Resources Policy 85 (2023) 103817

Contents lists available at ScienceDirect

Resources Policy

journal homepage: www.elsevier.com/locate/resourpol

Gold's hedging and safe haven properties for European stock and bond markets

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ARTICLE INFO

JEL classification:
C32
C52
C55

Keywords:
Gold market
Hedge
Safe haven
Stock market
Bond market

ABSTRACT

Most portfolio managers and risk managers strive to pick assets that lead to efficient financial risk mitigation; among them, gold stands out. This paper provides new insights into the role of gold as both a hedge and a safe haven towards European stock and sovereign bond markets. We base the analysis on evidence spanning the Euro's inception to the COVID-19 pandemic spread across Europe. To capture gold's hedge ability, we use the ADCC-GARCH and DCC-GARCH models, while for testing gold's safe haven property we use OLS regressions for different quantiles. Our results show that gold is a hedge for stocks, particularly after the Lehman Brothers collapse. Gold also shows strong safe haven properties for the most extreme negative returns (1% and 2.5% quantiles), and during specific events, such as the Lehman Brothers collapse, the Greek bailout and the Brexit Referendum. Still, for the COVID-19 pandemic outbreak, the results do not confirm this property. Conversely, for bonds, both hedge and safe haven effects are not strongly evident, with gold characterised, at best, as a weak hedge and safe haven. These findings have portfolio allocation implications for investors in European markets, namely fund and risk managers, by pointing out gold hedging and safe haven attributes.

1. Introduction

The intrinsic value of gold and its historical acceptance as commodity money, together with a relatively stable value over time, encourage investors to consider gold as an asset to own within their portfolios. Especially under uncertain economic conditions, whereupon a flight to quality phenomena in investments tends to occur and investors favour relatively stable investments instead of riskier assets, gold often stands out. In effect, for many investors, this asset is usually regarded as an investment able to confer to its holders protection against financial market losses. If the protection against losses is observed on average, with gold returns negatively correlated with the portfolio's returns, gold offers a hedging ability for that portfolio. In case the protection occurs in troubled periods only, gold represents a safe haven, wherein the negative correlations with gold are observed during a period of market turbulence. In both cases, considering the fundamentals of diversification and portfolio selection outlined in the seminal work of Markowitz (1952), gold should be a non-negligible component of a portfolio of assets.

Most literature on gold's hedge and safe haven properties (e.g., Baur and Lucey, 2010; Ciner et al., 2013; Baur and McDermott, 2016; Burdekin and Tao, 2021) focus on the US and other G7 markets. We analyse the contribution of gold to European markets since the introduction of the Euro and bring new insights on this matter by assessing medium and long-term relationships. Our analysis centres on gold's hedge and safe haven properties against stock and bond market declines. Specifically, we investigate (i) the relationships that exist, on average, among gold returns and the returns of assets to be hedged by gold, and (ii) whether the negative returns of a candidate asset are counterbalanced by positive returns in gold, allowing gold to confer protection against losses in periods of turmoil.

To the best of our knowledge, there is a shortage of literature in two

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https://doi.org/10.1016/j.resourpol.2023.103817
Received 3 October 2022; Received in revised form 12 May 2023; Accepted 13 June 2023

ways: (i) the assessment of gold's role against the bond market in terms of different bond maturities[1]; (ii) the evaluation of the hedging and safe haven properties of gold based on subsample analysis across most markets, when an extended timespan is considered.[2] We fill this gap by directly comparing gold hedging and safe haven abilities relative to different assets issued in the Eurozone using a data set spanning over 21 years, from the January 4, 1999 to the April 30, 2020. This fairly long period enables us to investigate the behaviour of gold in the presence of events of different natures. For stock markets, we consider two European stock indices (STOXX Europe 600 and EURO STOXX Banks), whereas for bonds we analyse government bonds with alternative maturities and issued by different countries to allow for a short/medium and long-term outlook. With the analysis of subsamples, we compare shorter to longer (full sample) timespans, which allows us to understand the hedge and safe haven dynamics and behaviour throughout time, thus contributing to the awareness of the implications for portfolio allocation and risk management.

To assess gold's hedging ability, we estimate the Asymmetric Dynamic Conditional Correlation Generalised Autoregressive Conditional Heteroskedasticity (ADCC-GARCH) (Cappiello et al., 2006) and the DCC-GARCH (Engle, 2002) models, to get daily time-varying conditional correlations estimates between Gold and each asset candidate to be hedged. Such approaches provide a long-term overview of the hedging potential of each pair of assets, as stated by Ciner et al. (2013). Then, the final step to confirm the hedging ability is to test the nullity of the mean of conditional correlations resulting from the multivariate GARCH models. We base the analysis of the safe haven dynamics on Baur and McDermott (2016), although we add the 2.5% quantile to their OLS regressions for different quantiles, reducing the gap between the 1% and 5% quantiles of returns distributions, to better describe the left tail. In all cases what is estimated is the conditional mean of the dependent variable for different quantiles. To find structural breaks in each time series, we generate subsamples based on Bai and Perron (2003).

Regarding the EU stock markets, we observe that gold's hedging ability exists, especially after the Lehman Brothers collapse, whereas at the most extreme negative market returns the gold's safe haven property is observed. Concerning the bond markets, we find that some hedging properties for gold exist after the global financial crisis of 2008 and up to the European sovereign debt crisis, and that a safe haven role is present during the European Sovereign Debt Crisis for the markets most affected. These results imply that gold's hedge and safe haven properties are asset specific, market specific and event specific. By extending the knowledge on gold's relation to other assets, our findings are relevant to policy-makers, investors, risk managers and fund managers, as they signal insightful and useful approaches to portfolio selection, by showing whether gold should feature in portfolios composed of European equity and sovereign bond assets, as well as under which circumstances holding gold serves as a hedge or a safe haven.

The remainder of the paper is composed of 4 sections. Section 2 summarizes previous research on the hedging and safe haven properties of gold. Section 3 explains the methodology. Section 4 presents the data and discusses the results of the study. Section 5 shows the conclusions.

2. Hedging and safe haven properties of gold

2.1. Hedging abilities

The hedge and safe haven properties of an asset are analysed by Baur and Lucey (2010), Baur and McDermott (2010), and subsequently by Ciner et al. (2013), Hood and Malik (2013), Gürgün and Ünalmış (2014), and Baur and McDermott (2016). According to Baur and McDermott (2010: 1889), "a strong (weak) hedge is defined as an asset that is negatively correlated (uncorrelated) with another asset or portfolio on average". Conversely, "a strong (weak) safe haven is defined as an asset that is negatively correlated (uncorrelated) with another asset or portfolio in certain periods only, e.g., in times of falling stock markets". In addition, an asset would be a diversifier if it is positively (but not perfectly correlated) with another asset or portfolio on average.

Baur and Lucey (2010) conclude that gold is a hedge for stocks in the United States and the United Kingdom, although they do not observe the same for Germany. Likewise, using regression with a dynamic process, Baur and McDermott (2010) suggest that gold is a strong hedge for the North American market, as well as for other developed markets, such as France, Germany, Italy, Switzerland, and the UK. Still, the same is not observed for Canada, Japan, and Australia. The lack of consistent results for the German market may be attributed to the different timespans analysed in both papers: 30 years in Baur and McDermott (2010), well above the 10 years used in Baur and Lucey (2010). Hood and Malik (2013), and Shahzad et al. (2020), also base their analysis on Baur and McDermott (2010) and reach similar conclusions. Shahzad et al. (2020) analyse the UK and Japanese markets and, different from Baur and McDermott (2010), find a weak hedge property. Regarding the hedging and safe haven properties of gold towards the sovereign bond markets, Agyei-Ampomah et al. (2014) show that gold acts as a strong hedge only for a handful of markets (Belgium, Greece, Italy, the Netherlands and Portugal).

