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VOLATILNOST BITKOINA I RIZIČNOST FINANSIJSKOG PORTFOLIJA

Prof. dr Almir Alihodžić
redovni profesor,
Ekonomski fakultet Univerziteta u Zenici
almir.dr2@gmail.com

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Rezime: Osnovni cilj ovog istraživanja je procena prinosa i rizika sledećih oblika imovine: bitkoina, EUR Stoxx 50, zlata, obveznica: državne obveznice ICE Bof A 1-10 Year isključujući Italiju i Grčku i korporativnog indeksa obveznica ICEBof A 1-10 Year AA. U radu su testirana ukupno deset portfolija prema različitim scenarijima za digitalnu i finansijsku imovinu. Takođe, u radu su proračunate veće mere rizika i prinosa sa ciljem formiranja optimalnog portfolija sa minimalnim rizikom. Rezultati ovog istraživanja su otkrili da je korelacija između Bitkoina i drugih oblika finansijske imovine uglavnom niska i negativna, što može biti dobar instrument za diversifikaciju portfolija, te da pozitivno utiče na performanse portfolija. Takođe, rezultati ove studije su pokazali da je u pogledu volatilnosti i mere povrata od ukupno deset portfolija drugi portfolio (čiju strukturu čine Bitkoin, Euro Stoxx 50, zlato, državne obveznice ICE Bof A 1-10 Year - isključujući Italiju i Grčku i korporativni indeks obveznica ICEBof A 1-10 Year AA) najoptimalniji portfolio. Nalazi ovog istraživanja mogu da posluže u procenama rizika i gubitaka portfolio menadžera, investitora i regulatora.

Ključne reči: rizična vrednost, VaR, tržišni rizik, bitkoin, efikasan portfolio, optimizacija portfolija.

JEL klasifikacija: G11, G32

Uvodna razmatranja

Nastanak moderne portfolio teorije vezuje se za čuveni tekst koji je 1952. godine objavio Harry Markowitz, a u kojem je razvio model očekivane stope prinosa i očekivanog rizika portfolija. Markowitz je pokazao da je varijansa stope prinosa portfolija ujedno i mera rizika portfolija pod određenim pretpostavkama. Tokom razvijanja matematičkog modela varijanse prinosa portfolija, Markowitz je ukazao ne samo na presudan značaj diversifikacije investicija sa ciljem redukcije ukupnog rizika portfolija, već i na način na koji se diversifikacija efikasno izvodi i koristi. Jedno od najvećih unapređenja investicionih analiza proteklih decenija krije se dakako u saznanju da kreiranje optimalnog portfolija hartija od vrednosti nije prost posao investiranja u hartije od vrednosti na osnovu poželjnih, tj. ciljanih karakteristika prinosa i rizika svake pojedinačne hartije od vrednosti. Nasuprot, teorija dokazana u praksi ukazuje na potrebu razmatranja i analize međusobnih odnosa karakteristika prinosa i rizika svake pojedinačne hartije od vrednosti uključene u investicioni portfolio (Krneta, 2006).

Koncept rizika je u velikoj meri korišćen u finansijama. Postoje značajne razlike u tačnoj definiciji ovog pojma, što otežava davanje zajedničkog odgovora na naizgled jednostavno pitanje: šta je rizik? Upravljanje i merenje rizika je postalo ključno pitanje za mnoge portfolio analitičare i investitore. U zadnjih nekoliko godina finansijska literatura se fokusirala na sam segment upravljanja rizikom. Pri ulaganju u pojedinu hartiju od vrednosti, rizik portfolija predstavlja mogućnost da se ne ostvari planirani prinos, odnosno da investirana sredstva donesu manju dobit od očekivane ili čak ostvare i gubitak (Alihodžić, 2011).

U pogledu investitora, uvek se postavljalo još jedno važno pitanje, a to je: koji je maksimalni gubitak koji moram da podnesem ako postoji? Koncept rizične vrednosti je predložen 1996. godine, da bi se sugerisali odgovori na ovo pitanje. Sastoji se u jednostavnom određivanju rizika dajući mu tačnu vrednost. Jorion (1996) navodi da VaR opisuje najgori očekivani scenario, odnosno gubitak za dati horizont i nivo poverenja. Menadžeri rizika, regulatori i trgovci treba da budu svesni određenih karakteristika volatilnosti kada procenjuju buduću volatilnost.

Poslednjih godina, oblast pokrivena kriptovalutama, odnosno virtuelnim valutama u platnim sistemima se ubrzano širi, gde su ove valute privukle pažnju investitora na finansijskim tržištima iz celog sveta. Takođe, kriptovalute privlače pažnju programera, rizičnog kapitala i investitora svojim inovativnim tehnologijama, visokobezbedonosnim arhitekturama, te sposobnošću da budu investicioni instrumenti (Klein i ostali, 2018). Bitkoin je najranije objavljena valuta među kriptovalutama i takođe je najpopularnija jer ima najveću tržišnu vrednost. Iako se navodi da je bitkoin uvela osoba po imenu Satoši Nakamoto 2009. godine, ostaje misterija da li je ova osoba ili pseudonim koji koriste neki ljudi i grupe koje su kreirale bitkoin. Različiti pogledi na kriptovalute i budućnost kriptovaluta i dalje su pokretačka snaga i pored ekstremne volatilnosti na ovim tržištima. Ova situacija je dovela do povećanog interesovanja istraživača na ovu temu kako bi se razotkrila misterija složenog sveta kriptovaluta, koja je i dalje nejasna i zbunjujuća za većinu učesnika na tržištu (Guesmi i ostali, 2019).

U svetlu ovih razmišljanja i studija sprovedenih na ovu temu u ovom radu, glavni cilj će biti usmeren na revidiranju postojanosti volatilnosti za odabranu digitalnu i finansijsku imovinu, odnosno proračun očekivanog rizika i prinosa digitalne i finansijske imovine, kao i odabir najoptimalnijeg portfolija od ukupnog seta portfolija.

Ovo istraživanje je dizajnirano iz pet delova. Prvi deo odnosi se na uvodnu problematiku sa fokusom na kratak opis definicije moderne portfolio teorije i značaja rizične vrednosti. Drugi deo opisuje pregled dosadašnjih istraživanja u pogledu značaja metodologije rizične vrednosti za procenu rizika i gubitaka za različite oblike digitalne i finansijske imovine, te formiranja optimalnog portfolija. Treći deo opisuje izabranu metodologiju istraživanja, sa posebnim akcentom na neophodne formule za proračun očekivanog prinosa portfolija, standardne devijacije portfolija, varijanse i proračuna rizične vrednosti. Četvrti deo odnosi se na podatke i varijable potrebne za analizu. Peti deo predstavlja dobijene rezultate istraživanja, kao i određena zapažanja i preporuke.

Pregled relevantne literature

VaR analizom se meri maksimalan gubitak vrednosti portfolija tokom unapred određenog vremenskog perioda za dati nivo poverenja. Metodologija rizične vrednosti (VaR) se koristi za tumačenje izloženosti finansijskom riziku od 1995. godine. VaR je zaista mera koja objašnjava koliko su promenljivi finansijski instrumenti. Zajednička lekcija iz različitih finansijskih kriza i katastrofa je da milijarde dolara mogu biti izgubljene zbog lošeg nadzora i upravljanja finansijskim rizicima. Rizična vrednost (VaR) razvijena je kao odgovor na finansijske katastrofe 1990-tih, i dobija sve važniju ulogu u upravljanju tržišnim rizikom. VaR je sumirao najgori gubitak u ciljnom horizontu za dati nivo poverenja. VaR je pre svega popularan pristup jer daje jednu količinu koja sumira ukupan rizik sa kojim se institucija suočava (Gencay i Selcuk, 2004). Popularnost VaR-a je zasnovana na njegovoj sposobnosti da objedini nekoliko komponenti tržišnog rizika preduzeća u jedan broj. Šta više, fokusira se na veliku zabrinutost viših menadžera, kao i potencijal za značajan gubitak u portfoliju imovine preduzeća. U svojim različitim oblicima, VaR je takođe dobio snažnu podršku industrije i regulatornih tela kao što su Grupa 30 (G30, 1993), Banke za međunarodna poravnanja i Evropske unije.

Tržišni rizik se obično kvantifikuje korišćenjem metodologije Value-at-Risk (VaR). Pomoću date metodologije se procenjuje vrednost tržišnog rizika pri datim nivoima poverenja. U praksi se obično koriste nivoi poverenja od 99% ili 95%. Može se slobodno reći da se pomoću VaR-a meri verovatnoća nastanka gubitka po osnovu aktivnosti koje se registruju u knjizi trgovanja, kako na strani kapitala, tako i na strani prihoda, pri datom nivou poverenja (Đukić, 2011).

Procena vrednosti portfolija metodom VaR je predmet opsežnog istraživanja koji još ima rastuću popularnost. Dostupno je nekoliko analitičkih tehnika, kao i tehnika zasnovanih na simulacijama, u zavisnosti od stepena nelinearnosti instrumenata u portfoliju i spremnosti da se naprave stroge pretpostavke o osnovnim statističkim distribucijama. VaR je jedina metrika rizika koja se redovno koristi i koja se može primeniti na skoro svaku klasu imovine, što je jedan od razloga zašto je postala toliko popularna.

Markowitz (1952) i tri meseca kasnije Roy (1952) su nezavisno objavili VaR mere koje su bile iznenađujući slične. I Markowitz i Roy su radili na razvoju načina odabira portfolija, koji bi na neki način optimizovao nagradu za dati nivo rizika. U tu svrhu svaka predložena VaR mera koja je uključivala kovarijanse između faktora rizika imala je za cilj efekte zaštite i diversifikacije. Iako su ove dve mere bile matematički slične one su podržavale različite VaR metrike. Markowitz je koristio varijansu jednostavne metrike povrata. Roy je koristio metriku rizika od manjka koja predstavlja gornju granicu verovatnoće da bruto prinos portfolija bude manji od nekog specificiranog „katastrofalnog“ prinosa.

Rockafellar i Uryasev (2000) definisali su rizičnu vrednost kao gubitak tržišne vrednosti tokom vremenskog horizonta t koji je prevaziđen sa verovatnoćom 1-p za određeni vremenski horizont t i nivo poverenja p. Banka za međunarodna poravnanja (engl. The Bank for International Settlements – BIS) je finansijska institucija sa sedištem u Švajcarskoj, koja je za potrebe izračunavanja adekvatnosti kapitala banaka postavila p na 99 procenata i t na deset dana, iako bi to omogućilo ograničeno korišćenje prednosti statističke diversifikacije u različitim periodima.

Hendricks (1996) nasumično bira 1.000 portfolija valutnih opcija da bi testirao efikasnost VaR modela. Cilj njegove studije je bio da demonstrira i uporedi sličnost broja rizika merenog VaR metodom i realnog rizika. Jedan faktor koji on razmatra je tržišni rizik uporedo sa korišćenjem tri fundamentalne metode, i to: a) jednako ponderisani pokretni prosek, b) eksponencijalno ponderisani pokretni prosek, i c) metod istorijske simulacije. Na osnovu datih metoda zaključio je da se dobijaju različiti VaR brojevi. Ipak konačno on ne može zaključiti da je jedan metod superiorniji od drugih. U svom testu on takođe pokazuje da 95% i 99% nivo poverenja proizvodi različite VaR brojeve.

Jorion (1997) ima slične kritike o VaR-u, da on nije savršen alat za merenje. Dakle, VaR jednostavno ilustruje različite brzine rizika koji su ugrađeni u derivatne finansijske instrumente. VaR je dobar alat kojeg menadžeri rizika treba da budu svesni kako bi delovali na zaštiti svojih rizičnih pozicija. Takođe, VaR se prihvata kao standardno merenje za određivanje regulatornog kapitala od strane BIS-a (Karelse, 2001). Mnoge strane na finansijskim tržištima kao što su institucije, bogati investitori, vlasti, revizori i rejting agencije u mogućnosti su da redovno prate tržišni rizik i prihvataju različite nivoe poverenja za svoje VaR proračune (Culp i ostali, 1999).

