresents the element of the relational vector R^{e}, $n^{(l)e}_{Cn}$ the left distribution of the fuzzy priority vector, $n^{(r)e}_{Cn}$ ethe right distribution of the fuzzy priority vector, and $n^{(m)e}_{Cn} m$ the value at which the membership function of the fuzzy priority vector is equal to one.

Step 4.5 Calculation of weight coefficients of aggregated fuzzy vectors $\omega_j = (\widetilde{\omega}_1, \widetilde{\omega}_2, \ldots, \widetilde{\omega}_n)^T$

The weight coefficients of the aggregated fuzzy vectors $\omega_j = (\widetilde{\omega}_1, \widetilde{\omega}_2, \ldots, \widetilde{\omega}_n)^T$ Tare determined using the Boneferroni aggregator (Yager, 2009) as follows:

$$\widetilde{\omega}_j = \left(\frac{1}{k(k-1)} \sum_{\substack{i,j=1 \\ i \neq j}}^{k} \widetilde{\omega}_i^{(e)p} \widetilde{\omega}_j^{(e)q}\right)^{\frac{1}{p+q}} = \left\{\left(\frac{1}{k(k-1)} \sum_{\substack{i,j=1 \\ i \neq j}}^{k} \widetilde{\omega}_i^{(l_e)p} \widetilde{\omega}_j^{(l_e)q}\right)^{\frac{1}{p+q}}, \left(\frac{1}{k(k-1)} \sum_{\substack{i,j=1 \\ i \neq j}}^{k} \widetilde{\omega}_i^{(m_e)p} \widetilde{\omega}_j^{(m_e)q}\right)^{\frac{1}{p+q}}, \left(\frac{1}{k(k-1)} \sum_{\substack{i,j=1 \\ i \neq j}}^{k} \widetilde{\omega}_i^{(r_e)p} \widetilde{\omega}_j^{(r_e)q}\right)^{\frac{1}{p+q}}\right\} \tag{5}$$

where $p,q \geq 0$ it represents the stabilization parameters of the Bonoferroni aggregator, $\widetilde{\omega}_j^{e}$ weighting coefficients obtained on the basis of the evaluation of the e -th expert $1 \leq e \leq k$, $\omega_j^{(l_e)}$ the left distribution of fuzzy weighting coefficients $\widetilde{\omega}_j^{e}$, $\omega_j^{(r_e)}$ he right distribution of fuzzy weighting coefficients $\widetilde{\omega}_j^{e}$, i $\omega_j^{(m_e)}$ and the right value at which the fuzzy weighting coefficient function is $\omega_j^{(l_e)}$ equal to one.

Step 4.6 Calculation of final values of weighting coefficients $\omega_j = (\widetilde{\omega}_1, \widetilde{\omega}_2, \ldots, \widetilde{\omega}_n)^T$

The calculation of the final value of the weight coefficients of the criteria is performed by defuzzification as follows:

$$\omega_j = \frac{l+4m+r}{6} \tag{6}$$

Step 5. Calculation of the weight matrix (N)

The elements of the weight matrix $N = \left[\tilde{\xi}_{ij}\right]_{mxn}$ were obtained as follows:

$$\tilde{\xi}_{ij} = \frac{2\widetilde{\varphi}_{ij}^{\omega_j}}{(2-\widetilde{\varphi}_{ij})^{w_j} + \widetilde{\varphi}_{ij}^{\omega_j}} = \left(\frac{2{\varphi_j^{(l)}}^{\omega_j}}{\left(2-\varphi_j^{(r)}\right)^{\omega_j} + {\phi_j^{(r)}}^{\omega_j}}, \frac{2{\varphi_j^{(m)}}^{\omega_j}}{\left(2-\varphi_j^{(m)}\right)^{\omega_j} + {\phi_j^{(m)}}^{\omega_j}}, \frac{2{\varphi_j^{(r)}}^{\omega_j}}{\left(2-\varphi_j^{(l)}\right)^{\omega_j} + {\phi_j^{(l)}}^{\omega_j}}\right) \tag{7}$$

gde je

$$\tilde{\varphi}_{ij} = \frac{ln\left(\tilde{\vartheta}_{ij}\right)}{ln\left(\prod_{i=1}^{m} \tilde{\vartheta}_{ij}\right)} = \left(\frac{ln\left(\vartheta_{ij}^{\prime(l)}\right)}{ln\left(\prod_{i=1}^{m} \vartheta_{ij}^{\prime(r)}\right)}, \frac{ln\left(\vartheta_{ij}^{\prime(m)}\right)}{ln\left(\prod_{i=1}^{m} \vartheta_{ij}^{\prime(m)}\right)}, \frac{ln\left(\vartheta_{ij}^{\prime(r)}\right)}{ln\left(\prod_{i=1}^{m} \vartheta_{ij}^{\prime(l)}\right)}\right) \tag{8}$$

where it $\tilde{\vartheta}_j$, represents the elements of the normalized matrix ~ = $[\vartheta_{ij}]_{mxn}$, ω_j the weight elements of the criteria, *l* – the left distribution of the fuzzy number, *r* – the right distribution of the fuzzy number, and *m* is the value at which the membership function of the fuzzy number is equal to one.