Similarly, Gürgün and Ünalmış (2014) apply the Baur and McDermott (2010) methodology to emerging and developing markets focusing on both domestic and foreign investors' perspectives. They conclude that, for domestic investors, gold provides strong or weak hedging properties in many markets, but for foreign investors, this is observed for much fewer markets.

Ciner et al. (2013) apply a DCC-GARCH methodology (Engle, 2002), which produces time-varying correlations between assets, in the UK and the US markets, and confirm a negative relation between gold and equities for the US market. This highlights the hedging ability of gold regarding the stock market in the US.

Using monthly real returns on gold and stocks, Coudert and Raymond-Feingold (2011) conclude that gold is a hedge in most cases analysed (seven out of ten). Still, Beckmann et al. (2015) add that gold's hedging and safe haven abilities are market specific, as they depend on the economic setting. Baur and Lucey (2010) had already put forward that gold is a hedge only in bear markets. Focusing on the period between September 2008 and September 2013, Gürgün and Ünalmış (2014) find that gold is a strong hedge, particularly for domestic investors in a lower number of markets, and a weak hedge in a higher number of markets. Hood and Malik (2013) produce different volatility regimes in the volatility of the S&P, based on the Iterative Cumulative Sums of Squares (ICSS) algorithm (Inclán and Tiao, 1994), and conclude that gold is a hedge for the US stock market, though not having a negative correlation in periods of extreme volatility (high and low). In addition, they detect that gold is an inferior hedging tool than a volatility index as represented by VIX, which is strongly negatively correlated with the S&P500 in all the regimes.

Concerning other assets, the hedging abilities of gold seem to vary. Regarding the bond market, Ciner et al. (2013) suggest that there is little relation between gold and bonds in the US. This is consistent with Baur and Lucey (2010) who conclude that gold is not a hedge for the US and the UK bond markets, albeit it is a hedge for the German bond market.

2.2. Safe haven properties

Estimating the regression equation for different quantiles, Baur and Lucey (2010) conclude that gold is a safe haven in severe stock market

[1] Agyei-Ampomah et al. (2014) analyse different gold properties against distinct bond maturities but do not detail the different results.

[2] For instance, Akhtaruzzaman et al. (2021) compute subsamples analysis based on high-frequency data and a limited timespan, whereas Gürgün and Ünalmış (2014) perform both a full sample analysis and a subsample analysis also using a shorter timespan than ours.

conditions (2.5% and 1% quantiles) in the US and Germany. They also show that the safe haven effect is short-lived (15 trading days). This effect is confirmed by Baur and McDermott (2016), who point out that gold is a safe haven for the S&P500 and the MSCI World when those indices exhibit extreme negative returns, namely left-tailed returns below or equal to the 1% quantile.

Baur and McDermott (2010) find evidence of the safe haven effects for most developed countries and regional stock markets, which are particularly strong when extreme negative market shocks (1% quantile) occur with daily data. Yet, they do not observe the same regarding emerging markets which seems to suggest that investors in these markets react differently. Opposite to other authors, Ciner et al. (2013) detect that gold is not a safe haven for equities in the US market, arguing that this could be related to the dataset they used, in which gold has sharply increased its price. In effect, Baur and Glover (2016) show that the more investors hold gold, the more likely gold prices are negatively affected in troubled periods, due to an increasing co-movement, which contributes to weakening the safe haven properties. Accordingly, the increase in gold investments during the first decade of the 21st century may have reduced the duration of the safe haven effect of gold.

Regarding the role of gold in the COVID-19 pandemic crisis, some literature has been published. Akhtaruzzaman et al. (2021) state that gold serves as a safe haven asset in the first phase of the pandemic (until mid-March 2020), which is confirmed by Ji et al. (2020), and that lost its safe haven property from mid-March 2020 to April 2020. In the second phase, several fiscal monetary incentive measures were announced in some countries to mitigate the pandemic's adverse economic effects. Though Cui et al. (2023) suggest that the validity of gold as a safe haven was preserved during the COVID-19 pandemic, other studies show that gold revealed lower safe haven abilities during the pandemic compared to preceding periods. This conclusion is reached by Salisu et al. (2021a), which point to a lower effectiveness of gold as a safe haven during the pandemic compared to the pre-COVID-19 period. Likewise, Gomis-Porqueras et al. (2022) analyse multiple risk factors and show that gold is a weak safe haven for investors during the COVID-19 pandemic. The results in Chemkha et al. (2021) substantiate that gold stands as a weak safe haven for major world stock market indices and currencies during the pandemic. According to Burdekin and Tao (2021), gold provided strong protection for exposures in US stocks during the global financial crisis of 2008–2009, but it did not consistently display this property in 2020, which the authors attribute to the quick recovery of the market from the March 2020 lows.

Coudert and Raymond-Feingold (2011) base their work on an ARMA-GARCH (1,1)-X model and find that gold is a strong safe haven for the French and German stock markets and a weak safe haven for the US and the UK markets. In the same vein, Beckmann et al. (2015) find evidence of the safe haven ability of gold to be market specific. A strong safe haven exists in India, the UK and MSCI World, but no evidence is found in the MSCI EMU, Indonesia and Russia, and a weak safe haven exists in the other markets analysed. A conceivable explanation for gold's performance being market-specific is that, as underlined by Baur and McDermott (2010), foreign investors reveal different reactions to shocks in emerging markets compared to developed markets (in which gold is not found to be a safe haven, as highlighted by Gürgün and Ünalmış (2014)).

Gold's hedging and safe haven properties against the US stock market, when compared to those of potentially alternative safe haven assets, reveal a different performance. Hood and Malik (2013) show that gold is perceived as a strong safe haven at the 10% quantile, while at more extreme quantiles it is a weak safe haven, as the estimates for the latter coefficients are negative (but not statistically significant), thus outperforming similar characteristics of silver and platinum, which are not found as a safe haven at any quantile. Still, the VIX is a strong safe haven at all quantiles, even better and stronger than gold. Despite recognizing that gold has safe haven properties in some periods, Lucey and Li (2015) point out that, in some periods, other precious metals (e.g., silver and palladium) show better abilities of safe haven than gold.

Also, the safe haven properties of gold seem to be time specific. Baur and McDermott (2010) analyse the safe haven properties of gold during specific crises. They find that at the peak of the financial crisis of 2008 gold was a strong safe haven for the majority of developed markets, the same being observed for the markets of the US and Canada around the 1987 stock market crash. However, the same is not observed during the Asian crisis.

As shown by Baur (2012), gold as a safe haven also seems to depend on specific market conditions. The author states that a positive shock in gold's price increases more its volatility than what is caused by a negative shock. So, opposite to stock markets, a positive shock in the gold market could be related to adverse financial and macroeconomic news, whereas negative returns in gold could mean good economic news. This inverted asymmetric volatility pattern of gold strengthens its safe haven effect. Baur and Lucey (2010) also conclude that gold is a safe haven mainly in bear market periods, while Gürgün and Ünalmış (2014) find that gold is a strong safe haven for domestic investors during extreme negative returns in a wide range of developing and emerging markets. Even within the same bear market, the safe haven role of gold may change.

The flight to quality often observed in stressed market conditions, which are characterised by investors' fear and peaks of the volatility of stock markets, raises the question of causality between gold prices and market volatility according to Cohen and Qadan (2010). They analyse Granger causality between gold and VIX and find that, in their full sample, the VIX rate of change does not Granger cause gold returns, but gold returns Granger cause VIX. Nevertheless, when the sample is restricted to low volatility periods, they detect a bi-directional causality between gold and the VIX, while in high volatility periods, VIX does not Granger cause gold returns, but gold returns Granger cause VIX.

