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Global uncertainty and potential shelters: gold, bitcoin, and currencies as weak and strong safe havens for main world stock markets

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Abstract

This article investigates five safe-haven asset responses from 2014 to 2022, including the unprecedented COVID-19 crisis, Russian invasion of Ukraine, and sharp US interest rate increases of 2015 and 2022. We apply the unique approach of the multivariate factor stochastic volatility (MSV) model, which is extremely efficient for financial market analysis and allows us to conduct dynamic factor analysis of safe-haven relationships that cannot be observed directly. The research sample consists of five prospective safe-haven assets—gold, bitcoin, the euro, the Japanese yen, and the Swiss franc—and five primary world stock market indices—the S&P 500, Financial Times Stock Exchange (FTSE) 100, DAX, STOXX Europe 600, and Nikkei 225. Our findings are useful for investors searching for the best safe-haven assets among gold, bitcoin, and currencies to hedge against financial turmoil in global stock markets. Our unique findings suggest that safe-haven effects work differently for gold and the yen; that is, the Japanese yen acts as the strongest safe haven across all stock indices. Bitcoin is not a strong safe-haven currency since it has zero days of negative correlations with the considered stock indices, but it is a weak safe-haven during times of financial distress. Consequently, we state that strong and weak safe-haven properties vary across time and place. The novelty of our study lies in the methodological complexity of the MSV model (used for the first time to find the best safe-haven asset properties), dynamic factor analysis, a long-term research sample covering the Russian invasion of Ukraine in 2022, and an international investor perspective focusing on the world's leading stock markets. We extend earlier studies by analyzing the interrelations of the world's leading stock market indices with five potential safe-haven assets during the long period of 2014–2022 and using a unique dynamic factor analysis to show the differentiated behaviors of the Japanese yen and gold. Additionally, the main innovative contribution is a new framework of weak and strong safe-haven asset classifications not previously applied in the literature.

Keywords: Bitcoin, Global uncertainties, Gold, Hedging, Reserve currencies, Safe haven, Stock indices

JEL Classification: C11, C22, C58, F30, G11, G15

Introduction

The definition of a safe-haven asset varies. To some extent, the evolutionary character of this notion results from two coexisting, analogous terms for depicting special, risk-free investments, namely, safe-haven assets and safe assets. Although the two terms are used interchangeably, over time, the distinction between them has become much more evident.

Several assets are labeled safe havens—in most cases, gold and other commodities, debt instruments, currencies, and cryptocurrencies, such as bitcoin or Ethereum (Będowska-Sójka and Kliber 2021). A safe-haven asset is an investment expected to retain its value or increase in value during market downturns or crises, enabling investors to protect their portfolios. Portfolio managers invest in assets that are either negatively correlated or uncorrelated with their main portfolio constituents to limit exposure to losses during market turmoil.

Our paper examines the safe-haven properties of gold, bitcoin, the euro, the Japanese yen, and the Swiss franc during several turbulent periods: the COVID-19 crisis, Russian invasion of Ukraine in 2022, and sharp US interest rate increases in 2015 and 2022. The candidate assets are used to hedge a portfolio of five world-leading stock market indices—the S&P 500, FTSE 100, DAX, STOXX Europe 600, and Nikkei 225—from 2014 to 2022. We assume that gold, bitcoin, the euro, the yen, and the Swiss franc behave as safe havens from stock risks in major advanced countries; ergo, the main research question is, Can gold, bitcoin, the euro, the yen, and the franc act as safe havens from risks in the world's leading stock markets during periods of market distress from 2014 to 2022? These findings can provide useful information for international investors desiring to protect their savings in times of economic uncertainty and unforeseen global events.

Our contribution is as follows. First, we extensively analyze the financial literature on safe-haven assets and how they differ from assets commonly referred to as safe assets. Additionally, we distinguish between hedging and safe-haven functions within a portfolio. Thus, this article offers logically consistent explanations of the relationships between safe-haven assets and stock market investments. Second, we build a joint analysis with the world's leading stock market indices and five potential safe-haven assets over a prolonged period. We uncover considerable patterns in the gold, bitcoin, euro, yen, and franc reactions to crises, showing their safe-haven properties. Third, we use the advanced methodology of the MSV model estimated in R, which allows us to conduct dynamic factor analysis. Fourth, we propose a new definition of weak and strong safe-haven assets that has not been applied in the literature thus far: the interval of two standard deviations from the mean of posterior conditional correlation includes or is below zero during periods of market distress.

The article is structured as follows: Sect. "Introduction" introduces the topic, Sect. "Literature Review" presents the literature review, Sect. "Data and sample description" depicts the data and research sample, Sect. "Research Methodology" presents the proposed methodology, Sect. "Results and discussion" discusses the experimental results, and the last section concludes the paper.

Literature review

Safe haven overview and characteristics

The term safe haven has evolved. It has primarily been used to describe an asset with low risk and high liquidity (Upper 2000), making it similar to what is termed a safe asset. With ongoing crises, the term evolved to depict an asset that investors wish to hold in uncertain times (Kaul and Sapp 2006). This attribute became crucial to indicate safe-haven assets. Kaul and Sapp demonstrated that the US dollar was used as a safe-haven asset around the change of the millennium and later during the global financial crisis of 2007–2009. Thus, the term safe-haven asset emphasizes its function as a hedging asset—one whose return is uncorrelated with (or negatively related to) that of the reference portfolio. In extreme cases, it is an asset that performs well when the reference portfolio suffers significant losses (Ranaldo and Soderlind 2007).

Another important feature of safe-haven assets is that they depend on information flows (Baur and McDermott 2010). This feature is immensely important, as it indicates the short-lived phenomenon of safe havens (Baur and McDermott 2010). This was empirically confirmed by Ranaldo and Soderlind (2007), who found that safe-haven effects are evident in hourly as well as weekly data but seem to be strongest at frequencies of 1–2 days.

Baur and McDermott (2010) distinguished between strong and weak safe-haven effects. A strong safe haven is an asset negatively correlated with another asset or portfolio in times of falling stock prices, while a weak safe haven asset is uncorrelated. This division is mostly used in ongoing research, and it is the difference between a safe-haven property and a hedge property of financial assets. A safe haven is defined as a security uncorrelated with stock market returns when a market crash occurs. This feature contrasts with that of a hedging property, defined as a security uncorrelated with the stock market on average (Baur and Lucey 2009).[1] Therefore, in contrast to the previous confusion in definitions, Baur and Lucey (2009), followed by Baur and McDermott (2010), introduced precise conceptual distinctions between the terms hedge (formerly considered to be a function of a safe haven) and safe haven. They added one more term, diversifier, which is an asset that is positively but not perfectly correlated with another asset, on average. Yet both sets of authors talk about a weak (strong) hedge, defining it analogously as a weak (strong) safe haven as assessed on average. At the same time, they agree that distinguishing between weak and strong safe-haven assets, as described, is not comprehensive since it focuses on extreme stock market shocks during periods of turmoil. To make it more comprehensive, a broader set of shocks, including shocks from different asset classes over longer periods, should be considered (Baur and McDermott 2010).

Another important aspect of our conceptual analysis is ascertaining the special properties of assets labeled safe havens. Taking a perspective on safe-haven assets as a way to escape from uncertainty, i.e., the "flight to quality" attribute, makes it necessary to distinguish such a behavioral strategy from home bias. These two examples of investors' reactions to uncertainty can coexist and shape global patterns of returns and exchange

[1] Going further, Baur and McDermott (2010) and Baur and Lucey (2010) distinguish between strong and weak hedge, defining the former as an asset that is negatively correlated, and the latter as uncorellated with another asset or portfolio, on average.

rate movements. For example, after the stock market crash of 1987, investors tended to sell foreign equities, which heightened investors' bias toward their home assets. In contrast to this "homing" strategy, during the global financial crisis of 2007–2009, there was a flight to quality by private foreign investors to US treasury securities, which strengthened the US dollar (McCauley, McGuire 2009). The "flight to quality" literature indicates that an increase in perceived riskiness stimulates a demand for safety (Caballero, Krishnamurthy, 2008). According to the literature on the contagion phenomenon, risks and market crashes spill over across international markets (Hartman et al. 2004), enhancing movements in the financial markets and, in effect, searching for assets that hold their value and appreciations of safe-haven currencies. Additionally, increasing integration of financial markets leads to synchronizing stock markets worldwide.