Step 6. Calculation of the final ranking index of alternatives (Q_i)

The final ranking of the alternatives is defined on the basis of value Q_i , whereby the alternative with a higher value is ranked better Q_i. The value Q_i was obtained with the defuzzification of the value $\tilde{Q}_i$ using equation (6). The value $\tilde{Q}_i$ is calculated using the following equation:

$$\tilde{Q}_i = \sum_{j=1}^{n} \tilde{\xi}_{ij} = \left(\sum_{j=1}^{n} \xi_{ij}^{(l)}, \sum_{j=1}^{n} \xi_{ij}^{(m)}, \sum_{j=1}^{n} \xi_{ij}^{(r)}\right) \tag{9}$$

where $\tilde{\xi}_{ij}$ represents the elements of the weight matrix $\tilde{N} = [\tilde{\xi}_{ij}]_{mxn}$, *l* – the left distribution of the fuzzy number, *r* – the right distribution of the fuzzy number, im the value at which the value of belonging to the fuzzy number is equal to one.

The MARCOS (measurement alternatives and ranking according to compromise solution) **method** is based on defining the relationship between alternatives and reference values (ideal and anti-ideal alternatives). Based on the defined relationships, the utility functions of the alternatives are determined, and a compromise ranking is made in relation to ideal and anti-ideal solutions. Decision preferences are defined based on a utility function. Utility functions represent the position of alternatives in relation to ideal and anti-ideal solutions. The best alternative is the one that is closest to the ideal and at the same time furthest from the anti-deal reference point. The MARCOS method proceeds procedurally through the following steps (Stević, 2020a, b):

Step 1: Formation of the initial decision-making matrix

A multi-criteria model involves defining a set of n criteria and m alternatives. In the case of group decision-making, a set of r experts is formed who evaluate the alternatives in relation to the criteria. In that case, the expert evaluation matrices are aggregated into the initial group decision matrices.

Step 2: Forming the expanded initial matrix

In this step, the expansion initial matrix is defined with ideal (*AI*) and anti-ideal (*AAI*) solutions.

$$X = \begin{array}{c} \\ AAI \\ A_1 \\ A_2 \\ \cdots \\ A_m \\ AI \end{array} \begin{array}{c} \begin{array}{cccc} C_1 & C_2 & \cdots & C_n \end{array} \\ \begin{bmatrix} x_{aa1} & x_{aa2} & \cdots & x_{aan} \\ x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ x_{m1} & x_{m2} & \cdots & x_{mn} \\ x_{ai1} & x_{ai2} & \cdots & x_{ain} \end{bmatrix} \end{array} \tag{10}$$

Anti-ideal solution (AAI) is the worst alternative. The ideal solution (AI) is, on the contrary, the alternative with the best characteristics. Depending on the nature of the criteria, AAI and AI are defined by applying the following equations:

$$AAI = \min_i x_{ij} \; if \; j \in B \; and \; \max_i x_{ij} \; if \; j \in C \tag{11}$$

$$AI = \max_i x_{ij} \; if \; j \in B \; and \; \min_i x_{ij} \; if \; j \in C \tag{12}$$

where B represents a benefit and C a cost group of criteria.

Step 3: Normalization of the expanded initial matrix (X)

The elements of the normalized matrix $N = \left[n_{ij}\right]_{mxn}$ are obtained by applying the following equations:

$$n_{ij} = \frac{x_{ai}}{x_{ij}} \; if \; j \in C \tag{13}$$

$$n_{ij} = \frac{x_{ij}}{x_{ai}} \; if \; j \in B \tag{14}$$

where the elements x_{ij} and x_{ai} represent the elements of the matrix X.

Step 4: Defining the weight matrix $V = \left[v_{ij}\right]_{mxn}$

The weighting matrix V is obtained by multiplying the normalized matrix N with the weighting coefficients of the criterion w_j using the following equation:

$$v_{ij} = n_{ij} x v_j \tag{15}$$

Step 5: Determining the degree of utility of alternatives K_i and

The degree of usefulness of alternatives in relation to anti-ideal and ideal solutions is determined using the following equations:

$$K_i^- = \frac{S_i}{S_{aai}} \tag{16}$$

$$K_i^+ = \frac{S_i}{S_{ai}}$$

where $S_i (i=1,2,..,m)$ represents the sum of the elements of the weight matrix V, shown in the following equation:

$$S_i = \sum_{i=1}^{n} v_{ij} \tag{18}$$

Step 6 : Determining the utility function of alternatives $f(K_i)$.

The utility function is the compromise of the observed alternative in relation to ideal and anti-ideal solutions. The utility function of alternatives is defined by the following equation:

$$f(K_i) = \frac{K_i^+ + K_i^-}{1+\frac{1-f(K_i^+)}{f(K_i^+)}+\frac{1-f(K_i^-)}{f(K_i^-)}}; \tag{19}$$

where $f(K_i^-)$ represents the utility function in relation to the anti-ideal solution and $f(K_i^+)$ represents the utility function in relation to the ideal solution.

Utility functions in relation to ideal and anti-ideal solutions are determined using the following equations:

$$f(K_i^-) = \frac{K_i^+}{K_i^+ + K_i^-} \tag{20}$$

$$f(K_i^+) = \frac{K_i^-}{K_i^+ + K_i^-} \tag{21}$$

Step 7: Ranking of alternatives.

The ranking of alternatives is based on the final value of the utility function. The alternative that has the highest possible value of the utility function is preferred.

Results and Discussion

The selected criteria for analyzing the dynamics of the efficiency of the banking sector in Serbia are: C1 - return on assets, C2 - return on capital, C3 - interest margin in relation to gross profit, C4 - non-interest expenses in relation to gross profit and C5 - employee expenses in relation on non-interest expenses. The alternatives were observed in the period 2008 - 2022. Table 1 shows the initial data.