Gold's safe haven properties seem as well to be asset specific. Relative to gold's role as a safe haven for other assets, Ciner et al. (2013) observe that gold is a safe haven for the US bond market. This is consistent with Baur and Lucey (2010), who notice that gold is a safe haven for bonds at the 5% quantile for the US and Germany, but not for the UK. Agyei-Ampomah et al. (2014) report that gold demonstrates strong safe haven properties for Finland, Spain and the EMU bond markets, but they state that, after an extremely negative bond price decline, copper and palladium are the best performing industrial and precious metals, respectively.

Furthermore, according to Ciner et al. (2013), gold contains safe haven properties against declines in the US dollar and the British pound, which supports their conclusion of gold as a monetary asset. Still, Joy (2011) reports that gold's role as a safe haven against the US dollar is negligible. Reboredo (2013), and Salisu et al. (2021b) find that gold is an effective safe haven for oil in different periods of stressed oil markets.

3. Methodology

3.1. Assessing hedge and safe haven properties

To assess whether an asset is a hedge to another asset or portfolio, we use the Dynamic Conditional Correlation (DCC-GARCH) model of Engle (2002) and the Asymmetric Dynamic Conditional Correlation (ADCC-GARCH) model of Cappiello et al. (2006). Both approaches reflect time-varying correlations, which provide a long-term overview of the hedging potential of each pair of assets, as stated in Ciner et al. (2013), permitting us to conclude about the hedging ability of gold.

We use the Exponential Generalised Autoregressive Conditional Heteroscedastic (EGARCH) model of Nelson (1991) and the Glosten-Jagannathan-Runkle GARCH (GJR-GARCH) model (Golsten et al., 1993) as specifications in the GARCH (Bollerslev, 1986) component of the models, with Normal, Student's t and Generalised Error Distribution (GED) distributions. The choice of the better model is based on the minimization of both the Akaike and Bayesian Information

Table 1
Formulation of hypotheses.

For the stock market			For the bond market		
Hypothesis H1a:			**Hypothesis H1b:**		
H0:	$\overline{\rho}_t = 0$	Gold is a weak hedge	H0:	$\overline{\rho}_t = 0$	Gold is a weak hedge
H1:	$\overline{\rho}_t \neq 0$	Gold is a strong hedge or a diversifier	H1:	$\overline{\rho}_t \neq 0$	Gold is a strong hedge or a diversifier
Hypothesis H2a:			**Hypothesis H2b:**		
H0:	$\overline{\rho}_t = 0$	Gold is a weak hedge	H0:	$\overline{\rho}_t = 0$	Gold is a weak hedge
H1:	$\overline{\rho}_t < 0$	Gold is a strong hedge	H1:	$\overline{\rho}_t > 0$	Gold is a strong hedge
Hypothesis H3a:			**Hypothesis H3b:**		
H0:	$\overline{\rho}_t = 0$	Gold is a weak hedge	H0:	$\overline{\rho}_t = 0$	Gold is a weak hedge
H1:	$\overline{\rho}_t > 0$	Gold is a diversifier	H1:	$\overline{\rho}_t < 0$	Gold is a diversifier

Criteria (AIC and BIC). When the information criteria diverge, we choose the BIC.

To deal with the DCC-GARCH and ADCC-GARCH processes, we estimate primarily each univariate GARCH model per asset time series. Then, we estimate the ADCC-GARCH and the DCC-GARCH models and produce the daily conditional correlations. The model is defined as:

$$r_t | I_{t-1} \sim N(0, H_t) \tag{1a}$$

$$H_t = D_t R_t D_t \tag{2b}$$

$$\varepsilon_t = H_t^{1/2} z_t \tag{3c}$$

$$R = \left[diag(Q_t)^{-1/2}\right] Q_t \left[diag(Q_t)^{-1/2}\right] \tag{4d}$$

where $r_t = [r_{1,t}, r_{2,t}]$ is a 2×1 vector of returns including the assets ($r_{1,t}$) relative to which the hedging role of gold ($r_{2,t}$) is analysed, H_t denotes the conditional covariance matrix of r_t, D_t is the diagonal matrix containing the conditional standard deviations from the univariate EGARCH and GJR-GARCH models, and R_t represents the daily time-varying conditional correlation matrix wherein $diag(Q_t)^{-1/2}$ is a diagonal matrix with the square roots of the diagonal elements of Q_t. Q_t is a symmetric positive definite matrix with conditional correlations of standardised returns. ε_t represents the innovation process, where, analogously to the univariate case assumptions, z_t is a $2\times$ 1 independently and identically distributed vector process such that $E(z_t) = 0$ and $E(z_t z_t^{'}) = I$.

We derive H_t from the asymmetric univariate GARCH (1,1) models. The first is the EGARCH (Nelson, 1991):

$$\ln(h_{i,t}) = \omega_i + \sum_{i=1}^{q} \alpha_i \frac{|\varepsilon_{t-i}|}{h_{t-i}} + \sum_{i=1}^{q} \gamma_i \frac{\varepsilon_{t-i}}{h_{t-i}} + \sum_{i=1}^{p} \beta_i \ ln(h_{t-i}) \tag{2}$$

where $h_{i,t}$ is the conditional variance of the return time series, ω_i is a constant term, α_i is the ARCH effect, γ_i is the asymmetric effect, and β_i reflects the persistence effect. For the second asymmetric univariate GARCH model, we use the GJR-GARCH (Golsten et al., 1993):

$$h_{i,t} = \omega_i + \sum_{i=1}^{q} (\alpha_i + \gamma_i I\varepsilon_{t-i<0}) \varepsilon_{t-i}^2 + \sum_{i=1}^{p} \beta_i h_{t-i} \tag{3}$$

where $I\varepsilon_{t-i<0} = \begin{cases} 1 & if\ \varepsilon_{t-i} < 0 \\ 0 & if\ \varepsilon_{t-i} > 0 \end{cases}$ and the other terms maintain their meaning.

The dynamics of Q in the ADCC-GARCH model are defined as:

$$Q_t = (1 - \theta_1 - \theta_2) Q - \varphi N + \theta_1 \left(z_{t-1} z_{t-1}^{'}\right) + \theta_2 Q_{t-1} + \varphi \left(\eta_{t-1} \eta_{t-1}^{'}\right) \tag{4}$$

where θ_1, θ_2 and φ are parameter matrices, $\eta_t = Iz_{t<0} \circ z_t$ is an indicator function that takes the value of one when the argument is true and zero otherwise, $\circ$ indicates the Hadamard product and $Q_j = E[z_t, z_t^{'}]$ and $N = E[\eta_t, \eta_t^{'}]$ are the unconditional correlation matrices of z_t and η_t, respectively. φ is the parameter of correlation asymmetry. When $\varphi = 0$, ADCC-GARCH is reduced to a standard DCC-GARCH model with no asymmetric effect in the conditional variance.

Given the definition of a strong (weak) hedge proposed by Baur and McDermott (2010: 1889), we accordingly define a set of hypotheses, as presented in Table 1, to assess the extent to which gold is a hedge for an asset. To test these hypotheses, we follow the following process. If the null hypothesis of H1a (H1b) is rejected, we test H2a (H2b). In the latter, gold is considered a strong hedge for the stock (bond) markets, if on average the predicted values for conditional correlations $\overline{\rho}_t$ are negative (positive, in the case of yields) and statistically significant. If the null hypotheses of H1a (H1b) and H2a (H2b) are both rejected, gold is considered a strong hedge for the asset under analysis, but in case the null of H2a (H2b) is not rejected, gold could be a diversifier for that asset. The confirmation, in this case, requires testing H3a (H3b).

Regarding the safe haven properties, firstly we follow the Baur and McDermott (2016) framework. We model gold returns by introducing interaction effects resulting from the 1%, 2.5%, 5%, and 10% quantiles, corresponding to the most negatively distributed returns of the asset against which gold may be a safe haven. We introduce the 2.5% quantile (not explored in Baur and McDermott (2016)), as an extreme quantile in-between the 1% and 5% quantiles. To capture these extreme returns, we use dummy variables (1 $\equiv$ the return belongs to the quantile; 0 $\equiv$ otherwise).