Categories of safe-haven assets

Reserve currencies

The list of safe-haven assets contains assets categorized by their natures, issuance features, and historical roles within financial systems (traditional assets versus financial innovations). Primarily, however, it is currencies that fill the role of a safe haven. A list of safe-haven currencies is compatible with a list of main reserve currencies, indicating the quasi-monopolistic position of the US dollar followed by the euro in fulfilling this function. Thus, the determinants of safe-haven currency status are largely compatible with the determinants of international currencies (Bogołębska et al. 2019). However, the global structure of foreign exchange reserves does not explain the strong representation of the yen and franc as safe-haven assets and overestimates the role of the euro.

The literature on safe-haven currency drivers emphasizes the structural features of the economy. Based on monthly data for 52 currencies over a quarter of a century, Habib and Stracca (2012) showed that only a few country-specific factors, such as net foreign asset positions and stock market sizes, and in the case of advanced countries, interest spreads vis-à-vis those in the USA, are somewhat systematic drivers of safe-haven currency behavior. Masujima (2019) indicated that the drivers are not permanent; they tend to change dynamically. The panel regression results suggested that determinants of safe havens shifted from external sustainability factors (current account surplus) to market-driven factors (carry trade opportunity and high liquidity) during and after the global financial crisis. Moreover, the results highlighted the increasing effects that changes in monetary policy stance and market risk appetites have on a currency's safe-haven status.

An important property of safe-haven currencies is that they serve as the funding currency in carry trade transactions. Empirical studies confirm that because of the unwinding of carry trade transactions, safe-haven currencies have a nonlinear appreciation with increasing foreign exchange risk (Ranaldo and Soderlind 2007). However, as noted by McCauley and McGuire (2009), this contradicts the theory of interest rate parity, which holds that what investors gain on an interest rate differential, they lose over some horizon to currency depreciation. Searching for the properties of currencies that make them serve as funding currencies in carry trades, based on the experiences of the franc and the yen, shows that low yields play the primary role. Structural features of the economy, as highlighted in the traditional literature, are crucial for fulfilling the role of safe-haven currencies. These features encompass the country's political, institutional, social, and financial stability, low inflation, comfortable official foreign reserves, high savings, and net foreign asset positions (as confirmed empirically by Habib and Stracca (2012, 2020)), and confidence in the central bank (as confirmed later by Jansen and Studer (2017)). However, low yields played the premier role when using the yen and the franc as funding currencies. Moreover, this feature of Swiss interest rates has been evident for many decades (Baltensperger and Kugler 2016). Funding carry trade currencies (mostly the yen and the franc) puts additional pressure on appreciation in addition to the demand for currencies perceived as safe havens, in effect delivering a "safety premium." The latter source of appreciation is sometimes quoted as the key attribute of a safe-haven currency (e.g., Masujima 2019).

Empirical research confirms the different paths of safe-haven currency behavior. For example, Ranaldo and Soderlind (2007, 2009) confirmed that the Swiss franc, along with the yen and, to a lesser extent, the euro, has significant safe-haven characteristics and moves inversely with international equity markets and foreign exchange volatility. Coudert et al. (2014), based on a daily data analysis of 26 currencies issued by advanced and emerging economies from 1999 to 2013, found that only the yen and the US dollar exhibit safe-haven properties. The yen's safe-haven status was documented by De Bock and de Carvalho Filho (2013), who showed that the yen appreciates against the US dollar during risk-off episodes. Hossfeld and MacDonald (2015) found in their monthly frequency analysis of data spanning more than 26 years that the dollar and, even more, the franc qualify as safe-haven currencies. Grisse and Nitschka (2015) noted that the currency's safe-haven status has changed over time and that the Swiss franc appreciates against the euro in response to increases in global risk but depreciates against the dollar, the yen, and the British pound. Using daily data, Fatum and Yamamoto's (2016) empirical analysis indicated that during the global financial crisis, the yen exhibited the most profound safe-haven behavior. They also demonstrated that safe-haven currency behavior is time-dependent, confirming the theoretical predictions of Baur and Lucey (2009, 2010).

Gold

Gold as a safe-haven asset is unique, as confidence in gold is not derived from the fundamentals of any economy. Instead, it is rooted in its historical role in monetary systems as a reference unit and a store of value, which bestowed this commodity with its high intrinsic value. Today, it can be viewed as insurance against the current monetary system based on the fiat US dollar (Todorova 2020). It also protects investors from inflation, currency, and default risk. In contrast to other safe assets, it is not based on debt, which is regarded as the best way to provide such categories of assets. On the other hand, default risk is currently perceived in the post-COVID-19 era as a rising threat to financial stability. Gold returns are not fixed but volatile and thus risky. Empirical analysis shows that gold is riskier than other safe-haven assets, such as US government bonds.[2]

[2] In most empirical studies, the role of gold as a safe-haven asset is investigated against the US markets (e.g.,Baur and Lucey (2010), Ciner et al. (2013), and Hood and Malik (2013)). Baur and Lucey (2010) and Baur and McDermott (2010) delineated the role of gold against European stock markets and confirmed that gold is a true safe-haven asset for advanced economies' stock markets. However, in regard to equity markets in emerging and developing countries, the results are mixed.

Empirical results on the safe-haven properties of gold are mixed. Reboredo (2013) and Beckman et al. (2015) indicated that gold can play the role of both a hedge and an effective safe-haven asset. It was a particularly strong safe-haven asset in the aftermath of September 11, 2001, and the Lehman bankruptcy in September 2008 (Baur and McDermott 2010). Meanwhile, Hood and Malik (2013) suggested that gold is a hedge for the US stock market, but its role as a safe haven is weak relative to the VIX volatility index. Thus, gold's role as a safe-haven asset indicates that it is not necessarily explained by a risk–return profile but by a behavioral factor. This motivation is especially visible in the case of central banks' foreign reserve accumulation strategies to reduce the risk of sudden capital reversals and strengthen current account sustainability. Given the stylized fact that gold and US dollars are negatively correlated, gold holdings also provide diversification for central banks accumulating US dollar reserves (Bulut and Rizvanoghlu 2019). The latest research by Kaczmarek et al. (2022) demonstrated that gold has no potential as a safe haven, although some research conducted regarding the COVID-19 pandemic produced different results. Adekoya et al. (2021) analyzed 91 pandemic days and showed that gold provided a hedge for stock market investors during the COVID-19 crisis. This safe-haven property of gold was supported by Ji et al. (2020) and Yousaf et al. (2021), who concluded that gold was a strong safe haven in China, Indonesia, Singapore, and Vietnam. Lastly, the safe-haven property of gold was confirmed by Widjaja et al. (2023), who stated that gold was a safe-haven asset for conventional and Islamic investors during the COVID-19 pandemic period.

Bitcoin

Being a decentralized digital currency (independent of any political centers, either governments or central banks), cryptocurrencies have the potential to become safe-haven assets. Although the supply of bitcoin is limited by the protocol's design (Bouri et al. 2017), in times of growing public debt and doubts about its sustainability, the private production of safe assets may be challenging. However, empirical studies are skeptical about the prospects for cryptocurrencies as safe-haven assets. Bouri et al. (2017) used a dynamic conditional correlation model to examine whether bitcoin can act as a hedge and a safe haven for major world stock indices, bonds, oil, gold, the general commodity index, and the US dollar index based on daily weekly data spanning July 2011 to December 2015. The empirical results indicate that bitcoin is a poor hedge and suitable for diversification purposes only. However, it serves as a strong safe haven against weekly extreme downmovements in Asian stocks. They also show that safe-haven properties vary between horizons. Bitcoin's status as a safe haven is partly inconsistent with the literature.