Table 1 - Initial Data - Profitability Indicators of the Banking Sector in Serbia

		Return on assets	Return on capital	Interest margin in relation to gross profit	Non-interest expenses in relation to gross profit	Employee expenses in relation to non-interest expenses
		C1	C2	C3	C4	C5
A1	2008	2.1	9.0	60.5	62.3	36.6
A2	2009	1.0	4.6	62.6	65.6	36.8
A3	2010	1.1	5.3	64.2	65.7	37.4

A4	2011	0.0	0.2	67.3	67.5	35.9
A5	2012	0.4	2.0	64.4	65.9	35.7
A6	2013	-0.1	-0.4	67.5	68.3	35.1
A7	2014	0.1	0.6	66.6	66.9	33.6
A8	2015	0.3	1.5	65.7	64.9	33.0
A9	2016	0.7	3.3	64.6	67.7	33.4
A10	2017	2.1	10.5	58.4	63.2	32.9
A11	2018	2.2	11.3	60.0	62.1	34.0
A12	2019	1.8	9.8	58.8	63.4	32.5
A13	2020	1.1	6.5	60.6	66.3	33.8
A14	2021	1.2	7.8	58.2	71.0	30.2
A15	2022	1.4	10.0	55.8	67.0	28.7
	Statistics					
	Mean	1.0267	5.4667	62.3467	65.8533	33.9733
	Std. Error of Mean	.20318	1.06179	.95966	.62479	.62263
	Median	1.1000	5.3000	62.6000	65.9000	33.8000
	Std. Deviation	.78692	4.11229	3.71673	2.41982	2.41142
	Skewness	.108	-.023	-.133	.188	-.654
	Std. Error of Skewness	.580	.580	.580	.580	.580
	Kurtosis	-1.238	-1.582	-1.235	.089	.315
	Std. Error of Kurtosis	1.121	1.121	1.121	1.121	1.121
	Minimum	-.10	-.40	55.80	62.10	28.70
	Maximum	2.20	11.30	67.50	71.00	37.40
	NPar Tests **Friedman Test**					
	Ranks					
		Mean Rank				
	Return on assets	1.07				
	Return on capital	1.93				
	Interest margin in relation to gross profit	4.7				
	Non-interest expenses in relation to gross profit	4.93				
	Employee expenses in relation to non-interest expenses	3.00				
	Test Statistic[a]					

	N	15				
	Chi-Square	58.507				
	df	4				
	Asymp. Sig.	.000				
	a. Friedman Test					

Source: National Bank of Serbia

Note: The data for 2022 is given for the first quarter. Author's calculated statistics

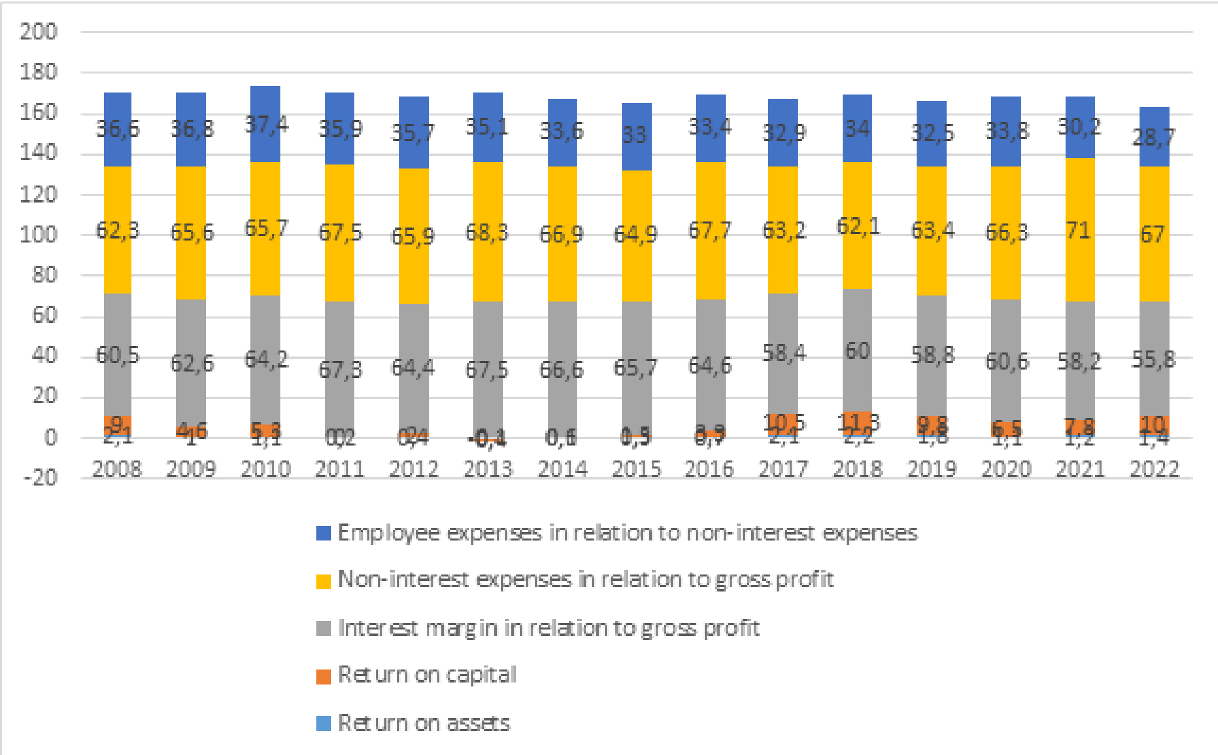

Figure 1 - Indicators of Profitability of the Banking Sector in Serbia

Source: Author's picture

There is a significant difference between the observed statistical variables, so the null hypothesis is rejected.

