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ANALIZA DINAMIKE ADEKVATNOSTI KAPITALA BANKARSKOG SEKTORA U SRBIJI NA BAZI LMAW-DNMA METODE

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Rezime: Problematika analize adekvatnosti kapitala bankarskog sektora je vrlo izazovna, značajna, kontinuirano aktuelna i složena. Polazeći od toga, u ovom radu se analizira adekvatnost kapitala bankarskog sektora u Srbiji na bazi LMAW-DNMA metode. Rezultati LMAW-DNMA metode pokazuju da u top pet godina po adekvatnosti kapitala bankarskog sektora u Srbiji u posmatranom vremenskom periodu 2008 – 2022. god. spadaju po redosledu: 2016, 2012, 2015, 2017. i 2013. god. Najlošija adekvatnost kapitala bankarskog sektora u Srbiji je bila u 2008. god. To znači, drugim rečima, da je u toj godini bankarski sektor u Srbiji bio najviše izložen rizicima poslovanja. Može se slobodno kazati da se u poslednje vreme blago povećavala adekvatnost kapitala bankarskog sektora u Srbiji.

Ključne reči: adekvatnost kapitala, faktori, bankarski sektor, Srbija, LMAW-DNMA metoda

JEL klasifikacija: D40, G21

Uvod

Adekvatnost kapitala je odnos između kapitala i rizične aktive banke, odnosno sposobnost banke da apsorbuje gubitke nastale lošim plasmanima. On osigurava finansijsku stabilnost, likvidnost, solventnost i profitabilnost bankarskog sektora, kao i zaštitu klijenata od potencijalne izloženosti svih vrsta rizika. Istraživanje adekvatnosti kapitala bankarskog sektora je vrlo izazovno, kontinuirano aktuelno, značajno i složeno (Rose, 1996). Imajući to u vidu, predmet analize u ovom radu je adekvatnost kapitala bankarskog sektora u Srbiji na bazi LMAW-DNMA metode. Cilj i svrha toga je da se što realnije sagleda adekvatnost kapitala bankarskog sektora u Srbiji u funkciji unapređenja u budućnosti primenom relevantnih mera. Implikacije su dakle poboljšanje adekvatnosti kapitala bankarskog sektora u Srbiji kao odbrambeni mehanizam zaštite od potencijalnih rizika. U tome se ogleda naučno-stručni doprinos ovog rada.

U uvodu je ukazano na dve vrste literature. Literatura koja se odnosi isključivo na bankarstvo. I literatura koja se odnosi na metode višekriterijumskog odlučivanja. Poznavanje jedne i druge literature je pretpostavka za razumevanje tretiranog problema u ovoj studiji.

Literatura posvećena razvoju i značaju primene DEA modela u svim sektorima, što znači i u finansijskim institucijama vrlo je bogata (Hwang & Yoon,1981, 1995; Chen et al., 2021; Chang & Wang, 2020; Guo & Cai, 2020; Lee et al., 2011; Lin, 2020; Tone, 2002; Podinovski Podinovski & Bouzdine-Chameeva, 2021; Bouzdine-Chameeva et al., 2021; Rostamzadehet al., 2021; Fenyves & Tarnóczi, 2020; Stević & Brković, 2020; Stević et al., 2020). Ona se vrlo uspešno primenjuju i u analizi efikasnosti banaka i osiguravajućih kompanija (Radojicic et al., 2018; Cvetkoska & Savic, 2017; Cvetkoska & Cikovic, 2020; Cvetkovska et al., 2021; Lukic et al., 2017; Lukic & Hadrovic Zekic, 2019; Lukić, 2018a,b, 2021). Isto tako, prilikom analize finansijskih performansi (profitabilnost, likvidnost) i efikasnosti banaka sve se više primenjuju, integralno ili pojedinačno, i različiti metodi višekriterijumskog odlučivanja, uključujući LMAW-DNMA metodu (Ünlü et al., 2022; Ali et al.,2022, Lukic, 2022a,b; 2023a,b,c,d,e; Demir, 2022, Ecer & Pamucar, 2022). Sva relevantna literatura u ovom radu se koristi kao teorijsko-metodološka i empirijska osnova za analizu dinamike adekvatnosti kapitala bankarskog sektora u Srbiji pomoću LMAW-DNMA metode.

Istraživačka hipoteza u ovom radu je zasnovana na činjenici da je kontinuirano praćenje dinamike adekvatnosti kapitala bankarskog sektora, u konkretnom slučaju u Srbiji, osnova za unapređenje u budućnosti primenom relevantnih mera. U tome značajnu ulogu ima i primena LMAW-DNMA metode.

U odnosu na klasičnu racio analizu, LMAW-DNMA metoda pruža realnije informacije o ostvarenoj adekvatnosti kapitala bankarskog sektora u Srbiji jer se bazira na integrisanju nekoliko pokazatelja. Zato se, pored racio analize, preporučuje u analizi dinamike adekvatnosti kapitala bankarskog sektora u Srbiji.

Potrebni empirijski podaci za analizu adekvatnosti kapitala bankarskog sektora u Srbiji na bazi LMAW-DNMA metode su prikupljeni od Narodne banke Srbije. Oni su „proizvedeni" u skladu sa relevantnim međunarodnim standardima. U pogledu međunarodne komparacije dobijenih rezultata adekvatnosti kapitala bankarskog sektora u Srbiji pomoću LMAW-DNMA metode ne postoje s obzirom na to nikakva ograničenje.

Metodologija

Vrlo je izazovno istraživati dinamičke pozicioniranosti adekvatnosti kapitala bankarskog sektora u Srbiji primenom metoda višekriterijumskog odlučivanja. Oni vrlo precizno ukazuju na to u kojim godinama je a u kojim nije bila zadovoljavajuća adekvatnost kapitala. Na osnovu toga se može pouzdano sagledati izloženost bankarskog sektora u Srbiji rizicima poslovanja i neophodnosti preduzimanja relevantnih mera za njihovo optimiziranje. Drugim rečima, u cilju unapređenja adekvatnosti kapitala bankarskog sektora u Srbiji neophodno je, pored ostalog, poznavati i selekciju i rangiranosti po pojedinim godinama. S obzirom na to istraživanje dinamičke pozicioniranosti adekvatnosti kapitala bankarskog sektora u Srbiji izvršićemo primenom LMAW-DNMA metode. U daljim izlaganjima tretirane problematike ukazaćemo na karakteristike LMAW i DNMA metode.

LMAW metoda je najnovija metoda koja se koristi za izračunavanje težina kriterijuma i rangiranje alternativa (Liao, & Wu, 2020; Demir, 2022). Ona se odvija kroz sledeće korake: m alternativa $A = \{A_1, A_2, \dots, A_m\}$ se vrednuju u poređenju sa n kriterijuma $C = \{C_1, C_2, \dots, C_n\}$ učešćem k eksperta $E = \{E_1, E_2, \dots, E_k\}$ prema unapred definisanoj lingvističkoj skali (Pamučar et al, 2021).

Korak 1: Određivanje težinskih koeficijenata kriterijuma

Eksperti $E = \{E_1, E_2, \dots, E_k\}$ određuju prioritete kriterijumima $C = \{C_1, C_2, \dots, C_n\}$ u odnosu na prethodno definisane vrednosti lingvističke skale. Pri tom dodeljuju veću vrednost kriterijumu veće značajnosti i manju vrednost kriterijumu manje važnosti na lingvističkoj skali. Uzgred, dobija se vektor prioriteta. Oznaka γ_{cn}^{e} predstavlja vrednost lingvističke skale koju ekspert e(1≤e≤k) dodeljuje kriteriju- $C_t (1 \le t \le n)$. ≤R^e i Re reprezentuje relacioni vektor e(1≤e≤k) .

Korak 1.1: Definisanje apsolutne anti-idealne tačke γ_{AIP}

Apsolutna idealna tačka treba da bude manja od najmanje vrednosti u vektoru prioriteta. To se izračunava prema jednačini:

$$\gamma_{AIP} = \frac{\gamma_{min}^{e}}{S}$$

gde je γ_{min}^{e} minimalna vrednost vektora prioriteta i S treba da bude veće od bazne logaritamske funkcije. U slučaju korišćenja funkcije Ln, vrednost S se može izabrati kao 3.

Korak 1.2: Određivanje odnosa između vektora prioriteta i apsolutne anti-idealne tačke

Odnos između vektora prioriteta i apsolutne anti-idealne tačke izračunava se korišćenjem sledeće jednačine:

$$n_{Cn}^{e} = \frac{\gamma_{Cn}^{e}}{\gamma_{AIP}} \quad (1)$$

Tako da se relacioni vektor $R^e = (n_{C1}^{e}, n_{C2}^{e}, \dots, n_{Cn}^{e})$ dobija. Pri čemu n_{Cn}^{e} predstavlja vrednost relacionog vektora izvedene iz prethodne jednačine, i R^e reprezentuje relacioni vektor e(1≤e≤k) .

Korak 1.3: Određivanje vektora težinskih koeficijenata

Vektor težinskih koeficijenata $w = (w_1, w_2, \ldots, w_n)^T$ se izračunava od strane eksperta e(1≤e≤k) primenom sledeće jednačine:

$$w_j^e = \frac{\log_A(n_{Cn}^e)}{\log_A\left(\prod_{J=1}^n n_{Cn}^e\right)}, A > 1 \tag{2}$$

gde w_j^e predstavlja težinske koeficijente dobijene prema ocenama eksperta e^{th} i n_{Cn}^e elemente relacionog vektora R. Dobijene vrednosti za težinske koeficijente moraju ispunjavati uslov da je ∑_ $\sum_{j=1}^n w_j^e = 1$.