Choi and Shin (2022) and Będowska-Sójka and Kliber (2021) showed that, unlike gold, bitcoin prices decline in response to financial uncertainty shocks. This contrasts with the safe-haven quality of gold. This complex economic phenomenon could be explained by the fact that the responses of bitcoin prices to economic shocks are different from those of gold, instead behaving like commodities such as crude oil (Gronwald 2019). Shahzad et al. (2019) reached similar conclusions. They found that while gold is an effective safe-haven asset for all G7 stock indices, bitcoin only offers a safe-haven role for the Canadian stock index. Smales (2019) went further, arguing that bitcoin should not be considered a potentially safe asset given its lack of liquidity, high volatility, and high transaction fees. In a related study on gold and bitcoin, Fabris and Jesic (2023) stated that gold may be a safe-haven asset for the DAX 40 index and the EURONEXT 100 index, unlike bitcoin. Their study covered December 2014 to August 2022, including the COVID-19 pandemic and the Russian–Ukrainian conflict. This hypothesis was verified by Cheema et al. (2020). Based on COVID-19 experiences, they indicated that cryptocurrencies were not used as safe-haven assets during this period of turmoil.

However, the role of safe-haven assets may vary with global risk aversion. According to Umar et al. (2023), gold and bitcoin cannot be considered consistent safe havens. Barbu et al. (2022) analyzed whether bitcoin and Ethereum showed short-term safe haven or diversifier properties in stock and bond markets during the COVID-19 pandemic. Both fulfill a diversifier role for sustainable stock market indices, a safe-haven role for bond markets, and a mixed role for stock market indices. Notably, Bhuiyan et al. (2023) found that bitcoin provides relatively better diversification opportunities during crises than gold.

Yousaf et al. (2023) recently studied Facebook, Apple, Amazon, Netflix, and Alphabet (FAANA) stocks acting as hedges, diversifiers, and safe havens against four alternative assets—gold, US treasury bonds, the US dollar, and bitcoin. They revealed that most FAANA stocks acted as weak or strong safe havens against gold, bonds, bitcoin, and the US dollar. Furthermore, few of those stocks had a strong safe-haven property against US treasury bonds or the US dollar during the COVID-19 pandemic. Their study differs from the existing literature because it examines FAANA stocks as safe havens and fills the gap in safe-haven research by changing the commonly used patterns.

The fast-growing research on safe-haven asset methodology is complex and demanding. Usually, quantile regressions or multivariate GARCH models are used in safe-haven analysis. However, new methodological approaches, such as Markov-switching CAPM (He et al. 2018), wavelet analysis (Bouri et al. 2020), conditional VaR analysis (Conlon and McGee 2020), or recurrent neural networks (Kaczmarek et al. 2022), are sometimes employed.

Data and sample description

Our research uses daily closing prices from January 2, 2014, to March 9, 2022, for five primary stock market indices[3]: the American Standard & Poor's 500 (SPX), the British Financial Times Stock Exchange (FTSE), the German Deutscher Aktienindex (DAX), the European STOXX Europe 600, and the Japanese NIKKEI 225 (NIKKEI). The SPX features leading US publicly traded companies, emphasizing market capitalization as listed on the American exchange. The FTSE comprises the 100 most highly capitalized companies listed on the London Stock Exchange, and the DAX consists of the 40 biggest German blue-chip companies. The STOXX represents large-, mid-, and small-capitalization companies across 17 European Union (EU) countries, and the NIKKEI is a stock market index for the Tokyo Stock Exchange of the most prominent issuers in Japan.[4]

[3] Three main financial markets—American, Japanese, and European—account for about 80% of the world's financial stock market; for more, see Miziołek et al. (2020), pp. 18–20.

[4] 4 Indices are quoted in local currency. Exchange rates can make some contribution to local currency index returns for international investors.

According to the literature, data on five potential safe-haven assets are used: gold, bitcoin, the euro, the Japanese yen, and the Swiss franc, which are the most discussed in the literature as potential safe havens. All exchange rates are quoted in US dollars,[5] and the data (1,751 daily observations) come from the EIKON Refinitiv Database.[6]

The first step was to prepare the full time series. Days with at least one missing data point were deleted, and logarithmic returns multiplied by 100 were then calculated. For estimation purposes, each time series was mean-corrected. Table 1 presents descriptive statistics for all series (before mean correction). Bitcoin has the highest standard deviation, while the euro has the lowest. Exchange rates seem less volatile than indices, except for bitcoin, which has the highest volatility of any of the considered assets. In terms of kurtosis, stock indices also outperform exchange rates (except for the franc), suggesting that stock indices are more prone to extreme values than currencies are. Gold, with a low standard deviation and the lowest kurtosis, seems to be the least volatile potential safe-haven asset. The minimum and maximum values of the time series confirm that stock indices and bitcoin offer more opportunities for extraordinary profit than currencies at the expense of exposure to the risk of large losses.

Figure 1 presents a correlogram of the time series used in the study based on the entire sample. The strongest positive correlation is observed between the DAX, STOXX, FTSE, and STOXX, which can be explained by the strong economic relations of those countries and the fact that they are EU members (apart from the UK). The correlation between exchange rates is also positive but weaker. Exchange rates are negatively correlated with stock indices, but the strength of this correlation is weak or negligible. Gold and bitcoin have low correlations or are not correlated with stock indices. However, a small negative correlation is observed for gold, which is positive for bitcoin. These two assets are positively but poorly correlated with exchange rates.

Research methodology

Various models are used in the literature. However, we chose the MSV model, which has three main advantages: (1) we can conduct the joint analysis of the main stock indices with possible safe-haven assets, (2) we can use the factor analysis to reduce the state-space of the analyzed assets to a lower-orthogonal latent factor space, and (3) we can study the time-varying correlation for each pair of potential safe-haven asset and stock indices separately. For economic and econometric reasons, MSV models have been applied extensively in recent years to characterize the volatility inherently linked with financial time series data. Knowledge of correlation structures is crucial in many financial applications, such as asset pricing, optimal portfolio risk management, and asset allocation. Additionally, as the volatilities of financial assets move together across different markets, modeling volatility in a multivariate framework generates greater statistical efficiency (Asai et al. 2006).

Or study uses the MSV model based on the formulation proposed by Chib et al. (2006) and efficiently estimated via Kastner et al.'s (2017) Bayesian inference. The

[5] We do not analyze the US dollar as a safe-haven currency because all our safe-haven assets are quoted in US dollars.

[6] Abbreviations are used to save space and to avoid distracting the reader by use of repetitious words or phrases: SPX, DAX, FTSE, STOXX, NIKKEI for indices, and gold, bitcoin, euro, yen, and franc for currencies.