Table 2 shows the correlation matrix of the initial data.

Table 2 - Correlation

Correlations						
		1	2	3	4	5
1. Return on assets	Pearson Correlation	1	.968**	-.834**	-.637*	-.188
	Sig. (2-tailed)		.000	.000	.011	.503
	N	15	15	15	15	15

2. Return on capital	Pearson Correlation	.968**	1	-.932**	-.495	-.390
	Sig. (2-tailed)	.000		.000	.060	.151
	N	15	15	15	15	15
3. Interest margin in relation to gross profit	Pearson Correlation	-.834**	-.932**	1	.245	.596*
	Sig. (2-tailed)	.000	.000		.379	.019
	N	15	15	15	15	15
4. Non-interest expenses in relation to gross profit	Pearson Correlation	-.637*	-.495	.245	1	-.297
	Sig. (2-tailed)	.011	.060	.379		.282
	N	15	15	15	15	15
5. Employee expenses in relation to non-interest expenses	Pearson Correlation	-.188	-.390	.596*	-.297	1
	Sig. (2-tailed)	.503	.151	.019	.282	
	N	15	15	15	15	15
**. Correlation is significant at the 0.01 level (2-tailed).						
*. Correlation is significant at the 0.05 level (2-tailed).						

Note: Author's calculation

The correlation matrix shows that there is a strong correlation between interest margin in relation to gross profit and return on assets, return on capital and employee costs in relation to non-interest expenses in the banking sector of Serbia at the level of statistical significance. However, there is a weak correlation between the interest margin in relation to gross profit and non-interest expenses in relation to gross profit. Between non-interest expenses in relation to gross profit and return on assets, there is a significant correlation at the level of statistical significance. In contrast, there is a weak correlation between non-interest expenses in relation to gross profit and return on capital, interest margin in relation to gross profit and employee expenses in relation to non-interest expenses. There is a weak correlation between employee expenses in relation to non-interest expenses and return on assets, return on capital and non-interest expenses in relation to gross profit. Therefore, in order to improve the profitability of the banking sector in Serbia, it is necessary to manage primarily the cost elements as efficiently as possible.

The weight coefficients of the criteria were determined using the FLMAW method. In Table 3, for these purposes, the fuzzy scale of criteria prioritization is presented.

Table 3 - Fuzzy Scale for Criteria Prioritization

Fuzzy scale for criteria prioritization				
Fuzzy Linguistic Descriptor	**Abbreviation**	Fuzzy Number		
Absolutely Low	**AL**	1	1	1
Very Low	**VL**	1	1.5	2
Low	**L**	1.5	2	2.5
Medium Low	**ML**	2	2.5	3
Equal	**E**	2.5	3	3.5

Medium High	**MH**	3	3.5	4
High	**H**	3.5	4	4.5
Very High	**VH**	4	4.5	5
Absolutely High	**AH**	4.5	5	5

Table 4 shows the expert evaluation of the criteria.

Table 4 - Evaluation of Criteria

KIND	**1**	**1**	**1**	**-1**	**-1**
	C1	**C2**	**C3**	**C4**	**C5**
P1	**AH**	**L**	**VL**	**E**	**VL**
P2	**AH**	**ML**	**AL**	**H**	**AL**
P3	**AH**	**ML**	**AL**	**MH**	**VL**
P4	**AH**	**E**	**AL**	**VH**	**AL**
P5	**AH**	**E**	**AL**	**VH**	**AL**

YAIP	**0.5**	**0.5**	**0.5**

	C1			**C2**			**C3**			**C4**			**C5**		
P1	9	10	10	3	4	5	2	3	4	5	6	7	2	3	4
P2	9	10	10	4	5	6	2	2	2	7	8	9	2	2	2
P3	9	10	10	4	5	6	2	2	2	6	7	8	2	3	4
P4	9	10	10	5	6	7	2	2	2	8	9	10	2	2	2
P5	9	10	10	5	6	7	2	2	2	8	9	10	2	2	2

Note: Author's calculation

Table 5 shows the vector weight coefficients.

Table 5 - Weight Coefficients Vector

Weight Coefficients Vector	**C1**			**C2**			**C3**			**C4**			**C5**		
W1j	0.255	0.300	0.366	0.127	0.181	0.256	0.080	0.143	0.220	0.186	0.233	0.309	0.080	0.143	0.220
W2j	0.286	0.312	0.333	0.181	0.218	0.259	0.090	0.094	0.100	0.253	0.282	0.318	0.090	0.094	0.100
W3j	0.266	0.301	0.341	0.168	0.210	0.265	0.084	0.091	0.103	0.217	0.254	0.308	0.084	0.144	0.205
W4j	0.277	0.300	0.317	0.203	0.233	0.268	0.087	0.090	0.095	0.262	0.286	0.317	0.087	0.090	0.095
W5j	0.277	0.300	0.317	0.203	0.233	0.268	0.087	0.090	0.095	0.262	0.286	0.317	0.087	0.090	0.095

Note: Author's calculation

Table 6 shows the aggregated fuzzy vectors, the aggregated fuzzy weight coefficient vectors, and the final values of the weight coefficients.