Yamai i Yoshiba (2002) pokazuju da su VaR i očekivani manjak oslobođeni od rizika kada su dobitak i gubitak normalno raspoređeni. Posmatrano sa druge strane, VaR može pokazati rizičnu vrednost ako dobitak i gubitak nisu normalno raspoređeni. Glavni uzročnik neravnomerne raspodele dobitka i gubitka je nelinearnost pozicija portfolija, ili nelinearnost cena osnovne imovine.

Woods i ostali (2008) su definisali VaR kao statistički indikator finansijskog rizika koji predstavlja najveći verovatni gubitak portfolija tokom određenog vremenskog perioda. Kao rezultat toga, iznos VaR-a zavisi od dva proizvoljna parametra: perioda zadržavanja ili vremenskog horizonta i verovatnoće poznate kao nivo poverenja. Primera radi, VaR banke u njenom trgovačkom portfoliju može biti 20 miliona funti sa nivoom poverenja od 95% i rokom držanja sledećeg trgovačkog dana. To znači da banka veruje da ima 95% šanse da ostvari profit ili da izgubi ne više od 20 miliona funti sledećeg trgovačkog dana.

Bouri i ostali (2016) su ispitivali odnos između prinosa na cene i promene volatilnosti na tržištu Bitkoina u različitim valutama (američki dolar, australijski dolar, kanadski dolar, britanska funta, evro i japanski jen). Studija je podeljena na dva perioda s obzirom na kolaps cene Bitkoina u decembru 2013. godine. Prema nalazima studije, dok nije bilo dokaza o asimetričnom odnosu prinosa i volatilnosti na tržištu Bitkoina za ceo period posmatranog uzorka, utvrđeno je da postoji značajna inverzna veza između volatilnosti i prošlih šokova pre pada cene u decembru 2013. godine, ali tada nije bio značajan odnos. Autori su ovaj nalaz koji je bio suprotan očekivanjima, objasnili kao efekat sigurnog utočišta, sličan ulaganju u zlato. Štaviše, samo rezultati perioda pre kolizije su pokazali značajnu negativnu vezu između nesigurnosti na berzi u SAD-u i promenljivosti Bitkoina.

Dyhrberg (2016) je ispitao sposobnost finansijske imovine Bitkoina koristeći GARCH model. Rezultati analize su pokazali da Bitkoin ima mnogo sličnosti sa zlatom i dolarom, gde je prema opštem rezultatu studije konstatovano da je Bitkoin negde između novca i robe zbog svoje decentralizovane strukture i ograničene veličine tržišta.

Carrick (2016) je ispitivao da li se bitkoin može smatrati dopunskom ili zamenskom valutom razvijenih zemalja i zemalja u nastajanju, te kako bi uključivanje bitkoina u korpu valuta uticalo na prinose prilagođene riziku već diversifikovanog portfolija valuta. U istraživanju su korišćeni podaci koji se odnose na vrednost i volatilnost glavnih valuta (austrijski dolar, britanska funta, kanadski dolar, euro, japanski jen i švajcarski franak) i valuta tržišta u razvoju (brazilski real, čileanski pezo, kineski juan, kolumbijski pezo, indonežanska rupija, indijska rupija, malezijski ringit, meksički pezo, filipinski pezo, poljski zlot, ruska rublja, južnokorejski von, tajlandski baht i turska lira) sa kojima su upoređena vrednost i volatilnost bitkoina. Posmatrani period istraživanja je trajao od 01. januara 2011. godine, do 31. decembra 2015. godine. Utvrđeno je da je bitkoin u negativnoj korelaciji na statistički značajnom nivou sa svim glavnim valutama u analiziranom periodu, osim švajcarskog franka, i svim valutama tržišta u razvoju osim kineskog juana. Negativna korelacija između valuta tržišta u nastajanju i bitkoina zanimljiv je nalaz jer je valutni rizik glavni problem kod valuta za tržišta u nastajanju. Valute tržišta u nastajanju postale su uobičajen način za diversifikaciju rizika i balansiranja valutnog i investicionog portfolija. Zbog negativnih korelacija između bitkoina i većine valuta, uključivanje bitkoina u korpe valuta moglo bi biti od koristi za portfolio menadžere da smanje rizik i povećaju prinose prilagođene riziku. Stoga, se bitkoin može smatrati dopunom drugim valutama, posebno valutama zemalja u razvoju.

Nam (2017) je imao za cilj da pronađe odgovore na pitanja poput: „Može li Bitkoin poboljšati efikasnost portfolija"? i „Koja strategija optimizacije portfolija može da stvori najbolji profil rizika i prinosa u koji je uključen Bitkoin"? U svojoj metodologiji Nam je koristio Sharpe Ratio, VaR, i CVaR, da ispita odnos Bitkoin-a, Eura, Britanske funte, Švajcarskog franka, Japanskog jena, Australijskog dolara, Kanadskog dolara i Zlata za period: 2010-2016. Rezultati istraživanja su pokazali da Bitkoin ima potencijal da poboljša performanse portfolija.

Byström i Krygier (2018) su se fokusirali na odnos između promenljivosti na Bitkoin tržištu i drugim tradicionalnim tržištima. Pronađena je značajna korelacija između promenljivosti Bitkoina i obima pretrage na Google. Pored toga, pošto se smatralo da aktivnost pretraživanja interneta pretežno kreiraju maloprodajni investitori i šira javnost, zaključeno je da su promenljivost Bitkoina prouzrokovali maloprodajni investitori, a ne institucionalni investitori.

Klein i ostali (2018) su svoje istraživanje podelili u tri celine. Prvo, istraženo je volatilno ponašanje kriptovaluta u poređenju sa indeksima akcija i robom. Drugo, mogućnosti zaštite i bezbednost utočišta kriptovaluta u poređenju sa zlatom su istražene dinamičkom korelacionom analizom. Konačno, primenjena je analiza portfolija koja naglašava ponašanje zlata i bitkoina u teškim vremenima. Prema rezultatima, postojale su razlike u strukturama bitkoina i zlata u pogledu svojstava uslovne varijanse. Takođe, dok je zlato imalo važnu ulogu u teškim vremenima na finansijskim tržištima sa prelaskom na kvalitet , bitkoin je bio upravo suprotno. Zaključeno je da su bitkoin i zlato imali različite karakteristike uglavnom kao veze sa imovinom i berzama. Dok je efekat asimetrije bio značajan za bitkoin, sa druge strane nije bio značajan za zlato.

Kajtazi i Moro (2019) su ispitali da li Bitkoin pruža prednosti u kontekstu diversifikacije portfolija. Kao rezultat, došli su do zaključka da su performanse portfolija povećane dodavanjem Bitkoina, ali ne treba zanemariti da je ova situacija uglavnom posledica povećanja prinosa, a ne smanjenja volatilnosti i da je ovo povećanje performansi povezano sa performansama Bitkoina u 2013. godini. Generalno, u ovom okviru oni su naveli da iako je Bitkoin spekulativan, on može igrati važnu ulogu u diversifikaciji portfolija.

Symitsi i Chalvatzis (2019) istraživali su učinak Bitkoina u portfolijima. Koristeći podatke od septembra 2011. godine, do jula 2017. godine, došli su do zaključka da Bitkoin pruža statistički značajne prednosti diversifikacije, te može dodati vrednost portfolijima.

Soyaslan (2020) je analizirao korelaciju između Bitkoin-a i BIST Banke, BIST Tehnologije i BIST 100 indeksa dnevnih podataka između 2011., i 2020. god., koristeći metode analize vremenskih serija. Kao rezultat studije, postoji dugoročna korelacija između Bitkoin-a i BIST 100 indeksa, ali ne postoji korelacija između BIST banke i BIST Tehnologije u kratkom roku.

Papafotis (2021) je istraživao ponašanje cena, fluktuacije, potencijalne vrhove, minimalne vrednosti kriptovaluta, te postojanje koherentnosti i veza između ponašanja jednih u odnosu na druge kriptovalute. Autor je izvršio korelacione analize i Johansen kointegracionu analizu dnevnih cena Bitkoina-a (BTC), Litecoin-a (LTC), Ethereum-a (ETH), Ripple (XRP) i Monero (XMR) za period od 2013., do 2020. Rezultati analize su se razlikovali za i pre 2017. godine. Istraživanje je pokazalo da je pet kriptovaluta pre 2017. godine imalo nestabilan model, ali je s druge strane sličan i stabilan model primećen među kriptovalutama nakon 2017. godine.

Metodologija istraživanja

Rizična vrednost (engl. Value at Risk – VAR) se definiše kao maksimalni gubitak tokom datog vremenskog horizonta i za dati nivo poverenja. Široko se koristi za merenje potencijalnog rizika od ekonomskih gubitaka na finansijskim tržištima. U kontekstu predviđanja obično se portfolio menadžeri, investitori i trgovci fokusiraju na duže horizonte. Value at Risk se izračunava na jednodnevnom nivou pouzdanosti od 95% i 99%. Takođe, obično se signalizira da je gubitak veći od prijavljene vrednosti pod rizikom portfolija u samo 5% i 1% slučajeva. Pri odabiru nivoa pouzdanosti treba voditi računa da što je manji nivo pouzdanosti to je tačnija procena i suprotno, što je veći nivo pouzdanosti veći je iznos proračunatog maksimalnog gubitka što konsekventno vodi do većih troškova rezervisanja, tj. većih potrebnih iznosa za pokrivanje potencijalnih gubitaka. Portfolio menadžeri, trgovci i investitori moraju da procene ne samo dugu trgovačku poziciju, već i kratke trgovačke pozicije. U slučaju duge trgovačke pozicije (levi rep distribucije) rizik od gubitka se javlja kada se cena imovine kojom se trguje smanji. S druge strane, u slučaju kratke trgovačke pozicije (desni rep distribucije) rizik od gubitka se javlja kada cena imovine kojom se trguje raste (Demiralay i Ulusoy, 2014).

Kao što je Fama naveo 1970. godine, cene na finansijskim tržištima bi bile sigurne pod hipotezom da u potpunosti odražavaju sve dostupne finansijske informacije. Činjenica da se informacije na finansijskim tržištima neprestano menjaju otežava korišćenje informacija u procesu donošenja odluka i otežava efikasnost tržišta. Ovakva situacija omogućava bolje informisanim investitorima da ostvare visok profit (Fama, 1970). Teorija implicira da je u normalnim uslovima tržište efikasno, što znači da su investitori pravilno informisani i da racionalno donose odluke.

Ali nedostatak odlučnog okvira ili modela za kriptovalute otežava predviđanje vrednosti tržišta i utiče negativno na karakteristike slabe forme efikasnosti (Naeem i ostali, 2021). Sa ove tačke gledišta, da bi se razumele osnove finansijskih tržišta i kriptovaluta trebalo bi testirati hipotezu efikasnosti tržišta. Volatilnost je jako važno pitanje u finansijama, jer se smatra glavnim inputom za proces donošenja odluka u različitim oblastima kao što su cene hartija od vrednosti, trgovanje, upravljanje rizikom i monetarna politika. Dakle, procena volatilnosti je suštinska oblast istraživanja koja ima nekoliko teorijskih i praktičnih zaključaka (Naimy i Hayek,2018).