Table 1 Descriptive statistics of logarithmic returns (multiplied by 100) of time series used in the study

	SPX	FTSE	STOXX	DAX	NIKKEI	Gold	Bitcoin	Euro	Franc	Yen
Mean	0.045	0.002	0.012	0.017	0.030	0.023	0.237	− 0.012	− 0.001	− 0.007
SD	1.170	1.101	1.148	1.331	1.322	0.928	4.871	0.519	0.650	0.550
Skewness	− 1.168	− 0.893	− 1.208	− 0.774	− 0.095	− 0.207	− 0.328	0.021	10.473	0.302
Kurtosis	22.808	15.422	15.447	13.043	7.734	7.157	10.045	5.440	277.846	8.708
Min	− 12.765	− 11.512	− 12.191	− 13.055	− 8.253	− 6.254	− 34.236	− 2.413	− 2.475	− 3.161
Q1	− 0.342	− 0.476	− 0.462	− 0.550	− 0.588	− 0.452	− 1.618	− 0.307	− 0.300	− 0.304
Median	0.069	0.052	0.083	0.087	0.065	0.033	0.196	− 0.009	− 0.014	− 0.011
Q3	0.550	0.551	0.579	0.677	0.696	0.500	2.165	0.288	0.284	0.251
Max	8.968	8.667	8.070	10.414	7.731	5.477	34.605	3.029	17.141	3.771

Source own study

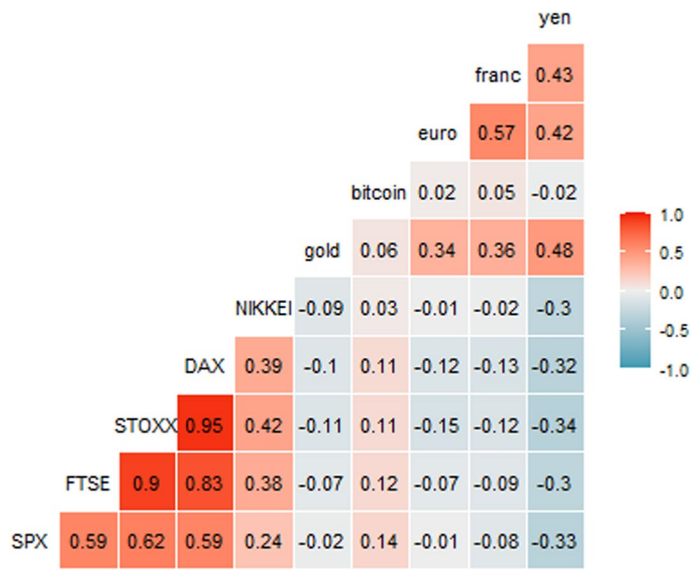

Fig. 1 Correlogram of time series used in the study. *Source*: own study

factor model can reduce the high-dimensional observation space to a lower-orthogonal latent factor space. Moreover, these latent factors are stochastic volatility processes, making the model more flexible, as it considers volatility clustering. Finally, idiosyncratic innovations are also stochastic volatility processes that allow volatility comovement to vary over time. Recently, various MSV models have been proposed in the literature. For example, Ishihara and Omori (2012) considered a general MSV model with cross-leverage and heavy-tailed errors; Ishihara and Omori (2017) proposed dynamic factor stochastic volatility with leverage and heavy-tailed errors; and Ishihara et al. (2016) introduced MSV with cross-leverage effects and dynamic correlation using the matrix exponential. The model proposed by Kastner et al. (2017) has neither leverage effects nor fat-tailed errors. However, it combines two crucial features for further analysis: it is a stochastic volatility factor model with an easily computable dynamic correlation.

Let $y_t = \left(y_{1t}, \ldots, y_{mt}\right)^T$ be the zero-mean vector of m observed logarithmic returns and $f_t = \left(f_{1t}, \ldots, f_{rt}\right)^T$ be a vector of r unobserved latent factors. MSV may be present as a system of equations:

$$\begin{cases} y_t = \Lambda f_t + U_t\left(h_t^U\right)^{\frac{1}{2}}\epsilon_t \\ f_t = V_t\left(h_t^V\right)^{1/2}\xi_t \end{cases}, \tag{1}$$

where Λ is the $m \times r$ dimensional factor loading matrix, $U_t\left(h_t^U\right) = \text{diag}\left(\exp(h_{1t}), \ldots, \exp(h_{mt})\right)$ is the $m \times m$ diagonal matrix of series-specific (idiosyncratic) variances and $V_t\left(h_t^V\right) = \text{diag}\left(\exp(h_{m+1t}), \ldots, \exp(h_{m+rt})\right)$ is the $r \times r$ diagonal matrix of latent factor variances (Kastner et al. 2017). Both idiosyncratic and latent factor innovations are assumed to be independent standard multivariate distributions: $\epsilon_t \sim N(0, I_m), \xi_t \sim N(0, I_r)$. Logarithms of variances follow an autoregressive process of order one:

$$\begin{cases} h_{it} = (1-\phi_i)\mu_i + \phi_i h_{i,t-1} + \sigma_i \eta_{it}, & i = 1, \ldots, m, \\ h_{m+j,t} = \phi_{m+j} h_{m+j,t-1} + \sigma_{m+j} \eta_{m+j,t}, & j = 1, \ldots, r. \end{cases} \tag{2}$$

Both static and dynamic factor models often face the problem of identifying parameters when certain combinations of parameter values result in very close maxima of the likelihood function. Consequently, certain restrictions on the parameter space must be added. For identification purposes, we follow two strategies from Kastner et al. (2017). First, to prevent perfect nonidentifiability, the latent factor volatility means are fixed at zero. Consequently, the diagonal elements of Λ matrix are left unrestricted (alternatively, one may fix the diagonal elements Λ at one). This approach allows a factor to be led by several series (the alternative method would cause the first *r* variables to lead the *r* factors). Second, to prevent factor rotation and column switching, the upper diagonal part of Λ is set to zero (for details, see Kastner et al. 2017).

A primary reason for using MSV in our study is the straightforward formula for time-varying conditional covariance—$cov(y_t|h_t) = \Lambda V_t(h_t^V)\Lambda^T + U_t(h_t^U)$ (Kastner et al. 2017)—which can be easily standardized to a conditional correlation.

The model was estimated using the Bayesian approach with the R CRAN package *factorstochvol* (Hosszejni and Kastner 2021). Consequently, all parameters and variables are treated as random. Thus, instead of point estimates, we obtained whole posterior distributions based on Monte Carlo Markov chain draws.

Our study consists of four steps, with the results discussed in phases a–d:

(1) selection of a proper number of factors,
(2) imposing a lower triangular constraint to prevent factor rotation,
(3) estimation model using the Bayesian approach,
(4) discussion of results:

  a. exploration of factor loading.
  b. factor volatilities analysis.
  c. time-varying correlation analysis.
  d. study of safe-haven properties.

The first step when estimating with latent factor models is to select an appropriate number of factors. In our study, we used the popular scree plot. Figure 2 presents posterior draws of the eigenvalues of the $\Lambda^T\Lambda$ matrix in the form of box plots. The orange line connects the posterior means of these draws. The chart flattens out after the third eigenvalue, suggesting that after the third latent factor, the relative gain per additional factor would be slight. Considering that a greater number of factors makes interpreting factor loadings more difficult, three seems to be the optimal number of latent factors.

In the second step, a lower triangular constraint must be imposed on the factor loading matrix, Λ, for identification purposes. With three hidden factors, it should have r(r − 2)/2 = 3 zero restrictions (Kastner et al. 2017). Thus, variables must be reordered through preliminary static factor analysis according to the absolute value of factor loadings (Hosszejni and Kastner 2021). In our study, STOXX leads the first latent factor (and consequently has two zero restrictions), the euro leads the second factor (one zero restriction), and the yen leads the third factor (unrestricted).

