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## Article

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# Can gold-backed cryptocurrencies have dynamic hedging and safe-haven abilities against DeFi and NFT assets?

Rihab Belguith<sup>a,\*</sup>, Yasmine Snene Manzli<sup>a</sup>, Azza Bejaoui<sup>b</sup>, Ahmed Jeribi<sup>c</sup>

<sup>a</sup> Faculty of Economics and Management of Sfax, Tunisia

<sup>b</sup> Higher School of Commerce of Tunis, Manouba University, Tunisia

<sup>c</sup> Faculty of Economics and Management of Mahdia, Tunisia

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## ABSTRACT

Given that the interconnections of NFT and DeFi digital assets with other stablecoins still not sufficiently studied, this paper is two-fold. We first examine the dynamic conditional correlation between gold-backed cryptocurrencies and NFTs and DeFi assets during the period 02/11/2021-05/01/2023. We thereafter assess the diversification potential of gold-backed cryptocurrencies against NFT and DeFi. To this end, we use the time-varying Student's copula to investigate the cross-markets linkages among different assets in dynamic fashion. We afterwards compute the optimal hedging ratios and effectiveness index to better explore the effectiveness of portfolio risk management. Our findings clearly show that the degree of dependence between gold-backed cryptocurrencies and NFT and DeFi tokens tends to vary over time. Our results also display that gold-backed cryptocurrencies act as suitable hedging (or diversifying) assets during normal times. Nevertheless, such assets can be considered as robust safe havens during the 2022 bear market for the most of NFT and DeFi assets. More specifically, PAXG and PMGT are found to be the best safe haven instruments for both NFT and DeFi tokens. DGX also serves as safe-haven assets for some NFT and DeFi assets, but with a lower risk-mitigation capacity compared to PAXG and PMGT. In most cases, DGX tends to act as a strong diversifier. Its hedging feature is only recorded for the NFT Protocol (xNFT) and the DeFi token Chainlink (LINK). Our results are of particular interest to investors and portfolio managers who search for safe havens to mitigate the risk of their NFT and DeFi portfolios.

## 1. Introduction

Overall, cryptocurrencies have captured the general public's interest, the media, investors, and politicians during the last decade. A flourishing in Blockchain technology and the emergence of several digital assets have increasingly attracted investors in financial markets. In this respect, Decentralized Finance (DeFi) is a new system in which financial assets and services are accessible on a public decentralized Blockchain network to eliminate middlemen in financial transactions and improve access through smart contracts (Corbet, Goodell, & Gunay, 2022; Schär, 2021). DeFi utilizes smart contracts, which are automated agreements and transactions that execute and enforce themselves. By eliminating reliance on conventional financial intermediaries, DeFi establishes a financial system that is more readily available, transparent, and secure to individuals with internet access, irrespective of their geographical location or financial standing (Corbet et al., 2022; Schär, 2021). DeFi assets encompass a diverse range of financial tools, spanning

cryptocurrencies like Bitcoin and Ethereum, stablecoins such as DAI and USDC, as well as decentralized platforms like exchanges (DEXs), lending/borrowing hubs (e.g., Aave, Compound), and insurance protocols (e.g., Nexus Mutual). These assets serve various purposes, including facilitating lending or borrowing activities, engaging in speculation via derivatives, conducting cryptocurrency trading, hedging against risks, and generating interest through savings-oriented accounts (Alawadhi & Alshamali, 2022; Ante, 2022; Dowling, 2021a, 2021b).

Non-Fungible Tokens (NFTs) are rather virtual asset rights on Blockchain which include a unique identity and information (e.g. image, music, video, coded piece of virtual land, a virtual trading card) (Alawadhi & Alshamali, 2022; Ante, 2022; Dowling, 2021a, 2021b; Schär, 2021). NFTs diverge from conventional cryptocurrencies in that they lack interchangeability, with each NFT possessing a distinct identity and set of information (NFT Now, 2021; TechTarget, 2021). Their surge in popularity stems from their capacity to furnish evidence of ownership and genuineness for digital assets, consequently opening up novel

\* Corresponding author.

E-mail address: [belguithrihab@gmail.com](mailto:belguithrihab@gmail.com) (R. Belguith).

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avenues for artists, musicians, and other creators to capitalize on their creations (NFT Now, 2021; TechTarget, 2021). Despite the market is still in its early stages, there is a remarkable increase in trade volumes for NFT and DeFi assets in recent years; most of which has been connected with significant profits (Corbet et al., 2022; Karim, Lucey, Naeem, & Uddin, 2022).

From an academic standpoint, the ongoing literature on NFT and DeFi tokens still remains scarce. For instance, Aharon and Demir (2021) find that NFTs may provide diversification benefits during stressful periods (e.g. the COVID-19 crisis and the March 2020 market crash). Dowling (2021a) shows a continuous increase in the value of NFT. Dowling (2021b) examines if the NFT price is correlated to the cryptocurrency price. The empirical results show that the volatility spillover effects between cryptocurrencies and NFTs are low. Juan, Angeles, Aleksander, and Isaac (2022) analyze the link between the returns of DeFi tokens, other conventional assets, and user-generated information. They show that DeFi operates as a safe-haven asset. Karim et al. (2022) use the quantile connectedness approach to investigate the extreme risk propagation of Blockchain markets. They reveal that NFTs provide more diversification channels with a significant risk-bearing ability to protect investments and prevent severe risks. Ko, Son, Lee, Jang, and Lee (2022) examine the diversification benefits of including NFTs in a portfolio of traditional assets. Using the mean-variance technique, they display that incorporating NFTs enhances the Sharpe ratio effectiveness of equally weighted and tangency portfolio strategies. Hence, the diversification effect of NFTs on conventional asset-based portfolios is well-documented. Corbet, Goodell, Gunay, and Kaskaloglu (2021) investigate the occurrence of bubbles in DeFi-focused tokens and identify major driving mechanisms that separate DeFi tokens from traditional cryptocurrencies. They reveal that the DeFi market can be considered as a distinctive asset class. DeFi assets should be included in portfolio to enhance risk diversification. Yousaf and Yarovaya (2022a) compute the static and dynamic optimal weights, hedging ratios, and effectiveness for NFTs/other assets and DeFi/other assets portfolios. They indicate that investors and portfolio managers should include NFTs and DeFi assets in portfolios of traditional assets (i.e. gold, oil, and stock markets). Using the NARDL model, Zhang, Sun, and Ma (2022) investigate the hedging and safe-haven abilities of NFTs against traditional digital and financial assets. They reveal that NFTs act as hedges during the pre-COVID-19 pandemic period and safe havens during the COVID-19 pandemic period.

In spite of its fast popularity and market expansion, the frequency of speculation and fraud linked to NFT trading is well-documented (Chalmers, Christian, Russell, William, & Jan, 2022). The NFT pricing behavior also appears to be vulnerable according to inconsistencies, pricing bubbles, and fast price rises. These inconsistencies can be explained by liquidity limits caused by the freshness of NFTs marketplaces (Horky, Rachel, & Fidrmuc, 2022). DeFi assets have also experienced a number of frauds and hacks at various periods (Corbet et al., 2022; Grassi, Lanfranchi, Faes, & Renga, 2022). According to Schär (2021), DeFi can improve the efficiency, transparency, and accessibility of financial infrastructure. Nevertheless, some issues (e.g. smart contract execution risks, operational security concerns, dependence on other protocols, and external data risks) are well-documented. Maouchi, Lanouar, and Ghassen (2021), Corbet et al. (2021), and Wang, Horky, Baals, Lucey, and Vigne (2022), among others, identify the presence of financial bubbles in the NFT and DeFi marketplaces. Xia, Li, and Fu (2022) and Yousaf and Yarovaya (2022a) report high volatility spillovers between NFT and DeFi tokens and other types of conventional assets, especially during periods of severe crisis.

On the other hand, stablecoins can be considered a substitute for conventional cryptocurrencies (Wang, Ma, & Wu, 2020). Such digital assets are different from conventional cryptocurrencies. They are designed to maintain a (relatively) stable price by being pegged to other (relatively) stable assets such as gold and the US Dollar. In this regard, gold-backed cryptocurrencies are a famous type of stablecoins. Some

researchers have focused on such assets from Islamic finance perspective (Adzimatinur, Manalu, & Rahimi, 2020; Alam, Gupta, & Zameni, 2019; Ali et al., 2022; Aloui, Hamida, & Yarovaya, 2021; Ncir, Jarboui, & Alyoubi, 2021). For instance, Díaz, Esparcia, and Huélamo (2023) examine the capacity of stablecoins to limit portfolio risk. They show that all stablecoins (gold-backed and USD-backed) have significant diversification abilities by lowering portfolio tail risk. Mnif, Salhi, Trabelsi, and Jarboui (2022) evaluate the efficiency of gold-backed cryptocurrency markets. They reveal that the gold-backed cryptocurrency market is the most efficient market in the long-term and the Bitcoin market is only efficient in the short-term. Ncir et al. (2021) indicate that gold-backed cryptocurrencies are less risky assets than both Bitcoin and stablecoins and more stable during the COVID-19 crisis period. Wang et al. (2020) compare the diversifying, hedging and safe-haven properties of stablecoins against conventional cryptocurrencies. They indicate that stablecoins can be considered as safe havens in some cases. Nevertheless, most of them act as efficient diversifiers in normal market situations. They also show that gold-backed stablecoins operate in worse way as safe havens compared to USD-backed stablecoins. But, both assets outperform their underlying assets in mitigating severe losses.

By leafing through literature on cryptocurrencies, it is worth noting to mention that the dynamic analysis of relationship among NFT and DeFi and other asset classes needs more attention to better understand the degree and nature of such linkages. That is why this research attempts to address this knowledge gap by studying the interactions and the diversification potential of stablecoins against NFT and DeFi assets. In other words, it is crucial to investigate whether gold-backed cryptocurrencies may help investors minimize portfolio volatility-related risks and hedge against bear markets. Gold-backed stablecoins differ significantly from regular cryptocurrencies. They serve as an efficient store of wealth, a reliable unit of account, or a medium of trade (Wang et al., 2020). In this paper, we examine the role of gold-backed cryptocurrency assets to act as diversifiers, hedges, and safe havens for NFT and DeFi tokens during the period 02/11/2021-05/01/2023, encompassing the disruptive waves of the COVID-19 pandemic, the escalating tensions of the Russia-Ukraine military conflict, the crash of Terra and Luna on May 2022, and the FTX crash (November 11, 2022). In particular, we first investigate the dynamic connectedness between gold-backed cryptocurrencies and NFT and DeFi assets using a dynamic GARCH-copula method. We afterwards compute the optimal hedging ratios and hedging effectiveness.

Our study contributes to the current literature on cross-broad asset holdings in several ways. First and foremost, investigating the correlation between gold-backed cryptocurrencies and NFT and DeFi tokens could provide insightful information about the connectedness structure among different assets. Not only that, it could interestingly offer some insights into some features from portfolio management. In this regard, several researchers have rather focused on the returns and characteristics of NFT and DeFi assets, but a thorough understanding of how investors who own such assets might mitigate their portfolio risk needs to be improved. In other words, portfolio managers and investors could establish cross-asset hedging strategies by taking into account the diversification advantages of including stablecoins in NFT/DeFi portfolios. Third, the recent increase in the cryptocurrency market uncertainty and the advent of unprecedented event such as the Terra-USD stablecoin collapse on May 2022 and the failure of FTX (one of the largest trading cryptocurrencies) on November 2022 strive to revive the issue of the hedging, diversification and safe-haven features of cryptocurrencies. As previously reported, Maouchi et al. (2021), Corbet et al. (2021), Wang et al. (2022), Xia et al. (2022), and Yousaf and Yarovaya (2022a) detect the existence of financial bubbles in the NFT and DeFi markets and report high volatility spillovers from these markets to other ones. In this regard, analyzing the hedging, diversification and safe-haven features is highly recommended, particularly with the outbreak of the Covid-19 pandemic and the Russia-Ukraine war.