Primenom Bonferroni agregatora prikazanog u sledećoj jednačini, određuje se agregirani vektor težinskih koeficijenata $w = (w_1, w_2, \ldots, w_n)^T$:

$$W_j = \left(\frac{1}{k.(k-1)} . \sum_{x=1}^{k} \left(w_j^{(x)}\right)^p . \sum_{\substack{y=1 \\ y \neq x}}^{k} \left(w_{ij}^{(y)}\right)^q\right)^{\frac{1}{p+q}} \tag{3}$$

Vrednost p i q su parametri stabilizacije i p,q ≥0 . Rezultirajući težinski koeficijenti treba da ispune uslov da je $\sum_{j=1}^n w_j = 1$.

DNMA metoda je novija metoda za prikazivanje alternativa (Demir, 2022). Koriste se dve različite normalizovane (linerana i vektorska) tehnike, kao i tri različite funkcije spajanja (puna kompenzacija – CCM, nekompenzacija – UCM i nepotpuna kompenzacija – ICM). Koraci primene ove metode su sledeći (Liao & Wu, 2020; Ecer, 2020):

Korak 1: Normalizovana matrica odlučivanja

Elementi matrice odlučivanja normalizuju se sa lineranom $\left(\hat{x}_{ij}^{1N}\right)$ normalizacijom primenom sledeće jednačine:

$$\hat{x}_{ij}^{1N} = 1 - \frac{\left|x^{ij} - r_j\right|}{max\left\{\max_i x^{ij}, r_j\right\} - min\left\{\min_i x^{ij}, r_j\right\}} \tag{4}$$

Vektor $\left(\hat{x}_{ij}^{2N}\right)$ je normalizovan sa korišćenjem sledeće jednačine:

$$\hat{x}_{ij}^{2N} = 1 - \frac{\left|x^{ij} - r_j\right|}{\sqrt{\sum_{i=1}^m (x^{ij})^2 + \left(r_j\right)^2}} \tag{5}$$

Vrednost r_j je ciljna vrednost za c_j kriterijum i smatra se kao $\max_i x^{ij}$ za korisne i $\min_i x^{ij}$ za troškovne kriterijume.

Korak 2: Određivanje težine kriterijuma

Ovaj korak se sastoji od tri faze:

Korak 2.1: U ovoj fazi, standardna devijacija (σ_j) za kriterijum c_j se određuje sa sledećom jednačinom gde je m broj alternativa:

$$\sigma_j = \sqrt{\frac{\sum_{i=1}^{m}\left(\frac{x^{ij}}{\max\limits_{i} x^{ij}} - \frac{1}{m}\sum_{i=1}^{m}\left(\frac{x^{ij}}{\max\limits_{i} x^{ij}}\right)\right)^2}{m}} \tag{6}$$

Korak 2.2: Vrednosti standardne devijacije izračunate za kriterijume se normalizuju sa sledećom jednačinom:

$$w_j^{\sigma} = \frac{\sigma_j}{\sum_{i=1}^{n} \sigma_j} \tag{7}$$

Korak 2.3: Konačno, težine se prilagođavaju sa sledećom jednačinom:

$$\widehat{w}_j = \frac{\sqrt{w_j^{\sigma}.w_j}}{\sum_{i=1}^{n}\sqrt{w_j^{\sigma}.w_j}} \tag{8}$$

Korak 3: Izračunavanje modela agregacije

Tri funkcije agregacije (CCM, UCM i ICM) se izračunavaju posebno za svaku alternativu.

CCM (kompletni kompenzacioni model model) se izračunava primenom sledeće jednačine:

$$u_1(a_i) = \sum_{j=1}^{n} \frac{\widehat{w}_j . \hat{x}_{ij}^{1N}}{\max\limits_{i} \hat{x}_{ij}^{1N}} \tag{9}$$

UCM (nekompenzacioni model) se izračunava pomoću sledeće jednačine:

$$u_2(a_i) = \max_{j} \widehat{w}_j \left(\frac{1 - \hat{x}_{ij}^{1N}}{\max\limits_{i} \hat{x}_{ij}^{1N}}\right) \tag{10}$$

ICM (nepotpuni kompenzacioni model) se izračunava korišćenjem sledeće jednačine:

$$u_3(a_i) = \prod_{j=1}^{n} \left(\frac{\hat{x}_{ij}^{2N}}{\max_i \hat{x}_{ij}^{2N}} \right)^{\hat{w}_j} \qquad (11)$$

Korak 4: Integracija vrednosti korisnosti

Izračunate funkcije korisnosti se integrišu sa sledećom jednačinom korišćenjem Euklidskog (Euclidean) principa udaljenosti:

$$DN_i = w_1 \sqrt{\varphi \left(\frac{u_1(a_i)}{\max_i u_1(a_i)} \right)^2 + (1-\varphi) \left(\frac{m - r_{1(a_i)+1}}{m} \right)^2} - w_2 \sqrt{\varphi \left(\frac{u_2(a_i)}{\max_i u_2(a_i)} \right)^2 + (1-\varphi) \left(\frac{r_2(a_i)}{m} \right)^2} + w_3 \sqrt{\varphi \left(\frac{u_3(a_i)}{\max_i u_3(a_i)} \right)^2 + (1-\varphi) \left(\frac{m - r_3(a_i) + 1}{m} \right)^2} \quad (12) \qquad (12)$$

U ovoj jednačini $r_1(a_i)$ i $r_3(a_i)$ predstavljaju redni broj alternative a_i sortirane prema funkcijama CCM i ICM po opadajućoj vrednosti (prvo veća vrednost). S druge strane, $r_2(a_i)$ pokazuje redni broj u dobijenom redosledu prema rastujućoj vrednosti (prvo manja vrednost) za korišćenu funkciju UCM. Oznaka φ je relativni značaj korišćene podređene vrednosti i u rasponu je [0,1]. Smatra se da se može uzeti kao φ=0,5 . Koeficijenti w_1, w_2, w_3 su dobijene težine korišćenih funkcija CCM, UCM i ICM, respektivno. Suma treba da je jednaka $w_1 + w_2 + w_3 = 1$. Prilikom određivanja težina, ako donosilac odluka pridaje značaj širem rasponu performansi alternativa, on može odrediti veću vrednost za w_1 .U slučaju da donosilac odluka nije spreman da rizikuje, tj. da izabere siromašnu alternativu prema nekom kriterijumu, on može dodeliti veću težinu za w_2 . Međutim, donosilac odluka može dodeliti veću težinu za w_3 ako istovremeno uzima u obzir ukupne performanse i rizik. Najzad, vrednosti DN su sortirane po opadajućoj vrednosti, pri čemu su alternative sa većom vrednošću najbolje.

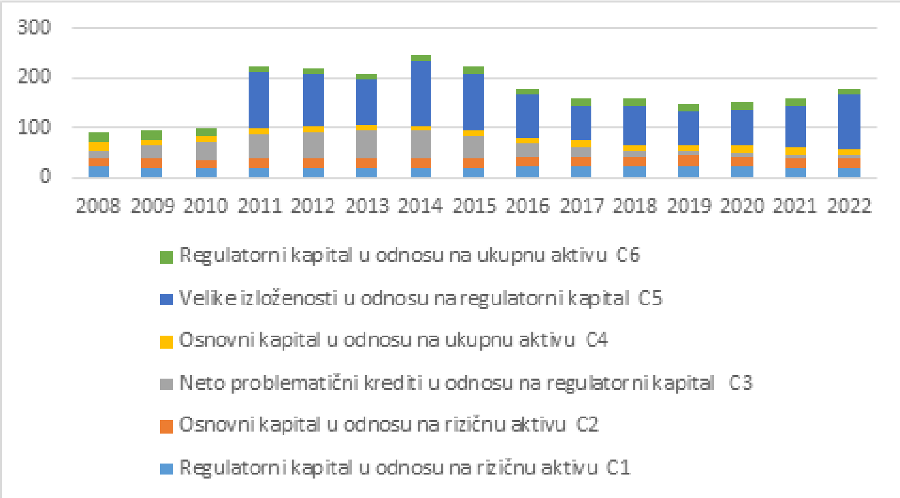
Rezultati i diskusija

U kontekstu analize dinamike adekvatnosti kapitala bankarskog sektora u Srbiji kao kriterijumi su uzeti najvažniji pokazatelji (C1-C6). Alternative (A1-A15) su posmatrane godine. Oni su, kao i inicijalni podaci prikazani u Tabeli 1. Na Slici 1. su prikazani pokazatelji adekvatnosti kapitala bankarskog sektora u Srbiji. (U ovom radu sva izračunavanja i rezultati su autorovi.)