S obzirom da postoji nekoliko metoda za izračunavanje VaR-a, to otežava odabir najprikladnijeg koji predviđa rizik za određena finansijska sredstva, imovinu ili portfolio finansijskih sredstava. Najčešće korišćene metode izračunavanja VaR- a su sledeće: istorijska metoda, metoda varijanse-kovarijanse i Monte Carlo metoda. Istorijska metoda bazira se na istorijskim podacima, dok metoda varijanse-kovarijanse i Monte Carlo metoda koriste istorijske podatke za procenu statističkih parametara. Očekivani prinos portfolija se izračunava kao ponderisana suma prinosa pojedinih hartija od vrednosti koje čine portfolio. Udeo pojedine hartije od vrednosti u portfoliju služi kao ponder:

$$E(R_{port}) = \sum_{i=1}^{N} X_i \, E(R_i) \tag{1}$$

gde je: $E(R_{port})$ – očekivani prinos na portfolio, X_i – procentni udeo hartije od vrednosti (i) u portfoliju, $E(R_i)$ – očekivani prinos hartije od vrednosti (i). Varijansa portfolija se izračunava na sledeći način:

$$\sigma^2 = \sum_{i=1}^{N} X_i^2 \, \sigma_i^2 + \sum_{i=1}^{N} \sum_{j=1}^{N} X_i X_j \sigma_i \sigma_j \rho_{ij} \tag{2}$$

gde je: σ_i^2 – varijansa i-te hartije od vrednosti, σ_i – standardna devijacija i-te hartije od vrednosti, ρ_{ii} - koeficijent korelacije između prinosa hartija od vrednosti (i) i (j). Poslednji deo jednačine (2) $(\sigma_i \sigma_j \rho_{ij})$, može se zameniti statističkim izrazom $Cov_{i,j}$ (kovarijansa), kako bi se pojednostavila jednačina, budući da je:

$$\rho_{ij} = \frac{Cov_{i,j}}{\sigma_i \sigma_j} \tag{3}$$

Kovarijansa se dobija iz sledeće formule (Berenson i Levine, 1996):

$$Cov_{i,j} = \frac{1}{N-1} \sum_{i=1}^{N} [(x_i - \bar{x})(y_i - \bar{y})] \tag{4}$$

Investitor koji je diversifikovao svoje ulaganje ne vodi računa o pojedinačnom riziku neke imovine, već o njenom učinku na rizičnost ukupnog portfolija (Bawa i ostali, 1979). Kako standardna devijacija i varijansa mere rizik neke imovine kada se ona posmatra izolovano, potrebno je u proceni korporacijskog rizika koristiti mere koje vezuju jednu imovinu za drugu. Utvrđivanje očekivanog prinosa i standardne devijacije prinosa, omogućava formiranje krive distribucije verovatnoće prinosa. Putem krive distribucije verovatnoće prinosa posmatraju se verovatnoće odstupanja od očekivanog prinosa. VaR pokazatelj se dobija kao proizvod standardne devijacije portfolija (σ_p) i koeficijenta pouzdanosti standardizovane normalne distribucije (Z_α), odnosno izražava se pomoću sledeće formule (Megla i ostali, 2017):

$$VaR = \sigma_P \cdot P \cdot Z_\alpha \tag{5}$$

gde je:

P- inicijalna tržišna vrednost portfolija.

Postoje određeni parametri koje analitičar treba da odredi pre nego što pređe na izračunavanje VaR-a. Parametri su sledeći: vremenski interval, nivo poverenja, vrednost portfolija i standardna devijacija. Vremenski interval ulaganja varira od investicije do investicije. Može biti jedan dan, mesec dana, godina ili duže. Vremenski interval ulaganja je generalno povezan sa lakoćom likvidnosti investicije. Iako se koriste dnevni ili mesečni periodi, period zavisi od ulaganja. Prilagođeno vreme se koristi za izračunavanje VaR-a. Nivo poverenja kod VaR-a proračunat je parametar koji daje pouzdanost proračuna. Bazelski komitet zahteva nivo poverenja od 99% i jednostrani interval poverenja. Što je veći interval poverenja, to će biti veći rezultujući iznos VaR-a (Kayahan i Topal, 2009). Vrednost portfolija predstavlja ukupan iznos uložen u hartiju od vrednosti ili portfolio. Standardna devijacija se izračunava prema fluktuacijama cena hartija od vrednosti. Takođe, standardna devijacija se izračunava procentom promene cena hartija od vrednosti. Za izračunavanje dnevne standardne devijacije koristi se najmanje 250 podataka i to predstavlja period uzorkovanja (Irs, 2017).

Najslabiji aspekt metode izračunavanja VaR-a je to što ne pokazuje „najgori slučaj". Kao što je poznato distribucije verovatnoće predstavljaju opseg unutar navedenog intervala poverenja. Međutim, iako je verovatnoća u stvarnom životu veoma mala, postoje neki događaji van ove oblasti. Iako je verovatnoća veoma mala, ne može se reći da se takav događaj nikada neće dogoditi. Još jedno važno pitanje je da VaR modeli ne pokazuju potpuni gubitak. Na primer, VaR pokazuje da je milion dolara u opasnosti na dan trgovanja, i ne može da pruži informaciju o gubicima u drugom, trećem i narednim danima. Debeli rep distribucije može biti glavni faktor rizika za investitore. Debeli rep jednostavno znači iznenadna i velika povećanja/smanjenja vrednosti hartija od vrednosti ili druge finansijske imovine. Činjenica je da se fluktuacije u velikim količinama ne mogu predvideti VaR metodom je jedan od nedostataka koji metod čini neadekvatnim (Demireli i Taner, 2009).

Podaci za analizu

U radu su istraživani dnevni istorijski podaci o kretanju sledeće digitalne i finansijske imovine: Bitkoin-a, EUR Stoxx 50, zlata, obveznica: državne obveznice ICE Bof A 1-10 Year isključujući Italiju i Grčku i korporativni indeks obveznica ICEBof A 1-10 Year AA. Kao izvor dnevnih istorijskih podataka poslužila je široka Bloomberg baza podataka za period od 28 februara 2013. godine, do 20. aprila 2023. godine, što obuhvata ukupno 10 godina i 51 dan. Međutim, nedostatak analize na dnevnoj osnovi su bili nedostajući podaci, koji ukazuju na činjenicu da se pojedinim oblikom finansijske i digitalne imovine nije trgovalo jedan ili više dana. U tom kontekstu podaci su nadopunjeni ili prosečnom vrednošću ili cenom trgovanja iz prethodnog dana, što je i implementirano u ovom istraživanju. Takođe, u ovom istraživanju procena dobijenih portfolija kao i VaR pokazatelja zasniva se na dnevnim prinosima posmatranih oblika imovine.

Tabela 1 - Kratki opis analiziranih varijabli

Digitalna i finansijska imovina	Kratka definicija	Očekivani efekat
Bitkoin	Bitkoin je originalna kriptovaluta bazirana na blokovima. Stvoren 2009. godine, od strane pseudonimnog Satoshi Nakamota. Od tada Bitkoin je privukao milione investitora, da bi postao najveća kriptovaluta merena po tržišnoj kapitalizaciji.	-
Euro Stoxx 50	Predstavlja neke od najvećih kompanija u evrozoni u kontekstu tržišne kapitalizacije u slobodnom prometu. Indeks obuhvata oko 60% tržišne kapitalizacije u slobodnom prometu, što zauzvrat pokriva oko 95% free float tržišne kapitalizacije predstavljenih zemalja.	(+)
Zlato	Zlato je oduvek imalo tradicionalnu ulogu u deviznim rezervama zemlje. Takođe, zlato se smatralo krajnjim utočištem sigurnosti, odnosno osnovom jačanja domaće valute, posebno u slučajevima finansijske nestabilnosti i neizvesnosti.	(-)
Državne obveznice ICE Bof A 1-10 Year (isključujući Italiju i Grčku)	Indeks državnih obveznica koji prati učinak korporativnog duga denominiranog u eurima ispod investicionog ranga koji je javno emitovan na domaćem tržištu evra ili na tržištu evroobveznica.	(+)
Korporativni indeks obveznica ICEBof A 1-10 Year AA	Indeks koji prati isto učinak korporativnog duga denominiranog u američkim dolarima koji je javno objavljen na domaćem tržištu SAD-a.	(+)

Izvor: Autor

Bitkoin - kao jedna od najvažnijih finansijskih inovacija poslednjih godina je digitalna kripto valuta koja je privukla veliko interesovanje javnosti, ali i investitora i finansijskih institucija. Prvi i najvažniji po tržišnoj kapitalizaciji je Bitkoin. Prvi put je predstavljen 2008. godine, kao peer-to-peer elektronski gotovinski sistem od strane misteriozne osobe ili grupe koja koristi nadimak Satoši Nakamoto, čiji identitet još nije poznat. U povezanom članku, elektronska valuta je definisana kao „lanac digitalnih potpisa" (Nakamoto, 2008). U centru Bitkoina nalazi se globalna knjiga ili bilans stanja koji se zove blockchain (Kelly, 2014). Blockchain tehnologija je zasnovana na logici stvaranja lanca od ovih blokova zatvaranjem podataka koji se žele čuvati u „blokovima". Dakle, transakcije se beleže hronološki na blok lancu i podaci se ne mogu menjati retrospektivno (Aksoy, 2018).

EURO Stoxx 50 - je berzanski indeks akcija eurozone koji je dizajnirao STOXX dobavljač indeksa u vlasništvu Deutsche Börse Group. EURO STOXX 50 je počeo da se kotira tek od 1998. godine, ali su njegove cene izračunate retroaktivno do 1986. godine. Bazna vrednost indeksa je 1.000 poena na dan 31. decembar 1991. godine. Indeks se sastoji od 50 akcija iz 11 zemalja eurozone. Dakle, EURO STOXX 50 predstavlja kompanije iz eurozone koje se smatraju liderima u svojim sektorima. Fjučersi i opcije na posmatrani indeks EURO STOXX 50 kojima se trguje na Eurex-u spadaju među najlikvidnijim proizvodima u Evropi i svetu (en.wikipedia.org).

Zlato – je od davnina služilo kao sredstvo razmene i skladištenja bogatstva. Cena zlata je uglavnom povezana sa ekonomskom i političkom nestabilnošću, jer nema suvereni kreditni rizik. Zlato je jedinstvena imovina sa sigurnim utočištem i svojstvima zaštite, jer je u slaboj korelaciji sa drugim finansijskim investicijama (Hillier i ostali, 2006).

Državne obveznice ICE Bof A 1-10 Year (isključujući Italiju i Grčku) – ovaj indeks prati učinak korporativnog duga denominiranog u eurima ispod investicionog ranga, koji je javno emitovan na domaćem tržištu evra ili na tržištu evroobveznica. Kvalifikovane hartije od vrednosti moraju imati rejting ispod investicionog ranga (na osnovu proseka Moody's, S&P i Fitch). Kvalifikovane hartije od vrednosti moraju imati najmanje godinu dana preostalog roka do dospeća, fiksni raspored kupona i minimalni iznos od 100 miliona evra (https://fred.stlouisfed.org).

Korporativni indeks obveznica ICEBof A 1-10 Year AA – ovaj indeks prati takođe učinak korporativnog duga denominiranog u američkim dolarima koji je javno objavljen na domaćem tržištu SAD-a. Ovaj indeks uključuje sve hartije od vrednosti sa datim investicijskim rejtingom od AAA. Hartije od vrednosti koje ulaze u sastav ovog indeksa moraju imati najmanje godinu dana do konačnog dospeća, fiksni raspored kupona i minimalni iznos od 250 miliona dolara (https://www.doubleline.com).

Rezultati i diskusija

Sa nedavnim rastom tržišta kripto valuta, neki su tvrdili da se kripto valute mogu posmatrati kao nova vrsta investicionog alata (Corbet i ostali, 2018). Kada je u pitanju viđenje kriptovaluta kao novog investicionog alata ili alternativne imovine, postoje dva pitanja koja investitori treba da razmotre. Prvi od njih su rizici specifični za ulaganja, drugi su odnosi kripto valuta sa drugom imovinom što je još važnije u kontekstu prednosti diversifikacije i hedžing sposobnosti kriptovaluta (Feng i ostali, 2018). Uklanjanje digitalne imovine iz investicionih alternativa biće jednako restriktivno, kao i uklanjanje svih drugih sredstava (Elender i ostali, 2018). Modeliranje volatilnosti je takođe važno za upravljanje rizikom. Štaviše, kriptovalute se uglavnom koriste kao imovina umesto valuta, uprkos tome što je tržište prilično špekulativno. Isto tako, promenljivije je od drugih valuta i podložnije špekulativnim balonima. S tim u vezi, kriptovalute imaju važno mesto na finansijskim tržištima i u upravljanju portfoliom. Samim tim je analiza njihove volatilnosti izuzetno značajna. Tabela u nastavku teksta ilustruje tendenciju kretanja mera povrata i rizika digitalne imovine (Bitkoin) i ostalih predstavnika finansijske imovine (EUR 50 Stoxx 50, Zlato, Državne obveznice ICE Bof A 1-10 Year, Korporativni indeks obveznica ICE Bof A 1-10 Year AA) za period: 28.02.2013.- 20.04.2023. godine.