Hence, we estimate the following regression:

$$r_{G,t} = \alpha + \beta_2 r_{A,t} + \beta_3 r_{A,t} Dq_{1\%} + \beta_4 r_{A,t} Dq_{2.5\%}\ \beta_5 r_{A,t} Dq_{5\%} + \beta_6 r_{A,t} Dq_{10\%} + \varepsilon_t \tag{5}$$

where r_G is gold return, r_A is the return of asset A, $r_A * Dq_{1\%}$, $r_A * Dq_{2.5\%}$, $r_A * Dq_{5\%}$ and $r_A * Dq_{10\%}$ are interaction terms, where $Dq_{1\%}$, $Dq_{2.5\%}$, $Dq_{5\%}$ and $Dq_{10\%}$ are dummy variables (dummy $\equiv$ 1 if the return of asset A is less than the respective threshold; 0 $\equiv$ otherwise) capturing the 1%, 2.5%, 5%, and 10% most negatively distributed returns of asset A, respectively. t denotes time. The existence of negative (positive in the case of bonds) and statistically significant estimates for the coefficients related to the quantiles indicate that gold has a safe haven role for the asset analysed.

In addition to the OLS regressions for different quantiles, we estimate regressions using only observations from periods based on major events of different natures (financial, economic, political, sanitary, and terrorist) that generated extreme losses or extreme yield increases, respectively in the stock and bond markets. This approach is based on Baur and McDermott (2010). We extend their analysis by including some more recent events (not only financial events), such as the Madrid bombings, the European sovereign debt crisis, the Brexit referendum, and the COVID-19 pandemic outbreak. The beginning of each period is defined as the day when the event broke out, while the end of the period is mostly based on the day when market volatility returned to its levels before the shock. We estimate conditional volatility by the EGARCH (Eq. (2)) and GJR-GARCH (Eq. (3)) models with three different distributions of errors: Normal, Student's t and GED, which correspond to six GARCH models. We rely on the AIC and BIC values to select the best GARCH specification.

To eliminate variables with insignificant estimates from our model, we also run a stepwise algorithm (Venables and Ripley, 2002) in the regression. Thus, instead of OLS regressions that simply use the observations in which the changes fall within a given quantile, the alternative of a regression on a specific period contains all observations referring to that period only. In this regard, we consider the following 14 stress events of different nature observed in specific periods since the Euro's start up to the COVID-19 pandemic outbreak: the September 11, 2001; the Madrid train bombings; Lehman Brothers collapse; the first bailout of Greece; the bailout of Ireland; the bailout of Portugal; the request for a second bailout of Greece; the political turmoil within Europe from September 2011 to October 2012; the approval for a second bailout of Greece; the election in Greece in 2012; the bailout of banks in Spain; the third bailout of Greece; The Brexit referendum; the COVID-19 pandemic outbreak. For each of these events, we define a dummy, leading to the following model:

$$r_{G,t} = \alpha + \beta_2 r_{A,t} + \beta_3 r_{A,t} DSept11 + \ldots + \beta_{16} r_{A,t} DCOVID19 + \varepsilon_t \tag{6}$$

r_G is gold return, r_A is the return of asset A, $D(\bullet)$ are dummy variables which take the value 1 during the stress event and 0 otherwise, $r_A DSept11$ is the return of asset A during the September 11 terrorist attacks (the first period). This extends to $r_A DCOVID19$, which denotes the return of asset A during the COVID-19 pandemic outbreak (the last period).

The conditional variance of the gold returns for each quantile and specific period regressions are modelled as EGARCH and GJR-GARCH processes with Normal, Student's t and GED distributions for each specification. The selection of the best GARCH model depends again on the AIC and the BIC.

3.2. Subsample analysis

We explore the hedge and safe haven effects in the full sample, as well as in the subsamples. This allows us to identify properties in the full sample, i.e., by spanning all the period, which could differ from those in some specific shorter periods. We adopt the Bai and Perron (2003) algorithm to produce structural breaks in each of the time series in levels, where each of the breaks defines the end of a subsample and the beginning of the next. This algorithm suggests various breaks; we select the one that minimises the BIC.

After defining the subsamples, for the analysis of hedge and safe haven properties, we perform a similar analysis to the one applied to the full sample. However, we do not use the regression for specific periods to avoid any potential conflict between the breaks in the pre-defined periods and those in the subsamples.

4. Data and empirical analysis

For the empirical analysis, we retrieve data from Bloomberg and Datastream. Our sample ranges from the January 4, 1999, after the Euro was introduced, until the April 30, 2020, corresponding to 5434 daily closing returns. This dataset includes a commodity (gold measured in euros), nine stock indices, fourteen government bonds, and the Goldman Sachs Financial Conditions Index for the Euro Area (GSFCIEA), which is an indicator of financial conditions, used as a proxy to gauge the risk across European markets. We select this indicator due to its completeness to assess risk, as it is composed of interest rates, corporate spreads, sovereign spreads, equity prices, commodity prices and trade weighted exchange rates variables, which are the variables under study. We note that indicators of financial conditions disclosed by Goldman Sachs have been used in other studies (e.g., Ciccarelli et al., 2013).

On an aggregate level, the stock indices encompass the STOXX Europe 600, reflecting the performance of 600 European large, mid, and small capitalization companies across 17 European countries, and the EURO STOXX Banks, reflecting the evolution of banks in the EMU. We also consider several national stock indices, namely the German DAX, the French CAC, the Italian FTSE MIB, the Spanish IBEX, the Portuguese PSI, the Irish ISEQ, and the Greek ASE. Regarding the government bond market, we analyse the 2- and 10-year yield rates for France, Germany, Greece, Ireland, Italy, Portugal, and Spain.

Returns in stocks and gold are measured with the relative change in prices (arithmetic returns), as follows:

$$SGr_t = \frac{P_t}{P_{t-1}} - 1 \tag{7}$$

where SGr_t denotes the stock or gold return on day t, P_t is the closing price on day t and P_{t-1} is the closing price on day $t-1$. Regarding bonds, we compute the absolute change in yields to prevent extremely high absolute values generated from relative yield changes, which would occur with very small absolute changes in the yields in the presence of previously very low yields. So, we use:

$$Bc_t = y_t - y_{t-1} \tag{8}$$

Bc_t denotes the absolute change in the yield on day t, y_t is the yield on day t, and y_{t-1} is the yield on day $t-1$.

Table 2 shows descriptive statistics which underline that gold's most extreme returns (both, positive and negative) are, in absolute value, lower than those of stock markets. Compared to a Normal distribution, both stocks and gold exhibit excess kurtosis, revealing a leptokurtic distribution with fatter tails than the Normal distribution. Opposite to stocks, which generally depict negative skewness, gold shows a higher and positive skewness, signalling frequent small losses and uncommonly large gains. This asymmetric behaviour between gold and stocks is an a priori indication of gold's hedge property relative to stocks.

Bond markets display negative mean changes, indicating reductions in yields (in line with the expansionary monetary policy measures taken by the ECB). Higher standard deviations of the changes exist in the countries more affected by the European sovereign debt crisis between 2010 and 2012, particularly in short-term maturities. The kurtosis reveals some yields with a leptokurtic and (in many cases) extreme leptokurtic distribution, indicating fat tails of the empirical distribution. In turn, higher absolute skewness coefficients are detected for countries more affected by the European sovereign debt crisis, although there is no noticeable pattern for the sign of skewness.

4.1. Sample analysis

4.1.1. Hedging properties

Gold's hedging ability to equity and bond markets is computed based on daily time-varying correlations obtained by the ADCC-GARCH and the DCC-GARCH. From a preliminary analysis, we choose the DCC-EGARCH with Normal distribution as it provides the lowest values for the BIC for most assets. The DCC-GARCH with GED distribution is chosen for the 10-year Irish bonds and 2-year Greek bonds, while the ADCC-GJR-GARCH and the DCC-GJR-GARCH, both with Normal distribution, are chosen for the 10-year Portuguese bonds, for the ASE, and the 2-year Irish bonds, respectively.