Tabela 1 - Inicijalni podaci

		Regulatorni kapital u odnosu na rizičnu aktivu	Osnovni kapital u odnosu na rizičnu aktivu	Neto problematični krediti u odnosu na regulatorni kapital	Osnovni kapital u odnosu na ukupnu aktivu	Velike izloženosti u odnosu na regulatorni kapital	Regulatorni kapital u odnosu na ukupnu aktivu
		C1	C2	C3	C4	C5	C6
A1	2008	21,9	17,9	15,5	16,8	0,0	20,5
A2	2009	21,4	16,5	26,9	13,1	0,0	17,1
A3	2010	19,9	15,9	35,5	12,8	0,0	16,1
A4	2011	19,1	18,1	52,1	11,5	110,1	12,2
A5	2012	19,9	19,0	52,3	11,6	104,5	12,2
A6	2013	20,9	19,3	55,9	11,2	90,4	12,2
A7	2014	20,0	17,6	56,0	10,1	130,5	11,4
A8	2015	20,9	18,8	44,0	10,7	115,7	11,9
A9	2016	21,8	20,0	27,1	11,6	86,0	12,7
A10	2017	22,6	21,6	17,7	13,7	69,3	14,4
A11	2018	22,3	21,1	9,7	13,5	77,4	14,2
A12	2019	23,4	22,4	6,3	14,4	66,5	15,1
A13	2020	22,4	21,6	6,7	13,1	73,8	13,6
A14	2021	20,8	19,7	7,6	11,8	86,0	12,4
A15	2022	19,5	18,2	7,4	11,0	109,3	11,8
	Statistics						
	Mean	21,1200	19,1800	28,0467	12,4600	74,6333	13,8533
	Std. Error of Mean	,32881	,49331	5,07575	,44388	11,01505	,64549
	Median	20,9000	19,0000	26,9000	11,8000	86,0000	12,7000
	Std. Deviation	1,27347	1,91057	19,65829	1,71914	42,66110	2,49996
	Skewness	,082	,079	,320	1,079	-,939	1,542
	Std. Error of Skewness	,580	,580	,580	,580	,580	,580
	Kurtosis	-,987	-,728	-1,637	1,548	-,134	2,386
	Std. Error of Kurtosis	1,121	1,121	1,121	1,121	1,121	1,121
	Minimum	19,10	15,90	6,30	10,10	,00	11,40
	Maximum	23,40	22,40	56,00	16,80	130,50	20,50

Napomena: Podaci za 2022. su prikazani za III kvartal. Podaci su iskazani u %. Statistika je autorova
Izvor: Narodna banka Srbije



Slika 1 - Pokazatelji adekvatnost kapitala bankarskog sektora u Srbiji

Izvor: Autorova slika

Tako, na primer, prema prikazanoj statistici najveća izloženost rizicima poslovanja u odnosu na regulatorni kapital bankarskog sektora u Srbiji je bila u 2014. god.

Tabela 2. pokazuje prioritizacionu skalu.

Tabela 2 - Prioritizaciona skala

Prioritizaciona skala		
Lingvističke varijable	**Skraćenica**	**Određivanje prioriteta**
Apsolutno nizak	**AL**	1
Veoma nizak	**VL**	1,5
Nizak	**L**	2
Srednje	**M**	2,5
Jednako	**E**	3
Srednje visoko	**MH**	3,5
Visoko	**H**	4
Veoma visoko	**VH**	4,5
Apsolutno visoko	**AH**	5

Tabela 3 - pokazuje evaluaciju kriterijuma od strane donosilaca odluke i njihove težinske koeficijente.

Tabela 3 - Evaluacija, vektor težinskih koeficijenata, agregirani fuzzy vektori i agregirani težinski koeficijenti vektora

Tip	**1**	**1**	**1**	**1**	**1**	**1**
	C1	**C2**	**C3**	**C4**	**C5**	**C6**
E1	**H**	**AH**	**H**	**E**	**MH**	**MH**
E2	**VH**	**VH**	**MH**	**H**	**H**	**MH**
E3	**E**	**MH**	**VH**	**AH**	**AH**	**H**
E4	**MH**	**E**	**E**	**VH**	**AH**	**E**

γ_{AIP}	0.5

	C1	C2	C3	C4	C5	C6	LN(Πη)
R1	8	10	8	6	7	7	12,145
R2	9	9	7	8	8	7	12,445
R3	6	7	9	10	10	8	12,620
R4	7	6	6	9	10	6	11,821

Vektor koeficijenata težine	C1	C2	C3	C4	C5	C6
W1j	0,171	0,190	0,171	0,148	0,160	0,160
W2j	0,177	0,177	0,156	0,167	0,167	0,156
W3j	0,142	0,154	0,174	0,182	0,182	0,165
W4j	0,165	0,152	0,152	0,186	0,195	0,152

Agregirani vektori	C1	C2	C3	C4	C5	C6
W1j	0,007	0,008	0,007	0,007	0,007	0,006
W2j	0,007	0,007	0,006	0,007	0,007	0,006
W3j	0,006	0,007	0,007	0,008	0,008	0,006
W4j	0,007	0,007	0,006	0,008	0,008	0,006
SUM	0,027	0,028	0,027	0,029	0,031	0,025
Vektori agregiranih težinskih koeficijenata	0,1634	0,1677	0,1632	0,1705	0,1760	0,1582

Napomena: Autorovo izračunavanje

Prema tome, u konkretnom slučaju najznačajniji kriterijum je C5 - Velika izloženost u odnosu na regulatorni kapital. To znači, drugim rečima, da se adekvatnim upravljanjem velikim izloženostima (rizicima poslovanja) u odnosu na regulatorni kapital može znatno uticati na ostvarenje ciljne adekvatnosti kapitala bankarskog sektora u Srbiji.

Proračun po fazama i rezultati istraživanja dinamičke pozicioniranosti adekvatnosti kapitala bankarskog sektora u Srbiji primenom date metodologije je prikazano u nižim navedenim tabelama.

U Tabeli 4 - je prikazana inicijalna matrica.

Tabela 4 - Inicijalna matrica

Inicijalna matrica	Tip	1	1	1	1	1	1
	Weight	0,1634	0,1677	0,1632	0,1705	0,1760	0,1582
		C1	**C2**	**C3**	**C4**	**C5**	**C6**
	A1	21,9	17,9	15,5	16,8	0	20,5
	A2	21,4	16,5	26,9	13,1	0	17,1
	A3	19,9	15,9	35,5	12,8	0	16,1
	A4	19,1	18,1	52,1	11,5	110,1	12,2
	A5	19,9	19	52,3	11,6	104,5	12,2
	A6	20,9	19,3	55,9	11,2	90,4	12,2
	A7	20	17,6	56	10,1	130,5	11,4
	A8	20,9	18,8	44	10,7	115,7	11,9
	A9	21,8	20	27,1	11,6	86	12,7
	A10	22,6	21,6	17,7	13,7	69,3	14,4
	A11	22,3	21,1	9,7	13,5	77,4	14,2
	A12	23,4	22,4	6,3	14,4	66,5	15,1
	A13	22,4	21,6	6,7	13,1	73,8	13,6
	A14	20,8	19,7	7,6	11,8	86	12,4
	A15	19,5	18,2	7,4	11	109,3	11,8
	MAX	23,4000	22,4000	56,0000	16,8000	130,5000	20,5000
	MIN	19,1000	15,9000	6,3000	10,1000	0,0000	11,4000

Napomena: Autorovo izračunavanje

Tabela 5 - pokazuje lineranu normalizovanu matricu.

Tabela 5 - Linerna normalizovana matrica

Linearna normalizovana matrica		C1	C2	C3	C4	C5	C6	MAX
	A1	0,6512	0,3077	0,1851	1,0000	0,0000	1,0000	1,0000
	A2	0,5349	0,0923	0,4145	0,4478	0,0000	0,6264	0,6264
	A3	0,1860	0,0000	0,5875	0,4030	0,0000	0,5165	0,5875
	A4	0,0000	0,3385	0,9215	0,2090	0,8437	0,0879	0,9215
	A5	0,1860	0,4769	0,9256	0,2239	0,8008	0,0879	0,9256
	A6	0,4186	0,5231	0,9980	0,1642	0,6927	0,0879	0,9980
	A7	0,2093	0,2615	1,0000	0,0000	1,0000	0,0000	1,0000
	A8	0,4186	0,4462	0,7586	0,0896	0,8866	0,0549	0,8866
	A9	0,6279	0,6308	0,4185	0,2239	0,6590	0,1429	0,6590
	A10	0,8140	0,8769	0,2294	0,5373	0,5310	0,3297	0,8769

	A11	0,7442	0,8000	0,0684	0,5075	0,5931	0,3077	0,8000
	A12	1,0000	1,0000	0,0000	0,6418	0,5096	0,4066	1,0000
	A13	0,7674	0,8769	0,0080	0,4478	0,5655	0,2418	0,8769
	A14	0,3953	0,5846	0,0262	0,2537	0,6590	0,1099	0,6590
	A15	0,0930	0,3538	0,0221	0,1343	0,8375	0,0440	0,8375

Napomena: Autorovo izračunavanje

Tabela 6 - pokazuje vektor normalizovane matrice.

Tabela 6 - Vektor normalizovane matrice

Vektor normalizovane matrice		**C1**	**C2**	**C3**	**C4**	**C5**	**C6**	**MAX**
	A1	0,9824	0,9422	0,7161	1,0000	0,0000	1,0000	1,0000
	A2	0,9765	0,9243	0,7960	0,9282	0,0000	0,9416	0,9765
	A3	0,9589	0,9166	0,8563	0,9223	0,0000	0,9244	0,9589
	A4	0,9495	0,9448	0,9727	0,8971	0,9425	0,8574	0,9727
	A5	0,9589	0,9564	0,9741	0,8990	0,9268	0,8574	0,9741
	A6	0,9707	0,9602	0,9993	0,8913	0,8871	0,8574	0,9993
	A7	0,9601	0,9384	1,0000	0,8699	1,0000	0,8436	1,0000
	A8	0,9707	0,9538	0,9159	0,8816	0,9583	0,8522	0,9707
	A9	0,9812	0,9692	0,7974	0,8990	0,8747	0,8660	0,9812
	A10	0,9906	0,9897	0,7315	0,9398	0,8276	0,8952	0,9906
	A11	0,9871	0,9833	0,6754	0,9359	0,8504	0,8917	0,9871
	A12	1,0000	1,0000	0,6516	0,9534	0,8197	0,9072	1,0000
	A13	0,9883	0,9897	0,6544	0,9282	0,8403	0,8814	0,9897
	A14	0,9695	0,9653	0,6607	0,9029	0,8747	0,8608	0,9695
	A15	0,9542	0,9461	0,6593	0,8874	0,9403	0,8505	0,9542
	Adj Wj	0,1039	0,1317	0,2636	0,1455	0,2023	0,1530	

Napomena: Autorovo izračunavanje

Tabela 7 - pokazuje CCM (Kompletni Kompenzacioni Model).