By determining if digital gold assets are hedges or safe havens for

NFT and DeFi tokens, we foreshadow the main results as follows. We show that gold-backed cryptocurrencies act as robust hedging or diversifying assets during normal times and as robust safe havens during the 2022 bear market for the majority of the NFT and DeFi markets. Interestingly enough, PAXG and PMGT are found to be the best safe haven instruments for both NFT and DeFi tokens. DGX also serves as a safe haven for some NFT and DeFi assets, but with a lower risk-mitigation capacity compared to PAXG and PMGT. Such findings could help NFT and DeFi investors better understand the interdependence between gold-backed cryptocurrencies and NFT and DeFi assets at different time scales.

The rest of the paper is as follows. Section 2 presents the literature review. Section 3 reports the methodology. Section 4 presents data and a set of descriptive statistics. The empirical results are reported in Section 5. Finally, Section 6 discusses and Section 7 concludes.

## 2. Literature review

Overall, Decentralized Finance (DeFi) and Non-Fungible Tokens (NFTs) are garnering widespread media attention and remarkable market development (Maouchi et al., 2021; Schaar & Kampakis, 2022; Schär, 2021). By leafing through the literature on cryptocurrencies, many research questions have been addressed by researchers to better understand the behavior of DeFi and NFT assets. First, many researchers have interestingly investigated the financial features of NFT and DeFi assets (e.g. Dowling, 2021a, 2021b; Juan et al., 2022; Karim et al., 2022; Yousaf, Nekhili, & Gubareva, 2022; Yousaf & Yarovaya, 2022a). Using diverse approaches, Corbet et al. (2021) show the occurrence of bubbles in the DeFi market throughout the third quarter of 2020. They also report that the DeFi market is not completely uncorrelated to cryptocurrency markets due to the strong correlation between some DeFi tokens and Bitcoin. Maouchi et al. (2021) examine NFTs, DeFis, and traditional cryptocurrencies' financial bubbles during the COVID-19 pandemic. They also identify DeFi and NFT-specific bubbles in the summer of 2020. This indicates specific driving dynamics for these asset classes. Using the SADF and GSADF methods, Wang et al. (2022) identify the presence and timing of price bubbles in the NFT and DeFi markets. They show that both NFT and DeFi markets experience speculative bubbles. In this respect, NFT bubbles seem to be more frequent and have larger amplitude than DeFi bubbles. They also reveal that price bubbles in the NFT and DeFi markets are significantly associated to market boosts and general market uncertainty in the cryptocurrency market.

The second research question has analyzed the relationship between NFT/DeFi assets and other assets. For instance, Xia et al. (2022) investigate the quantile connectedness between NFTs and main asset classes using a new Q-Joint spillover model. They find that cross-asset return and volatility spillovers are substantially greater during severe market situations than in regular ones. The directional connection and hierarchical clustering of directional spillovers are well-documented during extreme market situations. So, NFTs cannot be regarded as a different asset class. Yousaf and Yarovaya (2022a) assess the return and volatility spillovers among NFTs, DeFi assets and other asset classes (Bitcoin, gold, oil, and S&P500). They suggest that the dynamic return and volatility connections increase during the first stages of the COVID-19 pandemic and the 2021 cryptocurrency boom. Using the TVP-VAR approach, Yousaf et al. (2022) report large spillovers from traditional currencies to the DeFi markets at the beginning of the COVID-19 pandemic. Urom, Ndubuisi, and Guesmi (2022) investigate the return and volatility connectedness between NFTs and digital and financial assets using the Quantile Vector-Autoregressive (Q-VAR) connectedness approach. They show that the return and volatility interconnections differ across market situations, with higher levels during bearish and bullish market situations. They also report that NFTs are net return shock absorbers unless the market is bullish. In this case, they are net transmitters. Regardless of market conditions, NFTs are net volatility shock absorbers. Under a connectedness framework, Umar, Abrar, Zaremba, Teplova, and Vo

(2022) investigate the link between the return and volatility of NFTs and media coverage with the advent of the COVID-19 crisis. They show that media coverage is a net transmitter of spillover for both NFT return and volatility. This suggests that the diversification ability of NFT decreases during turmoil periods.

On the other hand, many researchers have increasingly focused on the potential safe-haven, hedging and diversification features of gold-backed cryptocurrencies as new stablecoins against asset classes. For instance, Ali et al. (2022) evaluate the safe-haven capability of two gold-backed Islamic cryptocurrencies (OneGramCoin (OGC) and X8X Token) for 15 Islamic equities indices. They display that OGC serves as a powerful safe-haven asset for numerous Islamic equities markets, particularly during the COVID-19 outbreak. Mnif et al. (2022) examine the behavior of gold-backed cryptocurrency, traditional cryptocurrency and gold markets. They show that gold-backed cryptocurrency markets exhibit less herding behavior than traditional cryptocurrencies in the long run. Using the wavelet analysis technique, Ncir et al. (2021) investigate the Islamic cryptocurrencies' risk of volatility in comparison to conventional stable and non-stable coins. They demonstrate that gold-backed cryptocurrencies are less risky than both Bitcoin and stablecoins, particularly for short to medium investment horizons. They afterwards display higher stability during the COVID-19 crisis period. Aloui et al. (2021) compare the performance of Islamic and non-Islamic gold-backed cryptocurrencies to gold. Islamic tokens are found to be less exposed to geopolitical risk than non-Islamic tokens. Yousaf and Yarovaya (2022b) examine the return and volatility propagation among gold-backed digital currencies and Islamic stock markets before and during the COVID-19 pandemic. They reveal that adding gold-backed cryptocurrencies to Islamic stock portfolios help Islamic investors reduce their portfolio risk before and during the COVID-19 crisis. Díaz et al. (2023) evaluate the capacity of two dollar-backed and one gold-backed stablecoin to curb portfolio losses. All stablecoins have significant diversification potential by consistently lowering portfolio tail risk.

In this regard, mixed findings results about the associations between gold-backed cryptocurrencies and other asset classes are reported. Using the ARCH-GARCH approach, Adzimatunur et al. (2020) compare the volatility and risk of gold-backed cryptocurrencies to Bitcoin, Ethereum, S&P500, and gold. They show that these assets are more volatile than Bitcoin, Ethereum, and the S&P500. Using the ARMA/ARIMA and EGARCH models, Irfan, Abdur-Rehman, Nawazish, and Hao (2023) show that gold-backed cryptocurrencies are significantly related to traditional cryptocurrencies. Jalan, Matkovskyy, and Yarovaya (2021) compare the performance of five gold-backed stablecoins to gold, Bitcoin, and Tether. During the COVID-19 pandemic, they reveal that such assets are subject to volatility transmitted from gold markets. They fail to serve as safe havens during this crisis. Kang, Xie, and Zhao (2021) show that Digix (a gold-backed cryptocurrency) does not act as a safe-haven asset during the COVID-19 crisis. Rizvi and Ali (2022) investigate whether the Islamic gold-backed stablecoins (OGC and X8X) do not offer any diversification opportunity for Indonesian Islamic investors during the COVID-19 pandemic. They show that the health crisis exacerbates the spillover effect among Islamic gold-backed cryptocurrency assets and Islamic stocks. Indonesian investors may prefer traditional cryptocurrency to reduce portfolio risks during the COVID-19 outbreak. Wasiuzzaman, Azwan, and Nordin (2022) assess the efficiency of the gold-backed currency market amid the 2020 market downturn. They reveal high volatility of these assets.

Based on this crux, it is worth interesting to investigate how to hedge NFT and DeFi tokens' volatility and mitigate the portfolio risk. In this case, gold-backed crypto assets may play a significant role as they are linked to the value of gold. On the other hand, as previously reported, the mixed results about the safe-haven and hedging proprieties of gold-backed cryptocurrency assets invite to investigate their proprieties against the new digital assets. That is why we opt for exploring the hedging abilities of other assets which are well-known as stablecoins such as gold-backed cryptocurrencies. More precisely, the purpose of

this paper is two-fold. First, we try to investigate the dynamic relationship between gold-backed cryptocurrencies and NFT and DeFi assets. Second, we attempt to evaluate the diversification potential of gold-backed cryptocurrencies against NFT and DeFi. This study assesses such features against NFT and DeFi assets based on [Baur and Lucey's \(2010\)](#) classification.<sup>1</sup> To do so, we use copulas which provide useful and insightful tool to study and estimate dependence structure in different multivariate phenomena in various fields such as engineering, economics, environmental science and finance (e.g. [Fontaine, Frostig, & Ombao, 2020](#); [Cooray, 2019](#)). In this regard, [Mohtashami-Borzadaran, Amini, & Ahmadi \(2019\)](#) and [Durante, Fernandez-Sanchez, & Pappada \(2015\)](#), among others, use bivariate copulas to perform bivariate distributions coupled with suitable dependence characteristics. In this study, we employ the time-varying Student copula without worrying about their specific marginal distributions given that multivariate copulas ignore the marginal distribution of the variables. Afterwards, this paper attempts to determine the optimal hedging ratio for a couple of variables, not for all the markets. Therefore, performing bivariate copulas seem to be suitable in our case. [Table A](#) reports some interesting studies.

### 3. Methodology

The purpose of this paper is twofold. First, one might examine the dynamic conditional dependence pattern between gold-backed cryptocurrencies and NFT and DeFi assets using a time-varying GARCH-copula approach during the period 02/11/2021-05/01/2023. Second, one might explore the effectiveness of portfolio risk management using optimal hedging ratios. That is, we estimate the time-varying dependence coefficients which are used to calculate the hedging ratios. This allows us to examine how NFTs and DeFi tokens can be effectively hedged by gold-backed cryptocurrencies over time.

In this regard, the dynamic conditional return's volatility is estimated using an AR (1)-GARCH (1,1) for all NFTs, DeFis, and gold-backed cryptocurrencies except for XAUT.<sup>2</sup> The estimated volatility is then used to determine dynamic Kendall's tau for all combinations using a bivariate Student-t Copula. The choice of the copula is based on different information criteria calculated after estimating Gaussian and Student's t copulas. The Student's t-copula allows for heavier tails compared to a normal (Gaussian) distribution. This means that it attributes a relatively higher probability to extreme events. Moreover, Student dynamic copula is often considered as more flexible for modeling dependence in the tails of distributions. The R Studio statistical software is used for computing the empirical findings.

#### 3.1. Time-varying student's t copula

This approach allows to take into consideration crucial stylized facts in financial returns, including volatility clustering, time-varying volatility, and short- and long-run dependence behavior. As well, it allows to better computing residuals that are approximately independently and identically distributed (i.i.d.), making them suitable for subsequent statistical analyses ([Grégoire, Genest, & Gendron, 2008](#)). To accommodate potential fat tails in the error term, one might employ the Student's t-distribution instead of the Gaussian distribution used in several

<sup>1</sup> According to [Baur and Lucey \(2010\)](#), an asset is observed as a hedge if it is not correlated or adversely linked to another asset or a portfolio, and an asset is observed as a diversifier if it is positively but not perfectly correlated to another asset or a portfolio. Both hedge and diversifier assets do not reduce risks during severe market conditions. On the other hand, an asset is observed as a safe haven if it is uncorrelated or negatively associated with another asset or a portfolio during times of turmoil.

<sup>2</sup> This is due to the non-significant value of the autoregressive conditional heteroskedasticity-Lagrange multiplier (ARCH-LM) test.

empirical studies. Furthermore, Student's t-dependence structure supports joint extreme movement regardless of the marginal behavior of the individual random variable. The two random variables are uniformly distributed and obtained after transformation using the cumulative distribution of the two standardized residuals time series (x and y). The latter two time series are obtained after estimating the appropriate ARIMA-GARCH model.