Tabela 2 - Mere povrata i rizika digitalne (Bitkoin) i finansijske imovine za period: 28.02.2013.- 20.04.2023. godine (u%)

Mere povrata i rizika	Bitkoin	EURO Stoxx 50	Zlato	Državne obveznice ICE Bof A 1-10 Year (isključujući Italiju i Grčku)	Korporativni indeks obveznica ICEBof A 1-10 Year AA
Srednja vrednost	11,57	0,51	0,24	0,03	0,05
Standardna devijacija	49,30	4,84	4,22	0,87	0,93
Freq<0	43,90	44,72	52,03	42,28	41,46
Parametarski VaR	-69,52	-7,45	-6,70	-1,41	-1,49
Empirijski VaR	-29,48	-6,79	-6,14	-1,25	-1,44
Parametarski CVaR	-90,13	-9,47	-8,46	-1,77	-1,88
Empirijski CVaR	-34,50	-9,12	-7,62	-2,19	-2,48

Izvor: Autor

Iz prethodne tabele se da primetiti da je najveću rizičnost u pogledu prve mere rizika tj. standardne devijacije ostvario Bitkoin od oko 49,30% kao i najveći povrat od 11,57%. Takođe, i u kontekstu ostvarivanja potencijalnog gubitka merenog putem parametarske i empirijske VaR vrednosti pri nivou pouzdanosti od 95% Bitkoin je ostvario visoke vrednosti od 69% (parametarska VaR metoda) i 29% (empirijska VaR metoda).

Povećanje i fluktuacija cena Bitkoina poslednjih godina privuklo je veliku pažnju. Naročito povećanje cene Bitkoina u poslednjih pet godina dalo je primer super (eksponencionalnog) rasta koji se obično ne vodi ni u jednom finansijskom polju osim na tržištu kriptovaluta (Pichl i Kaizoji, 2017). Cena Bitkoina, kojom se trgovalo na 1.000 dolara početkom 2017. godine, značajno je porasla na 15.000 dolara u decembru 2017. godine. Međutim, neki događaji su doprineli povećanju volatilnosti Bitkoina. Monetarne restrikcije kineske Vlade od 01. jula 2017. godine, prekomerno su povećale cene Bitkoina zbog sve veće potražnje, a zabrana trgovine digitalnom valutom u avgustu 2017. godine, takođe je uticala na prekomerno smanjivanje cene Bitkoina (Aksoy, 2018).

Drugo mesto po visini rizičnosti merene preko standardne devijacije pripada berzanskom indeksu EURO Stoxx 50 (4,84%) i zlatu (4,22%). Najmanju rizičnost su ostvarile državne i korporativne obveznice. Za razliku od digitalne imovine volatilnost zlata i tržišta akcija i obveznica se povećava tokom perioda političkih i ekonomskih previranja. Osim u drugom periodu u 2008. godini (kriza hipotekarnih kredita) visoka volatilnost finansijskih oblika imovine je zabeležena pred kraj 2011. godine, kao i sredinom 2013. godine. Kraj 2011. godine je obeležen krizom evropskog državnog duga, koja je izazvala kolaps finansijskih institucija i visokog državnog duga u nekim evropskim zemljama dok su debate o odlukama FED-a o monetarnoj politici planule sredinom 2013. godine. Visoka volatilnost kriptovaluta otežava investitorima da zauzmu pravu poziciju i razviju strategije ulaganja. Ulaganja u kripto tržište novca svakako da uključuje visoke rizike. Glavni među ovim rizicima su operativni rizici i sajber rizici. Posmatrano sa druge strane, i danas se vidi da investitori i dalje ozbiljno veruju u glasine i špekulacije o kriptovalutama. Određene studije u literaturi ističu da Bitkoin i druge kriptovalute treba posmatrati kao „špekulativnu" imovinu. Rano istraživanje dinamike cena Bitkoina navodi da Bitkoin ima izuzetno špekulativnu prirodu (Brauneis i Mestel, 2019).

Tabela 3 - Korelaciona matrica između digitalne (Bitkoin) i finansijske imovine za period: 28.02.2013.- 20.04.2023. godine

	Bitkoin	EURO Stoxx 50	Zlato	Državne obveznice ICE Bof A 1-10 Year (isključujući Italiju i Grčku)	Korporativni indeks obveznica ICEBof A 1-10 Year AA
Bitkoin	1,00				
EURO Stoxx 50	0,34	1,00			
Zlato	-0,04	0,03	1,00		
Državne obveznice ICE Bof A 1-10 Year (isključujući Italiju i Grčku)	0,26	0,27	-0,08	1,00	
Korporativni indeks obveznica ICEBof A 1-10 Year AA	0,40	0,63	-0,10	0,78	1,00

Izvor: Proračun autora na bazi Bloomberg baze podataka

Prethodna tabela ilustruje kretanje koeficijenata korelacije između kriptovalute (Bitkoin) i finansijske imovine koju reprezentuju određeni berzanski indeksi i imovina (EUR 50 Stoxx 50, Zlato, Indeks državnih obveznica, korporativni indeks obveznica). Najjača pozitivna korelacije je zabeležena između Bitkoina i indeksa korporativnih obveznica ICEBof A 1-10 Year AA (0.40), zatim i sa berzanskim indeksom akcija EUR50 Stoxx 50 je takođe ostvarena pozitivna korelacija (0,34). Nizak stepen rizičnosti portfolija rezultat je obrnutog odnosa između performansi portfolija.

Dakle, u recesiji i usporenom ekonomskom rastu cene akcija padaju, ali zato obveznice ostvaruju dobre rezultate. Suprotno tome, nakon naglog privrednog uspona cene obveznica padaju, ali cene akcija rastu (Bodie i ostali, 2009). Na osnovu datih koeficijenata korelacije i odnosa se može zaključiti da su jako niske vrednosti koeficijenata korelacije što pruža dobru priliku za diversifikaciju uključivanjem kriptovaluta. S druge strane, najviše kritikovani aspekt moderne portfolio teorije je povećanje korelacije između imovine u portfoliju u vremenima krize i gubitka koristi od diversifikacije kada je to najpotrebnije (AlKulaib i Almudhaf, 2011). Tvrdi se da sredstva niske korelacije koja se uzimaju u portfolio da obezbede koristi od diversifikacije povećavaju korelaciju između njih u kriznim periodima i ne pružaju stvarnu korist od diversifikacije (Baur i Lucey, 2010).

Posmatrano sa druge strane, najjača negativna kauzalnost je zabeležena između Bitkoin-a i zlata (-0,04). Ekstremna volatilnost kriptovaluta je temeljno dokumentovana, ali investitori i finansijski profesionalci na datu volatilnost različito gledaju u zavisnosti od njihovog stava prema Bitkoin-u. Investitori koji su prihvatili meteorski uspon Bitkoin-a u poslednjih nekoliko godina prihvatili su prekomernu volatilnost, dok sagovornici i Bitkoin medvedi ukazuju na visoku volatilnost kao goreću crvenu zastavu i razlog da se izbegnu ulaganja. Do kraja prvog kvartala 2018. godine, Bitkoin je pao za skoro 50%, a zlato je poskupelo za 7,5%. Dakle, Bitkoin se naziva alternativom zlata i shodno tome, hedžingom od inflacije zbog ograničene ponude i nedostatka centralizovane regulacije. U vremenima neizvesnosti, investitori će hrliti da ulažu u zlato i plemenite metale kao sigurno utočište da bi se držali dalje od valuta koje reguliše Vlada. Iako Bitkoin i zlato možda nisu „konkurenti" kao zaštita od inflacije, oni bi možda mogli biti komplementarni u nečijem portfoliju (http://www.cmegroup.com).

Mogućnosti za diversifikacijom portfolija na tržištima u razvoju mogu se sagledati i kroz moguće efekte ulaganja u različita sredstva iz različitih segmenata finansijskih tržišta, na primer ulaganja u akcije različitih industrija, diversifikovanih različitih fondova tržišta u razvoju, EFT fondova na tržištima kapitala, zlato, različite strane valute i bitkoin. U ovom istraživanju tokom analize korišćeni su statistički programi Microsoft Excel i MATLAB 7.1. Takođe, u ovoj studiji kreirano je deset portfolija prema različitim scenarijima za digitalnu i finansijsku imovinu, i izračunate su vrednosti kao što su prinos i standardna devijacija portfolija. Dodavanjem kriptovalute u ove portfolije ispitano je kako Bitkoin valuta utiče na portfolije i da li može eventualno da doda vrednost portfoliju.

Tabela 4 - Efikasan set portfolija – digitalne (Bitkoin) i finansijske imovine: prosečan prinos i rizik za period: 28.02.2013.- 20.04.2023. godine

	PORTFOLIO									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Prosečan povrat	0,03	0,05	0,10	0,15	0,20	0,25	0,27	0,30	0,35	0,40
Standardna devijacija	0,86	0,88	0,94	1,05	1,17	1,32	1,38	1,47	1,64	1,81
Sharpe ratio	0,04	0,06	0,11	0,14	0,17	0,19	0,20	0,20	0,21	0,22
Bitkoin	0,00	0,11	0,49	0,84	1,18	1,53	1,67	1,88	2,22	0,02
EURO Stoxx 50	0,00	0,00	0,65	2,15	4,63	5,15	6,18	7,07	8,78	0,10
Zlato	0,27	1,28	2,65	4,04	5,61	6,83	7,50	8,34	9,78	0,11
Državne obveznice ICE Bof A 1-10 Year (isključujući Italiju i Grčku)	76,85	70,77	68,32	66,66	88,43	63,36	73,63	72,65	76,14	0,74
Korporativni indeks obveznica ICEBof A 1-10 Year AA	22,87	0,28	0,28	26,31	0,15	23,13	11,02	10,06	3,08	0,01

Izvor: Proračun autora na bazi Bloomberg baze podataka

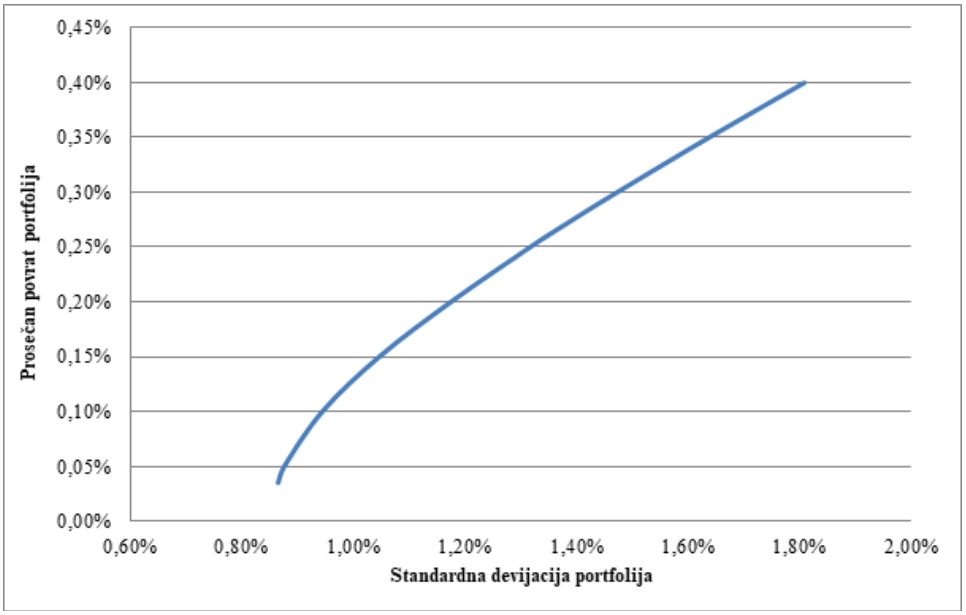
U svom ključnom članku iz 1952. godine, Harry Markowitz je izjavio da je svrha selekcije portfolija da se odredi alokacija sredstava u portfoliju kako bi se dobio maksimalni očekivani prinos s obzirom na određeni rizik, ili minimalni rizik portfolija kada se datom portfoliju da očekivani prinos (Johnson, 2014). Takođe, Harry Markowitz osnivač moderne portfolio teorije utvrdio je da je odnos sredstava među sobom važniji od njihovih pojedinačnih rizika i utvrdio da se rizik portfolija može smanjiti dodavanjem sredstava koja nisu u visokoj međusobnoj korelaciji. Što je niži odnos između sredstava u kontekstu korelacije koja su uključena u portfoliju, to je manji ukupan rizik portfolija (Markowitz, 1952).