Tabela 7 - CCM (Kompletni Kompenzacioni Model)

CCM (Kompletni Kompenzacioni Model)	**u1(ai)**	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**	**SUM**
	A1	0,0676	0,0405	0,0488	0,1455	0,0000	0,1530	0,4554
	A2	0,0887	0,0194	0,1744	0,1040	0,0000	0,1530	0,5395
	A3	0,0329	0,0000	0,2636	0,0998	0,0000	0,1345	0,5308
	A4	0,0000	0,0484	0,2636	0,0330	0,1852	0,0146	0,5448
	A5	0,0209	0,0679	0,2636	0,0352	0,1750	0,0145	0,5771
	A6	0,0436	0,0690	0,2636	0,0239	0,1404	0,0135	0,5541
	A7	0,0217	0,0345	0,2636	0,0000	0,2023	0,0000	0,5221
	A8	0,0490	0,0663	0,2256	0,0147	0,2023	0,0095	0,5674
	A9	0,0990	0,1261	0,1674	0,0494	0,2023	0,0332	0,6774
	A10	0,0964	0,1317	0,0690	0,0891	0,1225	0,0575	0,5663
	A11	0,0966	0,1317	0,0225	0,0923	0,1500	0,0588	0,5520

	A12	0,1039	0,1317	0,0000	0,0934	0,1031	0,0622	0,4943
	A13	0,0909	0,1317	0,0024	0,0743	0,1305	0,0422	0,4720
	A14	0,0623	0,1169	0,0105	0,0560	0,2023	0,0255	0,4735
	A15	0,0115	0,0557	0,0070	0,0233	0,2023	0,0080	0,3078

Napomena: Autorovo izračunavanje

Tabela 8 - pokazuje UCM (Nekompenzacioni Model).

Tabela 8 - UCM (Nekompenzacioni Model)

UCM (Nekompenzacioni Model)	u2(ai)	C1	C2	C3	C4	C5	C6	MAX
	A1	0,0362	0,0912	0,2148	0,0000	0,0000	0,0000	0,2148
	A2	0,0152	0,1123	0,0892	0,0415	0,0000	0,0000	0,1123
	A3	0,0710	0,1317	0,0000	0,0457	0,0000	0,0185	0,1317
	A4	0,1039	0,0833	0,0000	0,1125	0,0171	0,1384	0,1384
	A5	0,0830	0,0639	0,0000	0,1103	0,0273	0,1384	0,1384
	A6	0,0603	0,0627	0,0000	0,1215	0,0619	0,1395	0,1395
	A7	0,0821	0,0973	0,0000	0,1455	0,0000	0,1530	0,1530
	A8	0,0548	0,0654	0,0381	0,1308	0,0000	0,1435	0,1435
	A9	0,0049	0,0056	0,0962	0,0961	0,0000	0,1198	0,1198
	A10	0,0075	0,0000	0,1947	0,0563	0,0798	0,0955	0,1947
	A11	0,0072	0,0000	0,2411	0,0532	0,0523	0,0941	0,2411
	A12	0,0000	0,0000	0,2636	0,0521	0,0992	0,0908	0,2636
	A13	0,0130	0,0000	0,2612	0,0712	0,0718	0,1108	0,2612
	A14	0,0416	0,0149	0,2532	0,0895	0,0000	0,1275	0,2532
	A15	0,0923	0,0761	0,2567	0,1221	0,0000	0,1449	0,2567

Napomena: Autorovo izračunavanje

Tabela 9 - pokazuje ICM (Nekompletni Kompenzacioni Model).

Tabela 9 - ICM (Nepotpuni Kompenzacioni Model)

ICM (Nepotpuni Kompenzacioni Model)	u3(ai)	C1	C2	C3	C4	C5	C6	MAX
	A1	0,9982	0,9922	0,9157	1,0000	0,0000	1,0000	0,0000
	A2	1,0000	0,9928	0,9475	0,9926	0,0000	0,9944	0,0000
	A3	1,0000	0,9941	0,9706	0,9944	0,0000	0,9944	0,0000
	A4	0,9975	0,9962	1,0000	0,9883	0,9937	0,9809	0,9572
	A5	0,9984	0,9976	1,0000	0,9884	0,9900	0,9807	0,9557
	A6	0,9970	0,9948	1,0000	0,9835	0,9762	0,9768	0,9301
	A7	0,9958	0,9917	1,0000	0,9799	1,0000	0,9743	0,9428
	A8	1,0000	0,9977	0,9848	0,9861	0,9974	0,9803	0,9473
	A9	1,0000	0,9984	0,9468	0,9874	0,9770	0,9811	0,8946
	A10	1,0000	0,9999	0,9232	0,9924	0,9643	0,9846	0,8697
	A11	1,0000	0,9995	0,9048	0,9923	0,9703	0,9846	0,8573
	A12	1,0000	1,0000	0,8932	0,9931	0,9606	0,9852	0,8395

	A13	0,9998	1,0000	0,8967	0,9907	0,9674	0,9824	0,8442
	A14	1,0000	0,9994	0,9038	0,9897	0,9794	0,9820	0,8598
	A15	1,0000	0,9989	0,9071	0,9895	0,9970	0,9825	0,8783

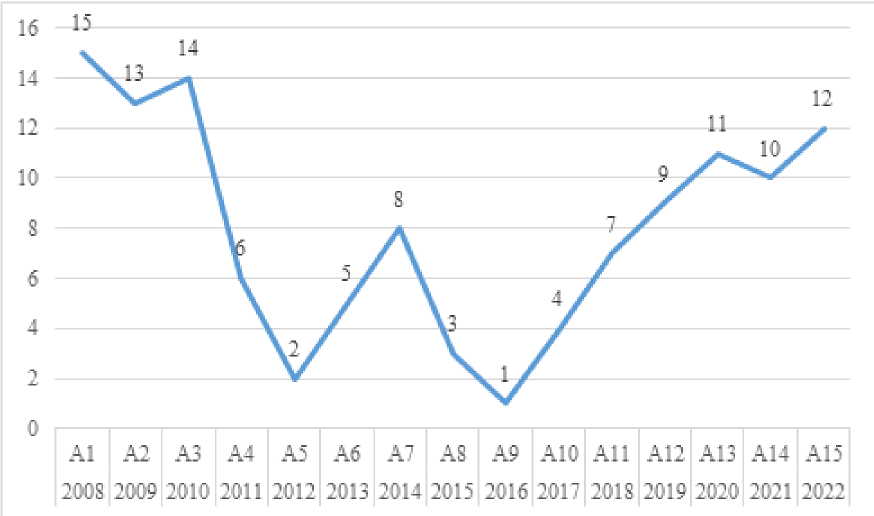
Napomena: Autorovo izračunavanje

Tabela 10 i Slika 2 pokazuju rezultate LMAW-DNMA metode.

Tabela 10 - Rezultati LMAW-DNMA metode

										w1	**w2**	**w3**	
										0.6	**0.1**	**0.3**	
		CCM		φ	**UCM**		φ	**ICM**		φ	**Korisne vrednosti**		**Hijerarhija**
		u1(ai)	**Rang**	**0.5**	**u2(ai)**	**Rang**	**0.5**	**u3(ai)**	**Rang**	**0.5**			
2008	A1	0,4554	14	0,4847	0,2148	10	0,7445	0,0000	13	0,1414	0,4077	0,4077	**15**
2009	A2	0,5395	8	0,6778	0,1123	1	0,3049	0,0000	13	0,1414	0,4796	0,4796	**13**
2010	A3	0,5308	9	0,6449	0,1317	3	0,3806	0,0000	13	0,1414	0,4674	0,4674	**14**
2011	A4	0,5448	7	0,7095	0,1384	4	0,4163	0,9572	1	1,0000	0,7674	0,7674	**6**
2012	A5	0,5771	2	0,8936	0,1384	5	0,4398	0,9557	2	0,9664	0,8701	0,8701	**2**
2013	A6	0,5541	5	0,7768	0,1395	6	0,4690	0,9301	5	0,8608	0,7712	0,7712	**5**
2014	A7	0,5221	10	0,6141	0,1530	8	0,5573	0,9428	4	0,8973	0,6934	0,6934	**8**
2015	A8	0,5674	3	0,8523	0,1435	7	0,5070	0,9473	3	0,9302	0,8411	0,8411	**3**
2016	A9	0,6774	1	1,0000	0,1198	2	0,3349	0,8946	6	0,8117	0,8770	0,8770	**1**
2017	A10	0,5663	4	0,8182	0,1947	9	0,6728	0,8697	8	0,7450	0,7817	0,7817	**4**
2018	A11	0,5520	6	0,7445	0,2411	11	0,8289	0,8573	10	0,6936	0,7377	0,7377	**7**
2019	A12	0,4943	11	0,5672	0,2636	15	1,0000	0,8395	12	0,6482	0,6348	0,6348	**9**
2020	A13	0,4720	13	0,5126	0,2612	14	0,9625	0,8442	11	0,6667	0,6038	0,6038	**11**
2021	A14	0,4735	12	0,5290	0,2532	12	0,8838	0,8598	9	0,7158	0,6205	0,6205	**10**
2022	A15	0,3078	15	0,3248	0,2567	13	0,9217	0,8783	7	0,7752	0,5196	0,5196	**12**
	MAX	0,6774			0,2636			0,9572					

Napomena: Autorovo izračunavanje



Slika 2 - Rangiranje
Izvor: Autorova slika

Vrlo je izazovno istraživati, kao što pokazuju napred navedeni proračuni po fazama i rezultati, dinamičke pozicioniranosti adekvatnosti kapitala bankarskog sektora u Srbiji primenom metoda višekriterijumskog odlučivanja. Oni vrlo precizno ukazuju na to u kojim godinama je, a u kojim nije bila zadovoljavajuća adekvatnost kapitala. Na osnovu toga se može pouzdano sagledati izloženost bankarskog sektora u konkretnom slučaju u Srbiji rizicima poslovanja i neophodnosti preduzimanja relevantnih mera za njihovo optimiziranje.