Let consider  $r_a$  and  $r_d$  digital asset returns (NFTs or DeFis) and  $r_g$  gold-backed cryptocurrencies.  $u_{a,t} = G(r_{a,t}|\varphi_{t-1})$  and  $u_{d,t} = G(r_{d,t}|\varphi_{t-1})$  are their marginal conditional cumulative distribution forms.  $\varphi_{t-1}$  represents previous information. Both time-varying cumulative distribution functions may be used to create the conditional copula function  $C_t(u_{a,t}; u_{d,t}|\varphi_{t-1})$ . By extending the Sklar's theorem, the bivariate conditional cumulative distribution functions of random variables  $r_a$  and  $r_d$  can be expressed as follows:

$$F(r_{a,t}; r_{d,t}|\varphi_{t-1}) = C(r_{a,t}; r_{d,t})$$

The conditional joint density can be written as follows:

$$f(r_{a,t}; r_{d,t}|\varphi_{t-1}) = \frac{\partial F(r_{a,t}; r_{d,t}|\varphi_{t-1})}{\partial r_{a,t}} \frac{\partial r_{d,t}}{\partial r_{d,t}} = C_t(r_{a,t}; r_{d,t}|\varphi_{t-1}) \times g_{a,t}(r_{a,t}|\varphi_{t-1}) \times g_{d,t}(r_{d,t}|\varphi_{t-1}) \text{ where } C_t(r_{a,t}; r_{d,t}|\varphi_{t-1}) = \frac{\partial^2 C_t(u_t, v_t|\varphi_{t-1})}{\partial u_t \partial v_t} \text{ is the conditional copula density function and } g(\cdot) \text{ is the density function corresponding to } G(\cdot). \text{ The likelihood function issued from the previous equation can be written as follows:}$$

$$L_{a,d}(\Phi) = L_d(\Phi_d) + L_d(\Phi_a) + L_{cop}(\Phi_{cop})$$

where  $\Phi_a$  and  $\Phi_d$  are the parameter vectors of marginal distributions of the NFTs and DeFis and gold-backed cryptocurrencies returns, respectively, and  $\Phi_{cop}$  is the copula function's vector of parameters. An evolution equation describes how the parameters of the time-varying copulas change.

When modeling copula approaches, one might use the univariate distribution to obtain the independently and identically distributed (i.i.d.) residuals that are required for the copula model estimation. In this study, we try to model the marginal distribution of the considered series by using a GARCH model. In terms of squared residuals, the simple GARCH(1,1) model can be written as an ARMA(1,1) model. In a similar vein, the GARCH(p,q) model is given as follows:

$$\sigma_t^2 = a + \sum_{i=1}^p a_i \varepsilon_{t-i}^2 + \sum_{j=1}^q b_j \sigma_{t-j}^2$$

It can be rewritten as follows:

$$\phi(L)\varepsilon_t^2 = a + b(L)u_t$$

$$\text{where } u_t = \varepsilon_t^2 - \sigma_t^2$$

$$\phi(L) = 1 - \phi_1 L - \phi_2 L^2 - \dots - \phi_m L^m$$

$$b(L) = 1 - b_1 L - b_2 L^2 - \dots - b_q L^q$$

with  $m = \max(p, q)$  and  $\phi_i = a_i + b_i$ . Eq.(3) refers to a ARMA (m, q) process in terms of squared residuals  $\varepsilon_t^2$  with  $u_t$  being a Martingale Difference Sequence (MDS) disturbance term.

The evolution of the linear dependency parameter  $\rho_t$  with the Gaussian and Student-t bivariate copulas follows an ARMA(1,q)-type process ([Patton, 2006](#)):

$$\rho_t = \lambda \left( \varphi_0 + \varphi_1 \rho_{t-1} + \varphi_2 \frac{1}{q} \sum_{j=1}^q \varphi^{-1}(u_{t-j}) \varphi^{-1}(v_{t-j}) \right)$$

where  $\lambda = (1 - e^{-x})(1 - e^{-x})^{-1}$  is the updated logistic transition which assures that  $\rho_t$  belongs to  $[-1, 1]$ . This indicates that the dependence parameter is defined by a constant parameter  $\varphi_0$ , the explanatory component of the past correlation as scaled by  $\varphi_1$ , and the mean product of the converted variables' last q observations,  $\varphi_2$ .

**Table A**  
Summary of literature review.

Authors	Variables	Time Period	Methods	Empirical Findings
Schär (2021)	DeFi and NFT assets		(G)SADF model, Q-Joint spillover model, TVP-VAR model, Q-VAR model, ARCH-GARCH model, ARMA/ARIMA, EGARCH model	<ul style="list-style-type: none"> <li>- They detect Bubbles in DeFi market during Q3 2020, with some correlation to Bitcoin. and NFT and DeFi-specific bubbles in summer 2020.</li> <li>- Both markets experience speculative bubbles. NFT bubbles are more frequent and larger in amplitude.</li> <li>- Media coverage acts as net transmitter of spillover for NFT return and volatility.</li> <li>- DeFi markets display large spillovers from traditional currencies, especially at the start of COVID-19.</li> <li>- NFTs exhibit net return shock absorption, except during bullish markets.</li> <li>- NFTs consistently act as net volatility shock absorbers.</li> <li>- They detect some financial characteristics of NFT and DeFi.</li> </ul>
Maouchi et al. (2021)		December 2017–March 2021		
Schaar and Kampakis (2022)		June 01, 2018–May 31, 2021		
Dowling (2021a, 2021b) Juan et al. (2022)	NFT and DeFi financial features	March 2019–March 2021 July 01, 2018–July 28, 2020	Ratio tests	<ul style="list-style-type: none"> <li>- They detect some financial characteristics of NFT and DeFi.</li> </ul>
Karim et al. (2022)		March 15, 2018–October 24, 2021	Quantile-VAR	
Yousaf et al. (2022)		March 14, 2018–October 26, 2021		
Xia et al. (2022)	NFT/DeFi assets and other assets	March 01, 2019–April 30, 2022 May 03, 2018–July 01, 2021	TVP-VAR Q-Joint spillover model, TVP-VAR, Q-VAR, connectedness framework	<ul style="list-style-type: none"> <li>- They show increased cross-asset return and volatility spillovers during severe market situations.</li> <li>- They report directional spillovers documented during extreme market conditions.</li> <li>- They show higher return and volatility connections during early COVID-19 stages and 2021 cryptocurrency boom.</li> <li>- Market interconnectedness differs across market situations.</li> <li>- NFTs act as net return shock absorbers, except during bullish markets.</li> <li>- NFTs act as net volatility shock absorbers regardless of market conditions.</li> <li>- Media coverage acts as a net transmitter of spillover for NFT return and volatility.</li> <li>- They show that OGC could be used as a safe-haven asset during the health crisis.</li> <li>- They display that gold-backed cryptocurrencies have less herding behavior than traditional cryptocurrencies.</li> <li>- Gold-backed cryptocurrencies seems to be less risky than Bitcoin and stablecoins, especially during short/ medium investment horizons.</li> <li>- They report that Islamic tokens are less exposed to geopolitical risk.</li> <li>- Including gold-backed cryptocurrencies to Islamic portfolios diminishes portfolio risk.</li> <li>- They show that Stablecoins have consistently lower portfolio tail risk.</li> <li>- They indicate that Gold-backed cryptocurrencies are more volatile than Bitcoin, Ethereum, and S&amp;P500.</li> <li>- They show that Gold-backed cryptocurrencies are substantially related to traditional cryptocurrencies.</li> <li>- They indicate that Gold-backed stablecoins are subject to volatility transmitted from gold markets during the health crisis.</li> <li>- They reject that Gold-backed cryptocurrencies act as safe havens during the health crisis.</li> <li>- They show that Indonesian investors could prefer traditional cryptocurrencies over Islamic gold-backed stablecoins during the health crisis.</li> <li>- They report that high volatility is shown in gold-backed cryptocurrency markets during market downturns.</li> </ul>
Yousaf and Yarovaya (2022a) Urom et al. (2022)		June 26, 2017–October 29, 2021		
Umar et al. (2022)				
Ali et al. (2022)	Gold-backed cryptocurrency features	February 17, 2019–May 05, 2021 December 31, 2019–May 05, 2022 October 2018–June 2021	wavelet analysis, connectedness framework	<ul style="list-style-type: none"> <li>- They show that OGC could be used as a safe-haven asset during the health crisis.</li> <li>- They display that gold-backed cryptocurrencies have less herding behavior than traditional cryptocurrencies.</li> <li>- Gold-backed cryptocurrencies seems to be less risky than Bitcoin and stablecoins, especially during short/ medium investment horizons.</li> <li>- They report that Islamic tokens are less exposed to geopolitical risk.</li> <li>- Including gold-backed cryptocurrencies to Islamic portfolios diminishes portfolio risk.</li> <li>- They show that Stablecoins have consistently lower portfolio tail risk.</li> <li>- They indicate that Gold-backed cryptocurrencies are more volatile than Bitcoin, Ethereum, and S&amp;P500.</li> <li>- They show that Gold-backed cryptocurrencies are substantially related to traditional cryptocurrencies.</li> <li>- They indicate that Gold-backed stablecoins are subject to volatility transmitted from gold markets during the health crisis.</li> <li>- They reject that Gold-backed cryptocurrencies act as safe havens during the health crisis.</li> <li>- They show that Indonesian investors could prefer traditional cryptocurrencies over Islamic gold-backed stablecoins during the health crisis.</li> <li>- They report that high volatility is shown in gold-backed cryptocurrency markets during market downturns.</li> </ul>
Mnif et al. (2022)		July 23, 2018–January 11, 2020		
Ncir et al. (2021)		February 15, 2019–February 26, 2021		
Aloui et al. (2021)		October 10, 2018–February 29, 2020		
Yousaf and Yarovaya (2022b) Díaz et al. (2023)		November 2019–November, 2020 January 01, 2021–June 30, 2022 March, 2020–August 2021	ARCH-GARCH, ARMA/ARIMA, EGARCH, models	
Adzimatunur et al. (2020)	Gold-backed cryptocurrency features vs. other assets	December 2018–June 2020		
Irfan et al. (2023)		January 01, 2019–July 28, 2022		
Jalan et al. (2021)		December 2019–November 2020		
Kang et al. (2021)				
Rizvi and Ali (2022)				
Wasiuzzaman et al. (2022)				

**Table 1**  
Descriptive statistics.

Panel A: Five Non-Fungible Tokens (NFT)							
	Mean	Std.Dev.	Skewness	Kurtosis	J-B	L-B	LM-Arch
PLAY	-0.005812	0.143081	0.235796	15.91446	4592***	16.22***	55.43***
UPUNK	-0.003460	0.057002	-0.566044	6.406223	768.5***	13.11***	61.74***
SAND	-0.003724	0.065995	0.486408	4.293386	352.5***	0.4	52.44***
NFTL	-0.006574	0.085277	0.925294	11.76142	2569***	2.533	54.99***
xNFT	-0.009195	0.091553	1.144159	13.66763	3535***	6.97*	11.34***
Panel B: Five Decentralized Financial (DeFi)							
	Mean	Std.Dev.	Skewness	Kurtosis	J-B	L-B	LM-Arch
DPI	-0.00427	0.050524	-0.49538	2.805462	161.4***	0.03849	30.35***
LUNK	-0.02924	0.3725468	-10.59580	138.9388	357272***	116.6***	149.7***
AVAX	-0.003982	0.060588	-0.62848	3.056122	198.9***	0.101	32.2***
WBTC	-0.002991	0.033213	-0.61416	4.1632916	342.7***	0.089	8.67***
LINK	-0.004001	0.0524510	-0.51538	1.271618	49.1***	0.005	48.45***
Panel C: Four Gold-Backed crypto currencies							
	Mean	Std.Dev.	Skewness	Kurtosis	J-B	L-B	LM-Arch
PAXG	0.000054	0.007885	-0.063347	2.10146	81.2***	0.337	20.07**
XAUT	0.000044	0.007128	-0.07817	1.94885	70.1***	0.001	13.634
PMGT	0.000019	0.01058	-0.06988	0.47637	4.7*	24.6***	6.08**
DGX	-0.000305	0.174123	1.897215	50.9971	47318***	15.4***	31.74***

### 3.2. Optimal hedging strategy

To effectively assess the diversification potential of gold-cryptocurrencies, one might establish various NFTs/DeFis-gold backed cryptocurrencies optimal portfolios. The daily optimum weights, hedging ratios and the effectiveness of all portfolios might be estimated by utilizing time-varying dependence coefficients.