Iz prethodne tabele se može zaključiti da je od svih posmatranih deset portfolija, drugi portfolio najoptimalniji u kontekstu rizika, tj. standardne devijacije jer minimizira rizik portfolija. S obzirom na to, da su korelacije između kriptovalute (Bitkoin) i drugih oblika finansijske imovine niske ili negativne, data situacija može da utiče na povećanje prednosti u smislu diversifikacije. Takođe, se da primetiti da se sa povećavanjem Sharpe racia povećava i prosečan povrat i standardna devijacija portfolija.

Jedna od uobičajenih ideja koje se iznose da bi se objasnilo interesovanje investitora za kriptovalute su moguće koristi koje ovi digitalni novčići mogu pružiti u diversifikaciji portfolija. Smatra se da prinosi kriptovaluta imaju nisku ili negativnu korelaciju upoređujući ih sa prinosima tradicionalnih finansijskih sredstava, kao što su obveznice ili akcije. Stoga, kao rezultat uključivanja pomenutih kriptovaluta u portfolije, očekuje se da će se očekivani prinosi portfolija koji odgovaraju svakoj jedinici rizika povećati (Anyfantaki i ostali, 2018). Koristeći Markowitz-ov model srednje varijanse Brauneis i Mestel (2019) su iskoristili podatke za period od januara 2015. godine, do decembra 2017. godine, kako bi otkrili efikasnost portfelja kriptovaluta. Kao rezultat toga, oni su naveli da portfelji kreirani od različitih kriptovaluta imaju značajan potencijal za smanjenje rizika. Takođe, Guesmi i ostali (2019) analizirali su dinamiku odnosa između Bitkoina i druge finansijske imovine koju su posmatrali sa podacima za period: januar 2012 – januar 2018. godine. Cilj im je pre svega bio da utvrde da li Bitkoin pruža prednosti investitorima u kontekstu diversifikacije portfolija i upravljanja rizikom. Kao rezultat sprovedenog istraživanja, došli su do zaključka da bi Bitkoin mogao da pruži prednosti investitorima u smislu zaštite od rizika i diversifikacije portfolija.

Efikasna granica je skup svih portfolija koji se nalaze u uzlaznom delu grafičkog prikaza 1. Uzlazno kretanje znači kako portfoliji na efikasnoj granici sadrže odabire povećanja očekivanog prinosa portfolija i povećanja standardne devijacije portfolija. Za uspešno izračunavanje efikasne granice treba naći njenu početnu tačku, odnosno portfolio sa minimalnom standardnom devijacijom prinosa. U finansijama ovaj portfolio naziva se portfolio minimalne varijanse, što znači da ima minimalnu varijansu i minimalnu standardnu devijaciju (Vukičević i ostali, 2010). Grafik u nastavku teksta ilustruje tendenciju kretanja efikasne granice digitalne imovine (u našem slučaju Bitkoina) i finansijske imovine za period: 28.02.2013 – 20.04.2023. godine.

Grafik 1 - Efikasan set digitalne (Bitkoin) i finansijske imovine za period: 28.02.2013 - 20.04.2023. godine



Izvor: Proračun autora na bazi Bloomberg baze podataka

Kao što se može i primetiti sa povećanjem nagiba i prve mere rizika tj. standardne devijacije portfolija dolazi i do povećanja prosečnog povrata portfolija, ali ne u istoj meri, odnosno prosečni povrat raste u blažoj meri zbog različite strukture izabranog portfolija.

Zaključak

Finansijske vremenske serije često pokazuju stilizovane činjenice kao što su asimetrija, jaka volatilnost, karakteristike debelog repa itd. Stoga se literatura o finansijskoj ekonometriji fokusira na distributivna i statistička svojstva serija finansijskih prinosa. Predviđanje volatilnosti je važan zadatak za većinu investitora na finansijskim tržištima. VaR donosi standardizaciju kada se porede rizični portfoliji. Poslednjih godina, prednosti VaR-a čine ga savremenim alatom za upravljanje rizikom. Volatilnost se obično dešava u klasterima. Pretpostavka je da volatilnost koja ostaje konstantna u svakom trenutku može biti fatalna. Volatilnost se menja tokom vremena, posebno tokom finansijske krize kada ima tendenciju da se značajno poveća.

U ovom istraživanju je bio fokus da se proračuna volatilnost za različite oblike finansijske imovine, kao i za digitalnu imovinu tj. Bitkoin, te da se pronađe optimalni portfolio s minimalnim rizikom za period: 28.02.2013.- 20.04.2023. godine. Rezultati istraživanja su pokazali da je najveća volatilnost i fluktuacija u kontekstu prve mere rizika tj. standardne devijacije ostvarena kod Bitkoina, drugo mesto pripada berzanskom indeksu EURO Stoxx 50, zatim zlatu i indeksima obveznica na poslednjem mestu. Takođe i u kontekstu parametarske i empirijske VaR vrednosti prvo mesto u pogledu verovatnoće ostvarivanja ekonomskog gubitka pripada digitalnoj imovini tj. Bitkoinu, zatim berzanskom indeksu EURO Stoxx 50, zlatu, korporativnom indeksu obveznica i državnom indeksu obveznica isključujući Italiju i Grčku. U kontekstu formiranja optimalnog portfolija od ukupno 10 portfolija drugi portfolio se pokazao najoptimalniji u pogledu povrata i standardne devijacije.

Iako proces formiranja digitalne imovine, konkretno Bitkoina, još u potpunosti nije shvaćen, visoka cena i preterano nestabilna struktura počele su da privlače pažnju investitora. Modeliranje strukture volatilnosti cena Bitkoina je važno za one koji razmišljaju o ulaganju u Bitkoin. Pored svoje visoke volatilnosti Bitkoin može da posluži kao odličan oblik digitalne imovine u kombinaciji sa ostalim oblicima finansijske imovine zbog svoje niske korelacije i ostvarivanja prednosti diversifikacije. Ovo istraživanje bi trebalo da doprinese povećanju postojećeg korpusa znanja o finansijskim istraživanjima primenom VaR tehnike i modeliranja za procenu iznosa potencijalnog gubitka izabrane digitalne i finansijske imovine. Nadalje, moguće je razviti i proširiti ovo istraživanje korišćenjem različitih sredstava i različitih strategija portfolija. Na ovaj način će se dobiti sveobuhvatnije informacije o upotrebljivosti kriptovaluta u diversifikaciji portfolija. Međutim, treba imati u vidu da je ovo istraživanje rađeno na osnovu istorijskih podataka, gde ne treba zaboraviti da situacije koje su se desile u prošlosti možda nisu ogledalo budućnosti, jer je budućnost puna neizvesnosti.

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THE VOLATILITY OF BITCOIN AND THE RISKINESS OF THE FINANCIAL PORTFOLIO

Prof. Almir Alihodžić, PhD
tenured professor,
Faculty of Economics, University of Zenica
almir.dr2@gmail.com

Summary: The main goal of this research is to evaluate the returns and risks of the following types of assets: Bitcoin, EUR Stoxx 50, gold, bonds: government bonds ICE Bof A 1-10 Year excluding Italy and Greece and the corporate bond index ICEBof A 1-10 Year AA. The paper tested a total of ten portfolios according to different scenarios for digital and financial assets. Also, in the paper, greater measures of risk and return were calculated with the aim of forming an optimal portfolio with minimal risk. The results of this research revealed that the correlation between Bitcoin and other forms of financial assets is generally low and negative, which can be a good instrument for portfolio diversification, and positively affect portfolio performance. Also, the results of this study showed that in terms of volatility and return measure of a total of ten portfolios, the second portfolio (whose structure consists of Bitcoin, Euro Stoxx 50, gold, government bonds ICE Bof A 1-10 Year - excluding Italy and Greece and the corporate index bond ICEBof A 1-10 Year AA) is the most optimal portfolio. The findings of this research can serve in risk and loss assessments of portfolio managers, investors, and regulators.

Keywords: Value at risk, VaR, market risk, Bitcoin, efficient portfolio, portfolio optimization.

JEL classification: G11, G32

Introduction

The origin of modern portfolio theory is linked to the famous text published in 1952 by Harry Markowitz, in which he developed a model of the expected rate of return and expected portfolio risk. Markowitz showed that the variance of a portfolio rate of return is also a measure of portfolio risk under certain assumptions. During the development of the mathematical model of portfolio return variance, Markowitz indicated not only the crucial importance of diversification of investments to reduce the overall risk of the portfolio but also how diversification is effectively performed and used. One of the biggest improvements in investment analysis in the past decades is certainly hidden in the knowledge that creating an optimal portfolio of securities is not a simple job of investing in securities based on desirable ones, i.e., target return and risk characteristics of each security. On the other hand, the theory proven in practice indicates the need to consider and analyze the mutual relations of the return and risk characteristics of each security included in the investment portfolio (Krneta, 2006).

The concept of risk has been used extensively in finance. There are significant differences in the exact definition of this term, which makes it difficult to give a common answer to a seemingly simple question: what is risk? Managing and measuring risk has become a key issue for many portfolio analysts and investors. In the last few years, financial literature has focused on the segment of risk management. When investing in an individual security, portfolio risk represents the possibility that the planned return will not be achieved, that is, that the invested funds will bring a lower profit than expected or even result in a loss (Alihodžić, 2011).

From the point of view of investors, another important question has always been asked, namely: what is the maximum loss I have to bear if it exists? The concept of value at risk was proposed in 1996 to suggest answers to this question. It consists of simply determining the risk by giving it an accurate value. Jorion (1996) states that VaR describes the worst expected scenario, i.e., the loss for a given horizon and confidence level. Risk managers, regulators, and traders should be aware of certain volatility characteristics when assessing future volatility.

In recent years, the area covered by cryptocurrencies, i.e., virtual currencies in payment systems, has been rapidly expanding, and these currencies have attracted the attention of investors in financial markets from all over the world. Also, cryptocurrencies attract the attention of developers, venture capitalists, and investors with their innovative technologies, high-security architectures, and their ability to be investment instruments (Klein et al., 2018).

Bitcoin is the earliest published currency among cryptocurrencies and is also the most popular because it has the highest market value. Although it is stated that Bitcoin was introduced by a person named Satoshi Nakamoto in 2009, it remains a mystery whether this is a person, or a pseudonym used by some people and groups that created Bitcoin. Differing views on cryptocurrencies and the future of cryptocurrencies continue to be a driving force despite extreme volatility in these markets. This situation has led to an increased interest of researchers in this topic to unravel the mystery of the complex world of cryptocurrencies, which is still unclear and confusing for most market participants (Guesmi et al., 2019).

In light of these thoughts and the studies conducted on this topic, the main goal of this paper will be revising the persistence of volatility for selected digital and financial assets, i.e. calculating the expected risk and return of digital and financial assets, as well as selecting the most optimal portfolio from the total set of portfolios.

This research is designed in five parts. The first part refers to the introductory issue with a focus on a brief description of the definition of modern portfolio theory and the significance of value-at-risk. The second part describes an overview of previous research regarding the significance of the value-at-risk methodology for assessing risks and losses for various forms of digital and financial assets, and the formation of an optimal portfolio. The third part describes the selected research methodology, with a special emphasis on the necessary formulas for the calculation of the expected return of the portfolio, the standard deviation of the portfolio, the variance, and the calculation of the value-at-risk. The fourth part refers to the data and variables needed for the analysis. The fifth part presents the obtained research results, as well as certain observations and recommendations.