Prema tome, prema rezultatima LMAW-DNMA metode u top pet godina po adekvatnosti kapitala bankarskog sektora u Srbiji u posmatranom vremenskom periodu 2008 – 2022. spadaju po redosledu: 2016, 2012, 2015, 2017. i 2013. Najlošija adekvatnost kapitala bankarskog sektora u Srbiji je bila u 2008. On je u toj godini bio dakle najviše izložen rizicima poslovanja.

U poslednje vreme na adekvatnost kapitala bankarskog sektora u svetu, i u Srbiji, uticala je, pored ostalog, pandemija korona virusa COVID-19. Ona je prouzrokovala pada privrednih, a time i bankarskih aktivnosti. Delimično je negativan uticaj ublažen elektronskim bankarstvom.

U funkciji poboljšanja adekvatnosti kapitala bankarskog sektora u Srbiji neophodno je, pored ostalog, što adekvatnije upravljati rizicima poslovanja svih vrsta. To znači, drugim rečima, da se adekvatnim upravljanjem velikim izloženostima (rizicima poslovanja) u odnosu na regulatorni kapital može znatno uticati na ostvarenje ciljne adekvatnosti kapitala bankarskog sektora u Srbiji. U tome značajnu ulogu ima supervizija i revizija.

Zaključak

Na osnovu dobijenih rezultata empirijskog istraživanja adekvatnosti kapitala bankarskog sektora u Srbiji primenom LMAW-DNMA metode može se zaključiti sledeće: prema rezultatima LMAW-DNMA metode u top pet godina po adekvatnosti kapitala bankarskog sektora u Srbiji u posmatranom vremenskom periodu 2008 – 2022. spadaju po redosledu: 2016, 2012, 2015, 2017. i 2013. Najlošija adekvatnost kapitala bankarskog sektora u Srbiji je bila u 2008. U toj godini, drugim rečima, bankarski sektor u Srbiji je bio najviše izložen rizicima poslovanja.

U periodu 2019 – 2022. god. na adekvatnost kapitala bankarskog sektora u Srbiji, a što je slučaj i u svetu, uticala je u izvesnoj meri pandemija korona virus COVID-19 tako što je smanjila privredne aktivnosti a time i bankarske. To se negativno odrazilo i na ukupne performanse bankarskog sektora. Negativan uticaj delimično je ublažen elektronskim a.

U bankarskom sektoru Srbije sa adekvatnim upravljanjem rizicima poslovanja u odnosu na regulatorni kapital može se znatno uticati na ostvarenje ciljne adekvatnosti kapitala. Nesumnjivo je da u tome značajnu ulogu ima supervizija i revizija. Istraživanjem je utvrđeno da efikasna supervizija i revizija znatno ublažavaju negativan uticaj rizika na performanse bankarskog sektora.

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ANALYSIS OF THE DYNAMICS OF THE CAPITAL ADEQUACY OF THE BANK SECTOR IN SERBIA BASED ON THE LMAW-DNMA METHOD

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Summary: The issue of capital adequacy analysis in the banking sector is very challenging, significant, continuously updated, and complex. Based on that, this paper analyzes the capital adequacy of the banking sector in Serbia based on the LMAW-DNMA method. According to the results of the LMAW-DNMA method, the top five years in terms of capital adequacy of the banking sector in Serbia in the observed period 2008 - 2022 are in order: 2016, 2012, 2015, 2017, and 2013. This means, in other words, that in that year the banking sector in Serbia was more exposed to business risks. It is safe to say that recently the capital adequacy of the banking sector in Serbia has increased slightly.

Keywords: capital adequacy, factors, banking sector, Serbia, LMAW-DNMA method

JEL classification: D40, G21

Introduction

Capital adequacy is the ratio between the capital and risky assets of the bank, that is, the ability of the bank to absorb losses caused by bad placements. It ensures financial stability, liquidity, solvency, and profitability of the banking sector, as well as the protection of clients from potential exposure to all types of risks. Investigating the capital adequacy of the banking sector is very challenging, continuously updated, significant, and complex (Rose, 1996). Bearing that in mind, the subject of analysis in this paper is the capital adequacy of the banking sector in Serbia based on the LMAW-DNMA method. The aim and purpose of this is to assess the adequacy capital of the banking sector in Serbia as realistically as possible to improve it in the future by applying relevant measures. The implication is, therefore, the improvement of capital adequacy of the banking sector in Serbia as a defense mechanism of protection against potential risks. This is the scientific and professional contribution of this work.

In the introduction, two types of literature were pointed out. Literature related exclusively to banking, and literature related to multi-criteria decision-making methods. The knowledge of both is a prerequisite for understanding the problem treated in this study.

The literature devoted to the development and importance of the application of the DEA model in all economic sectors, which means also in financial institutions is plentiful (Hwang & Yoon,1981, 1995; Chen et al., 2021; Chang & Wang, 2020; Guo & Cai, 2020; Lee et al., 2011; Lin, 2020; Tone, 2002; Podinovski Podinovski & Bouzdine-Chameeva, 2021; Bouzdine-Chameeva et al., 2021; Rostamzadehet al., 2021; Fenyves & Tarnóczi, 2020; Stević & Brković, 2020; Stević et al., 2020). They are also very successfully applied in the analysis of the efficiency of banks and insurance companies (Radojicic et al., 2018; Cvetkoska & Savic, 2017; Cvetkoska & Cikovic, 2020; Cvetkovska et al., 2021; Lukic et al., 2017; Lukic & Hadrovic Zekic, 2019; Lukic, 2018a,b, 2021). Likewise, when analyzing financial performance (profitability, liquidity) and efficiency, banks increasingly apply, integrally or individually, different methods of multi-criteria decision-making, including the LMAW-DNMA method (Ünlü et al., 2022; Ali et al., 2022, Lukic, 2022a,b; 2023a,b,c,d,e; Demir, 2022; Ecer & Pamucar, 2022). All relevant literature in this paper is used as a theoretical-methodological and empirical basis for the analysis of capital adequacy dynamics of the banking sector in Serbia using the LMAW-DNMA method.

The research hypothesis in this paper is based on the fact that continuous monitoring of the capital adequacy dynamics of the banking sector, in the specific case of Serbia, is the basis for improvement in the future by applying relevant measures. The application of the LMAW-DNMA method plays a significant role in this.

Compared to the classic ratio analysis, the LMAW-DNMA method provides more realistic information about the capital adequacy of the banking sector in Serbia because it is based on the integration of several indicators. That is why, in addition to the ratio analysis, it is recommended in the analysis of capital adequacy dynamics of the banking sector in Serbia.

Necessary empirical data for capital adequacy analysis of the banking sector in Serbia based on the LMAW-DNMA method were collected from the National Bank of Serbia. They are "manufactured" by the relevant international standards. Regarding the international comparison of the obtained results of the capital adequacy of the banking sector in Serbia using the LMAW-DNMA method, there are no limitations.

Methodology

It is very challenging to investigate the dynamic positioning of the capital adequacy of the banking sector in Serbia using multi-criteria decision-making methods. They very precisely indicate in which years capital adequacy was and was not satisfactory. Based on this, one can reliably assess the exposure of the banking sector in Serbia to business risks and the necessity of taking relevant measures to optimize them. In other words, to improve the capital adequacy of the banking sector in Serbia, it is necessary, among other things, to know the selection and ranking by individual years. With that in mind, we will conduct research into the dynamic positioning of capital adequacy of the banking sector in Serbia using the LMAW-DNMA method. In further presentations of the treated issues, we will point out the characteristics of the LMAW and DNMA methods.

The **LMAW** method is the latest method used to calculate criteria weights and rank alternatives (Liao, & Wu, 2020; Demir, 2022). It takes place through the following steps: m alternatives $A = \{A_1, A_2, \dots, A_m\}$ are evaluated in comparison with n criteria $C = \{C_1, C_2, \dots, C_n\}$ with the participation of k experts $E = \{E_1, E_2, \dots, E_k\}$ and according to a predefined linguistic scale (Pamučar et al, 2021).

Step 1: Determination of weight coefficients of criteria

Experts $E = \{E_1, E_2, \dots, E_k\}$ set priorities with criteria $C = \{C_1, C_2, \dots, C_n\}$ about previously defined values of the linguistic scale. At the same time, they assign a higher value to the criterion of greater importance and a lower value to the criterion of less importance on the linguistic scale. By the way, the priority vector is obtained. The label γ_{cn}^{e} represents the value of the linguistic scale that the expert e(1≤e≤k) assigns to the criterion $C_t (1 \le t \le n)$.

Step 1.1: Defining the absolute anti-ideal point γ_{AIP}

The absolute ideal point should be less than the smallest value in the priority vector. It is calculated according to the equation:

$$\gamma_{AIP} = \frac{\gamma_{min}^{e}}{S}$$

where is γ_{min}^{e} the minimum value of the priority vector and S should be greater than the base logarithmic function. In the case of using the function Ln, the value of S can be chosen as 3.

Step 1.2: Determining the relationship between the priority vector and the absolute anti-ideal point

The relationship between the priority vector and the absolute anti-ideal point is calculated using the following equation:

$$n_{Cn}^{e} = \frac{\gamma_{Cn}^{e}}{\gamma_{AIP}} \quad (1)$$

So the relational vector $R^e = (n_{C1}^{e}, n_{C2}^{e}, \dots, n_{Cn}^{e})$. is obtained. Where n_{Cn}^{e} represents the value of the real vector derived from the previous equation, and R^e represents the relational vector e(1≤e≤k).