As shown in Table 3, gold is on average a strong hedge for almost all the stock markets considered, as the average of the conditional correlations is negative and statistically significant at all levels (we reject the null of H2a). This is consistent with previous research on gold's hedging abilities for other markets (e.g., Baur and McDermott, 2010; Ciner et al., 2013; Shahzad et al., 2020). Still, our results show that, for the STOXX Europe 600, gold is statistically considered on average a diversifier. From the coefficient estimates, we also detect that gold's hedging ability is stronger for EURO STOXX Banks ($\overline{\rho} = -0.0644$), FTSE MIB ($\overline{\rho} = -0.0367$) and PSI 20 ($\overline{\rho} = -0.0304$) when compared to the other stock markets, with DAX ($\overline{\rho} = -0.0076$) revealing the lowest coefficient in absolute value.

Regarding the bond market, we find that German and French bonds regardless of their maturity are not hedged by gold, as the coefficient is

Table 2
Descriptive statistics of the daily returns of the stock and bond markets analysed. The table reports the mean, standard deviation, maximum, minimum, kurtosis, and skewness.

Assets	Mean	Standard deviation	Maximum	Minimum	Kurtosis	Skewness
ASE	−0.011%	1.880%	14.375%	−16.233%	6.451	−0.205
CAC 40	0.012%	1.434%	11.176%	−12.277%	6.266	−0.047
DAX	0.024%	1.479%	11.402%	−12.239%	5.874	0.001
EURO STOXX Banks	−0.012%	1.916%	19.439%	−18.024%	8.920	0.036
FTSE MIB	−0.002%	1.523%	11.488%	−16.924%	7.953	−0.349
IBEX 35	0.003%	1.460%	14.435%	−14.059%	7.708	−0.117
ISEQ	0.011%	1.356%	10.223%	−13.032%	8.115	−0.526
PSI 20	−0.011%	1.184%	10.734%	−9.859%	7.264	−0.247
STOXX Europe 600	0.011%	1.219%	9.867%	−11.478%	7.021	−0.222
French Bonds 2 years	−0.0007	0.0405	0.4280	−0.2680	9.636	0.676
French Bonds 10 years	−0.0007	0.0425	0.2670	−0.2900	2.442	0.257
German Bonds 2 years	−0.0007	0.0393	0.3310	−0.3030	6.713	0.248
German Bonds 10 years	−0.0008	0.0426	0.2290	−0.2570	1.877	0.211
Greek Bonds 2 years	−0.0020	0.5679	10.9860	−8.4270	146.762	2.596
Greek Bonds 10 years	−0.0009	0.3885	3.9470	−19.9140	1292.874	−24.955
Italian Bonds 2 years	−0.0005	0.0840	1.8630	−1.0690	75.713	0.784
Italian Bonds 10 years	−0.0004	0.0623	0.5840	−0.7980	18.794	−0.394
Irish Bonds 2 years	−0.0007	0.1643	2.4260	−4.0100	181.422	−4.180
Irish Bonds 10 years	−0.0007	0.0754	0.9230	−1.1730	41.564	−0.120
Portuguese Bonds 2 years	−0.0006	0.1924	3.8310	−3.0960	130.172	4.127
Portuguese Bonds 10 years	−0.0006	0.1055	2.1730	−1.6340	109.220	2.304
Spanish Bonds 2 years	−0.0006	0.0723	0.7720	−1.1440	45.277	−1.683
Spanish Bonds 10 years	−0.0006	0.0601	0.4330	−0.8840	18.575	−0.961
Gold (in EUR)	0.039%	1.036%	9.291%	−8.571%	7.427	0.266

Table 3
Sample hedge ability: Test of significance of the daily time-varying correlation coefficients between gold and each asset.

		t-tests		
Stocks	$\overline{\rho}$	Hypothesis H1a (H1: $\overline{\rho} \neq 0$) p-value	Hypothesis H2a (H1: $\overline{\rho} < 0$) p-value	Hypothesis H3a (H1: $\overline{\rho} > 0$) p-value
ASE	−0.0206	0.0000	0.0000	1.0000
CAC 40	−0.0100	0.0000	0.0000	1.0000
DAX	−0.0076	0.0000	0.0000	1.0000
EURO STOXX Banks	−0.0644	0.0000	0.0000	1.0000
FTSE MIB	−0.0367	0.0000	0.0000	1.0000
IBEX 35	−0.0289	0.0000	0.0000	1.0000
ISEQ	−0.0128	0.0000	0.0000	1.0000
PSI 20	−0.0304	0.0000	0.0000	1.0000
STOXX Europe 600	0.0312	0.0000	1.0000	0.0000
Bonds	$\overline{\rho}$	Hypothesis H1b (H1: $\overline{\rho} \neq 0$) p-value	Hypothesis H2b (H1: $\overline{\rho} > 0$) p-value	Hypothesis H3b (H1: $\overline{\rho} < 0$) p-value
French Bonds 2y	−0.1129	0.0000	1.0000	0.0000
French Bonds 10y	−0.1056	0.0000	1.0000	0.0000
German Bonds 2y	−0.1349	0.0000	1.0000	0.0000
German Bonds 10y	−0.1394	0.0000	1.0000	0.0000
Greek Bonds 2y	−0.0306	0.0000	1.0000	0.0000
Greek Bonds 10y	0.0209	0.0000	0.0000	1.0000
Irish Bonds 2y	−0.0127	0.0000	1.0000	0.0000
Irish Bonds 10y	−0.0397	0.0000	1.0000	0.0000
Italian Bonds 2y	0.0054	0.0000	0.0000	1.0000
Italian Bonds 10y	−0.0005	0.6033	0.6983	0.3017
Portuguese Bonds 2y	0.0066	0.0000	0.0000	1.0000
Portuguese Bonds 10y	0.0060	0.0000	0.0000	1.0000
Spanish Bonds 2y	−0.0018	0.0413	0.9793	0.0207
Spanish Bonds 10y	−0.0130	0.0000	1.0000	0.0000

negative and statistically significant at all default significance levels. This means for these four assets gold is a diversifier (we reject the null of H3b). The same conclusion is obtained for the 10-year Spanish bonds, Irish (both maturities) and 2-year Greek bonds. For the 2-year Italian bonds, Portuguese bonds (both maturities), and the 10-year Greek bonds, we find gold to be a strong hedge, as it provides a positive and statistically significant correlation coefficient. For the 10-year Italian bonds, the correlation coefficient is not statistically significant under any of the hypotheses, suggesting that gold is a weak hedge. Lastly, for the 2-year Spanish bonds, we do not reject the null of H1b at the 1% and 2.5% significance levels. By testing the other hypotheses at 2.5% and 5% significance levels, we reject the null and conclude that gold is a diversifier. We detect that, for the Italian and Spanish bond markets, different bond maturities lead to different gold hedging performances, but this does not apply to other markets. Thus, unlike Ciner et al. (2013), who found insufficient relations between gold and bonds in the US, we find a significant relation in some European government bonds.

4.1.2. Safe haven

We use the OLS regressions based on quantiles and the specific period regression to assess the potential safe haven properties of gold. Accordingly, gold is a strong (weak) safe haven for an asset, if the coefficients of dummy variables related to the quantiles or the specific periods exhibit statistically significant (insignificant) negative coefficients in the case of the stock market (positive coefficients for the bond market). Otherwise, gold co-moves in these periods with the stock and bond markets, respectively. To estimate Eq. (5), we first compute the quantiles for each asset and after build the respective dummy variables. The subsequent estimated results are in Table 4.