Review of Relevant Literature

VaR analysis measures the maximum loss of portfolio value during a predetermined period for a given confidence level. The Value at Risk (VaR) methodology has been used to interpret financial risk exposure since 1995. VaR is a measure that explains how volatile financial instruments are. A common lesson from various financial crises and disasters is that billions of dollars can be lost due to poor oversight and management of financial risks. Value at Risk (VaR) was developed in response to the financial disasters of the 1990s and is gaining an increasingly important role in market risk management. VaR summarized the worst loss over the target horizon for a given confidence level. VaR is primarily a popular approach because it provides a single quantity that summarizes the total risk the institution is facing (Gencay and Selcuk, 2004). The popularity of VaR is based on the ability to combine several components of a company's market risk into a single number. Moreover, it focuses on the major concerns of senior managers, as well as the potential for significant loss in the company's asset portfolio. In its various forms, VaR has also received strong support from industry and regulatory bodies such as the Group of 30 (G30, 1993), the Bank for International Settlements, and the European Union.

Market risk is usually quantified using the Value-at-Risk (VaR) methodology. Using the given methodology, the value of the market risk is estimated at the given confidence levels. In practice, confidence levels of 99% or 95% are usually used. It is safe to say that VaR measures the probability of loss based on activities registered in the trading book, both on the capital side and on the income side, at a given level of confidence (Đukić, 2011).

Valuation of the portfolio using the VaR method is a subject of extensive research that is still growing in popularity. Several analytical techniques as well as simulation-based techniques are available, depending on the degree of non-linearity of the instruments in the portfolio and the willingness to make strict assumptions about the underlying statistical distributions. VaR is the only regularly used risk metric that can be applied to almost any asset class, which is one of the reasons why it has become popular.

Markowitz (1952) and three months later Roy (1952) independently published VaR measures that were surprisingly similar. Both Markowitz and Roy worked to develop ways of selecting portfolios that would somehow optimize the reward for a given level of risk. For this purpose, each proposed VaR measure included covariances between risk factors aimed at hedging and diversification effects. Although these two measures were mathematically similar, they supported different VaR metrics. Markowitz used the variance of a simple return metric. Roy used a shortfall risk metric that represents an upper bound on the probability that a portfolio gross return will be less than some specified „catastrophic" return.

Rockafellar and Uryasev (2000) defined value at risk as the loss of market value during a time horizon t that is exceeded with probability 1-p for a certain time horizon t and confidence level p. The Bank for International Settlements (BIS) is a financial institution based in Switzerland, which to calculate the capital adequacy of banks has set p at 99 percent and t at ten days, although this would allow limited use of the advantages of statistical diversification in different periods.

Hendricks (1996) randomly selects 1,000 portfolios of currency options to test the effectiveness of the VaR model. His study aimed to demonstrate and compare the similarity of the risk number measured by the VaR method and the real risk. One factor he considers is market risk along with the use of three fundamental methods, namely: a) equally weighted moving average, b) exponentially weighted moving average, and c) historical simulation method. Based on the given methods, he concluded that different VaR numbers are obtained. Ultimately, however, he cannot conclude that one method is superior to the others. In his test, he also shows that the 95% and 99% confidence levels produce different VaR numbers.

Jorion (1997) has similar criticisms about VaR, that it is not a perfect measurement tool. Therefore, VaR simply illustrates the different rates of risk that are embedded in derivative financial instruments. VaR is a good tool that risk managers should be aware of to, in order to act towards protecting their risk positions. Also, VaR is accepted as a standard measurement for determining regulatory capital by BIS (Karelse, 2001). Many parties in financial markets such as institutions, wealthy investors, authorities, auditors, and rating agencies can regularly monitor market risk and accept different confidence levels for their VaR calculations (Culp et al., 1999).

Yamai and Yoshiba (2002) show that VaR and expected shortfall are free from risk when profit and loss are normally distributed. On the other hand, VaR can show value at risk if profit and loss are not normally distributed. The main cause of the uneven distribution of profit and loss is the non-linearity of portfolio positions or the non-linearity of underlying asset prices.

Woods et al. (2008) defined VaR as a statistical indicator of financial risk that represents the largest probable loss of the portfolio during a certain period. As a result, the amount of VaR depends on two arbitrary parameters: the holding period or time horizon and a probability known as the confidence level. For example, a bank's VaR in its trading portfolio might be £20 million with a confidence level of 95% and a holding period of the next trading day. This means that the bank believes it has a 95% chance of making a profit or losing no more than £20 million on the next trading day.

Bouri et al. (2016) examined the relationship between price returns and volatility changes in the Bitcoin market in different currencies (US dollar, Australian dollar, Canadian dollar, British pound, Euro, and Japanese yen). The study is divided into two periods considering the collapse of the Bitcoin price in December 2013. According to the findings of the study, while there was no evidence of an asymmetric relationship between returns and volatility in the Bitcoin market for the entire period of the observed sample, it was determined that there was a significant inverse relationship between volatility and past shocks before the price drop in December 2013, but then there was no significant relationship. The authors explained this finding, which was contrary to expectations, as a haven effect, similar to investing in gold. Moreover, only the results of the pre-collision period showed a significant negative relationship between US stock market uncertainty and Bitcoin volatility.

Dyhrberg (2016) examined the financial asset performance of Bitcoin using a GARCH model. The results of the analysis showed that Bitcoin has many similarities with gold and the dollar, where, according to the general result of the study, it was concluded that Bitcoin is somewhere between money and commodity due to its decentralized structure and limited market size.

Carrick (2016) examined whether Bitcoin can be considered a complementary or replacement currency of developed and emerging countries, and how the inclusion of Bitcoin in a basket of currencies would affect the risk-adjusted returns of an already diversified portfolio of currencies. The research used data related to the value and volatility of the main currencies (Austrian dollar, British pound, Canadian dollar, Euro, Japanese yen, and Swiss franc) and developing market currencies (Brazilian real, Chilean peso, Chinese yuan, Colombian peso, Indonesian rupiah, Indian rupiah, Malaysian ringgit, Mexican peso, Philippine peso, Polish zloty, Russian ruble, South Korean won, Thai baht, and Turkish lira) against which the value and volatility of Bitcoin were compared. The observed research period lasted from January 1, 2011, to December 31, 2015. It was found that Bitcoin is negatively correlated at a statistically significant level with all major currencies in the analyzed period, except for the Swiss franc, and with all emerging market currencies except for the Chinese yuan. The negative correlation between emerging market currencies and Bitcoin is an interesting finding because currency risk is a major concern with emerging market currencies. Emerging market currencies have become a common way to diversify risk and balance currency and investment portfolios. Due to the negative correlations between Bitcoin and most currencies, including Bitcoin in a basket of currencies could be beneficial for portfolio managers to reduce risk and increase risk-adjusted returns. Therefore, Bitcoin can be considered as a complement to other currencies, especially the currencies of developing countries.

Nam (2017) aimed to find answers to questions such as: Can Bitcoin improve portfolio efficiency? Which portfolio optimization strategy can create the best risk-return profile involving Bitcoin? In his methodology Nam used Sharpe Ratio, VaR, and CVaR, to examine the relationship of Bitcoin, Euro, British Pound, Swiss Franc, Japanese Yen, Australian Dollar, Canadian Dollar, and Gold for the period: 2010-2016. The research results have shown that Bitcoin has the potential to improve portfolio performance.

Byström and Krygier (2018) focused on the relationship between volatility in the Bitcoin market and other traditional markets. A significant correlation was found between Bitcoin volatility and Google search volume. Additionally, since Internet search activity was thought to be predominantly generated by retail investors and the general public, it was concluded that Bitcoin volatility was caused by retail investors, not institutional investors.

Klein et al. (2018) divided their research into three parts. First, the volatile behavior of cryptocurrencies compared to stock indices and commodities was investigated. Second, the hedging capabilities and haven of cryptocurrencies compared to gold are explored through dynamic correlation analysis. Finally, a portfolio analysis was applied that highlights the behavior of gold and Bitcoin in difficult times. According to the results, there were differences in the structures of Bitcoin and gold in terms of conditional variance properties. Also, while gold played an important role in the difficult times in the financial markets with the transition to quality, Bitcoin was the exact opposite. It was concluded that Bitcoin and gold had different characteristics mainly related to assets and stock markets. While the asymmetry effect was significant for Bitcoin, on the other hand, it was not significant for gold.

Kajtazi and Moro (2019) examined whether Bitcoin provides advantages in terms of portfolio diversification. As a result, they concluded that the performance of the portfolio increased by adding Bitcoin, but it should not be ignored that this situation is mainly due to an increase in return, not a decrease in volatility and that this increase in performance is related to the performance of Bitcoin in 2013. In general, in this framework, they stated that although Bitcoin is speculative, it can play an important role in portfolio diversification.

Symitsi and Chalvatzis (2019) investigated the performance of Bitcoin in portfolios. Using data from September 2011 to July 2017, they concluded that Bitcoin provides statistically significant diversification benefits and can add value to portfolios.

Soyaslan (2020) analyzed the correlation between Bitcoin and BIST Bank, BIST Technology, and BIST 100 index daily data between 2011 and 2020, using time series analysis methods. As a result of the study, there is a long-term correlation between Bitcoin and the BIST 100 index, but there is no correlation between BIST Bank and BIST Technology in the short term.

Papafotis (2021) investigated price behavior, fluctuations, potential peaks, minimum values of cryptocurrencies, and the existence of coherence and connections between the behavior of some cryptocurrencies in relation to other cryptocurrencies. The author performed correlation analysis and Johansen cointegration analysis of the daily prices of Bitcoin (BTC), Litecoin (LTC), Ethereum (ETH), Ripple (XRP), and Monero (XMR) for the period from 2013 to 2020. The results of the analysis differed for and before 2017. The research showed that five cryptocurrencies had had an unstable model before 2017, but on the other hand, a similar and stable model was observed among cryptocurrencies after 2017.

Research Methodology

Volatility is a statistical measurement of asset price movements. The higher the volatility implies the possibility of higher returns or losses. However, in real life, volatility and correlations change over time. Value at Risk is defined as the maximum loss over a given time horizon and for a given confidence level. It is widely used to measure the potential risk of economic losses in financial markets. In terms of forecasting, portfolio managers, investors, and traders usually focus on longer horizons. Value at Risk is calculated at a one-day confidence level of 95% and 99%. Also, the loss is usually signaled to be greater than the reported value at risk of the portfolio in only 5% and 1% of cases.

When choosing a confidence level, it should be taken into account that the lower the confidence level, the more accurate the assessment, and vice versa, the higher the confidence level, the higher the amount of calculated maximum loss, which consequently leads to higher provisioning costs, i.e., larger amounts needed to cover potential losses. Portfolio managers, traders, and investors must evaluate not only long trading positions but also short trading positions. In the case of a long trading position (left tail of the distribution), the risk of loss occurs when the price of the traded asset decreases. On the other hand, in the case of a short trading position (right tail of the distribution), the risk of loss occurs when the price of the traded asset rises (Demiralay and Ulusoy, 2014).

As Fama stated in 1970, prices in financial markets would be safe under the hypothesis that they fully reflect all available financial information. The fact that information in financial markets is constantly changing makes it difficult to use information in the decision-making process and hinders market efficiency. This situation allows better-informed investors to make high profits (Fama, 1970). The theory implies that under normal conditions the market is efficient, which means that investors are properly informed and make rational decisions. However, the lack of a deterministic framework or model for cryptocurrencies makes it difficult to predict market value and adversely affects weak-form efficiency features (Naeem et al., 2021).

From this point of view, to understand the fundamentals of financial markets and cryptocurrencies one should test the market efficiency hypothesis. Volatility is a very important issue in finance because it is considered a major input to the decision-making process in various areas such as security prices, trading, risk management, and monetary policy. Therefore, volatility estimation is an essential field of research that has several theoretical and practical implications (Naimy and Hayek,2018).