According to [Kroner and Ng \(1998\)](#), the optimal cryptocurrency-financial asset portfolio weights at time  $t$  ( $w_{a,d,t}$ ) is formulated as follows:

$$w_{a,d,t} = \frac{h_{d,t} - h_{a,d,t}}{h_{a,t} - 2h_{a,d,t} + h_{d,t}}$$

where  $h_{d,t}$ ,  $h_{a,t}$ , and  $h_{a,d,t}$  refer to the time-varying variance of the gold-backed cryptocurrencies (PAXG, PMGT, and DGX) returns ( $r_{d,t}$ ), the time-varying variance of the digital assets (NFTs or DeFis) returns ( $r_{a,t}$ ), and the time-varying covariance between the digital assets and gold-backed cryptocurrencies' returns ( $h_{a,d,t}$ ). To reduce the risk of investing in NFTs, the investor should take an acceptable position on the gold-backed cryptocurrencies. The same steps are replicated for DeFis. The long position (buying) of one dollar on the NFTs and DeFi assets ( $a$ ) should be hedged by a short position (selling) of  $\beta_{a,d,t}$  dollars on the gold-backed cryptocurrency ( $d$ ). According to [Kroner and Sultan \(1993\)](#), the optimal hedge ratio ( $\beta$ ) is computed as the time-varying covariance between the returns of hedging assets and NFTs and DeFis assets  $h_{a,d,t}$ , to the variance of the returns of hedging assets,  $h_{d,t}$ , at time  $t$ :

$$\beta_{a,d,t} = \frac{h_{a,d,t}}{h_{d,t}}$$

We then assess each pair's hedging effectiveness to better identify the hedging capabilities of gold-backed cryptocurrencies. For this end, two different kinds of portfolios are constructed: (1) unhedged portfolios of NFT and DeFi assets and (2) hedged portfolios by investing  $w_t$  in gold-backed cryptocurrencies, and  $1 - w_t$  in NFT and DeFi assets. One might quantify the hedging effectiveness (HE) index as follows:

$$HE = \frac{\text{var}(\text{unhedged}) - \text{var}(\text{hedged})}{\text{var}(\text{unhedged})}$$

where  $\text{var}(\text{unhedged})$  and  $\text{var}(\text{hedged})$  refer to the variance of the hedged portfolio and the variance of the unhedged portfolio, respectively. A higher HE index indicates higher hedging effectiveness and a larger risk reduction.

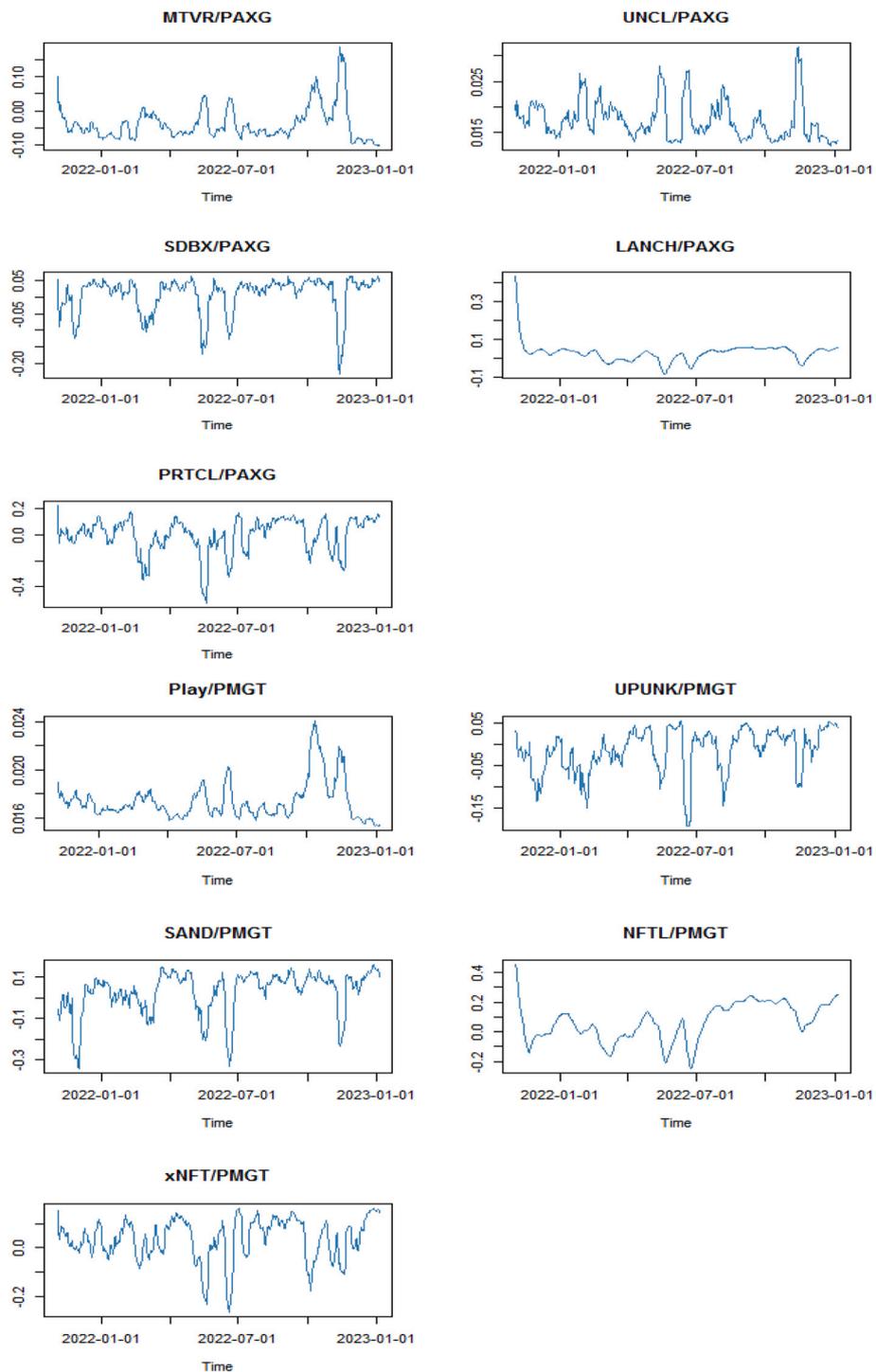
### 4. Data and descriptive statistics

Our dataset includes daily five Non-Fungible Tokens (NFTs) prices (Metaverse NFT Index (PLAY), Unicly CryptoPunks (UPUNK), Sandbox (SAND), NFTLaunch (NFTL), and xNFT Protocol (xNFT)), five Decentralized-Finance (DeFi) prices (DeFi Pulse Index (DPI), Terra Classic (LUNK), Avalanche (AVAX), Wrapped Bitcoin (WBTC), and Chainlink (LINK)) and four gold-backed gold-backed cryptocurrencies prices (Pax Gold (PAXG), Tether Gold (XAUT), Perth Mint Gold Token (PMGT), and Digix Global (DGX)).

The rationale behind choosing (five) NFTs, (five) DeFi and (four) cryptocurrencies and (four) gold-backed cryptocurrencies is based on two criteria: the availability of the data and the market capitalization. According to [Karim et al. \(2022\)](#), such cryptocurrencies, seem to be mature and have strong market capitalization whereas DeFis and NFTs remain emerging and show different market capitalization. We also use four gold-backed cryptocurrencies as stablecoins which are different from those used by [Díaz et al. \(2023\)](#) to better understand and assess the ability of such assets against new digital assets in terms of portfolio diversification.

The sample period is from November 02, 2021 to January 05, 2023. This period is characterized by the advent of tremendous events such as the crash of Terra and Luna on May 2022, the FTX crash (November 11, 2022), the COVID-19 pandemic and the Russia-Ukraine conflict. This allows us to better analyze the ability of some assets against new digital assets. The data is collected from the Coin Market Cap. Then, daily returns are computed as the difference in logarithm between two consecutive observations.

The descriptive statistics of the return series are presented in [Table 1](#). Contrarily to gold-backed cryptocurrencies (except for DGX), all NFT and DeFi tokens display negative mean returns. The highest mean return is recorded by PAXG (0.000054). The standard deviation indicates that PLAY is the most volatile NFT asset (0.1430), LUNK is the most volatile DeFi asset (0.3725), and DGX is the most volatile gold-backed cryptocurrency (0.1741). Except for DGX, other gold-backed cryptocurrency assets display low levels of volatility compared to NFT and DeFi tokens. The skewness coefficients reveal that the distribution of all digital assets is positively and negatively skewed and all returns exhibit significant kurtosis values (except for DPI, LINK, PAXG, XAUT and PMGT). This can reject the null hypothesis of the Jarque-Bera test that the series follows a normal distribution. The results of the Ljung-Box test reject the absence of autocorrelation in all returns. This suggests that volatility may occur



**Fig. 1.** a. Time-varying dependence parameter from the Student-*t* copula for the PAXG with five NFTs.  
 b. Time-varying dependence parameter from the Student-*t* copula for the PMGT and five NFT.  
 c. Time-varying dependence parameter from the Student-*t* copula for DGX and five NFTs.

in each series. That is why one might use a GARCH-type model. The Lagrange Multiplier test shows the stability of an ARCH effect for all return series (except for XAUT). This enables the ARCH approach to identify the volatility of assets' returns.

## 5. Empirical results and interpretation

### 5.1. Time-varying-GARCH-copula results

Fig. 1 (a-c) displays the time-varying dependence copula between gold-backed cryptocurrencies and NFT tokens. From these Figures, the degrees of dependence vary over time. The correlation between gold-backed cryptocurrencies and NFTs seems to fluctuate between positive

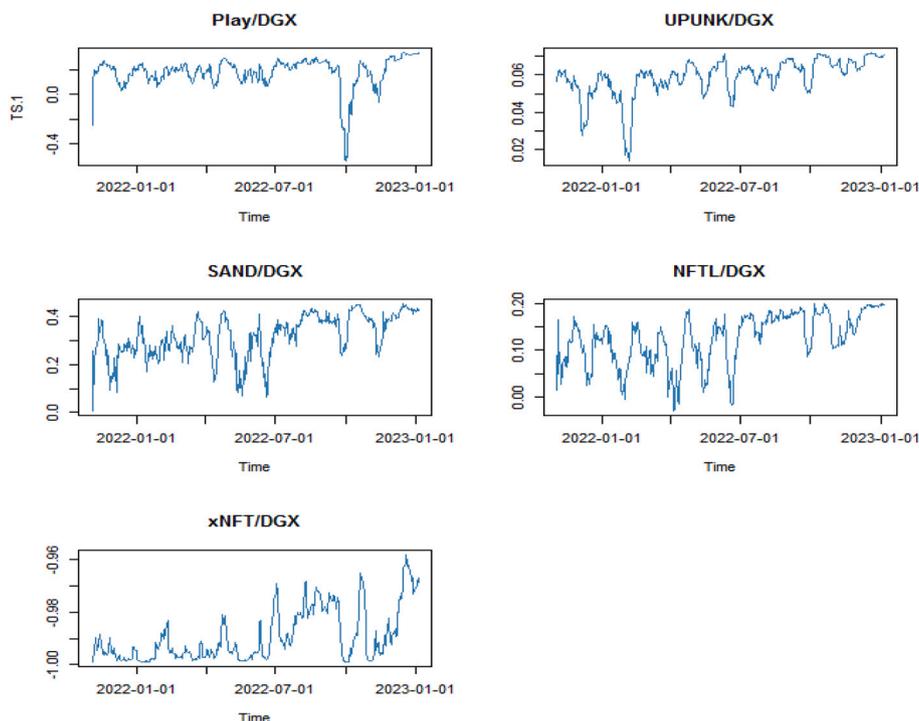


Fig. 1. (continued).

and negative values. This suggests the diversification and hedging abilities of these digital gold assets. For the pairs of PAXG-NFTs (Fig. 1a), PAXG acts as a strong diversifier for UPUNK. However, for the rest of the NFTs, it can be considered as a diversifier in normal times. PAXG seems to be a strong safe-haven asset during the 2022 bear market, especially during the Terra-USD (USDT) breakdown on May 2022 and the cryptocurrency market crash on November 2022. From Fig. 1b, PMGT can be considered as a strong hedging instrument in normal times and a strong safe haven during the 2022 crises for all NFTs (except for PLAY, for which it acts as a strong diversifier). Fig. 1c displays that DGX mainly acts as a strong diversifier and a hedging tool only for xNFT. The safe haven ability of DGX is recorded only for xNFT during both crises and for PLAY at the end of 2022.