Step 1.3: Determination of the vector of weight coefficients

The vector of weight coefficients $w = (w_1, w_2, \dots, w_n)^T$ is calculated by the expert $e(1 \le e \le k)$ using the following equation

$$w_j^e = \frac{\log_A(n_{Cn}^e)}{\log_A\left(\prod_{J=1}^{n} n_{Cn}^e\right)}, A > 1 \tag{2}$$

where w_j^e represents the weighting coefficients obtained according to expert evaluations e^{th} and the n_{Cn}^e elements of the realization vector R. The obtained values for the weighting coefficients must meet the condition that $\sum_{j=1}^{n} w_j^e = 1$.

By applying the Bonferroni aggregator shown in the following equation, the aggregated vector of weight coefficients is determined $w = (w_1, w_2, \dots, w_n)^T$:

$$W_j = \left(\frac{1}{k.(k-1)} . \sum_{x=1}^{k} \left(w_j^{(x)}\right)^p . \sum_{\substack{y=1 \\ y \ne x}}^{k} \left(w_{ij}^{(y)}\right)^q \right)^{\frac{1}{p+q}} \tag{3}$$

The values of p and q are stabilization parameters and p,q ≥0. The resulting weight coefficients should fulfil the condition that $\sum_{j=1}^{n} w_j = 1$.

The **DNMA** method is a newer method for showing alternatives (Demir, 2022). Two different normalized (linear and vector) techniques are used, as well as three different coupling functions (full compensation - CCM, non-compensation - UCM, and incomplete compensation - ICM). The steps for applying this method are as follows (Liao & Wu, 2020; Ecer, 2020):

Step 1: Normalized decision matrix

The elements of the decision matrix are normalized with linear $\left(\hat{x}_{ij}^{1N}\right)$ normalization using the following equation:

$$\hat{x}_{ij}^{1N} = 1 - \frac{\left|x^{ij} - r_j\right|}{max\left\{\max_i x^{ij}, r_j\right\} - min\left\{\min_i x^{ij}, r_j\right\}} \tag{4}$$

The vector $\left(\hat{x}_{ij}^{2N}\right)$ is normalized using the following equation:

$$\hat{x}_{ij}^{2N} = 1 - \frac{\left|x^{ij} - r_j\right|}{\sqrt{\sum_{i=1}^{m} (x^{ij})^2 + \left(r_j\right)^2}} \tag{5}$$

The value ı r_j he target value for c_ C_j ꞉ criterion and is considered $\max_i x^{ij}$ for both utility and ı$\min_i x^{ij}$ cost criteria.

Step 2: Determining the weight of the criteria

This step consists of three phases:

Step 2.1: In this phase, the standard deviation (σ_j) for the criterion c_j determined with the following equation where m is the number of alternatives:

$$\sigma_j = \sqrt{\frac{\sum_{i=1}^{m}\left(\frac{x^{ij}}{\max_i x^{ij}} - \frac{1}{m}\sum_{i=1}^{m}\left(\frac{x^{ij}}{\max_i x^{ij}}\right)\right)^2}{m}} \tag{6}$$

Step 2.2: Values of the standard deviation calculated for the criteria normalize with the following equation:

$$w_j^{\sigma} = \frac{\sigma_j}{\sum_{i=1}^{n}\sigma_j} \tag{7}$$

Step 2.3: Finally, the weights are adjusted with the following equation:

$$\widehat{w}_j = \frac{\sqrt{w_j^{\sigma}.w_j}}{\sum_{i=1}^{n}\sqrt{w_j^{\sigma}.w_j}} \tag{8}$$

Step 3: Calculating the aggregation model

Three aggregation functions (CCM, UCM, and ICM) are calculated separately for each alternative.

The CCM (Complete Compensatory Model Model) is calculated using the following equation:

$$u_1(a_i) = \sum_{j=1}^{n}\frac{\widehat{w}_j.\hat{x}_{ij}^{1N}}{\max_i \hat{x}_{ij}^{1N}} \tag{9}$$

The UCM (Non Compensatory model) is calculated using the following equation:

$$u_2(a_i) = \max_j \widehat{w}_j\left(\frac{1-\hat{x}_{ij}^{1N}}{\max_i \hat{x}_{ij}^{1N}}\right) \tag{10}$$

The ICM (Incomplete Compensation Model) is calculated using the following equation:

$$u_3(a_i) = \prod_{j=1}^{n} \left(\frac{\hat{x}_{ij}^{2N}}{\max_i \hat{x}_{ij}^{2N}} \right)^{\hat{w}_j} \tag{11}$$

Step 4: Integration of utility values

The calculated utility functions are integrated with the following equation using the Euclidean principle of distance:

$$DN_i = w_1 \sqrt{\varphi \left(\frac{u_1(a_i)}{\max_i u_1(a_i)} \right)^2 + (1-\varphi) \left(\frac{m - r_{1(a_i)+1}}{m} \right)^2} - w_2 \sqrt{\varphi \left(\frac{u_2(a_i)}{\max_i u_2(a_i)} \right)^2 + (1-\varphi) \left(\frac{r_2(a_i)}{m} \right)^2} + w_3 \sqrt{\varphi \left(\frac{u_3(a_i)}{\max_i u_3(a_i)} \right)^2 + (1-\varphi) \left(\frac{m - r_3(a_i) + 1}{m} \right)^2} \tag{12}$$

In this case, the means $r_1(a_i)$ i $r_3(a_i)$ represent the ordinal number of the alternative a_i sorted by CCM and ICM functions in descending value (higher value first). On the other hand, $r_2(a_i)$ it shows the sequence number in the obtained order according to the increasing value (smaller value first) for the UCM function used. The label φ is the relative importance of the child value used and is in the range [0.1]. It is considered that it can be taken as φ=0.5. The coefficients w_1, w_2, w_3 are obtained weights of the used functions CCM, UCM, and ICM, respectively. The sum should be equal to $w_1 + w_2 + w_3 = 1$. When determining the weights, if the decision maker attaches importance to a wider range of performance alternatives, they can set a higher value for w_1. In case the decision maker is not willing to take risks, ie. to choose a poor alternative according to some criterion, they can assign a higher weight to w_2 . However, the decision maker may assign a greater weight to w_3 if they simultaneously consider overall performance and risk. Finally, the DN values are sorted in descending order, with the higher-value alternatives being the best.

Results and Discussion

In the context of the analysis of the capital adequacy dynamics of the banking sector in Serbia, the most important indicators were taken as criteria (C1-C6). Alternatives (A1-A15) have been observed for years. They, as well as the initial data, are shown in Table 1. Figure 1 shows the capital adequacy indicators of the banking sector in Serbia. (In this paper, all calculations and results are the author's.)

Table 1 - Initial data

		Regulatory capital to risk-weighted assets	Regulatory Tier 1 capital to risk-weighted assets	Nonperforming loans net of provisions to regulatory capital	Regulatory Tier 1 capital to assets	Large exposures to capital	Regulatory capital to assets
		C1	C2	C3	C4	C5	C6
A1	2008	21.9	17.9	15.5	16.8	0.0	20.5
A2	2009	21.4	16.5	26.9	13.1	0.0	17.1
A3	2010	19.9	15.9	35.5	12.8	0.0	16.1
A4	2011	19.1	18.1	52.1	11.5	110.1	12.2
A5	2012	19.9	19.0	52.3	11.6	104.5	12.2
A6	2013	20.9	19.3	55.9	11.2	90.4	12.2
A7	2014	20.0	17.6	56.0	10.1	130.5	11.4
A8	2015	20.9	18.8	44.0	10.7	115.7	11.9
A9	2016	21.8	20.0	27.1	11.6	86.0	12.7
A10	2017	22.6	21.6	17.7	13.7	69.3	14.4
A11	2018	22.3	21.1	9.7	13.5	77.4	14.2
A12	2019	23.4	22.4	6.3	14.4	66.5	15.1
A13	2020	22.4	21.6	6.7	13.1	73.8	13.6
A14	2021	20.8	19.7	7.6	11.8	86.0	12.4
A15	2022	19.5	18.2	7.4	11.0	109.3	11.8
	Statistics						
	Mean	21.1200	19.1800	28.0467	12.4600	74.6333	13.8533
	Std. Error of Mean	.32881	.49331	5.07575	.44388	11.01505	.64549
	Median	20.9000	19.0000	26.9000	11.8000	86.0000	12.7000
	Std. Deviation	1.27347	1.91057	19.65829	1.71914	42.66110	2.49996
	Skewness	.082	.079	.320	1.079	-.939	1.542
	Std. Error of Skewness	.580	.580	.580	.580	.580	.580
	Kurtosis	-.987	-.728	-1.637	1.548	-.134	2.386
	Std. Error of Kurtosis	1.121	1.121	1.121	1.121	1.121	1.121
	Minimum	19.10	15.90	6.30	10.10	.00	11.40
	Maximum	23.40	22.40	56.00	16.80	130.50	20.50

Note: Data for 2022 are shown for the 3rd quarter. Data is expressed in %. Statistics are the author's
Source: National Bank of Serbia

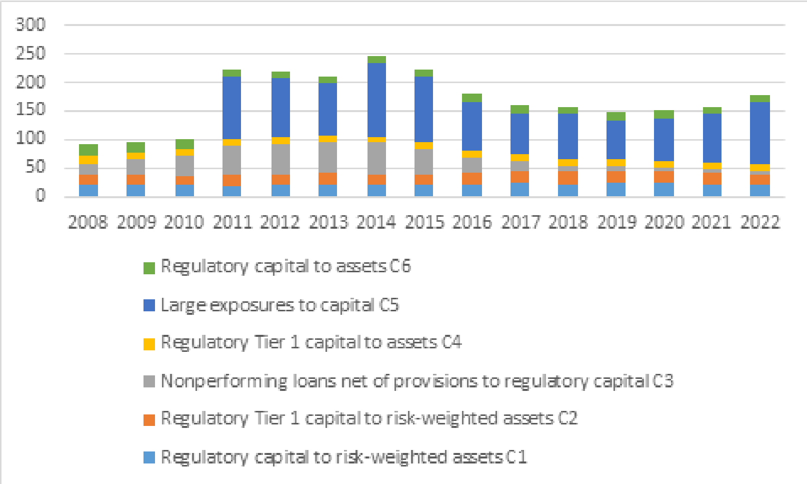

Figure 1 - Capital adequacy indicators of the banking sector in Serbia Source: Author's picture

Thus, for example, according to the presented statistics, the highest exposure to business risks about the regulatory capital of the banking sector in Serbia was in 2014.