Since there are several methods for calculating VaR, it is difficult to choose the most appropriate one that predicts the risk of a particular financial asset, asset, or portfolio of financial assets. The most commonly used methods of calculating VaR are the following: historical method, variance-covariance method, and Monte Carlo method. The historical method is based on historical data, while the variance-covariance method and the Monte Carlo method use historical data to estimate statistical parameters. The expected return of the portfolio is calculated as a weighted sum of the returns of individual securities that make up the portfolio. The share of individual security in the portfolio serves as a weight:

$$E(R_{port}) = \sum_{i=1}^{N} X_i \, E(R_i) \tag{1}$$

where is: $E(R_{port})$ - expected portfolio return; X_i - the percentage share of the security (i) in the portfolio, $E(R_i)$ - the expected return of the security (i). The portfolio variance is calculated as follows:

$$\sigma^2 = \sum_{i=1}^{N} X_i^2 \, \sigma_i^2 + \sum_{i=1}^{N} \sum_{j=1}^{N} X_i X_j \sigma_i \sigma_j \rho_{ij} \tag{2}$$

where is: σ_i^2 - the variance (i) of the security, σ_i – standard deviation i- of the security, ρ_{ij} – the coefficient of correlation between securities returns (i) and (j). The last part of equation (2) $(\sigma_i \sigma_j \rho_{ij})$ can be replaced by a statistical expression $Cov_{i,j}$ (covariance), in order to simplify the equation, since:

$$\rho_{ij} = \frac{Cov_{i,j}}{\sigma_i \sigma_j} \tag{3}$$

The covariance is obtained from the following formula (Berenson and Levine, 1996):

$$Cov_{i,j} = \frac{1}{N-1} \sum_{i=1}^{N} [(x_i - \bar{x})(y_i - \bar{y})] \tag{4}$$

An investor who has diversified their investment does not take into account the individual risk of an asset, but rather its effect on the riskiness of the overall portfolio (Bawa et al., 1979). As the standard deviation and variance measure the risk of an asset when viewed in isolation, it is necessary to use measures that link one asset to another in the assessment of corporate risk. Determining the expected return and the standard deviation of the return enables the formation of the return probability distribution curve. Probabilities of deviation from the expected return are observed through the return probability distribution curve. The VaR indicator is obtained as the product of the standard deviation of the portfolio (σ_p) and the coefficient of reliability of the standardized normal distribution (Z_α), that is, it is expressed using the following formula (Megla et al., 2017):

$$VaR = \sigma_P \cdot P \cdot Z_\alpha \tag{5}$$

where is:

P- the initial market value of the portfolio.

There are certain parameters that the analyst needs to determine before proceeding to VaR calculation. The parameters are as follows: time interval, confidence level, portfolio value, and standard deviation. The investment time interval varies from investment to investment. It can be a day, a month, a year, or longer. The time interval of the investment is generally related to the ease of liquidity of the investment. Although daily or monthly periods are used, the period depends on the investment. Adjusted time is used to calculate VaR. The confidence level in VaR is a calculated parameter that gives the reliability of the calculation. The Basel Committee requires a 99% confidence level and a one-sided confidence interval. The larger the confidence interval, the higher the resulting amount of VaR will be (Kayahan and Topal, 2009). The value of the portfolio is the total amount invested in a security or portfolio. The standard deviation is calculated according to the price fluctuations of the securities. Also, the standard deviation is calculated as a percentage of the change in the prices of securities. At least 250 data points are used to calculate the daily standard deviation, and this corresponds to the sampling period (Irs, 2017).

The weakest aspect of the VaR calculation method is that it does not show the "worst case scenario". As is known, probability distributions represent the range within the given confidence interval. However, although the probability in real life is very small, as there are some events outside this area. Although the probability is very low, it cannot be said that such an event will never happen. Another important issue is that VaR models do not show a complete loss. For example, VaR shows that $1 million is at risk on a trading day, and cannot provide information about losses on the second, third, and subsequent days. The fat tail of the distribution can be a major risk factor for investors. A fat tail simply means sudden and large increases/decreases in the value of securities or other financial assets. The fact that fluctuations in large quantities cannot be predicted by the VaR method is one of the shortcomings that makes the method inadequate (Demireli and Taner, 2009).

Data for Analysis

The paper investigated daily historical data on the movement of the following digital and financial assets: Bitcoin, EUR Stoxx 50, gold, bonds: government bonds ICE Bof A 1-10 Year excluding Italy and Greece and corporate bond index ICEBof A 1-10 Year AA. A broad Bloomberg database served as the source of daily historical data for the period from February 28, 2013, to April 20, 2023, covering a total of 10 years and 51 days. However, the lack of analysis on a daily basis was missing data, which indicates the fact that a certain form of financial and digital asset was not traded for one or more days. In this context, the data were supplemented with either the average value, or the trading price from the previous day, which was implemented in this research. Also, in this research, the assessment of the obtained portfolios, as well as the VaR indicators, is based on the daily returns of the observed forms of assets.

Table 1 - Brief Description of the Analyzed Variables

Digital and financial assets	Short definition	Expected effect
Bitcoin	Bitcoin is the original blockchain-based cryptocurrency. Created in 2009, by the pseudonymous Satoshi Nakamoto. Since then, Bitcoin has attracted millions of investors, becoming the largest cryptocurrency by market capitalization.	-
Euro Stoxx 50	It represents some of the largest companies in the Eurozone in terms of market capitalization in free circulation. The index covers about 60% of the market capitalization in free circulation, which in turn covers about 95% of the free float market capitalization of the represented countries.	(+)
Gold	Gold has always had a traditional role in the country's foreign exchange reserves. Also, gold was considered the ultimate refuge of safety, that is, the basis of strengthening the domestic currency, especially in cases of financial instability and uncertainty.	(-)
Government bonds ICE Bof A 1-10 Year (excluding Italy and Greece)	Government bond index that tracks the performance of corporate debt denominated in euros below investment grade that was publicly issued on the domestic euro market or on the eurobond market.	(+)
Corporate Bond Index ICEBof A 1-10 Year AA	An index that tracks the performance of US dollar-denominated corporate debt publicly traded in the US domestic market.	(+)

Source: Author

Bitcoin - one of the most important financial innovations in recent years is digital cryptocurrencies that have attracted great interest from the public, but also from investors and financial institutions. The first and most important market capitalization is Bitcoin. It was first introduced in 2008 as a peer-to-peer electronic cash system by a mysterious person or group using the alias Satoshi Nakamoto, whose identity is still unknown. In a related article, electronic currency is defined as a "chain of digital signatures" (Nakamoto, 2008). At the center of Bitcoin is a global ledger or balance sheet called the blockchain (Kelly, 2014). Blockchain technology is based on the logic of creating a chain of these blocks by enclosing the data to be stored in "blocks". Therefore, transactions are recorded chronologically on the blockchain, and data cannot be changed retrospectively (Aksoy, 2018).

EURO Stoxx 50 - is a Eurozone stock index designed by STOXX, an index provider owned by Deutsche Börse Group. The EURO STOXX 50 began to be listed only in 1998, but its prices were calculated retroactively until 1986. The base value of the index is 1.000 points on December 31, 1991. The index consists of 50 stocks from 11 eurozone countries. Therefore, the EURO STOXX 50 represents companies from the eurozone that are considered leaders in their sectors. Futures and options on the observed EURO STOXX 50 index traded on Eurex are among the most liquid products in Europe and the world (en.wikipedia.org).

Gold - has long served as a means of exchange and storage of wealth. The price of gold is mostly related to economic and political instability, as it has no sovereign credit risk. Gold is a unique asset with a safe haven and protection properties, as it is weakly correlated with other financial investments (Hillier et al., 2006).

Government bonds ICE Bof A 1-10 Year (excluding Italy and Greece) – this index tracks the performance of corporate debt denominated in euros below investment grade that was publicly issued on the domestic euro market or the Eurobond market. Qualifying securities must be rated below investment grade (based on an average of Moody's, S&P, and Fitch). Qualifying securities must have at least one year remaining to maturity, a fixed coupon schedule, and a minimum amount of €100 million (https://fred.stlouisfed.org).

Corporate Bond Index ICEBof A 1-10 Year AA - this index also tracks the performance of corporate debt denominated in US dollars publicly announced in the US domestic market. This index includes all securities with a given investment rating of AAA. Securities included in this index must have at least one year to maturity, a fixed coupon schedule, and a minimum principal amount of $250 million (https://www.doubleline.com).

Results and Discussion

With the recent growth of the cryptocurrency market, some have argued that cryptocurrencies can be seen as a new type of investment tool (Corbet et al., 2018). When it comes to seeing cryptocurrencies as a new investment tool or alternative asset, there are two questions that investors should consider. The first of them are investment-specific risks, the second are the relationships of cryptocurrencies with other assets, which is even more important in terms of the diversification benefits and hedging capabilities of cryptocurrencies (Feng et al., 2018).

The removal of digital assets from investment alternatives will be as restrictive as the removal of all other assets (Elender et al., 2018). Volatility modeling is also important for risk management. Moreover, cryptocurrencies are mostly used as assets instead of currencies, even though the market is quite speculative. It is also more volatile than other currencies and more subject to speculative bubbles. In this regard, cryptocurrencies have an important place in financial markets and portfolio management. Therefore, the analysis of their volatility is extremely important. The table below illustrates the tendency of the return and risk measures of digital assets (Bitcoin) and other representatives of financial assets (EUR 50 Stoxx 50, Gold, Government bonds ICE Bof A 1-10 Year, Corporate bond index ICE Bof A 1-10 Year AA) for the period: 28.02.2013 - 20.04.2023.

Table 2 - Measures of Return and Risk of Digital (Bitcoin) and Financial Assets for the Period: 28.02.2013 - 20.04.2023 (in%)

Measures of return and risk	Bitcoin	EURO Stoxx 50	Gold	Government bonds ICE Bof A 1-10 Year (excluding Italy and Greece)	Corporate Bond Index ICEBof A 1-10 Year AA
Mean	11.57	0.51	0.24	0.03	0.05
Standard deviation	49.30	4.84	4.22	0.87	0.93
Freq<0	43.90	44.72	52.03	42.28	41.46
Parametric VaR	-69.52	-7.45	-6.70	-1.41	-1.49
Empirical VaR	-29.48	-6.79	-6.14	-1.25	-1.44
Parametric CVaR	-90.13	-9.47	-8.46	-1.77	-1.88
Empirical CVaR	-34.50	-9.12	-7.62	-2.19	-2.48

Source: Calculation by the author based on the Bloomberg database

From the previous table, it can be noted that Bitcoin achieved the highest risk in terms of the first measure of risk, i.e., the standard deviation of about 49.30%, as well as the highest return of 11.57%. Also, in terms of achieving potential loss measured by parametric and empirical VaR values at a confidence level of 95%, Bitcoin achieved high values of 69% (parametric VaR method) and 29% (empirical VaR method).

The increase and fluctuation of Bitcoin prices in recent years have attracted a lot of attention. In particular, the increase in the price of Bitcoin in the last five years has provided an example of super (exponential) growth that is not usually seen in any financial field except the cryptocurrency market (Pichl and Kaizoji, 2017). The price of Bitcoin, which was trading at $1,000 in early 2017, rose significantly to $15,000 in December 2017. However, some events have contributed to the increase in the volatility of Bitcoin. The monetary restrictions of the Chinese Government since July 1, 2017, excessively increased the price of Bitcoin due to the increasing demand, and the ban on trading in digital currency in August 2017 also affected the excessive decrease in the price of Bitcoin (Aksoy, 2018).

The second place in terms of riskiness, measured by standard deviation, belongs to the EURO Stoxx 50 stock index (4.84%) and gold (4.22%). Government and corporate bonds achieved the lowest risk. Unlike digital assets, the volatility of gold and the stock and bond markets increases during periods of political and economic turmoil. Except for the second period in 2008 (mortgage credit crisis), high volatility of financial forms of assets was recorded towards the end of 2011, as well as in the middle of 2013. The end of 2011 was marked by the European sovereign debt crisis, which caused the collapse of financial institutions and high sovereign debt in some European countries while debates about the FED monetary policy decisions flared up in mid-2013. The high volatility of cryptocurrencies makes it difficult for investors to take the right position and develop investment strategies. Investing in the crypto money market certainly involves high risks. Chief among these risks are operational risks and cyber risks. On the other hand, even today it can be seen that investors still seriously believe in rumors and speculations about cryptocurrencies. Certain studies in literature point out that Bitcoin and other cryptocurrencies should be viewed as "speculative" assets. Early research into Bitcoin price dynamics indicates that Bitcoin has a highly speculative nature (Brauneis and Mestel, 2019).