Table 6 - Aggregated Fuzzy Vectors, Aggregated Fuzzy Weight Coefficient Vectors, and Final Values of the Weight Coefficients

Aggregated Fuzzy Vectors	C1			C2			C3			C4			C5		
W1j	0.014	0.018	0.024	0.005	0.008	0.014	0.001	0.003	0.004	0.009	0.013	0.019	0.001	0.003	0.005
W2j	0.015	0.019	0.022	0.006	0.009	0.014	0.002	0.002	0.003	0.012	0.015	0.020	0.002	0.002	0.003
W3j	0.015	0.018	0.023	0.006	0.009	0.014	0.001	0.002	0.003	0.010	0.014	0.019	0.001	0.003	0.005
W4j	0.015	0.018	0.021	0.007	0.010	0.014	0.001	0.002	0.002	0.012	0.015	0.020	0.001	0.002	0.003
W5j	0.015	0.018	0.021	0.007	0.010	0.014	0.001	0.002	0.002	0.012	0.015	0.020	0.001	0.002	0.003
SUM	0.074	0.092	0.112	0.031	0.046	0.069	0.007	0.010	0.014	0.056	0.072	0.098	0.007	0.012	0.020
Aggregated Fuzzy Weight Coefficient Vectors	0.272	0.303	0.334	0.176	0.215	0.263	0.086	0.101	0.120	0.236	0.268	0.314	0.086	0.112	0.140
Final Values Of The Weight Coefficients	**0.303**			**0.216**			**0.102**			**0.270**			**0.112**		

Note: Author's calculation

Table 7 shows the initial matrix.

Table 7 - Initial Matrix

Initial Matrix					
weights of criteria	0,303	0,216	0,102	0,27	0,112
kind of criteria	1	1	1	-1	-1
	C1	C2	C3	C4	C5
A1	2.1	9	60.5	62.3	36.6
A2	1	4.6	62.6	65.6	36.8
A3	1.1	5.3	64.2	65.7	37.4
A4	0	0.2	67.3	67.5	35.9
A5	0.4	2	64.4	65.9	35.7
A6	-0.1	-0.4	67.5	68.3	35.1
A7	0.1	0.6	66.6	66.9	33.6
A8	0.3	1.5	65.7	64.9	33
A9	0.7	3.3	64.6	67.7	33.4

A10	2.1	10.5	58.4	63.2	32.9
A11	2.2	11.3	60	62.1	34
A12	1.8	9.8	58.8	63.4	32.5
A13	1.1	6.5	60.6	66.3	33.8
A14	1.2	7.8	58.2	71	30.2
A15	1.4	10	55.8	67	28.7
MAX	2.2	11.3	67.5	71	37.4
MIN	-0.1	-0.4	55.8	62.1	28.7

Note: Author's calculation

Table 8 shows the expanded initial matrix.

Table 8 - Expanded Initial Matrix

Extended Initial Matrix					
weights of criteria	0.303	0.216	0.102	0.27	0.112
kind of criteria	1	1	1	-1	-1
	C1	**C2**	**C3**	**C4**	**C5**
AAI	-0.1	-0.4	55.8	71	37.4
A1	2.1	9	60.5	62.3	36.6
A2	1	4.6	62.6	65.6	36.8
A3	1.1	5.3	64.2	65.7	37.4
A4	0	0.2	67.3	67.5	35.9
A5	0.4	2	64.4	65.9	35.7
A6	-0.1	-0.4	67.5	68.3	35.1
A7	0.1	0.6	66.6	66.9	33.6
A8	0.3	1.5	65.7	64.9	33
A9	0.7	3.3	64.6	67.7	33.4
A10	2.1	10.5	58.4	63.2	32.9
A11	2.2	11.3	60	62.1	34
A12	1.8	9.8	58.8	63.4	32.5
A13	1.1	6.5	60.6	66.3	33.8
A14	1.2	7.8	58.2	71	30.2
A15	1.4	10	55.8	67	28.7
AI	2.2	11.3	67.5	62.1	28.7

Note: Author's calculation

Table 9 shows the normalized matrix.

Table 9 - Normalized Matrix

Normalized Matrix					
weights of criteria	0.303	0.216	0.102	0.27	0.112
kind of criteria	1	1	1	-1	-1
	C1	**C2**	**C3**	**C4**	**C5**
AAI	-0.04545	-0.0354	0.826667	0.874648	0.76738
A1	0.9545	0.7965	0.8963	0.9968	0.7842
A2	0.4545	0.4071	0.9274	0.9466	0.7799
A3	0.5000	0.4690	0.9511	0.9452	0.7674
A4	0.0000	0.0177	0.9970	0.9200	0.7994
A5	0.1818	0.1770	0.9541	0.9423	0.8039
A6	0.0000	0.0000	1.0000	0.9092	0.8177
A7	0.0455	0.0531	0.9867	0.9283	0.8542
A8	0.1364	0.1327	0.9733	0.9569	0.8697
A9	0.3182	0.2920	0.9570	0.9173	0.8593
A10	0.9545	0.9292	0.8652	0.9826	0.8723
A11	1.0000	1.0000	0.8889	1.0000	0.8441
A12	0.8182	0.8673	0.8711	0.9795	0.8831
A13	0.5000	0.5752	0.8978	0.9367	0.8491
A14	0.5455	0.6903	0.8622	0.8746	0.9503
A15	0.6364	0.8850	0.8267	0.9269	1.0000
AI	1	1	1	1	1

Note: Author's calculation

Table 10 shows the weight-normalized matrix.