Fig. 2 (a-c) displays the time-varying dependence copula between gold-backed cryptocurrencies and DeFi tokens. Fig. 2a shows that PAXG is a strong diversifier for the entire period and its safe-haven ability is only recorded for DPI, AVAX, and WBTC, especially during the cryptocurrency market crashes (May and November 2022). Fig. 2b displays that PMGT is a good diversifier during normal times and a strong safe haven during the 2022 bear market for all DeFi tokens. Fig. 2c shows that DGX acts as a good diversifier for all DeFi assets. However, it displays a strong hedging feature during normal times and strong safe haven ability during the 2022 crypto market crashes only for LINK.

Our empirical results indicate that gold-backed cryptocurrencies play a crucial role in mitigating the NFT and DeFi portfolio risk. In most cases, gold-backed cryptocurrencies act as strong diversifiers (or hedging instruments) during normal times and strong safe havens during stressful times. Hence, PAXG and PMGT seem to be the strongest safe haven gold-backed cryptocurrencies for both NFT and DeFi tokens. Our empirical findings corroborate those of Wang et al. (2020), Yousaf and Yarovaya (2022b), Mnif et al. (2022), Ali et al. (2022), and Díaz et al. (2023) who support the diversifying, hedging, and safe haven properties of gold-backed cryptocurrencies.

Fig. 1a-1b-1c illustrate the evolution of time-varying dependence parameter among gold-backed cryptocurrencies and NFTs during the period 02/11/2021–05/01/2023.

Figs. 2a-2b-1c display the evolution of time-varying dependence

parameter between gold-backed cryptocurrencies and DeFis during the period 02/11/2021–05/01/2023.

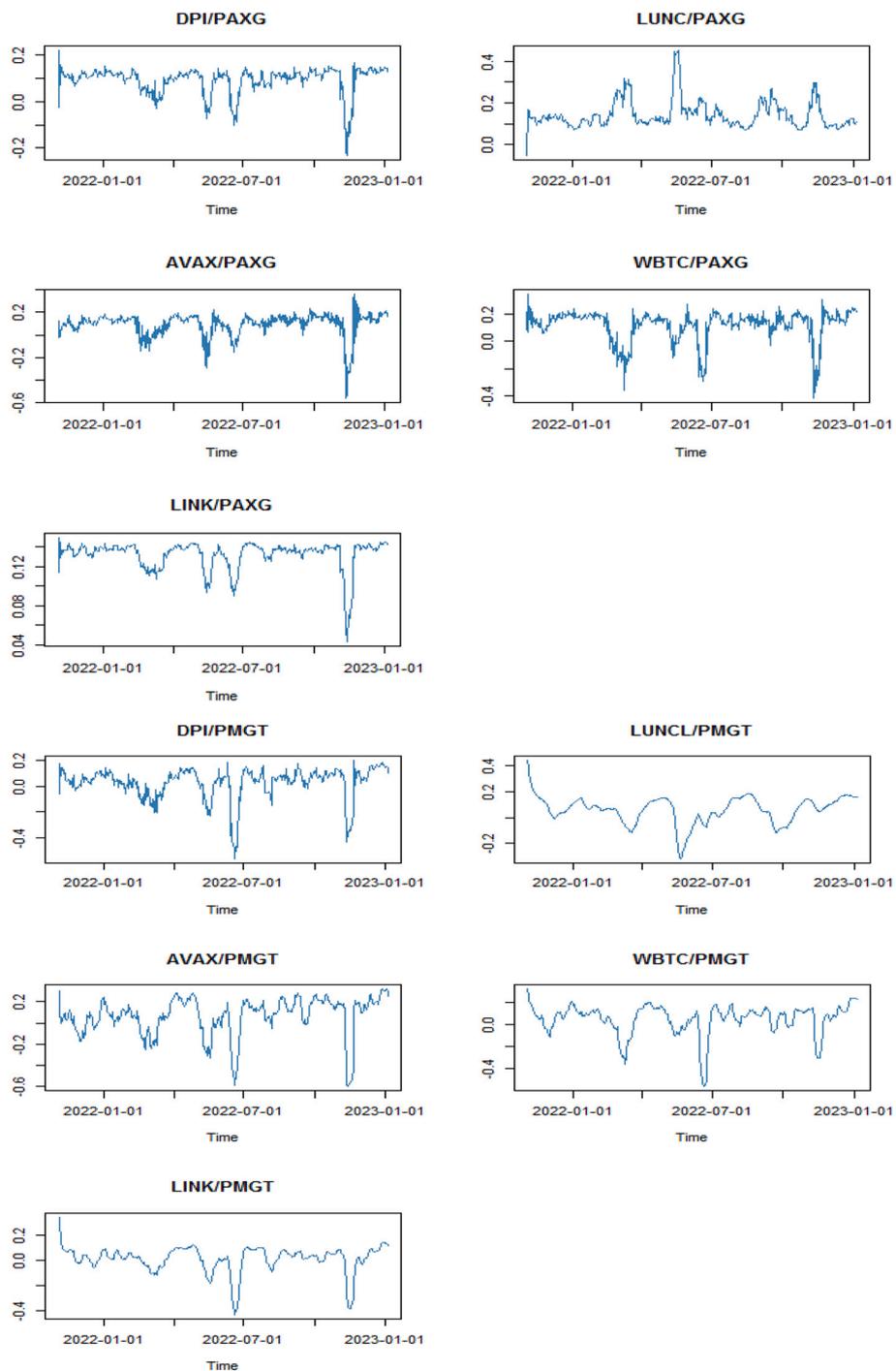
All the graphs display the relationships between gold-backed cryptocurrencies and NFT/DeFi using the copula approach. Such associations tend to be instable and ranges between negative and positive values during the period under study. This could be prima facie of the existences of low and high volatility regimes which govern the correlations between DeFi/NFT and gold-backed cryptocurrencies. Such empirical findings invite to analyze the advantages and NFT (DeFi)/gold-backed portfolio diversification.

## 5.2. Optimal hedging strategy results

To mitigate the risk of investing in NFTs or DeFi assets, an investor should hold an adequate position in gold-backed cryptocurrencies. The optimal hedge ratios (HR) and hedging effectiveness (HE) for NFT and DeFi assets are reported in Figs. (3–8) and Figs. (9–14), respectively.

Comparing between various portfolios mainly shows some heterogeneity which substantially depends on the time period and market type. In fact, negative HR values suggest that the same position (either long or short position) should be taken by investors in gold-backed cryptocurrencies and NFTs or DeFi tokens of the same portfolio. However, positive HR values suggest that a long position (buying) of one dollar in NFTs or DeFi assets should be hedged by a short position (selling) of  $\beta$  dollars in gold-backed cryptocurrencies. For instance, Fig. 3 shows that a long position (buying) of \$1 in PLAY should be hedged by a short position (selling) of about \$10 in PAXG. For the pairs PAXG/UPUNK and PAXG/NFTL, investors should also take inverse positions to reduce the risk of NFTs. For the pairs PAXG/SAND and PAXG/xNFT, the same position should be taken for both assets to reduce risk, except for the PAXG/xNFT pair during the summer of the 2022 year where an inverse position is needed to reduce the risk of NFT.

Fig. 4 shows the hedging ratios of PAXG and DeFi assets. For the pairs of PAXG/DPI, PAXG/AVAX, and PAXG/WBTC, the same position (either buying or selling) should be taken by investors for both types of assets to reduce the risk of DeFi portfolios, especially during the cryptocurrency market crash (November 2022). However, for the pairs of PAXG/LUNK



**Fig. 2.** a. Time-varying dependence parameter from the Student-*t* copula for the PAXG and five DeFis.  
 b. Time-varying dependence parameter from the Student-*t* copula for PMGT and five DeFis.  
 c. Time-varying dependence parameter from the Student-*t* copula for DGX and five DeFis.

and PAXG/LINK, inverse positions for both assets should be taken to reduce the portfolio risk.

Fig. 5 depicts the hedging ratios between PMGT and NFTs. For the couples of PMGT/UPUNK, PMGT/SAND, and PMGT/xNFT (only during the summer of 2022), investors should take the same position to reduce the risk of these assets. For the rest of the pairs, an inverse position is needed. Fig. 6 also shows that a long position of \$1 in LUNK should be hedged by a short position of about \$50 in PMGT. For other DeFi assets, investors should take the same position.

For the pairs of DGX/NFTs (Fig. 7) and DGX/DeFis (Fig. 8), the empirical results show that an inverse position should be taken in order to reduce the risk of portfolios, except for the pairs DGX/xNFT (Fig. 7) and DGX/LINK (Fig. 8) for which investors should take the same position.

The hedging effectiveness (HE) results are illustrated in Figs. (9–14). High value of HE indexes indicates higher hedging effectiveness and a larger risk reduction. PAXG and PMGT are considered as the best hedging tools for NFTs and DeFi assets during normal times and the

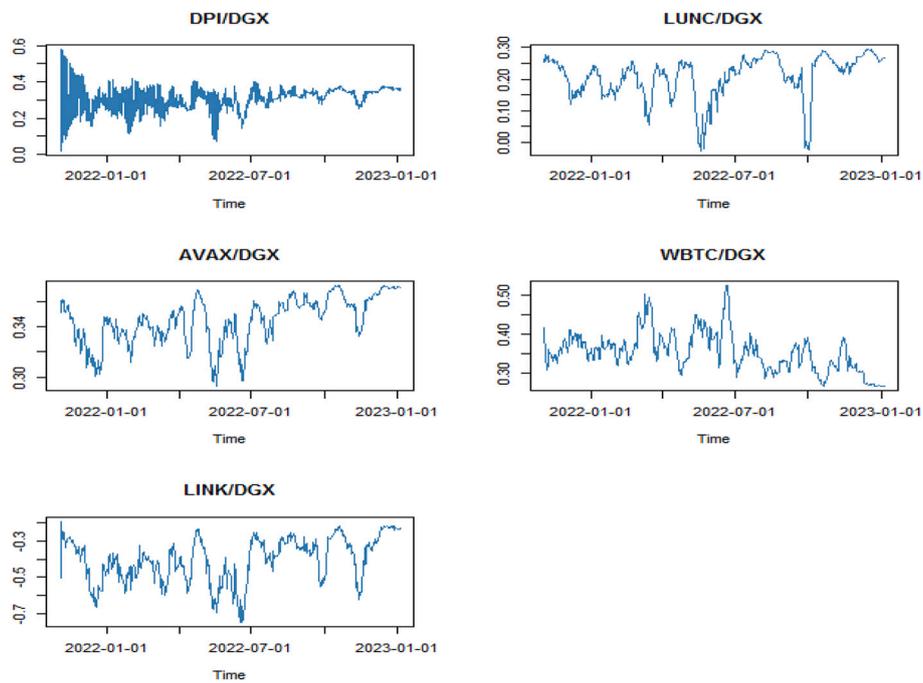


Fig. 2. (continued).