Table 3 - Correlation Matrix Between Digital (Bitcoin) and Financial Assets for the Period:28.02.2013 - 20.04.2023

	Bitcoin	EUR50 Stoxx 50	Gold	Government bonds ICE Bof A 1-10 Year (excluding Italy and Greece)	Corporate Bond Index CEBof A 1-10 Year AA
Bitcoin	1.00				
EURO Stoxx 50	0.34	1.00			
Gold	-0.04	0.03	1.00		
Government bonds ICE Bof A 1-10 Year (excluding Italy and Greece)	0.26	0.27	-0.08	1.00	
Corporate Bond Index ICEBof A 1-10 Year AA	0.40	0.63	-0.10	0.78	1.00

Source: Calculation by the author based on the Bloomberg database

The previous table illustrates the movement coefficients of correlation between cryptocurrency (Bitcoin) and financial assets represented by certain stock indices and assets (EUR 50 Stoxx 50, Gold, Government Bond Index, Corporate Bond Index). The strongest positive correlation was recorded between Bitcoin and the index of corporate bonds ICEBof A 1-10 Year AA (0.40), then with the stock exchange index EUR50 Stoxx 50, a positive correlation was achieved (0.34). The low level of portfolio risk is the result of an inverse relationship between portfolio performance.

Therefore, in a recession and slow economic growth, share prices fall, but on the other hand, bonds achieve good results. Conversely, after a sharp economic upswing, bond prices fall, but stock prices rise (Bodie et al., 2009). Based on the given coefficients of correlation and ratios, it can be concluded that the values of the coefficients of correlation are very low, which provides a good opportunity for diversification by including cryptocurrencies. On the other hand, the most criticized aspect of modern portfolio theory is the increase in correlation between portfolio assets in times of crisis and the loss of diversification benefits when it is most needed (AlKulaib and Almudhaf, 2011). It is argued that low-correlation assets taken into a portfolio to provide diversification benefits increase the correlation between them in crisis periods and provide no real diversification benefit (Baur and Lucey, 2010).

On the other hand, the strongest negative causality was observed between Bitcoin and gold (-0.04). The extreme volatility of cryptocurrencies has been thoroughly documented, but investors and financial professionals view a given volatility differently depending on their attitude toward Bitcoin. Investors who have embraced Bitcoin meteoric rise over the past few years have embraced excessive volatility, while bullies and Bitcoin bears point to high volatility as a burning red flag and a reason to avoid investing. By the end of the first quarter of 2018, Bitcoin had fallen by almost 50%, and gold had risen by 7.5%. Therefore, Bitcoin is called an alternative to gold and consequently, a hedge against inflation due to its limited supply and lack of centralized regulation. In times of uncertainty, investors will flock to invest in gold and precious metals as a haven to stay away from government-regulated currencies. While Bitcoin and Gold may not be competitors as inflation hedges, they may be complementary in one portfolio (http://www.cmegroup.com).

Opportunities for portfolio diversification in developing markets can also be seen through the possible effects of investing in different assets from different segments of the financial markets, for example investing in shares of different industries, diversified different funds in developing markets, EFT funds in capital markets, gold, different countries' currencies, and Bitcoin. In this research, the statistical programs Microsoft Excel and MATLAB 7.1 were used during the analysis. Also, in this study, ten portfolios were created according to different scenarios for digital and financial assets, and values such as return and standard deviation of the portfolio were calculated. By adding cryptocurrency to these portfolios, it was examined how the Bitcoin currency affects the portfolios and whether it can possibly add value to the portfolio.

Table 4 - Efficient Portfolio Set - Digital (Bitcoin) and Financial Assets: Average Return and Risk for the Period: 28.02.2013 – 20.04.2023

	PORTFOLIO									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Average return	0.03	**0.05**	0.10	0.15	0.20	0.25	0.27	0.30	0.35	0.40
Standard deviation	0.86	**0.88**	0.94	1.05	1.17	1.32	1.38	1.47	1.64	1.81
Sharpe ratio	0.04	**0.06**	0.11	0.14	0.17	0.19	0.20	0.20	0.21	0,22

Bitkoin	0.00	**0.11**	0.49	0.84	1.18	1.53	1.67	1.88	2.22	0.02
EURO Stoxx 50	0.00	**0.00**	0.65	2.15	4.63	5.15	6.18	7.07	8.78	0.10
Gold	0.27	**1.28**	2.65	4.04	5.61	6.83	7.50	8.34	9.78	0.11
Government bonds ICE Bof A 1-10 Year (excluding Italy and Greece)	76.85	**70.77**	68.32	66.66	88.43	63.36	73.63	72.65	76.14	0.74
Corporate Bond Index ICEBof A 1-10 Year AA	22.87	**0.28**	0.28	26.31	0.15	23.13	11.02	10.06	3.08	0.01

Source: Calculation by the author based on the Bloomberg database

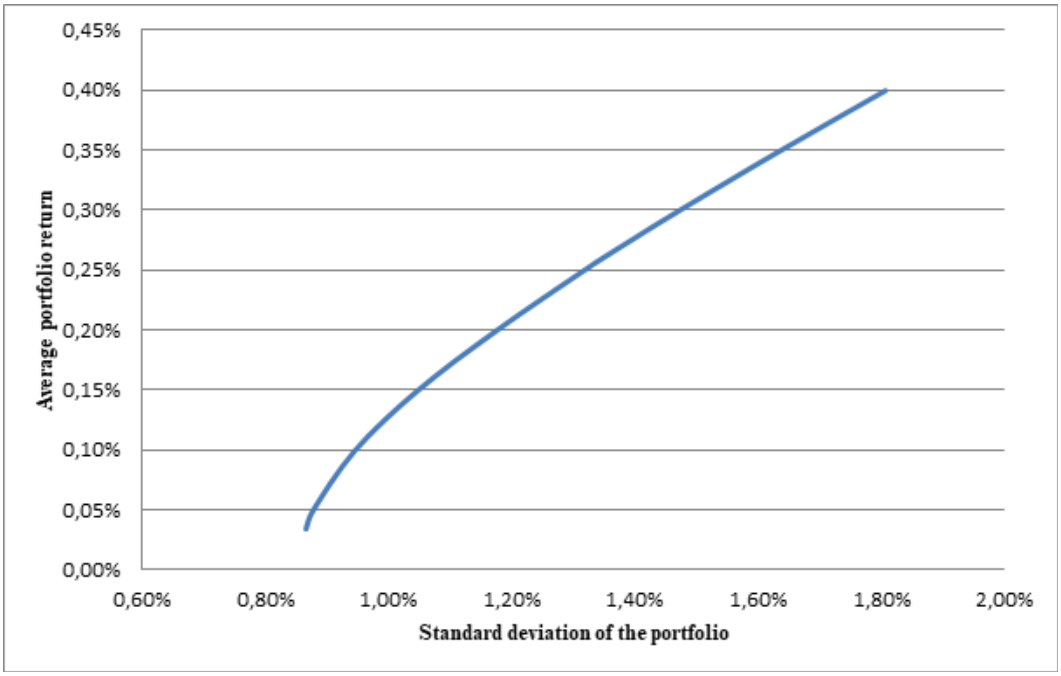
In his seminal article from 1952, Harry Markowitz stated that the purpose of portfolio selection is to determine the allocation of assets in a portfolio to obtain the maximum expected return given risk, or the minimum risk of a portfolio given a portfolio expected return (Johnson, 2014). Also, Harry Markowitz, the founder of modern portfolio theory, determined that the relationship between assets is more important than their risks and determined that portfolio risk can be reduced by adding assets that are not highly correlated. The lower the relationship between assets in terms of correlation that are included in the portfolio, the lower the total risk of the portfolio (Markowitz, 1952).

From the previous table, it can be concluded that out of all the ten portfolios observed, the second portfolio is the most optimal in terms of risk, i.e., standard deviations, because it minimizes portfolio risk. Considering that the correlations between cryptocurrency (Bitcoin) and other forms of financial assets are low or negative, this situation can have the effect of increasing the advantages in terms of diversification. Also, it should be noted that with an increase in the Sharpe ratio, the average return and the standard deviation of the portfolio also increase.

One of the common ideas put forward to explain investor interest in cryptocurrencies is the possible benefits these digital coins can provide in portfolio diversification. Cryptocurrency returns are considered to have a low or negative correlation when compared to the returns of traditional financial assets such as bonds or stocks. Therefore, as a result of the inclusion of the mentioned cryptocurrencies in portfolios, expected portfolio returns corresponding to each unit of risk are expected to increase (Anyfantaki et al., 2018). Using the Markowitz mean-variance model, Brauneis and Mestel (2019) used data for the period from January 2015 to December 2017 to reveal the efficiency of cryptocurrency portfolios. As a result, they stated that portfolios created from different cryptocurrencies have significant risk reduction potential. Also, Guesmi et al. (2019) analyzed the dynamics of the relationship between Bitcoin and other financial assets that they observed with data for the period: January 2012 - January 2018. Their primary goal was to determine whether Bitcoin provides benefits to investors in terms of portfolio diversification and risk management. As a result of the research conducted, they concluded that Bitcoin could provide benefits to investors in terms of risk protection and portfolio diversification.

The efficient frontier is the set of all portfolios that are in the ascending part of graphic representation 1. The upward movement means that portfolios on the efficient frontier contain selections that increase the portfolio expected return and increase the portfolio standard deviation. To successfully calculate the efficient frontier, its starting point should be found, i.e., the portfolio with the minimum standard deviation of returns. In finance, this portfolio is called a minimum variance portfolio, which means that it has minimum variance and minimum standard deviation (Vukičević et al., 2010). The graphic below illustrates the trend of the effective frontier of digital assets (in our case Bitcoin) and financial assets for the period: 28.02.2013 - 20.04.2023.

Graph 1 - Effective set of Digital (Bitcoin) and Financial Assets for the Period: 28.02.2013 - 20.04.2023



Source: Calculation by the author based on the Bloomberg database

As can be seen with the increase in slope and the first measure of risk i.e., of the standard deviation of the portfolio, there is also an increase in the average return of the portfolio, but not to the same extent, that is, the average return increases to a lesser extent due to the different structure of the chosen portfolio.

Conclusion

Financial time series often exhibit stylized facts such as skewness, high volatility, fat tail characteristics, etc. Therefore, the literature on financial econometrics focuses on the distributional and statistical properties of financial return series. Forecasting volatility is an important task for most investors in financial markets. VaR brings standardization when comparing risky portfolios. In recent years, the advantages of VaR have made it a modern risk management tool. Volatility usually occurs in clusters. The assumption is that volatility that remains constant at all times can be fatal. Volatility changes over time, especially during financial crises when it tends to increase significantly.

In this research, the focus was to calculate volatility for different forms of financial assets as well as for digital assets, i.e., Bitcoin, and to find the optimal portfolio with minimum risk for the period: 28.02.2013 - 20.04.2023. The results of the research showed that the highest volatility and fluctuation in terms of the first measure of risk, i.e., the standard deviation, was recorded with Bitcoin, the second place belongs to the EURO Stoxx 50 stock index, followed by gold and bond indices in last place.

Also, in the context of the parametric and empirical VaR value, the first place in terms of the probability of economic loss belongs to digital assets, i.e., Bitcoin, followed by the EURO Stoxx 50 stock index, gold, the corporate bond index, and the government bond index excluding Italy and Greece. In the context of forming an optimal portfolio out of a total of 10 portfolios, the second portfolio proved to be the most optimal in terms of return and standard deviation.

Although the process of formation of the digital asset, specifically Bitcoin, is not yet fully understood, the high price and excessively unstable structure have begun to attract the attention of investors. Modeling the volatility structure of Bitcoin prices is important for those considering investing in Bitcoin. In addition to its high volatility, Bitcoin can serve as an excellent form of digital asset in combination with other forms of financial assets due to its low correlation and the realization of diversification benefits. This research should contribute to increasing the existing body of knowledge on financial research by applying VaR techniques and modeling to estimate the amount of potential loss of selected digital and financial assets. It is further possible to develop and extend this research using different assets and different portfolio strategies. In this way, more comprehensive information about the usability of cryptocurrencies in portfolio diversification will be obtained. However, it should be kept in mind that this research was done based on historical data, where we should not forget that the situations that happened in the past may not be a mirror of the future, as the future is full of uncertainty.

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