Table 10 - Weighted Normalized Matrix

Weighted Normalized Matrix					
	C1	**C2**	**C3**	**C4**	**C5**
AAI	0	0	0.08432	0.236155	0.085947
A1	0.2892	0.1720	0.0914	0.2691	0.0878

A2	0.1377	0.0879	0.0946	0.2556	0.0873
A3	0.1515	0.1013	0.0970	0.2552	0.0859
A4	0.0000	0.0038	0.1017	0.2484	0.0895
A5	0.0551	0.0382	0.0973	0.2544	0.0900
A6	0.0000	0.0000	0.1020	0.2455	0.0916
A7	0.0138	0.0115	0.1006	0.2506	0.0957
A8	0.0413	0.0287	0.0993	0.2584	0.0974
A9	0.0964	0.0631	0.0976	0.2477	0.0962
A10	0.2892	0.2007	0.0882	0.2653	0.0977
A11	0.3030	0.2160	0.0907	0.2700	0.0945
A12	0.2479	0.1873	0.0889	0.2645	0.0989
A13	0.1515	0.1242	0.0916	0.2529	0.0951
A14	0.1653	0.1491	0.0879	0.2362	0.1064
A15	0.1928	0.1912	0.0843	0.2503	0.1120
AI	0.303	0.216	0.102	0.27	0.112

Note: Author's calculation

Table 11 and Figure 2 show the results of the MARCOS method.

Table 11 - Results of the MARCOS Method

	Results of the MARCOS Method								
		Si	Ki-	Ki+	f(K-)	f(K+)	f(K)		Ranking
	AAI	0.4064							
2008	**A1**	0.9096	2.2382	0.9069	0.2884	0.7116	0.8120	0.8120	**3**
2009	**A2**	0.6632	1.6318	0.6612	0.2884	0.7116	0.5920	0.5920	**9**
2010	**A3**	0.6910	1.7001	0.6889	0.2884	0.7116	0.6168	0.6168	**8**
2011	**A4**	0.4435	1.0911	0.4421	0.2884	0.7116	0.3959	0.3959	**14**
2012	**A5**	0.5351	1.3166	0.5335	0.2884	0.7116	0.4777	0.4777	**11**
2013	**A6**	0.4391	1.0803	0.4378	0.2884	0.7116	0.3920	0.3920	**15**
2014	**A7**	0.4722	1.1618	0.4708	0.2884	0.7116	0.4215	0.4215	**13**
2015	**A8**	0.5250	1.2918	0.5235	0.2884	0.7116	0.4687	0.4687	**12**
2016	**A9**	0.6010	1.4788	0.5992	0.2884	0.7116	0.5365	0.5365	**10**
2017	**A10**	0.9412	2.3158	0.9384	0.2884	0.7116	0.8402	0.8402	**2**
2018	**A11**	0.9742	2.3970	0.9713	0.2884	0.7116	0.8697	0.8697	**1**

2019	**A12**	0.8875	2.1836	0.8848	0.2884	0.7116	0.7922	0.7922	**4**
2012	**A13**	0.7153	1.7600	0.7132	0.2884	0.7116	0.6386	0.6386	**7**
2021	**A14**	0.7449	1.8328	0.7427	0.2884	0.7116	0.6650	0.6650	**6**
2022	**A15**	0.8305	2.0435	0.8281	0.2884	0.7116	0.7414	0.7414	**5**
	AI	1.0030							

Note: Author's calculation

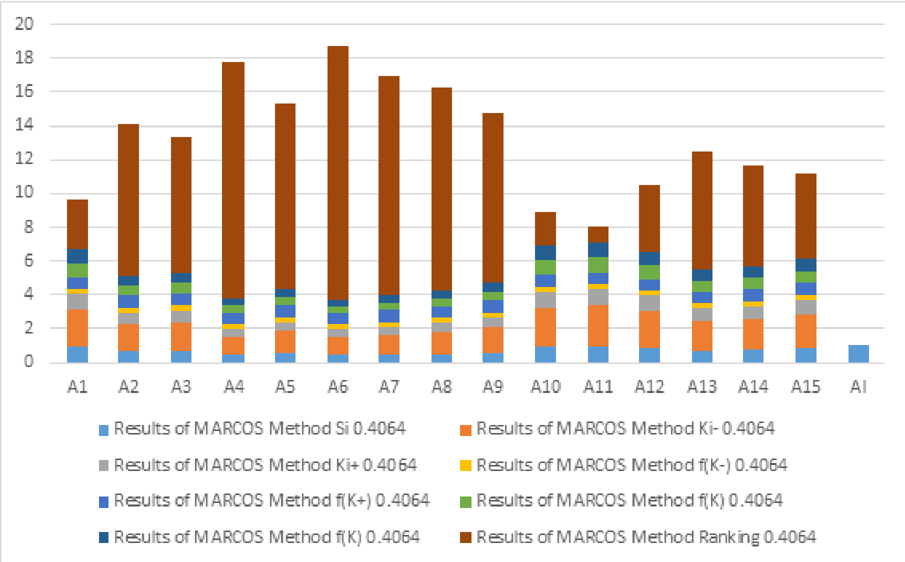

Figure 2 - Ranking of Alternatives
Source: Author's picture

Therefore, the five best years of achieved profitability in the banking sector in Serbia in the period 2008 - 2022 in order are: 2018, 2017, 2008, 2019 and 2022. The worst profitability was achieved in 2013. It is noticeable that profitability has recently improved the banking sector in Serbia. The profitability of the banking sector in Serbia was affected by the economic climate, management of human resources, assets, capital, sales of banking products, costs and profits, digitization of the entire business, the Covid-19 pandemic, and the global energy crisis.