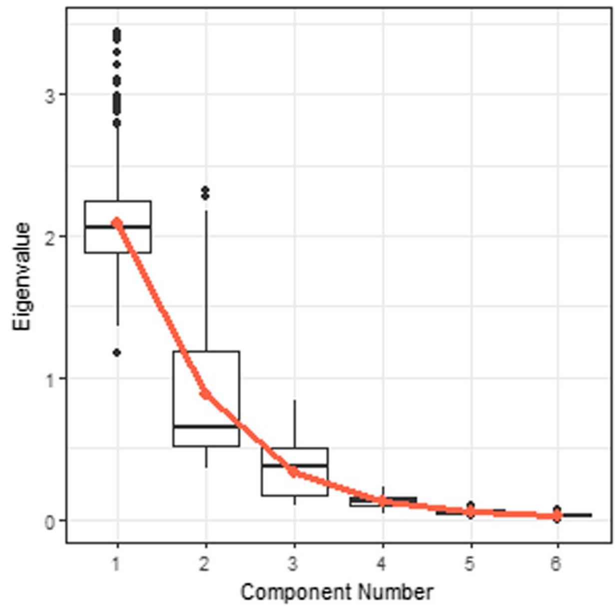

Fig. 2 Posterior draws (boxplots) and posterior means (gray dots) of the eigenvalues of $\mathbf{\Lambda}^T\mathbf{\Lambda}$. *Source*: own study

In the third step, the model was estimated using 10,000 draws with a thinning 10 plus 1,000 discarded burn-in draws. We adopt priors from Kastner et al. (2017).

Results and discussion

We begin our discussion of the results with a unique factor loadings analysis (phase a). This allows us to investigate safe-haven relationships that are not directly observable. It is possible to use factor analysis to distinguish three orthogonal (uncorrelated) latent factors from a 10-dimensional observation space. The factor loadings analysis expresses the relationships of each safe-haven asset and stock index to the underlying factor. The factor loading state space is three-dimensional, but to make the analysis easier, it was depicted with two-dimensional posterior distribution plots (see Fig. 3). The factor loading means with 95% credible posterior intervals are presented in Table 2. Our main finding is that of distinguishing three main factors (see Fig. 2) to explain the complex concept of potential safe-haven assets and their return relationships with the main stock market indices.

The first latent factor can be interpreted as European stock index-driven: stock market indices such as the European STOXX, German DAX, and British FTSE load very highly on this factor, while the US S&P 500 and Japanese NIKKEI 225 load slightly less. Other assets have small loads on this European latent factor: exchange rate loadings have negative signs, while bitcoin has a negligible positive loading (the 95% credible posterior interval contains zero). This first factor could be explained by the strong

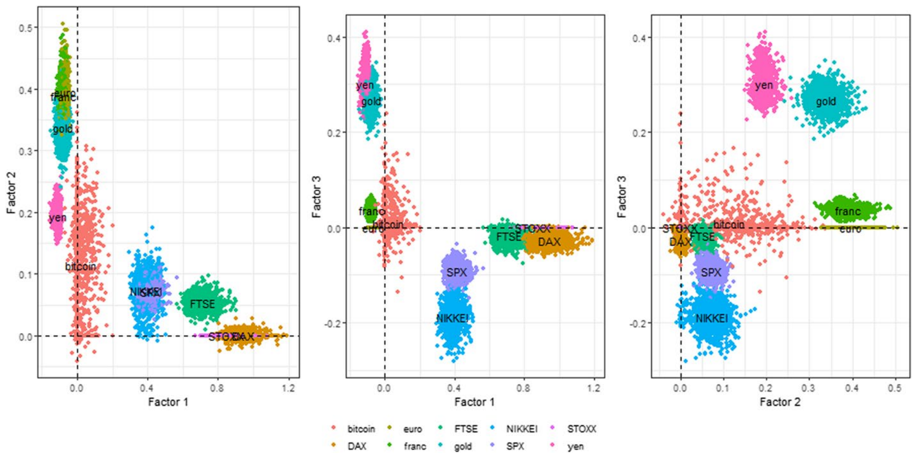

Fig. 3 The joint two-dimensional posterior distributions of factor loadings: monochrome clouds consist of MCMC draws, and names of series are placed in posterior means. *Source*: own study

Table 2 Posterior means and 95% credible posterior interval in parenthesis of factor loadings (x entries are set to zero by restriction)

	Factor 1	Factor 2	Factor 3
SPX	0.415 (0.352, 0.483)	0.071 (0.044, 0.102)	− 0.092 (− 0.121, − 0.063)
FTSE	0.717 (0.622, 0.825)	0.053 (0.032, 0.076)	− 0.016 (− 0.049, 0.002)
STOXX	0.850 (0.734, 0.973)	x	x
DAX	0.941 (0.816, 1.081)	0.000 (− 0.011, 0.013)	− 0.029 (− 0.052, 0.000)
NIKKEI	0.391 (0.326, 0.467)	0.073 (0.009, 0.122)	− 0.188 (− 0.246, − 0.138)
Gold	− 0.081 (− 0.119, − 0.044)	0.339 (0.290, 0.394)	0.268 (0.222, 0.314)
Bitcoin	0.023 (− 0.017, 0.124)	0.114 (− 0.002, 0.257)	0.008 (− 0.039, 0.098)
Euro	− 0.066 (− 0.089, − 0.047)	0.395 (0.353, 0.443)	x
Franc	− 0.079 (− 0.103, − 0.058)	0.389 (0.346, 0.438)	0.037 (0.019, 0.053)
Yen	− 0.111 (− 0.136, − 0.091)	0.194 (0.166, 0.226)	0.301 (0.256, 0.373)

Source: own study

economic relationships between EU countries. The STOXX Europe 600 contains issuers from 17 European countries.[7] The DAX index comprises 40 selected German blue-chip stocks traded on the Frankfurt Stock Exchange, while the British FTSE 100 comprises the 100 most highly capitalized blue-chip companies listed on the London Stock Exchange. This means that the first latent factor explains the comovement between EU area equity returns at national and industry levels. This observation about the first latent factor proves the stock market synchronization hypothesis fueled by capital flows within a single financial market across the EU.

Moreover, economic interlinkages are strengthened by high levels of intra-EU trade. The euro, the common currency in the Economic and Monetary Union, eliminates exchange rate risk, giving impetus to deeper trade integration. European financial markets are mostly driven by worldwide trends and those within Europe, and this was

[7] 7 Austria, Belgium, Denmark, Finland, France, Germany, Ireland, Italy, Luxembourg, the Netherlands, Norway, Poland, Portugal, Spain, Sweden, Switzerland and the United Kingdom.

observable in our results. The European financial market is a multicentric euro area with numerous financial hubs in Germany, Ireland, the Netherlands, and France that are strongly linked by EU regulations and supervision (European Central Bank 2022). Potential safe-haven assets such as gold, the euro, the franc, and the yen load negatively on the first factor (see Fig. 3 and Table 2). Only bitcoin has negligible loadings that differ from those of other assets.

The second latent factor seems to be European currency-driven, with the highest loadings from the euro and the franc. Gold and the yen also load considerably on this factor but less than European currencies. Stock indices (NIKKEI, SPX, FTSE) have small positive or negligible loadings (STOXX by restriction and DAX's with a posterior credible interval containing zero). Bitcoin has a very broad 95% posterior credible interval for factor loadings on the second factor from − 0.002 to 0.257, which includes zero but with a mean of 0.114, close to the mean of the yen's factor loadings. This second factor could be explained by the strong economic relations between EU countries and Switzerland. The EU is the most important trade partner for Switzerland (more than 40% of total exports), which makes the bilateral exchange rate a significant variable, *t*, representing economic competitiveness. The fear of worsening export competitiveness as a consequence of an appreciating franc was observed during the global financial crisis. The Swiss Central Bank (SCB) was forced to ease this appreciation pressure, introducing an exchange rate peg against the euro and intervening in the foreign exchange market to stabilize it. Both central banks (the ECB and the SCB) conduct similar exercises in policymaking by a close medium-term policy orientation and the important role assigned to monetary indicators of long-term risks that influence price stability in the euro area and Switzerland.