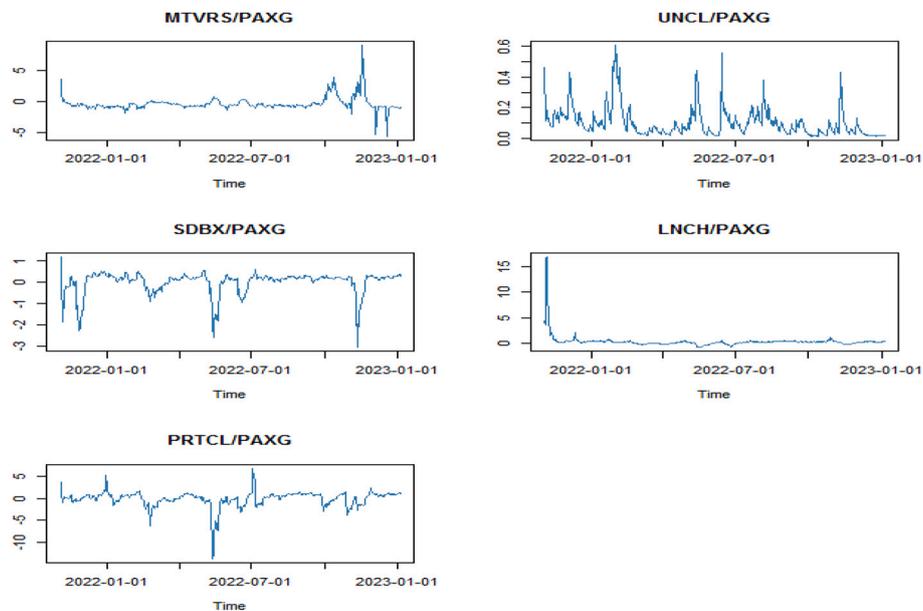


Fig. 3. Time-varying Beta for PAXG and five NFTs.

strongest safe havens for these tokens during bear markets. DGX is also considered as a more suitable safe-haven asset for NFTs more than DeFis, but with a lower risk-mitigation capacity compared to PAXG and PMGT. This safe haven feature is well-evidenced for DGX/SAND and DGX/PLAY at the end of 2022 (Fig. 13) and DGX/DPI, DGX/AVAX, and DGX/WBTC (Fig. 14). Indeed, such asset mainly acts as a strong diversifier. Our empirical results support the aforementioned findings for the time-varying GARCH-copula. They are also in line with those of Wang et al. (2020), Ali et al. (2022), Yousaf and Yarovaya (2022b), Mnif et al. (2022), and Díaz et al. (2023) who show that gold-backed cryptocurrencies are effective tools in mitigating portfolio risks.

Figs. 3–5–7 display the time-varying betas (i.e. optimal hedge ratios) between gold-backed cryptocurrency and NFTs during the period 02/11/2021–05/01/2023.

Figs. 4–6–8 illustrate the time-varying betas (i.e. optimal hedge ratios) between gold-backed cryptocurrency and DeFis during the period 02/11/2021–05/01/2023.

Each optimal hedge plotted in Figs. 3–4–5–6–7–8 does not evolve in similar fashion, even though all plots clearly show cyclical swings. The hedge ratio tends to high for some portfolios and negative and low for others, implying varying costs for hedging risk. In some cases, frequent and large spikes during the period are well-documented, leading to demand frequent rebalancing.

Figs. 9–11–13 display the time-varying hedging effectiveness for the couples of gold-backed cryptocurrencies and NFTs during the period 02/11/2021–05/01/2023.

Figs. 10–12–14 illustrate the time-varying hedging effectiveness for the couples of gold-backed cryptocurrencies and DeFis during the period

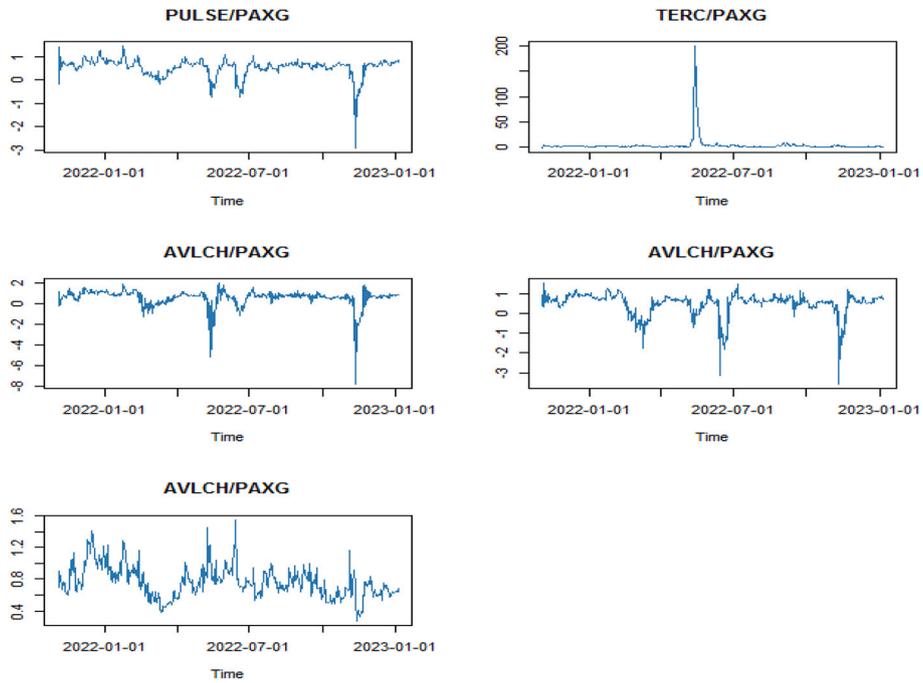


Fig. 4. Time-varying Beta for PAXG and five DeFis.

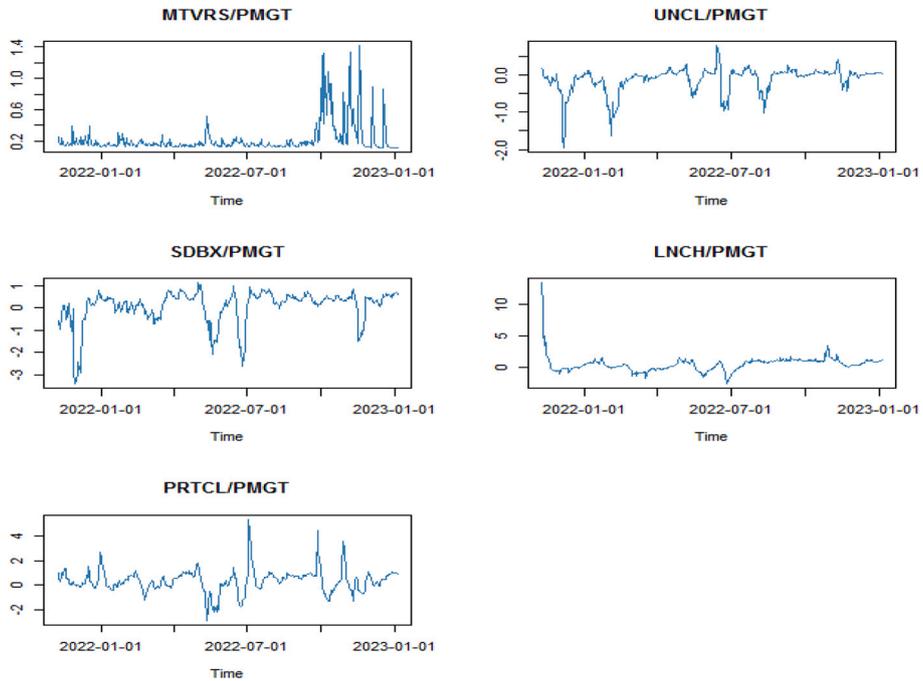


Fig. 5. Time-varying Beta for PMGT and five NFTs.

02/11/2021-05/01/2023.

The high value of hedging effectiveness indexes reports in Figs. 9–10–11–12–13–14 indicates higher hedging effectiveness and a larger risk reduction. Overall, the time-varying behavior of hedging effectiveness reveals that dynamic hedging strategy is prominent for a sustainable risk management.

### 6. Discussion

In the last decade, developments in Blockchain technology and the emergence of several digital assets have increasingly attracted investors

in financial markets, inviting researchers to investigate the diversification potential of such assets. In this respect, NFT and DeFi assets have played a significant role in the recent expansion of the cryptocurrency market. Despite the market still being in its early stages, Karim et al. (2022) and Corbet et al. (2022) have stated that there is proof of a remarkable increase in trade volumes for NFT and DeFi assets, most of which has been associated with significant profits. However, Corbet et al. (2021), Maouchi et al. (2021), and Wang et al. (2022) have argued that these assets are vulnerable to inconsistencies, pricing bubbles, and rapid price rises. On the other hand, gold-backed cryptocurrencies have shown significant diversification abilities by lowering portfolio risk, as

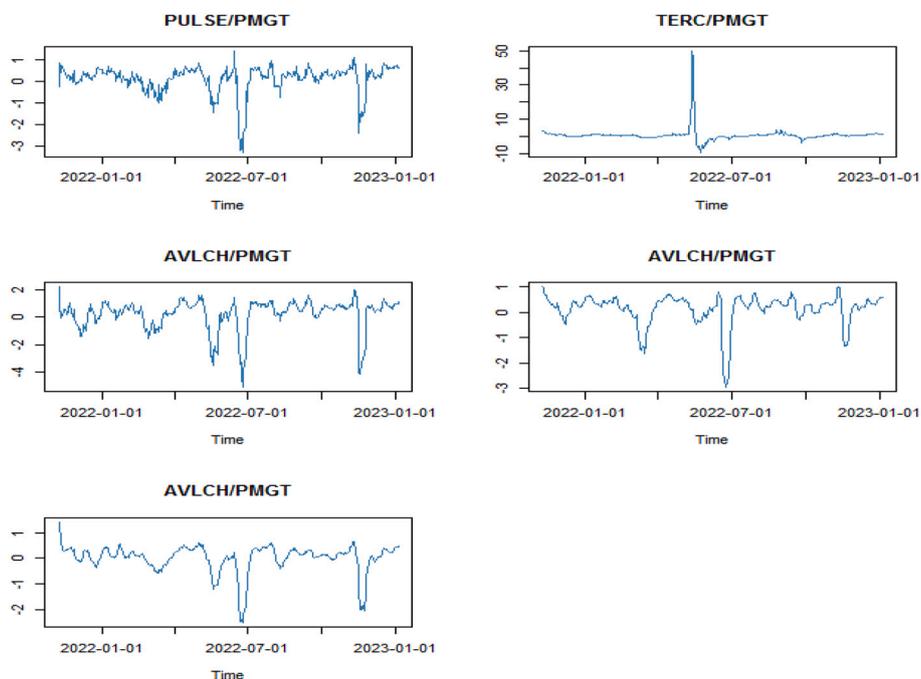


Fig. 6. Time-varying Beta for PMGT and five DeFis.

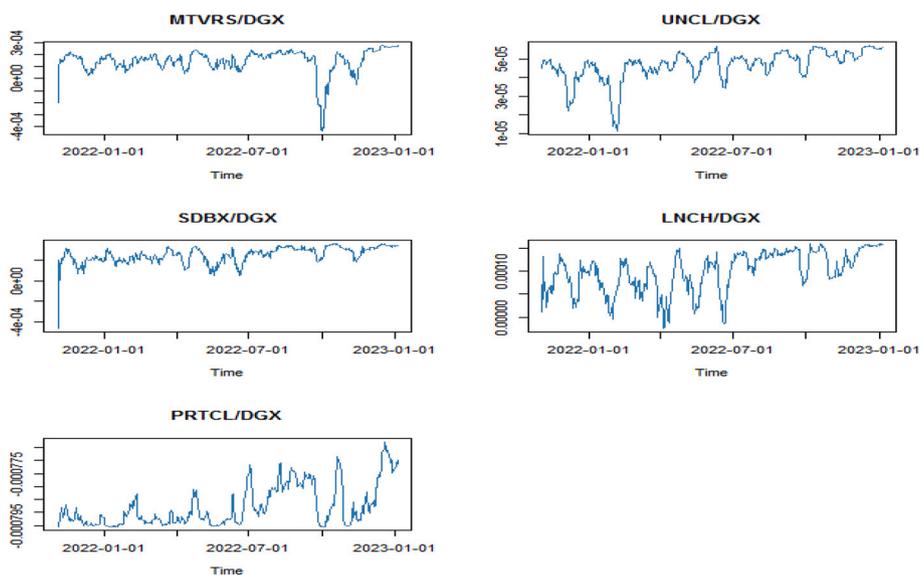


Fig. 7. Time-varying Beta for DGX and five NFTs.

indicated by Wang et al. (2022), Ncir et al. (2021), and Mnif et al. (2022).