Table 2 shows the prioritization scale.

Prioritization Scale		
Linguistic Variables	**Abbreviation**	**Prioritization**
Low	**AL**	1
Very Low	**VL**	1.5
Low	**L**	2
Medium	**M**	2.5
Equal	**E**	3
Medium High	**MH**	3.5
High	**H**	4
Very High	**VH**	4.5
High	**AH**	5

Table 3 shows the evaluation of the criteria by the decision makers and their weight coefficients.

Table 3 - Evaluation, Vector of Weighting Coefficients, Aggregated Fuzzy Vectors, and Aggregated Weighting Coefficients of the Vector

KIND	1	1	1	1	1	1
	C1	C2	C3	C4	C5	C6
E1	H	AH	H	E	MH	MH
E2	VH	VH	MH	H	H	MH
E3	E	MH	VH	AH	AH	H
E4	MH	E	E	VH	AH	E

γ_{AIP}	0.5

	C1	C2	C3	C4	C5	C6	LN(Πη)
R1	8	10	8	6	7	7	12.145
R2	9	9	7	8	8	7	12.445
R3	6	7	9	10	10	8	12.620
R4	7	6	6	9	10	6	11.821

Weight Coefficients Vector	C1	C2	C3	C4	C5	C6
W1j	0.171	0.190	0.171	0.148	0.160	0.160
W2j	0.177	0.177	0.156	0.167	0.167	0.156
W3j	0.142	0.154	0.174	0.182	0.182	0.165
W4j	0.165	0.152	0.152	0.186	0.195	0.152

Aggregated Fuzzy Vectors	C1	C2	C3	C4	C5	C6
W1j	0.007	0.008	0.007	0.007	0.007	0.006
W2j	0.007	0.007	0.006	0.007	0.007	0.006
W3j	0.006	0.007	0.007	0.008	0.008	0.006
W4j	0.007	0.007	0.006	0.008	0.008	0.006
SUM	0.027	0.028	0.027	0.029	0.031	0.025
Aggregated Weight Coefficient Vectors	0.1634	0.1677	0.1632	0.1705	0.1760	0.1582

Note: Author's calculation

Therefore, in this particular case, the most important criterion is C5 - Large exposures to capital. This means, in other words, that adequate management of large exposures (business risks) about regulatory capital can significantly influence the achievement of the target capital adequacy of the banking sector in Serbia.

The calculation by stages and the results of the research on the dynamic positioning of capital adequacy of the banking sector in Serbia using the given methodology are shown in the tables below.

Table 4 shows the initial matrix.

Table 4 - Initial Matrix

INITIAL MATRIX	KIND	1	1	1	1	1	1
	Weight	0.1634	0.1677	0.1632	0.1705	0.1760	0.1582
		C1	**C2**	**C3**	**C4**	**C5**	**C6**
	A1	21.9	17.9	15.5	16.8	0	20.5
	A2	21.4	16.5	26.9	13.1	0	17.1
	A3	19.9	15.9	35.5	12.8	0	16.1
	A4	19.1	18.1	52.1	11.5	110.1	12.2
	A5	19.9	19	52.3	11.6	104.5	12.2
	A6	20.9	19.3	55.9	11.2	90.4	12.2
	A7	20	17.6	56	10.1	130.5	11.4
	A8	20.9	18.8	44	10.7	115.7	11.9
	A9	21.8	20	27.1	11.6	86	12.7
	A10	22.6	21.6	17.7	13.7	69.3	14.4
	A11	22.3	21.1	9.7	13.5	77.4	14.2
	A12	23.4	22.4	6.3	14.4	66.5	15.1
	A13	22.4	21.6	6.7	13.1	73.8	13.6
	A14	20.8	19.7	7.6	11.8	86	12.4
	A15	19.5	18.2	7.4	11	109.3	11.8
	MAX	23.4000	22.4000	56.0000	16.8000	130.5000	20.5000
	MIN	19.1000	15.9000	6.3000	10.1000	0.0000	11.4000

Note: Author's calculation

Table 5 shows the linear normalized matrix.

Table 5 - Linear Normalization Matrix

Linear Normalization MATRIX		C1	C2	C3	C4	C5	C6	MAX
	A1	0.6512	0.3077	0.1851	1.0000	0.0000	1.0000	1.0000
	A2	0.5349	0.0923	0.4145	0.4478	0.0000	0.6264	0.6264
	A3	0.1860	0.0000	0.5875	0.4030	0.0000	0.5165	0.5875
	A4	0.0000	0.3385	0.9215	0.2090	0.8437	0.0879	0.9215
	A5	0.1860	0.4769	0.9256	0.2239	0.8008	0.0879	0.9256
	A6	0.4186	0.5231	0.9980	0.1642	0.6927	0.0879	0.9980
	A7	0.2093	0.2615	1.0000	0.0000	1.0000	0.0000	1.0000
	A8	0.4186	0.4462	0.7586	0.0896	0.8866	0.0549	0.8866
	A9	0.6279	0.6308	0.4185	0.2239	0.6590	0.1429	0.6590
	A10	0.8140	0.8769	0.2294	0.5373	0.5310	0.3297	0.8769

	A11	0.7442	0.8000	0.0684	0.5075	0.5931	0.3077	0.8000
	A12	1.0000	1.0000	0.0000	0.6418	0.5096	0.4066	1.0000
	A13	0.7674	0.8769	0.0080	0.4478	0.5655	0.2418	0.8769
	A14	0.3953	0.5846	0.0262	0.2537	0.6590	0.1099	0.6590
	A15	0.0930	0.3538	0.0221	0.1343	0.8375	0.0440	0.8375

Note: Author's calculation

Table 6 shows the normalized matrix vector.

Table 6 - Vector Normalization Matrix

Vector Normalization MATRIX		**C1**	**C2**	**C3**	**C4**	**C5**	**C6**	**MAX**
	A1	0.9824	0.9422	0.7161	1.0000	0.0000	1.0000	1.0000
	A2	0.9765	0.9243	0.7960	0.9282	0.0000	0.9416	0.9765
	A3	0.9589	0.9166	0.8563	0.9223	0.0000	0.9244	0.9589
	A4	0.9495	0.9448	0.9727	0.8971	0.9425	0.8574	0.9727
	A5	0.9589	0.9564	0.9741	0.8990	0.9268	0.8574	0.9741
	A6	0.9707	0.9602	0.9993	0.8913	0.8871	0.8574	0.9993
	A7	0.9601	0.9384	1.0000	0.8699	1.0000	0.8436	1.0000
	A8	0.9707	0.9538	0.9159	0.8816	0.9583	0.8522	0.9707
	A9	0.9812	0.9692	0.7974	0.8990	0.8747	0.8660	0.9812
	A10	0.9906	0.9897	0.7315	0.9398	0.8276	0.8952	0.9906
	A11	0.9871	0.9833	0.6754	0.9359	0.8504	0.8917	0.9871
	A12	1.0000	1.0000	0.6516	0.9534	0.8197	0.9072	1.0000
	A13	0.9883	0.9897	0.6544	0.9282	0.8403	0.8814	0.9897
	A14	0.9695	0.9653	0.6607	0.9029	0.8747	0.8608	0.9695
	A15	0.9542	0.9461	0.6593	0.8874	0.9403	0.8505	0.9542
	Adj Wj	0.1039	0.1317	0.2636	0.1455	0.2023	0.1530	

Note: Author's calculation

Table 7 shows the CCM (Complete Compensatory Model).

Table 7 - CCM (Complete Compensatory Model)

CCM (Complete Compensatory Model)	**u1(ai)**	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**	**SUM**
	A1	0.0676	0.0405	0.0488	0.1455	0.0000	0.1530	0.4554
	A2	0.0887	0.0194	0.1744	0.1040	0.0000	0.1530	0.5395
	A3	0.0329	0.0000	0.2636	0.0998	0.0000	0.1345	0.5308
	A4	0.0000	0.0484	0.2636	0.0330	0.1852	0.0146	0.5448
	A5	0.0209	0.0679	0.2636	0.0352	0.1750	0.0145	0.5771
	A6	0.0436	0.0690	0.2636	0.0239	0.1404	0.0135	0.5541
	A7	0.0217	0.0345	0.2636	0.0000	0.2023	0.0000	0.5221
	A8	0.0490	0.0663	0.2256	0.0147	0.2023	0.0095	0.5674
	A9	0.0990	0.1261	0.1674	0.0494	0.2023	0.0332	0.6774
	A10	0.0964	0.1317	0.0690	0.0891	0.1225	0.0575	0.5663
	A11	0.0966	0.1317	0.0225	0.0923	0.1500	0.0588	0.5520

	A12	0.1039	0.1317	0.0000	0.0934	0.1031	0.0622	0.4943
	A13	0.0909	0.1317	0.0024	0.0743	0.1305	0.0422	0.4720
	A14	0.0623	0.1169	0.0105	0.0560	0.2023	0.0255	0.4735
	A15	0.0115	0.0557	0.0070	0.0233	0.2023	0.0080	0.3078

Note: Author's calculation

Table 8 shows the UCM (Un-Compensatory Model).