The third latent factor is driven by the USA and Japan, but the interdependence between this factor and the analyzed assets is the least obvious. We have decided to relate it to the US and Japanese economies; thus, the highest loadings come from the yen and gold, with a small positive loading from the franc (the euro is restricted to zero). Gold is usually denominated in US dollars, which is why it is strongly linked to the American economy. Apart from that, the United States has the largest gold reserves in the world (World Gold Council 2022), which can be explained by the historical role of gold and US dollars in the Bretton Woods international monetary system. However, this factor also has significant negative loadings from two stock indices—the Japanese NIKKEI and US SPX—meaning that the performance of these indices may have an inverse relationship with that of gold and the yen. The rest of the stock indices have negligible loadings (STOXX by restriction). The US and Japanese economies are strongly linked, and their economic relations are mutually advantageous. They are highly integrated with trade in goods and services, as well as capital flows, both in portfolios (Japan's role in financing US public debt) and foreign direct investment.

This third factor could be explained by the dependence of yen and gold returns on different economic variables, which could potentially act as the best safe-haven assets for stock indices. The main implication of the third latent factor is that safe-haven effects work differently for gold and the yen than for other safe-haven currencies, which is why they are best for hedging risk. With regard to investment strategies, the

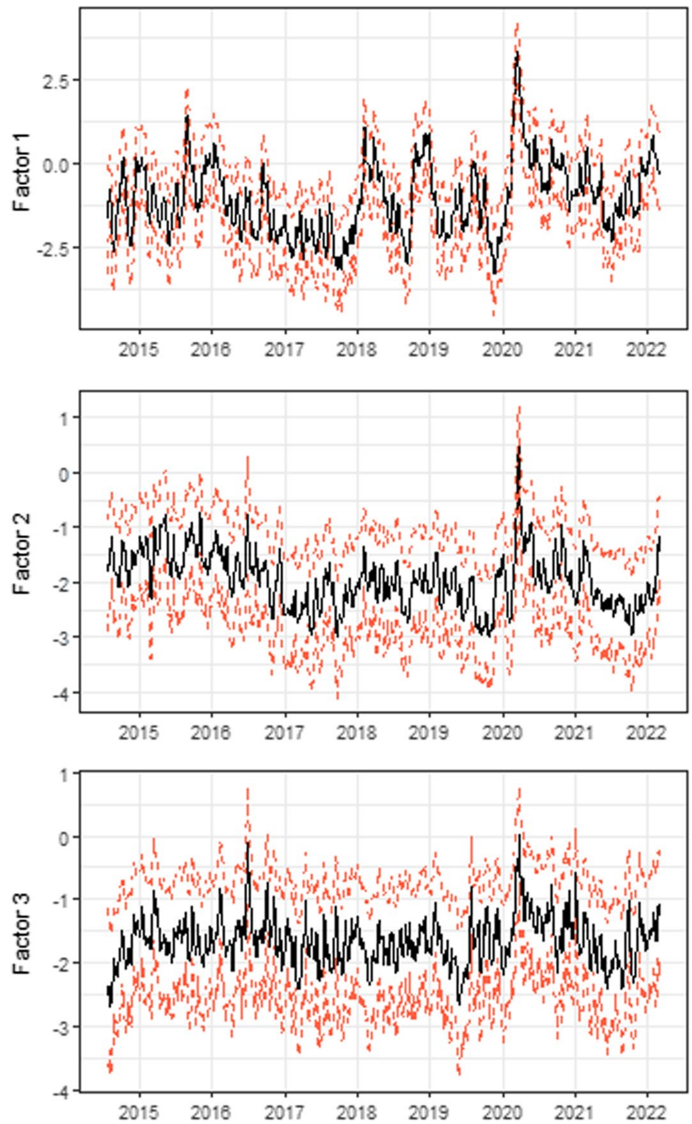

Fig. 4 Marginal posteriors of the factor log-variances (mean ± 2 × sd) *Source*: own study

yen and gold have significant loadings on both the second and third latent factors and thus act as hedges for all considered stock indices.

Moving to phase b, we verify the volatility of the three latent factors across the entire 2014–2022 period to present the periods with the highest volatility for each latent factor. Figure 4 presents the log-variance of the latent factors with ± two-standard-deviation bands. Model construction (decline in eigenvalues) causes a smaller variance for each successive factor. The relationships between the latent factors and the considered assets (Fig. 3 and Table 2) may be used to interpret their volatility changes. A quite large jump in variation occurred at the beginning of the COVID-19 pandemic for all latent factors. After the Russian invasion of Ukraine, a smaller increase in volatility occurred that was stronger for the second factor than for the first. Last, a small rise in volatility was observed in 2016 after the Brexit referendum (first factor) and the US presidential

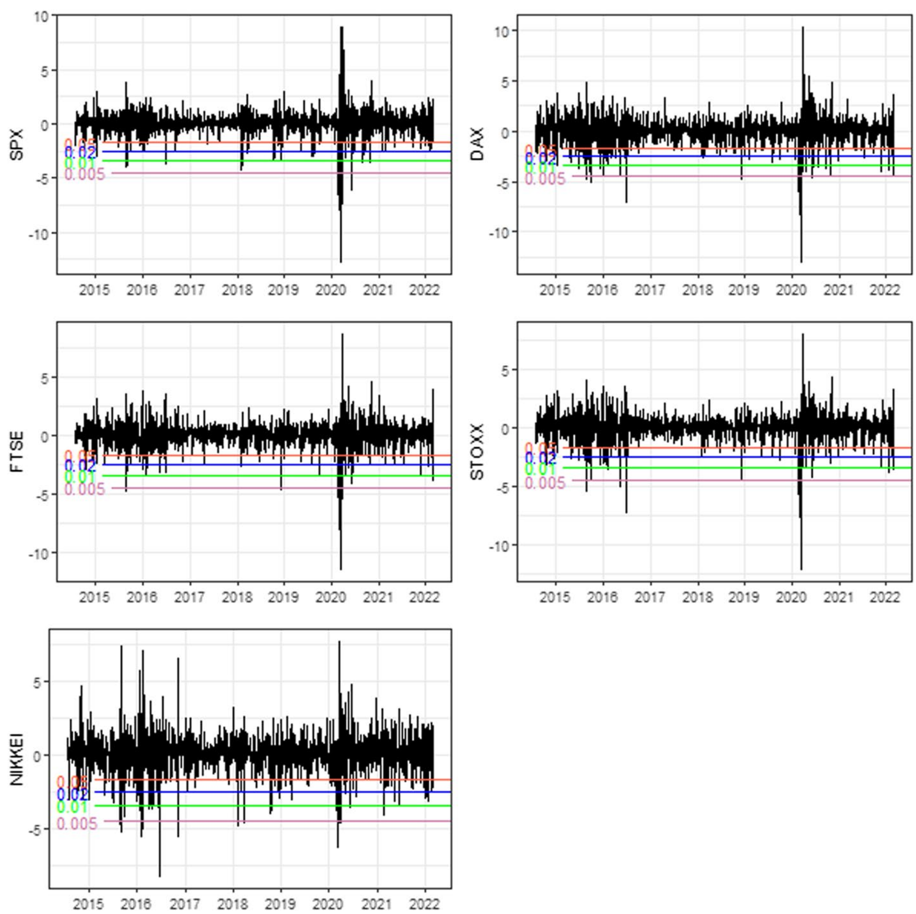

Fig. 5 Log returns of stock indices with horizontal lines drawn by the quantile values (0.05, 0.02, 0.01, 0.005) *Source*: own study

elections (third factor). The log-variance of the first latent factor responsible for European stock indices is the most volatile, and a few peaks of volatility are clearly visible. The least volatile is the third factor responsible for the Japanese and US economies, and its log-volatility stacks between − 2 and − 1 most of the time.

The next phase is phase c, which analyzes the correlation between the main stock indices and potential safe-haven assets. We begin the correlation analysis by defining strong and weak safe-haven assets. We propose new definitions that specify popular interpretations. In our study, we note that an asset is a weak (strong) safe haven when the interval of two standard deviations from the mean of posterior conditional correlation includes (is below) zero during a period of market distress. Bayesian interpretation of the credibility interval in combination with the Chebyshev inequality indicates that given the observed data with at least 75% probability, these intervals cover conditional correlation between considered assets.