The results confirm that gold is a strong safe haven for the most extreme negative returns, especially for the ISEQ and the STOXX Europe 600 equity markets where we find a high coefficient estimate in absolute value with strong statistical significance. For the ASE and the FTSE MIB, the coefficients are lower in absolute value and significant only at 10%.

At the 2.5% quantile, gold can be considered a strong safe haven for the CAC 40 (at the 5% significance level), as well as the PSI20 (10% significance level), but it is a weak safe haven for the EURO STOXX Banks, the DAX, and the IBEX 35. Concerning the 5% quantile, gold is only a strong safe haven for the EURO STOXX Banks, and a weak safe

Table 4
OLS regressions based on quantile results. The results (full sample) are for the mean equation (Panel A) and the variance of the residuals (Panel B).

	Hedge	Panel A - Safe haven				Panel B - GARCH				
		Quantile 1%	Quantile 2.5%	Quantile 5%	Quantile 10%	Omega	Alpha	Beta	Gamma	Shape
Stocks										
ASE	−0.0112	−0.0564 ˆ	−0.0371	0.0444	0.0068	−0.1904 ****	0.1243 ****	0.9894 ****	0.0281 ****	4.9697 ****
CAC 40	−0.0124	0.0408	−0.0967 *	0.1041 *	−0.0533	−0.1916 ****	0.1254 ****	0.9893 ****	0.0271 ****	4.9599 ****
DAX	−0.0084	−0.0090	−0.0291	0.0270	−0.0123	−0.1908 ****	0.1247 ****	0.9894 ****	0.0285 ****	4.9735 ****
EURO STOXX Banks	−0.0436 ****	−0.0097	−0.0264	−0.0637 ˆ	0.0665 *	−0.1887 ****	0.1262 ****	0.9897 ****	0.0260 ***	5.0079 ****
FTSE MIB	−0.0225 ˆ	−0.0646 ˆ	0.0229	−0.0493	0.0222	−0.1914 ****	0.1266 ****	0.9894 ****	0.0267 ****	4.9494 ****
IBEX 35	−0.0251 ˆ	0.0234	−0.0330	−0.0147	0.0083	−0.1887 ****	0.1245 ****	0.9896 ****	0.0277 ****	4.9908 ****
ISEQ	−0.0102	−0.1601 ****	0.0821 ˆ	0.0025	−0.0316	−0.1905 ****	0.1267 ****	0.9896 ****	0.0256 ***	4.9629 ****
PSI 20	−0.0208	0.0803	−0.0952 ˆ	−0.0342	0.0423	−0.1905 ****	0.1247 ****	0.9894 ****	0.0278 ****	4.9967 ****
STOXX Europe 600	0.0099	−0.1309 ***	0.1112 *	−0.0590	0.0226	0.0000 ****	0.0751 ****	0.9334 ****	−0.0324 ***	4.9292 ****
Bonds										
French 2 years	−0.0260 ****	0.0119	−0.0087	−0.0167	0.0224	−0.2006 ****	0.1301 ****	0.9888 ****	0.0270 ****	4.9835 ****
French 10 years	−0.0254 ****	−0.0459 ***	0.0074	−0.0013	0.0175	−0.1947 ****	0.1275 ****	0.9892 ****	0.0296 ****	5.0314 ****
German 2 years	−0.0270 ****	−0.0024	−0.0026	0.0084	−0.0010	−0.2007 ****	0.1302 ****	0.9888 ****	0.0266 ****	4.9843 ****
German 10 years	−0.0316 ****	−0.0016	0.0171	−0.0479 ***	0.0286 **	−0.1961 ****	0.1295 ****	0.9892 ****	0.0251 ***	4.9877 ****
Greek 2 years	−0.0004	0.0024	0.0040	−0.0140 ***	0.0068 ˆ	−0.2329 ***	0.1312 ****	0.9862 ****	0.0287 ˆ	5.8768 ****
Greek 10 years	0.0006	−0.0034 ˆ	0.0028	−0.0005	0.0008	−0.1916 ****	0.1249 ****	0.9893 ****	0.0282 ****	4.9633 ****
Irish 2 years	0.0001	−0.0044	0.0278 ***	−0.0171	−0.0024	−0.1599 ****	0.1194 ****	0.9923 ****	0.0259 ***	5.1801 ****
Irish 10 years	−0.0005	0.0147 ˆ	−0.0002	0.0021	−0.0081	−0.1959 ****	0.1263 ****	0.9889 ****	0.0290 ****	4.9619 ****
Italian 2 years	0.0021	0.0008	0.0011	−0.0049	0.0066	−0.1893 ****	0.1238 ****	0.9895 ****	0.0285 ****	4.9553 ****
Italian 10 years	−0.0021	−0.0011	−0.0058	0.0085	0.0032	−0.1901 ****	0.1242 ****	0.9894 ****	0.0290 ****	4.9496 ****
Portuguese 2 years	0.0003	−0.0008	0.0022	−0.0054	0.0066	−0.1902 ****	0.1251 ****	0.9895 ****	0.0277 ****	4.9780 ****
Portuguese 10 years	−0.0009	0.0115 ˆ	−0.0022	−0.0056	0.0039	−0.1893 ****	0.1236 ****	0.9894 ****	0.0299 ****	4.9567 ****
Spanish 2 years	0.0023	0.0180 *	−0.0189 ˆ	0.0093	−0.0005	−0.1858 ****	0.1220 ****	0.9897 ****	0.0290 ****	4.9723 ****
Spanish 10 years	−0.0027	−0.0075	0.0061	−0.0161	0.0215 *	−0.1884 ****	0.1241 ****	0.9896 ****	0.0284 ****	4.9464 ****

Note: Statistical significance (presented below the estimates) at: 10% ˆ; 5% *; 2.5% **; 1% ***; 0.1% ****.

haven for the STOXX Europe 600, the FTSE MIB, the IBEX 35 and the PSI 20. Overall, despite not being a safe haven for all markets or at all quantiles, gold can be considered a safe haven for stock markets.

The bond market shows much less significant coefficients, with some showing a different sign than what is economically expected for a safe haven asset. This is, for example, the case of the 10-year French bonds at the 1% quantile, for which the corresponding coefficient is negative and statistically significant at the 1% level. Thus, we cannot characterise gold as a strong safe haven for the bond markets analysed. At best, it would be a weak safe haven for some markets. For example, for the conventional significance levels, the 2-year German, French, and Italian bonds do not display statistically significant coefficients at any quantile.

An OLS regression based on quantiles only captures the relationship between assets when the change in an asset price exceeds a certain quantile. In turn, the regression on a specific period uses all data complying with a relevant generator event (financial, economic, political, terrorist, or sanitary). The specific periods are typically short time intervals wherein markets have a first extreme negative return, followed by a succession of negative and some positive returns. We follow Baur and McDermott (2010) to apply the regression to specific periods. The respective estimates are in Table 5.

Regarding the stock markets, the stepwise algorithm[3] helped us to select the events in which there is no significant coefficient during the terrorist attacks in Madrid (11th of March 2004), the Spanish banks' bailout and the third bailout of Greece. In some events the spectrum of assets selected is low. This is the case of the Portuguese bailout, where gold revealed to be a significant safe haven for the IBEX 35 at the 5% significance level. It is also the case of the approval of the second bailout to Greece, a period in which the Greek stock market is sheltered by gold

[3] To test the significance of some events in the relation between gold and assets returns, we included dummy variables included in the regression model. The stepwise algorithm (Venables and Ripley, 2002) retains or excludes the event from the regression model if the estimate for the coefficient of the dummy variable is statistically significant or not. Thus, OLS estimation is performed but only the dummies corresponding to events with statistically significant effect remain in the model; otherwise, they are excluded.

Table 5
Regression estimates on specific periods. The first part of the table shows the candidate events for a safe haven analysis and the second part is the variance of the residuals.