In order to improve the profitability of the banking sector in Serbia, it is necessary to manage human resources, assets, capital, sales, costs and profits as efficiently as possible. Likewise, timely adaptation to changes in the economic climate.

It is recommended that when analyzing the profitability dynamics of the banking sector in Serbia, several methods of multi-criteria decision-making should be used in a comparative manner. In this way, a more complete picture of the profitability dynamics of the banking sector in Serbia is obtained.

Conclusion

Based on the empirical results obtained using the given methodology, the following can be concluded:

1. The five best years of achieved profitability in the banking sector in Serbia in the period 2008 - 2022 in order are: 2018, 2017, 2008, 2019 and 2022. The worst profitability was recorded in 2013. Recently, the profitability of the banking sector in Serbia has improved.

2. The profitability factors of the banking sector in Serbia are the economic climate, management of human resources, assets, capital, sales of banking products, costs and profit. Digitization of the entire business has a significant role in this. The impact of the Covid-19 pandemic, as well as the global energy crisis, is not negligible. Their adequate control can significantly influence the achievement of the target profitability of the banking sector in Serbia.

In order to improve the profitability of the banking sector in Serbia, it is necessary to manage human resources, assets, capital, sales, costs and profits as efficiently as possible. In addition, timely adaptation to changes in the economic climate and the global environment.

References

1. Ali, S.M., Hoq, S.M.N., Bari, A.B.M.M., Kabir, G., Paul, S.K. (2022). Evaluating factors contributing to the failure of information system in the banking industry. PLoS ONE, 17(3): e0265674. https://doi.org/10.1371/journal.pone.0265674
2. Andersen, P.; Petersen, N.C. (1993). A procedure for ranking efficient units in data envelopment analysis. Management Science, 39, 1261-1264.
3. Banker, R.D., Charnes, A. and Cooper, W.W. (1984). Some models for estimating technical and scale inefficiencies in data envelopment analysis. Management Science, 30(9), 1078–1092.
4. Božanić, D., Pamučar, D., Milić,A., Marinković, M.and Komazec, N. (2022). Modification of the Logarithm Methodology of Additive Weights (LMAW) by a Triangular Fuzzy Number and Its Application in Multi-Criteria Decision Making. Axioms, 11(3), 89. https://doi.org/10.3390/axioms11030089
5. Chang, X. and Wang, X. (2020). Research Performance Evaluation of University Based on Super DEA Model. 2020 IEEE 9th Joint International Information Technology and Artificial Intelligence Conference (ITAIC), 1252-1255. doi: 10.1109/ITAIC49862.2020.9339131
6. Chen, Chunhua, Liu, Haohua, Tang, Lijun and Ren, Jianwei. (2021). A Range Adjusted Measure of Super-Efficiency in Integer-Valued Data Envelopment Analysis with Undesirable Outputs. Journal of Systems Science and Information, 9(4), 378-398. https://doi.org/10.21078/JSSI-2021-378-21
7. Cvetkoska, V., and Savić, G. (2017). Efficiency of bank branches: Empirical evidence from a two-phase research approach. Economic Research-Ekonomska istrazivanja, 30(1), 318–333. doi: 10.1080/1331677X.2017.1305775
8. Cvetkoska, V. and Ciković, K.F.(2020). Assessing the relative efficiency of commercial banks in the Republic of North Macedonia: DEA window analysis. Croatian Operational Research Review 217 CRORR 11, 217-227.