Furthermore, as our study covers periods of market distress, we chose days when the stock exchange index fell below a certain low quantile (0.05, 0.02, 0.01, 0.005). This simple method immediately indicates days with the greatest declines in stock indices. Figure 5 presents the log-returns of stock indices, with horizontal lines representing quantile values. A decline in the rate of return below the line indicates a market in

Table 3 The definition of weak/strong safe-haven properties

No	Name of the property	Definition
1	Strong safe haven	The asset is a strong safe haven when the interval of plus/minus two posterior standard deviations from the posterior mean of conditional correlation with the market index is below zero in times of market distress
2	Weak safe haven	The asset is a weak safe haven when the interval of plus/minus two posterior standard deviations from the posterior mean of conditional correlation with the market index includes zero in times of market distress

Source: own study

turmoil. A detailed list of dates when a stock market index fell below a certain quantile is included in the Additional file 1: Table A1.

This last phase is d, which studies the safe-haven properties of the analyzed assets during market declines. Weak and strong safe-haven properties are defined according to our definition (see Table 3).

In a similar paper, Baur and McDermott (2010) used a GARCH model with time-varying parameters to extract the relation between gold and the main stock indices with dummy variables to capture extreme stock market movements. Most previous studies have used DCC-GARCH models to estimate dynamic correlation (see, for example, Akhtaruzzaman et al. 2020; Bouri et al. 2017; Mariana et al. 2021). However, attempts to extract the safe-haven effect in these articles vary. Akhtaruzzaman et al. (2020) calculated optimal hedge ratios based on conditional volatilities and covariances. Bouri et al. (2017) regressed dynamic correlations on dummy variables representing extreme movements in the return distribution of analyzed assets. Mariana et al. (2021) compared sample statistics of dynamic correlations before and during the COVID-19 period. Our approach, meanwhile, is similar to that of Będowska-Sójka and Kliber (2021) study, which also used stochastic volatility models to estimate dynamic correlation and assumed that a strong safe haven is an asset for which the 95% credible posterior interval of conditional correlation covers negative values in moments of extreme drops in the stock market index. They also defined weak safe-haven assets as those for which the median of the posterior of the conditional correlation takes negative values on days with extreme negative returns on the observed stock index. We modified the definitions to more closely resemble the one-tailed Pearson linear correlation coefficient test. A strong safe-haven asset corresponds to a negative correlation, i.e., a situation where the entire credibility interval for conditional correlation is below zero. A weak safe-haven asset, meanwhile, corresponds to an uncorrelation, i.e., a situation where the credibility interval contains zero. Our approach is also distinguished by using a portfolio containing all the assets analyzed in the study instead of pairing individual indices with safe-haven candidates as in previous studies using stochastic volatility models (Kliber et al. 2019; Będowska-Sójka and Kliber 2021). This allows us to consider not only the correlation between the index and the candidate for a safe-haven asset but also the correlation between the indices and the safe-haven candidates.

Table 4 The percentage of days when proposed in the study weak/strong safe-haven property is met (interval of 2 standard deviations from the mean of posterior conditional correlation includes/is below zero during the period of market distress)

	Quantile	Gold Weak/strong	Bitcoin Weak/strong	Euro Weak/strong	Franc Weak/strong	Yen Weak/strong
SPX	0.05	88.6/11.4	100/0	95.5/4.5	92/8	3.4/96.6
	0.02	91.7/8.3	100/0	91.7/8.3	83.3/16.7	2.8/97.2
	0.01	88.9/11.1	100/0	83.3/16.7	66.7/33.3	5.6/94.4
	0.005	88.9/11.1	100/0	77.8/22.2	44.4/55.6	0/100
FTSE	0.05	33/67	100/0	40.9/59.1	29.5/70.5	3.4/96.6
	0.02	2.9/97.1	100/0	2.9/97.1	0/100	0/100
	0.01	5.6/94.4	100/0	0/100	0/100	0/100
	0.005	0/100	100/0	0/100	0/100	0/100
STOXX	0.05	0/100	100/0	0/100	0/100	0/100
	0.02	0/100	100/0	0/100	0/100	0/100
	0.01	0/100	100/0	0/100	0/100	0/100
	0.005	0/100	100/0	0/100	0/100	0/100
DAX	0.05	0/100	100/0	0/100	0/100	0/100
	0.02	0/100	100/0	0/100	0/100	0/100
	0.01	0/100	100/0	0/100	0/100	0/100
	0.005	0/100	100/0	0/100	0/100	0/100
NIKKEI	0.05	83/17	100/0	93.2/6.8	87.5/12.5	15.9/84.1
	0.02	77.8/22.2	100/0	88.9/11.1	83.3/16.7	19.4/80.6
	0.01	83.3/16.7	100/0	83.3/16.7	77.8/22.2	11.1/88.9
	0.005	77.8/22.2	100/0	77.8/22.2	66.7/33.3	22.2/77.8

For each index, there are, respectively, 88, 36, 18, and 9 days when the index dropped below the 0.05, 0.02, 0.01, and 0.005 quintiles; see Additional file 1: Table A1

Source: own study

Table 4 shows weak and strong safe-haven properties according to the definitions in Table 3. We classified extreme returns as those below a certain low quantile of returns (i.e., 0.05, 0.02, 0.01, 0.005). Figure 6 presents the marginal posteriors of the dynamic conditional correlation means (black line) with $+/-$ two-standard-deviation bands (orange lines) between potential safe-haven assets (rows) and stock indices (columns).

Table 4 begins our analysis of the American SPX. The best strong safe-haven property is observed for the yen, followed by the franc, the euro, gold, and finally, bitcoin. The weakest is observed for bitcoin, gold, the euro, the franc, and the yen. This means that those weak and strong safe-haven properties are adversely related during the entire period and that American SPX investors can use them all during market distress. Thus, the Japanese yen is their most efficient (strong) safe-haven asset.

In line with the numbers, the strongest safe-haven property against the FTSE is observed for the yen, the franc, the euro, gold, and bitcoin, following the pattern of the SPX. In line with the SPX, British FTSE investors should use the Japanese yen, which is the most efficient (strongest) safe-haven asset. The franc, the euro, and gold can also hedge the British portfolio but less efficiently. The European STOXX and German DAX produced interesting results. They showed that a strong safe-haven property is exhibited by the yen, the franc, the euro, and gold, and a weak safe-haven property by bitcoin. This means that investors who build European portfolios have