Safe haven	Hedge	September 11, 2001	Madrid train bombings	Lehman Brothers collapse	Greece: 1st Bailout	Ireland: Bailout	Portugal: Bailout	Greece: 2nd Bailout (request)	Political Turbulence Sept 2011 to Oct 2012
Stocks									
(1) ASE	–	–	–	−0.0706 ˆ	−0.1514 ***	–	–	−0.3077 ****	–
(2) CAC 40	–	−0.1383 *	–	−0.1096 ***	−0.1153 ˆ	−0.4242 *	–	−0.5358 ****	–
(3) DAX	–	−0.1096 ˆ	–	−0.1104 ***	–	–	–	−0.5194 ****	–
(4) EURO STOXX Banks	−0.0355 ****	–	–	−0.0616 *	−0.0793 *	−0.1919 ˆ	–	−0.3386 ****	–
(5) FTSE MIB	−0.0153	−0.0930 ˆ	–	−0.1171 ***	−0.1504 **	−0.3090 ˆ	–	−0.4306 ****	–
(6) IBEX 35	–	−0.1344 *	–	−0.0734 ˆ	−0.1449 ***	−0.2282 ˆ	−0.3798 *	−0.5334 ****	–
(7) ISEQ	–	–	–	−0.1784 ****	–	−0.4321 ˆ	–	−0.5220 ****	0.2016
(8) PSI 20	–	–	–	−0.1330 ***	−0.1442 **	−0.3532 ˆ	–	−0.5608 ****	–
(9) STOXX Europe 600	0.0307 **	−0.1643 **	–	−0.1613 ****	–	–	–	−0.6429 ****	–
Bonds									
(10) French 2 years	−0.0164 ****	−0.0667 **	–	−0.0223	−0.1130 ***	–	0.0490 ˆ	−0.0875 ***	−0.1054 ****
(11) French 10 years	−0.0188 ****	–	–	−0.0710 ***	–	−0.0908 *	−0.0820 ˆ	−0.0938 ***	−0.0403
(12) German 2 years	−0.0221 ****	0.0587 ˆ	–	–	−0.1252 ***	−0.1182 **	–	−0.1119 ****	−0.0664 ˆ
(13) German 10 years	−0.0255 ****	0.0943 ˆ	–	−0.0406 ˆ	−0.0656 *	−0.1004 **	−0.0795 *	−0.1278 ****	–
(14) Greek 2 years	–	–	–	–	–	–	–	–	–
(15) Greek 10 years	0.0006 ˆ	–	–	−0.0513 ***	–	–	0.0127 *	–	–
(16) Irish 2 years	0.0035 ***	–	–	–	–	–	–	−0.0049	–
(17) Irish 10 years	–	–	–	−0.0928 ****	0.0125	0.0189	0.0148 *	−0.0126 ˆ	–
(18) Italian 2 years	0.0049 ***	–	–	−0.0325 ˆ	0.0248 **	0.0314 ˆ	–	−0.0188 *	−0.0454 ˆ
(19) Italian 10 years	–	–	–	−0.0601 **	0.0586 **	0.0465	–	−0.0222 *	–
(20) Portuguese 2 years	0.0015 *	−0.0909 **	–	–	–	–	0.0126 *	–	0.0086
(21) Portuguese 10 years	0.0021	–	–	−0.0734 ***	0.0099 ˆ	–	–	−0.0221	–
(22) Spanish 2 years	0.0041 ˆ	–	–	−0.0406 ***	0.0238 ***	–	0.0551 **	−0.0187 *	–
(23) Spanish 10 years	–	–	–	−0.0704 ***	0.0417 **	0.0406 ˆ	0.0649 *	−0.0238 **	–

	Safe haven						GARCH				
	Greece: 2nd Bailout (approval)	Greece: Elections 2012	Spain: Banks Bailout	Greece: 3rd Bailout	Brexit Referendum	COVID-19 pandemic outbreak	Omega	Alpha	Beta	Gamma	Shape
(1)	−0.1596 ˆ	–	–	–	−0.5047 ****	0.1295 ****	−0.1754 ****	0.1178 ****	0.9905 ****	0.0311 ****	5.0968 ****
(2)	–	−0.2541 ˆ	–	–	−0.6795 ****	0.2176 ****	−0.1777 ****	0.1185 ****	0.9903 ****	0.0294 ****	5.0978 ****
(3)	–	−0.3993 ***	–	–	−0.7397 ****	0.2631 ****	−0.1775 ****	0.1184 ****	0.9903 ****	0.0292 ****	5.1055 ****
(4)	–	–	–	–	−0.3085 ****	0.1858 ****	−0.1776 ****	0.1199 ****	0.9904 ****	0.0284 ****	5.0890 ****
(5)	–	–	–	–	−0.4592 ****	0.1859 ****	−0.1788 ****	0.1196 ****	0.9903 ****	0.0284 ****	5.0746 ****
(6)	–	–	–	–	−0.5177 ****	0.1923 ****	−0.1782 ****	0.1186 ****	0.9903 ****	0.0300 ****	5.0707 ****
(7)	–	−0.3251 *	–	–	−0.4087 ****	0.1800 ****	−0.1804 ****	0.1198 ****	0.9901 ****	0.0299 ****	5.0144 ****
(8)	–	–	–	–	−0.7660 ****	0.2806 ****	−0.1792 ****	0.1188 ****	0.9902 ****	0.0307 ****	5.1288 ****
(9)	–	−0.4090 **	–	–	−0.7019 ****	0.2056 ****	−0.1783 ****	0.1185 ****	0.9903 ****	0.0311 ****	5.0985 ****

(*continued on next page*)

Table 5 (*continued*)

	Safe haven						GARCH				
	Greece: 2nd Bailout (approval)	Greece: Elections 2012	Spain: Banks Bailout	Greece: 3rd Bailout	Brexit Referendum	COVID-19 pandemic outbreak	Omega	Alpha	Beta	Gamma	Shape
(10)	–	−0.0757 ^	–	–	−0.6599 ****	–	−0.2009 ****	0.1305 ****	0.9888 ****	0.0277 ****	5.1325 ****
(11)	–	–	–	–	−0.2419 ****	–	−0.1988 ****	0.1307 ****	0.9890 ****	0.0282 ****	5.0247 ****
(12)	–	–	–	–	−0.7393 ****	0.1058 ***	−0.1942 ****	0.1282 ****	0.9893 ****	0.0252 ***	5.1201 ****
(13)	–	–	–	–	−0.3153 ****	–	−0.1976 ****	0.1322 ****	0.9893 ****	0.0237 ***	5.0675 ****
(14)	–	–	–	–	–	0.6543 ****	−0.2329 ***	0.1312 ****	0.9862 ****	0.0287 ^	5.8768 ****
(15)	–	−0.0026	–	–	0.0461 ****	–	−0.1916 ****	0.1249 ****	0.9893 ****	0.0282 ****	4.9633 ****
(16)	−0.0370 **	−0.0156 ^	–	–	0.2226 *	–	−0.1599 ****	0.1194 ****	0.9923 ****	0.0259 ***	5.1801 ****
(17)	–	–	–	–	–	−0.0516 *	−0.1959 ****	0.1263 ****	0.9889 ****	0.0290 ****	4.9619 ****
(18)	–	–	–	–	0.3699 ****	−0.0260 ***	−0.1901 ****	0.1245 ****	0.9894 ****	0.0294 ****	5.0243 ****
(19)	–	–	–	–	0.1878 ****	−0.0293 ****	−0.1921 ****	0.1252 ****	0.9893 ****	0.0309 ****	5.0752 ****
(20)	–	–	–	–	0.2002 ****	−0.0586 **	−0.1917 ****	0.1244 ****	0.9893 ****	0.0309 ****	5.0376 ****
(21)	−0.0103	–	–	–	0.1650 ****	−0.0314 **	−0.1907 ****	0.1247 ****	0.9894 ****	0.0310 ****	5.1003 ****
(22)	–	–	–	–	0.2103 ***	−0.0573 *	−0.1909 ****	0.1246 ****	0.9894 ****	0.0291 ****	4.9861 ****
(23)	–	–	–	–	0.1019 ***	−0.0261 ^	−0.1937 ****	0.1261 ****	0.9892 ****	0.0297 ****	5.0210 ****

Note 1: Statistical significance (presented below the estimates) at: 10% ^; 5% *; 2.5% **; 1% ***; 0.1% ****.
Note 2: "–" means stepwise regression excluded variable from the final period regression.

at the 10% significance level.