Table 8 - UCM (Un-Compensatory Model)

UCM (Un-Compensatory Model)	u2(ai)	C1	C2	C3	C4	C5	C6	MAX
	A1	0.0362	0.0912	0.2148	0.0000	0.0000	0.0000	0.2148
	A2	0.0152	0.1123	0.0892	0.0415	0.0000	0.0000	0.1123
	A3	0.0710	0.1317	0.0000	0.0457	0.0000	0.0185	0.1317
	A4	0.1039	0.0833	0.0000	0.1125	0.0171	0.1384	0.1384
	A5	0.0830	0.0639	0.0000	0.1103	0.0273	0.1384	0.1384
	A6	0.0603	0.0627	0.0000	0.1215	0.0619	0.1395	0.1395
	A7	0.0821	0.0973	0.0000	0.1455	0.0000	0.1530	0.1530
	A8	0.0548	0.0654	0.0381	0.1308	0.0000	0.1435	0.1435
	A9	0.0049	0.0056	0.0962	0.0961	0.0000	0.1198	0.1198
	A10	0.0075	0.0000	0.1947	0.0563	0.0798	0.0955	0.1947
	A11	0.0072	0.0000	0.2411	0.0532	0.0523	0.0941	0.2411
	A12	0.0000	0.0000	0.2636	0.0521	0.0992	0.0908	0.2636
	A13	0.0130	0.0000	0.2612	0.0712	0.0718	0.1108	0.2612
	A14	0.0416	0.0149	0.2532	0.0895	0.0000	0.1275	0.2532
	A15	0.0923	0.0761	0.2567	0.1221	0.0000	0.1449	0.2567

Note: Author's calculation

Table 9 shows the ICM (Incomplete Compensatory Model).

Table 9 - ICM (Incomplete Compensatory Model)

ICM (Incomplete Compensatory Model)	u3(ai)	C1	C2	C3	C4	C5	C6	MAX
	A1	0.9982	0.9922	0.9157	1.0000	0.0000	1.0000	0.0000
	A2	1.0000	0.9928	0.9475	0.9926	0.0000	0.9944	0.0000
	A3	1.0000	0.9941	0.9706	0.9944	0.0000	0.9944	0.0000
	A4	0.9975	0.9962	1.0000	0.9883	0.9937	0.9809	0.9572
	A5	0.9984	0.9976	1.0000	0.9884	0.9900	0.9807	0.9557
	A6	0.9970	0.9948	1.0000	0.9835	0.9762	0.9768	0.9301
	A7	0.9958	0.9917	1.0000	0.9799	1.0000	0.9743	0.9428
	A8	1.0000	0.9977	0.9848	0.9861	0.9974	0.9803	0.9473
	A9	1.0000	0.9984	0.9468	0.9874	0.9770	0.9811	0.8946
	A10	1.0000	0.9999	0.9232	0.9924	0.9643	0.9846	0.8697
	A11	1.0000	0.9995	0.9048	0.9923	0.9703	0.9846	0.8573
	A12	1.0000	1.0000	0.8932	0.9931	0.9606	0.9852	0.8395

	A13	0.9998	1.0000	0.8967	0.9907	0.9674	0.9824	0.8442
	A14	1.0000	0.9994	0.9038	0.9897	0.9794	0.9820	0.8598
	A15	1.0000	0.9989	0.9071	0.9895	0.9970	0.9825	0.8783

Note: Author's calculation

Table 10 and Figure 2 show the results of the LMAW-DNMA method.

Table 10 - Results of the LMAW-DNMA Method

										w1	**w2**	**w3**	
										0.6	**0.1**	**0.3**	
		CCM		**φ**	**UCM**		**φ**	**ICM**		**φ**	**Utility Values**		**Rank order**
		u1(ai)	**Rank**	**0.5**	**u2(ai)**	**Rank**	**0.5**	**u3(ai)**	**Rank**	**0.5**			
2008	A1	0.4554	14	0.4847	0.2148	10	0.7445	0.0000	13	0,1414	0.4077	0.4077	**15**
2009	A2	0.5395	8	0.6778	0.1123	1	0.3049	0.0000	13	0.1414	0.4796	0.4796	**13**
2010	A3	0.5308	9	0.6449	0.1317	3	0.3806	0.0000	13	0.1414	0.4674	0.4674	**14**
2011	A4	0.5448	7	0.7095	0.1384	4	0.4163	0.9572	1	1.0000	0.7674	0.7674	**6**
2012	A5	0.5771	2	0.8936	0.1384	5	0.4398	0.9557	2	0.9664	0.8701	0.8701	**2**
2013	A6	0.5541	5	0.7768	0.1395	6	0.4690	0.9301	5	0.8608	0.7712	0.7712	**5**
2014	A7	0.5221	10	0.6141	0.1530	8	0.5573	0.9428	4	0.8973	0.6934	0.6934	**8**
2015	A8	0.5674	3	0.8523	0.1435	7	0.5070	0.9473	3	0.9302	0.8411	0.8411	**3**
2016	A9	0.6774	1	1.0000	0.1198	2	0.3349	0.8946	6	0.8117	0.8770	0.8770	**1**
2017	A10	0.5663	4	0.8182	0.1947	9	0.6728	0.8697	8	0.7450	0.7817	0.7817	**4**
2018	A11	0.5520	6	0.7445	0.2411	11	0.8289	0.8573	10	0.6936	0.7377	0.7377	**7**
2019	A12	0.4943	11	0.5672	0.2636	15	1.0000	0.8395	12	0.6482	0.6348	0.6348	**9**
2020	A13	0.4720	13	0.5126	0.2612	14	0.9625	0.8442	11	0.6667	0.6038	0.6038	**11**
2021	A14	0.4735	12	0.5290	0.2532	12	0.8838	0.8598	9	0.7158	0.6205	0.6205	**10**
2022	A15	0.3078	15	0.3248	0.2567	13	0.9217	0.8783	7	0.7752	0.5196	0.5196	**12**
	MAX	0.6774			0.2636			0.9572					

Note: Author's calculation

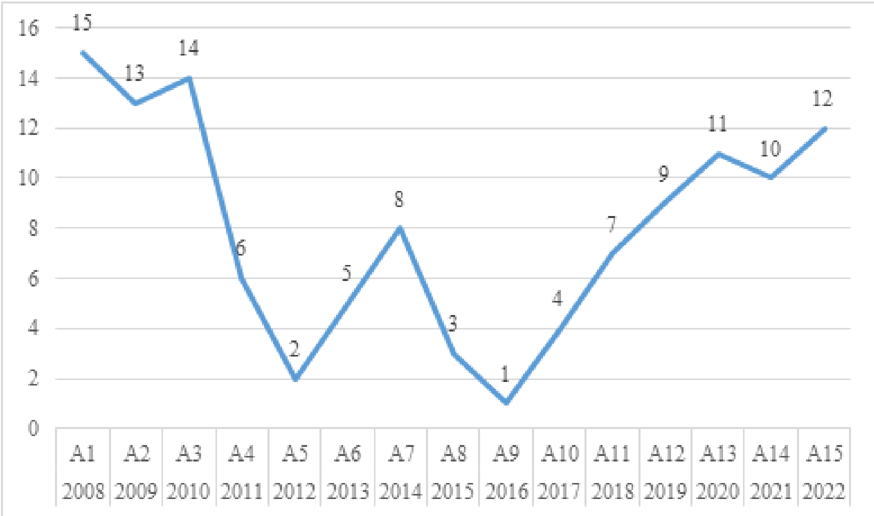

Figure 2- Ranking
Source: Author's picture

It is very challenging to investigate, as shown by the above-mentioned calculations by phases and results, the dynamic positioning of capital adequacy of the banking sector in Serbia by applying multi-criteria decision-making methods. They very precisely indicate in which years capital adequacy was and was not satisfactory. Based on this, one can reliably assess the exposure of the banking sector in the specific case of Serbia to business risks and the necessity of taking relevant measures to optimize them.

Therefore, according to the results of the LMAW-DNMA method, the top five years in terms of capital adequacy of the banking sector in Serbia in the observed period 2008 - 2022 are in order: 2016, 2012, 2015, 2017, and 2013. The worst capital adequacy of the banking sector in Serbia was in 2008. It was therefore most exposed to business risks in that year.

Recently, the capital adequacy of the banking sector in the world, and in Serbia, has been affected, among other things, by the pandemic of coronavirus COVID-19. It caused a decline in economic and therefore banking activities. The negative impact was partially mitigated by electronic banking.
To improve the capital adequacy of the banking sector in Serbia, it is necessary, among other things, to manage business risks of all kinds as adequately as possible. This means, in other words, that adequate management of large exposures (business risks) about regulatory capital can significantly influence the achievement of the target capital adequacy of the banking sector in Serbia. Supervision and auditing play a significant role in this.

Conclusion

Based on the results of the empirical research on the capital adequacy of the banking sector in Serbia using the LMAW-DNMA method, the following can be concluded: according to the results of the LMAW-DNMA method, the top five years in terms of capital adequacy of the banking sector in Serbia in the observed period 2008 - 2022 are in order: 2016, 2012, 2015, 2017 and 2013. The worst capital adequacy of the banking sector in Serbia was in 2008. In that year, in other words, the banking sector in Serbia was most exposed to business risks.

In the period 2019 - 2022, the capital adequacy of the banking sector in Serbia, which is also the case in the world, was affected to a certain extent by the pandemic coronavirus COVID-19 by reducing economic activities and banking. This hurt the overall performance of the banking sector. The negative impact is partially mitigated by electronic a.

In the banking sector of Serbia, adequate management of business risks about regulatory capital can significantly influence the achievement of the target capital adequacy. There is no doubt that supervision and auditing play a significant role in this. The research found that effective supervision and auditing significantly mitigate the negative impact of risk on the performance of the banking sector.

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