9. Cvetkoska, V., Fotova Ciković, K. and Tasheva, M. (2021). Efficiency of Commercial Banking in Developing Countries. Mathematic , 9, 1597. https://doi.org/10.3390/math9141597
10. Demir, G. (2022). Analysis of the financial performance of the deposit banking sector inthe Covid-19 period with LMAW-DNMA methods. International Journal of Insurance and Finance, 2(2), 17-36.https://doi.org/10.52898/ijif.2022.7
11. Fenyves, V. and Tarnóczi, T. (2020). Data envelopment analysis for measuring performance in a competitive market. Problems and Perspectives in Management, 18(1), 315-325. doi:10.21511/ppm.18(1).2020.27
12. Guo, D. and Cai, Z.Q. (2020). Super-Efficiency Infeasibility in the Presence of Nonradial Measurement. Mathematical Problems in Engineering, 2020, Article ID 6264852, 7 pages. https://doi.org/10.1155/2020/6264852
13. Lee, H.S., Chu, C.W. and J. Zhu, J. (2011). Super-efficiency DEA in the presence of infeasibility. European Journal of Operational Research, 212(1), 141–147.
14. Lin, R. (2020). Cross-efficiency evaluation capable of dealing with negative data: A directional distance function based approach. Journal of the Operational Research Society, 71(3), 505-516.
15. Lukic, R., Sokic, M. & Vojteski Kljenak, D. (2017). Efficiency Analysis Of Banking Sector In Republic Of Serbia. Business Excellence and Management, 7(4), 5-17.
16. Lukić, R. (2018a). Bankarsko računovodstvo. Beograd: Ekonomski fakultet.
17. Lukić, R. (2018d). Analysis of the efficiency of insurance companies. In: Insurance in the post-crisis era, Belgrade: Faculty of Economics, University of Belgrade. ISBN:978-86-403-1548-7.
18. Lukić, R. and Hadrović Zekić, B. (2019). Evaluation of efficiency of trade companies in Serbia using the DEA approach. Proceedings of the 19 th International Scientific Conference Business logistics in modern management October 10-11, Osijek, Croatia, Josip Juraj Strossmaye, 145-162.
19. Lukić, R. (2021). Application of the EDAS method in the evaluation of bank efficiency in serbia. Bankarstvo - Banking, 50(2), 13-24. doi: 10.5937/bankarstvo2102064L
20. Maletić, R., Kreća, M., & Maletić, P. (2013). Application of dea methodology in measuring efficiency in the banking sector. Economics of Agriculture, 60(4), 843–855. https://www.ea.bg.ac.rs/index.php/EA/article/view/423
21. Lukić, R. (2022). Evaluation of the efficiency of banks in Serbia using the MABAC method. Bankarstvo - Banking, 2, 35-60. DOI: 10.5937/bankarstvo2202010L
22. Radojko Lukić, (2022b). Analysis of financial performance and efficiency of banks in serbia using fuzzy LMAW and MARCOS methods. Bankarstvo – Banking, 4, 130-169.
23. Milenkovic, N., Radovanov, B., Kalaš, B. and Horvat, A.M. (2022). External Two Stage DEA Analysis of Bank Efficiency in West Balkan Countries. Sustainability, 14, 978. https://doi.org/10.3390/su14020978
24. Pamučar, D., Žižović, M., Biswas, S., Božanić, D. (2021). A new logarithm methodology of additive weights (LMAW) for multi-criteria decision-making: Application in logistics. Facta Univ. Ser. Mech. Eng., 2021, 19, 361–380. https://doi.org/10.22190/FUME210214031P
25. Puška, A., Božanić, D., Nedeljković, M., Janošević, M. (2022). Green Supplier Selection in an Uncertain Environment in Agriculture Using a HybridMCDM Model: Z-Numbers–Fuzzy LMAW–Fuzzy CRADIS Model. Axioms, 11, 427. https://doi.org/ 10.3390/axioms1109042
26. Pendharkar, P.C. (2021). Hybrid radial basis function DEA and its applications to regression, segmentation and cluster analysis problems. Machine Learning with Applications, 6, 100092. https://doi.org/10.1016/j.mlwa.2021.100092.

27. Peykani, P., Seyed Esmaeili, F.S., Mirmozaffari, M., Jabbarzadeh, A. and Khamechian, M. (2022). Input/Output Variables Selection in Data Envelopment Analysis: A Shannon Entropy Approach. Mach. Learn. Knowl. Extr., 4, 688–699. https://doi.org/10.3390/ make4030032
28. Peykani, P., Gheidar-Kheljani, J., Farzipoor Saen, R., & Mohammadi, E. (2022a).Generalized Robust Window Data Envelopment Analysis Approach for DynamicPerformance Measurement under Uncertain Panel Data. Operational Research, 1-36.https://doi.org/10.1007/s12351-022-00729-7.
29. Podinovski, V.V. and Bouzdine-Chameeva, T. (2021). Optimal solutions of multiplier DEA models. J Prod Anal, 56, 45–68. https://doi.org/10.1007/s11123-021-00610-3
30. Radojičić, M., Savić, G., & Jeremić, V. (2018). Measuring the efficiency of banks: the bootstrapped I-distance GAR DEA approach. Technological and Economic Development of Economy, 24(4), 1581-1605. https://doi.org/10.3846/tede.2018.3699
31. Rostamzadeh, R., Akbarian, O., Banaitis, A., & Soltani, Z. (2021). Application of DEA in benchmarking: a systematic literature review from 2003–2020. Technological and Economic Development of Economy, 27(1), 175-222. https://doi.org/10.3846/tede.2021.13406
32. Savić, G., Radosavljević, M., & Ilievski, D. (2012). DEA Window analysis approach for measuring the efficiency of Serbian banks. Management - časopis za teoriju i praksu menadžmenta, 17(65), 5-14.
33. Stević, Ž., Pamučar, D., Puška, A. and Chatterjee, P. (2020a). Sustainable supplier selection in healthcare industries using a new MCDM method: Measurement of alternatives and ranking according to COmpromise solution (MARCOS). Computers & Industrial Engineering, 140, 106231. https://doi.org/10.1016/j.cie.2019.106231.
34. Stević, Ž. and Brković, N. A. (2020b). Novel Integrated FUCOM-MARCOS Model for Evaluation of Human Resources in a Transport Company. Logistics, 4, 4. https://doi.org/10.3390/logistics4010004
35. Tone, K. (2002). A slacks-based measure of super-efficiency in data envelopment analysis. European Journal of Operational Research, 143, 32-41.
36. Tsai, Chi-Mao; Lee, Hsuan-Shih; and Gan, Guo-Ya (2021). A New Fuzzy DEA Model for Solving the MCDM Problems in Supplier Selection. Journal of Marine Science and Technology: 29(1) , Article 7. DOI: 10.51400/2709-6998.1006
37. Ünlü, U., Yalçın, N. and Avşarlıgil, N. (2022). Analysis of Efficiency and Productivity of Commercial Banks in Turkey Pre- and during COVID-19 with an Integrated MCDM Approach. Mathematics, 10(13), 2300. https://doi.org/10.3390/math10132300