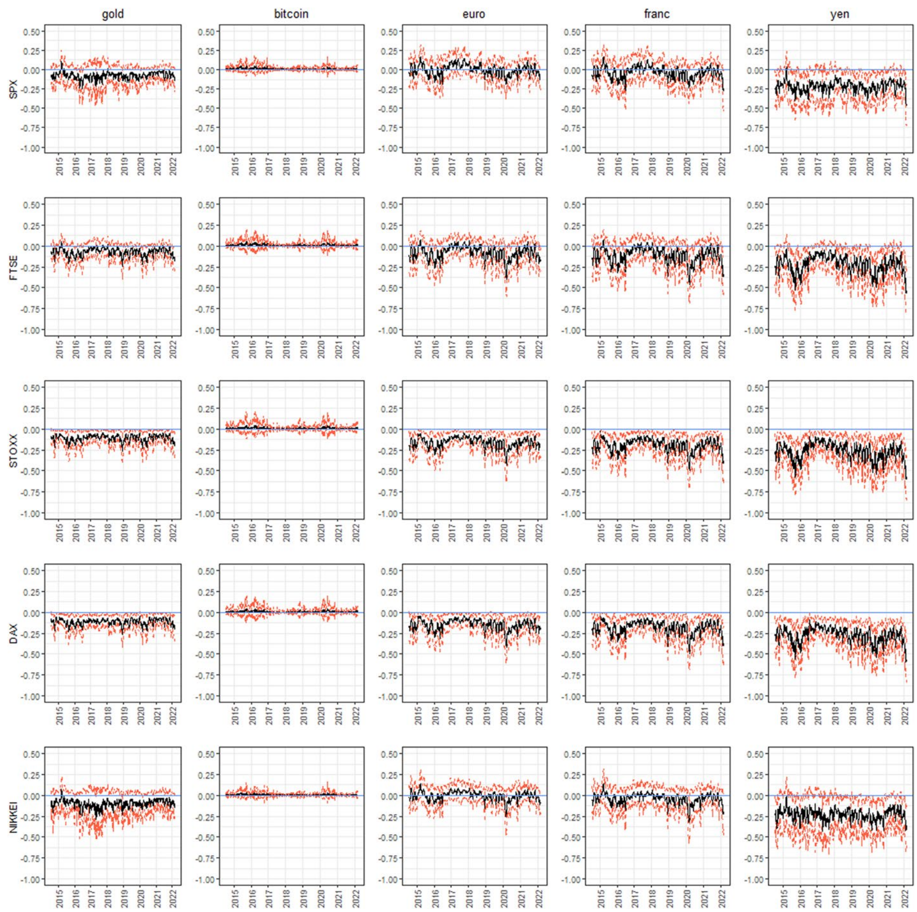

Fig. 6 Marginal posteriors of the dynamic conditional correlations (mean ± 2 × sd) *Source*: own study

broad opportunities to avoid market downturns by investing in all the save-haven assets mentioned. Last, the NIKKEI index should be hedged by the Japanese yen, which is the strongest safe-haven asset, and bitcoin, the weakest.

All things considered, the five investigated potential safe-haven assets can hedge[8] (i.e., reduce the risk of adverse price movements) the portfolio of main world stock indices during market turmoil. However, the Japanese yen is the most efficient, being the strongest safe-haven asset for all of them. The American portfolio of 500 leading publicly traded companies can be efficiently hedged by the yen as the strongest safe-haven currency during market distress. The Swiss franc, the euro, and gold can also play a strong safe-haven role against the FTSE, but to a somewhat lesser extent. To hedge the portfolio of European companies traded in the STOXX and DAX, the yen, the franc, the euro, and gold act as strong safe-haven assets.

The oldest stock index in Asia, the NIKKEI, appears difficult to hedge against market downturns. Nevertheless, it can be efficiently hedged by the home country currency—the yen—thus proving the home bias hypothesis. Otherwise, it can be linked to

[8] We use the term hedge to mean that this financial instrument can reduce the portfolio risk. We do not study the hedge property.

restrictions on international capital flows. Another explanation is the yen's role in carry trade transactions as a consequence of low interest rates. The phenomenon of the yen as a safe-haven asset can also be explained by a combination of fundamental factors, as indicated by Habib and Stracca (2012): a positive international investment position and market liquidity indicators, such as bid–offer spreads. The overall explanation is underscored by Japan's proximity to East Asian emerging markets (Indonesia, Malaysia, Thailand) and its role as a strong global technology leader.

Bitcoin always plays a weak safe-haven role for all indices. Additionally, it cannot hedge the portfolio. The behavior of bitcoin can also be explained by our proposed factor loading analysis. The yen and gold have significant loadings on both the second and the third latent factors and thus act as hedges for all considered stock indices. Bitcoin, which has no significant loading on either the second or the third latent factor, had zero days of negative correlations with the stock indices considered. We also observed that weak and strong safe-haven properties had adverse relationships during the entire 2014–2022 period, meaning that the safe-haven property is complex, and strong or weak safe-haven assets can vary with time and place. This observation may confirm Masujima's (2019) hypothesis of the changing nature of safe-haven asset drivers.

Conclusions

This article explored the properties of potential safe-haven assets such as gold, bitcoin, the euro, the Japanese yen, and the Swiss franc between 2014 and 2022. This period included several unprecedented events: the COVID-19 crisis, the Russian invasion of Ukraine, and sharp increases in US interest rates. To analyze the safe-haven phenomenon, we chose days when the stock exchange index fell below a certain low quantile. Based on a considerably large-scale empirical analysis of the MSV model, we found that the yen was once a strong safe haven against the main stock market indices. The model was estimated in R using the Bayesian approach and a new framework for classifying weak and strong safe-haven assets that had not been applied thus far in the international literature.

The novelty of the study is the dynamic factor analysis of the selected indices and safe-haven assets, distinguishing three main uncorrelated latent factors, with the first driven by European stock indices, the second by European currencies and gold, and the last by the USA and Japan. This third latent factor shows that safe-haven effects work differently for gold and the yen than they do for other safe-haven currencies; thus, those two currencies are major safe-haven assets for world stock indices, mostly those that are European-oriented. This unique dynamic factor analysis expresses the relationship between safe-haven assets and global stock market indices.

The American S&P 500 can be hedged, meaning risk is reduced, by the yen, which plays a strong safe-haven role for the world's large-cap US equities. British investors can hedge the portfolio of the FTSE index with the yen, the franc, and the euro, but the yen is still the best choice. For European investors, the yen, the franc, the euro, and gold play strong safe-haven roles against the STOXX and DAX. Unsurprisingly, the Japanese portfolio of the NIKKEI is the most difficult to hedge against market distress, and the yen might act as a safe-haven asset but less efficiently. Bitcoin is not a strong safe-haven currency since it had zero days of negative correlations with the considered stock indices and the weakest safe-haven property against all analyzed portfolios.

All investigated potential safe-haven assets can reduce the risk of the primary world stock index portfolios during the crisis, but the Japanese yen is the most efficient. However, the European FTSE, STOXX, and DAX indices can be efficiently hedged by the yen, the franc, the euro, and gold, which have strong safe-haven properties. Bitcoin has no strong safe-haven properties, although it acts as a weak safe-haven asset. Strong or weak safe-haven properties can vary across time and place, i.e., five safe-haven assets could hedge the portfolio of the main world stock indices during market turmoil, but the efficiency of hedging is different.

Future research should examine a larger group of safe-haven assets, such as precious metals, commodities, or long-term debt instruments issued by advanced economies and a greater number of leading stock market indices, including emerging markets. This could enhance the results by explaining regional patterns of safe-haven effects, as suggested by Baur and Lucey (2009, 2010) and Baur and McDermott (2010). Our findings are relevant to portfolio managers and all investors who use an active approach to hedge against risk. They might help to diversify portfolios and mitigate losses when unprecedented events occur. This paper also addressed possible interventions of central banks in currency markets to lower the volatility of the home currency's exchange rate. The findings suggest that safe-haven assets can change their nature, and policymakers should exercise caution in labeling bitcoin as an alternative to gold or other traditional "safe" investments.

Abbreviations

DAX	Deutscher Aktienindex DAX 40
EU	European Union
FAANA stocks	Facebook, Apple, Amazon, Netflix, and Alphabet stocks
FTSE	Financial Times Stock Exchange Index (FTSE 100)
MSV	Multivariate volatility stochastic
NIKKEI	Nikkei 225
SCB	Swiss Central Bank
SPX	Standard & Poor's 500
STOXX	STOXX Europe 600

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s40854-023-00589-w.

Additional file 1. **Appendix. Table A1.** List of dates when the stock exchange index declined below a certain low quantile (0.05, 0.02, 0.01, 0.005).

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Author contributions
EFS, PS, JB—conceptualization, JB literature writing, PS—methodology, PS calculations, and EFS discussion and conclusions.

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Availability of data and materials
The datasets used and analyzed during the current study are available from the corresponding author upon reasonable request.

Declarations

Competing interests
On behalf of all authors, the corresponding author states that there is no Competing interests.

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