From the foregoing, this paper examines the role of gold-backed cryptocurrencies to act as diversifiers, hedges, and safe havens for NFT and DeFi tokens over the period 02/11/2021–05/01/2023. The results obtained from the time-varying-GARCH-copula analysis provide valuable insights into the dynamic relationship between gold-backed cryptocurrencies (PAXG, PMGT, DGX) and both Non-Fungible Tokens (NFTs) and Decentralized Finance (DeFi) tokens. Figs. 1 and 2 exhibit the evolving dependence copula over time, highlighting the fluctuating degrees of dependence between gold-backed cryptocurrencies and these digital assets.

In examining the relationship between gold-backed cryptocurrencies and NFT tokens, the results indicate varying levels of dependence, with correlations oscillating between positive and negative values. This

variability suggests the diversification and hedging capabilities of gold-backed cryptocurrencies, particularly during times of market stress. For instance, PAXG emerges as a strong diversifier, with notable safe-haven characteristics during the 2022 bear market, particularly evident during significant market downturns such as the Terra-USD (USDT) breakdown in May 2022 and the broader cryptocurrency market crash in November 2022. Similarly, PMGT demonstrates strong hedging abilities during normal times and acts as a safe haven during crises, offering risk mitigation benefits across different NFT tokens. Meanwhile, DGX serves as both a diversifier and hedging tool, particularly notable for its safe-haven qualities during specific market downturns.

The analysis extends to the relationship between gold-backed cryptocurrencies and DeFi tokens, revealing similar dynamics. PAXG, PMGT, and DGX exhibit diverse roles as diversifiers, hedging instruments, and safe havens across different DeFi assets, with their effectiveness varying

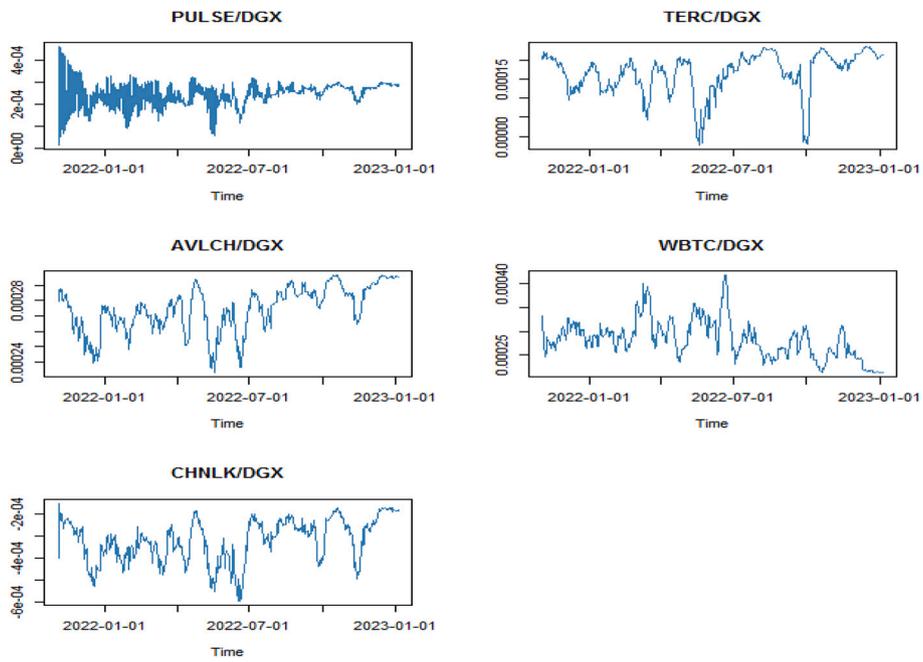


Fig. 8. Time-varying Beta for DGX and five DeFis.

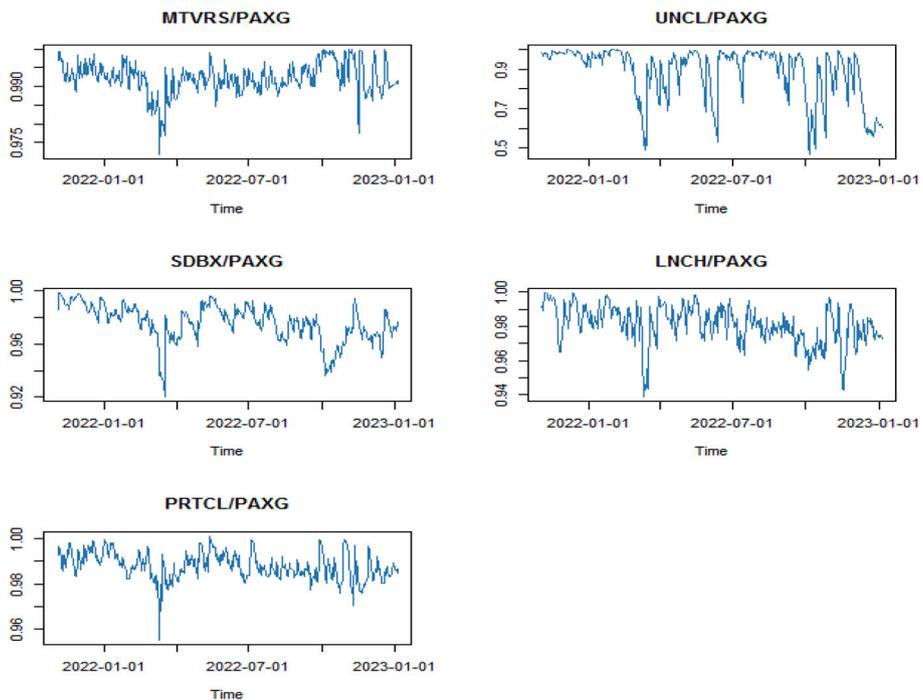


Fig. 9. Time-varying HE for PAXG and five NFT.

based on market conditions and token characteristics. Notably, these gold-backed cryptocurrencies prove instrumental in mitigating portfolio risk, with PAXG and PMGT emerging as the strongest safe havens for both NFTs and DeFi tokens.

Furthermore, the optimal hedging strategy analysis provides actionable insights for investors seeking to manage risk within NFT and DeFi portfolios. The hedge ratios and effectiveness metrics illustrate the importance of incorporating gold-backed cryptocurrencies into investment strategies to enhance risk-adjusted returns and mitigate downside risk. Negative hedge ratios suggest inverse positions, while positive ratios indicate strategies for long and short positions to offset risk exposure

effectively.

Overall, our empirical findings align with prior literature by Wang et al. (2020), Ali et al. (2022), Yousaf and Yarovaya (2022b), Mnif et al. (2022), and Díaz et al. (2023), highlighting the significant role of gold-backed cryptocurrencies in diversification, hedging, and serving as safe-haven assets. These results contribute to a deeper understanding of the dynamic relationships within digital asset portfolios and offer practical implications for risk management strategies in the cryptocurrency market.

Gold-backed cryptocurrencies play a pivotal role in mitigating the portfolio risk associated with NFT and DeFi assets through various

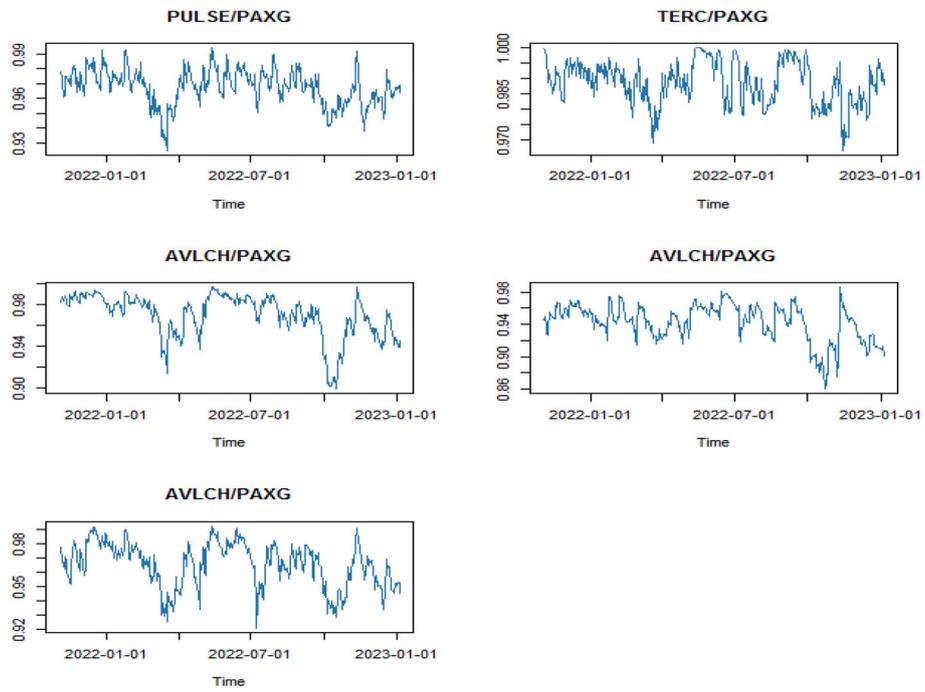


Fig. 10. Time-varying HE for PAXG and five DeFis.

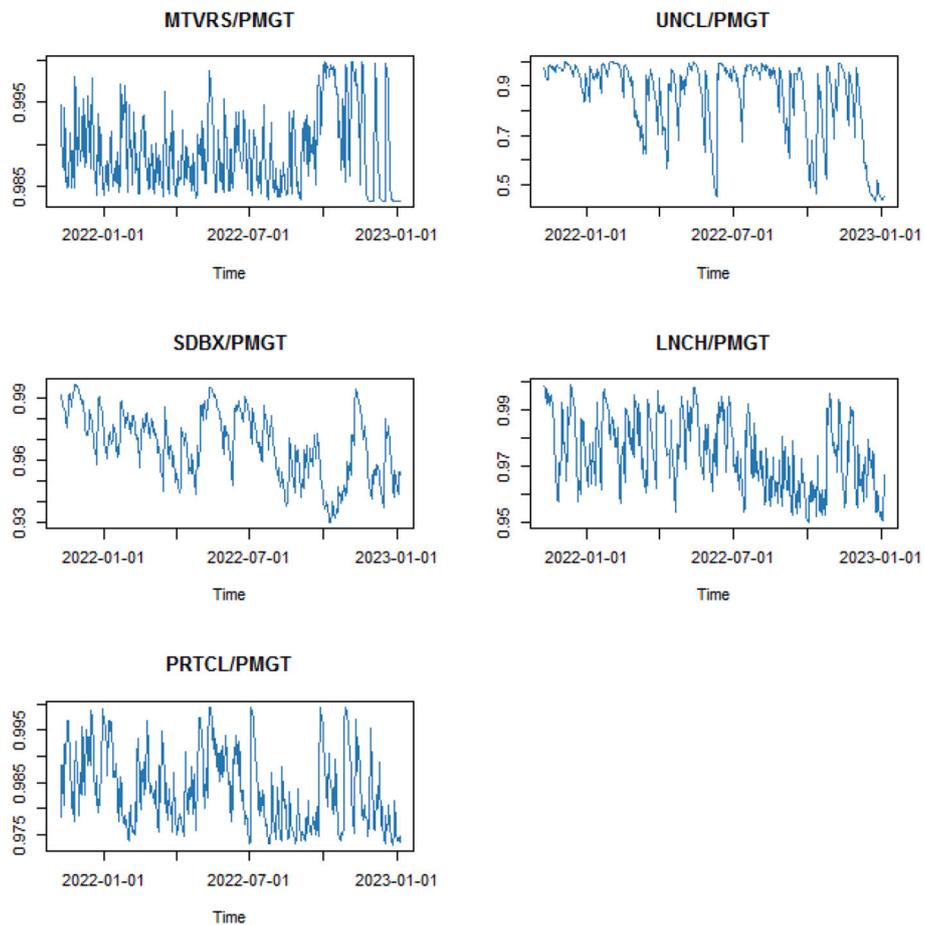


Fig. 11. Time-varying HE for PMGT and five NFTs.

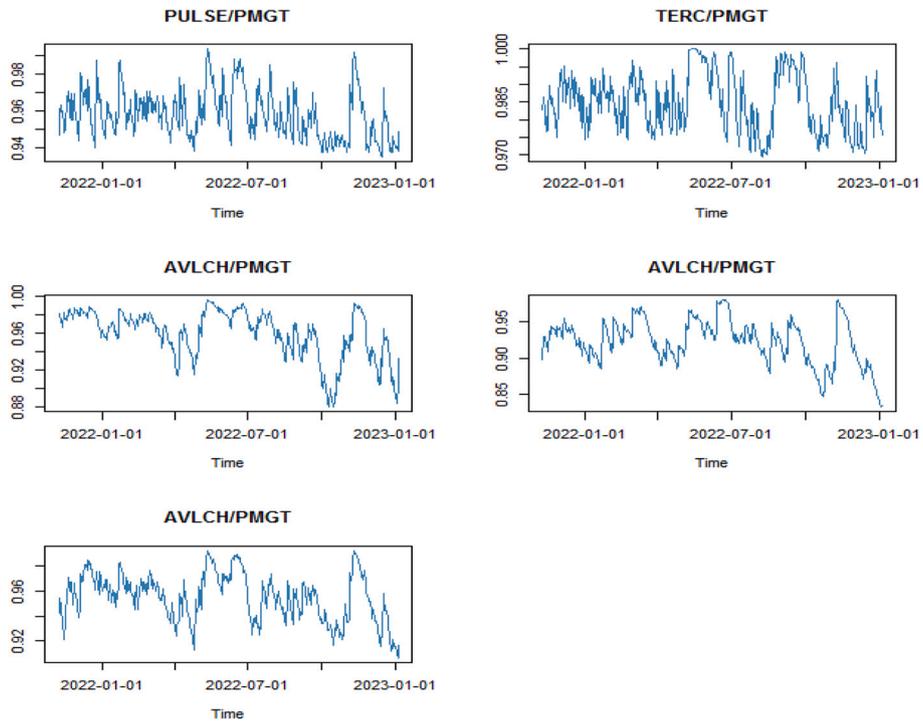


Fig. 12. Time-varying HE for PMGT and five DeFis.

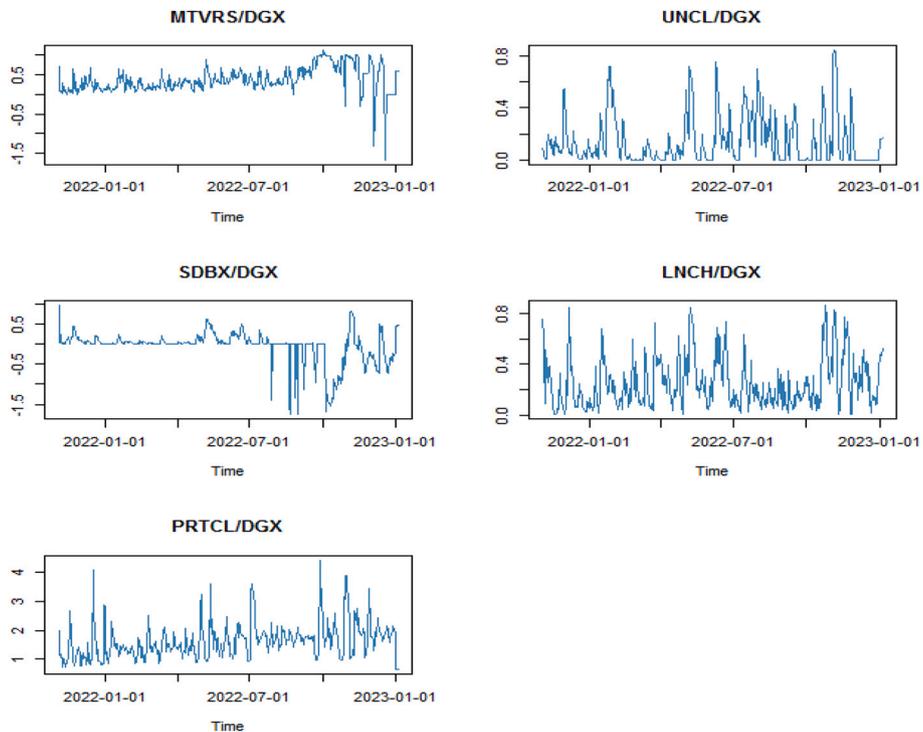


Fig. 13. Time-varying HE for DGX and five NFTs.

mechanisms, which contribute to their effectiveness across different market conditions. Firstly, gold-backed cryptocurrencies such as PAXG, PMGT, and DGX provide investors with exposure to the stability and intrinsic value of physical gold, which traditionally serves as a reliable store of value during times of market uncertainty. This inherent stability helps to offset the volatility inherent in NFT and DeFi assets, thereby reducing overall portfolio risk.

Furthermore, gold-backed cryptocurrencies exhibit diverse

behaviors across different market conditions, enhancing their effectiveness in risk mitigation. During normal market conditions, these assets often act as strong diversifiers or hedging instruments for NFTs and DeFis, providing investors with opportunities to spread risk and mitigate losses. However, during periods of market turmoil or crisis, such as the 2022 bear market mentioned in the empirical results, gold-backed cryptocurrencies tend to emerge as robust safe havens. Investors flock to these assets seeking refuge from volatile markets, thereby driving up

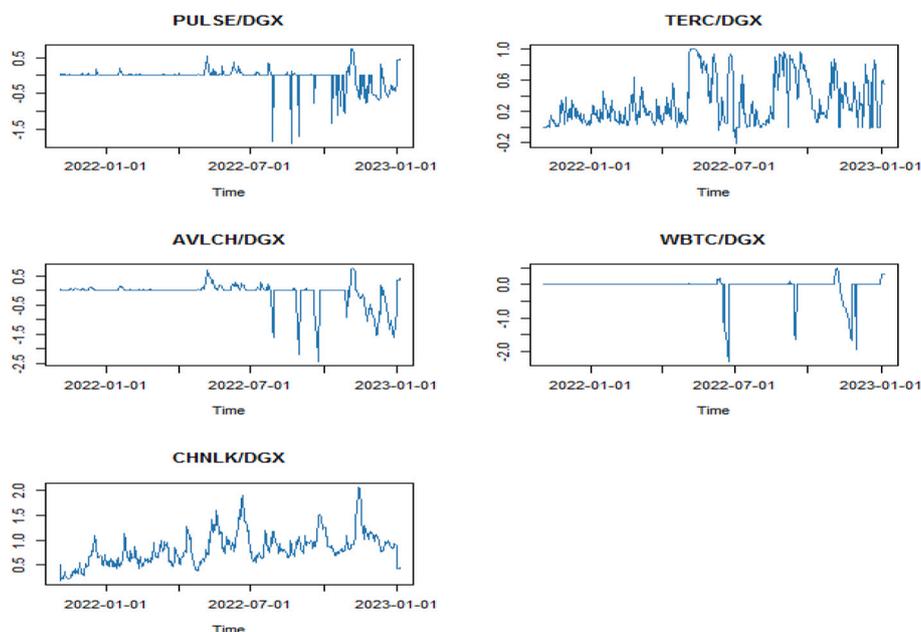


Fig. 14. Time-varying HE for DGX and five DeFis.

their value and further enhancing their risk-mitigation properties.

Several factors contribute to the effectiveness of gold-backed cryptocurrencies in mitigating portfolio risk. Firstly, their underlying asset, physical gold, is globally recognized for its stability and intrinsic value, making it an attractive investment choice during uncertain times. Additionally, the transparency and security offered by blockchain technology, upon which these cryptocurrencies are built, enhance investor confidence and reduce counterparty risk. Moreover, the finite supply of gold-backed cryptocurrencies, backed by physical gold reserves, provides protection against inflation and currency devaluation, further bolstering their risk-mitigation capabilities.

However, it is essential to note that the effectiveness of gold-backed cryptocurrencies in mitigating portfolio risk may vary depending on factors such as market sentiment, macroeconomic conditions, regulatory developments, and technological advancements. Investors should conduct thorough analysis and consider their risk tolerance and investment objectives before incorporating gold-backed cryptocurrencies into their portfolios.

In summary, gold-backed cryptocurrencies mitigate portfolio risk associated with NFT and DeFi assets by providing exposure to the stability and intrinsic value of physical gold, acting as diversifiers, hedging instruments, and safe havens across different market conditions. Factors such as the underlying asset quality, blockchain technology, and supply dynamics contribute to their effectiveness in risk mitigation, making them valuable components of a diversified investment portfolio.

## 7. Conclusion

Our paper uses a time-varying-GARCH-copula method to analyze the dynamic relationship between gold-backed cryptocurrencies (Pax Gold, Tether Gold, Perth Mint Gold Token, and Digix Global) and the newly developed digital assets (DeFi and NFT) during the period 02/11/2021–05/01/2023. Our empirical findings clearly display the existence of relationships DeFi, NFT and gold-backed cryptocurrencies. Interestingly enough, the degree of association among NFT and DeFi and gold-backed cryptocurrencies seems to be time-varying. We also report that gold-backed cryptocurrencies could be considered as adequate diversifying/hedging tool during calm periods. Such stablecoins are characterized by the safe-haven properties against NFT and DeFi during the year 2022. In particular, we show that PMGT and PAXG provide the best

safe-haven features for DeFi and NFT tokens. DGX can be used as safe-haven assets for some NFT and DeFi assets but with lower risk-reduction ability in comparison with PAXG and PMGT. DGX seems to play the role of strong diversifier. Its hedging feature is only recorded for the NFT Protocol (xNFT) and the DeFi token Chainlink (LINK). Our results are of particular interest to investors searching for safe havens to mitigate the risk of their NFT and DeFi portfolios. It can also be useful for investors looking for prospective investment opportunities in Blockchain technology.

Our study is nonetheless limited to investigate the relationship between one type of asset classes (gold-backed cryptocurrencies) and NFT and DeFi assets. It is also limited to see the pattern of lead/lag relationship between different assets. Future studies can focus on evaluating the flow information disclosed from different asset classes and NFT and DeFi assets during turbulent times. Our findings can be extended by employing alternative methods to explore the lead/lag relationships among different assets. For future studies, we also suggest to combine other methods to compare the behavior of connectedness structure between cryptocurrencies, commodities and NFT and DeFi assets. In particular, we can use Quantile Connectedness approach to examine the relationship between variables during extreme structural shocks, both positive (higher quantiles) and negative (lower quantiles) and Time-Frequency Connectedness Network model to explore dynamic information connectedness effects between assets for high- and low-frequency bands.

## CRedit authorship contribution statement

**Rihab Belguith:** Software, Methodology, Investigation, Formal analysis. **Yasmine Snene Manzli:** Writing – original draft. **Azza Bejaoui:** Writing – review & editing, Conceptualization. **Ahmed Jeribi:** Investigation, Formal analysis, Data curation.

## Declaration of competing interest

None.

## Data availability

Data will be made available on request.

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