A wider number of assets are selected by the stepwise algorithm in the case of September 11, 2001, the first bailout to Greece in 2010, the Irish bailout, also in 2010, and the Greek elections in 2012. In these periods, we detect negative coefficients, though many of them are statistically significant at the 10% level. Four periods are also selected by the algorithm for all stock markets, namely: (i) the Lehman Brothers collapse; (ii) the request for a second bailout by Greece; (iii) the Brexit referendum; (iv) the COVID-19 pandemic outbreak. In the first three periods, Gold shows a strong safe haven status, whereas, for the pandemic outbreak, the coefficients are positive. This means that in market turmoil generated by sanitary events, especially when the adverse economic effects are understood as being short-lived and monetary and economic authorities are mitigating those effects, gold seems not to have a safe haven role. This is in line with Akhtaruzzaman et al. (2021) and Burdekin and Tao (2021).

About bonds, the events of the terrorist attack in Madrid (11th of March 2004), the Spanish banks' bailout and the third bailout to Greece are excluded by the stepwise for all markets analysed. Inclusively for several other periods analysed (Lehman Brothers collapse, second bailout to Greece, political turbulence from September 2011 to October 2012, before an agreement between European leaders to a debt deal has been reached, and the Greek elections in 2012), we do not find evidence of gold being a safe haven for any bond market. In the September 11 attacks, the algorithm indicates four assets to analyse, namely the German bonds on both maturities and the 2-year French and Portuguese bonds, though showing a distinct relationship between them.

For the German bonds, there is evidence of a safe haven role at the 10% level, but for the other two markets, there is no such evidence. There is also different evidence as to the potential role of gold as safe haven in the first bailout to Greece, the Irish and the Portuguese bailouts, as well as in the Brexit referendum, despite the high yield increases around the European sovereign debt crisis. We note that the COVID-19 pandemic outbreak caused a statistically significant relationship between bonds and gold, with the latter being considered a safe haven in this case.

Overall, gold confirms to be a safe haven for European stock markets in periods of financial, economic and political turmoil, though not so much in market instability due to sanitary events (e.g., the COVID-19 pandemic outbreak), as suggested by the regression on specific periods estimates. This is consistent with the conclusions stated by Akhtaruzzaman et al. (2021) in their Phase II, as their Phase II timespan partially overlaid ours. Conversely, our results vary from those in Cui et al. (2023), who study (i) a wider period of the pandemic and not only the initial shock, as we did, and (ii) the relations with other commodities and not with equity and sovereign bond markets, as we did. For the bond market, no general conclusions can be stated, as the gold safe haven property widely depends on the period under analysis, the maturity of the bond (short/medium term or long-term bond), as well as the issuer.

4.2. Analysis of subsamples

We also compare results in some periods against those in the full sample, the hindmost denoting a long-term performance. We use the Bai and Perron (2003) algorithm to define time series structural breaks. The algorithm produces an optimal number of breaks for each time series as a function of the minimum BIC value. Our analysis shows five optimal breaks for most of the assets, corresponding to six subsample periods. Due to a short number of observations, we do not consider the optimal number of breaks produced by the algorithm for the 2-year Greek bonds, and instead, we just select one break which allows us to have a period larger than 2 years in each of the subsamples.

For the analysis of the hedging properties of gold, we apply the ADCC-GARCH and DCC-GARCH models with the same specifications and distribution as in the sample, which allows us to compute daily time-varying correlations amid assets. The results (not reported) in the subsample analysis allow us to conclude that gold's hedging ability towards European stock markets is observed since the 2008 financial crisis (though for some markets gold already performed this role earlier). From the Euro's introduction until the financial crisis, gold exhibits diversifying effects.

Regarding government bonds, we do not detect a gold hedging pattern in the subsamples as clearly as in stock markets. Equivalent to the full sample, when considering gold's hedging role in bonds, we should account for the issuer and the bond's maturity. In terms of issuers, we find a difference between German and France government bonds, against which gold only denotes hedge effects until 2002, compared to the other issuers, which show effects during the same period and from the global financial crisis until the European sovereign debt crisis.

To perform the analysis of the safe haven role of gold, we estimate the OLS regressions based on quantiles (Eq. (7)) in each of the subsamples separately. The results (not reported) corresponding to stock markets show that, compared to gold's behaviour in the long run (full sample), the subsamples display less negative and significant coefficients in each subsample. The most relevant results, with gold denoting a strong safe haven effect with a significance level below 1%, are around the global financial crisis and the European sovereign debt crisis. After that, the safe haven effect of gold relative to the stock market is almost negligible. Concerning the bond market and equivalent to what we find for the hedging properties of gold, we confirm that gold's safe haven role depends mostly on the issuers, particularly after the European sovereign debt crisis, with safe haven effects existing in the countries more affected by the European sovereign debt crisis.

5. Conclusion

This paper examines the contribution of gold as both a hedge and a safe haven towards distinct European stock and sovereign bond markets. To that end, we analyse data from 4.1.1999, following the Euro launch, to 30.4.2020, when the COVID-19 pandemic had already spread across Europe. To capture gold's hedge ability, we apply the ADCC-GARCH Cappiello et al. (2006) and DCC-GARCH Engle (2002) models to find the time-varying correlation estimates amid gold and each of the assets considered. We test gold's safe haven property using OLS regressions based on: (i) the quantiles of the return's distribution; and (ii) the specific periods that generated extreme losses or extreme yield increases. In addition to the full sample, we analyse subsamples, defined by the levels of structural breaks produced by the Bai and Perron (2003) algorithm, to study differences in gold's hedging and safe haven features in shorter periods throughout the sample and compare them with the long run. This last approach is novel compared to previous related literature.

The results we obtain suggest that gold can be seen as a hedge for stock markets, which is in line with the findings in other studies (e.g., Baur and McDermott, 2010; Ciner et al., 2013; Shahzad et al., 2020). However, our results also show that the hedge ability of gold is asset specific, as for the STOXX Europe 600 gold is found to be a diversifier. Despite this exception, the results we reach in the subsamples show that gold is a hedge for all stock markets under analysis after the Lehman Brothers collapse and a diversifier for most of the assets before that.

When we analyse bond markets, the results point to different behaviours depending on the issuer. For Germany and France, regardless of maturity, we find a diversifier effect, which is partially consistent with the findings of Agyei-Ampomah et al. (2014) who found co-movement among gold and UK and German bonds in periods of high bond market volatility. For the remaining bonds, we find that most are hedged by gold from the global financial crisis until the European sovereign debt crisis period. This means that the long run hedge effect does not exist for all the other bonds, with the differences depending on the issuer and maturity.

Regarding the safe haven role for stock markets, gold reveals to be a useful candidate when extremely negative returns occur (equal to or below the 1% and 2.5% quantiles). The same is observed when some striking negative events happened (the Lehman Brothers collapse, the request for a second bailout program by Greece, or the Brexit referendum). Yet, gold seemed not to present a safe haven ability in the COVID-19 pandemic outbreak. Other studies (e.g., Cui et al., 2023) suggest that, for a wider period of the pandemic, gold seems to have performed a safe haven ability.

The results we obtain indicate no clear safe haven effect for bond markets, neither in terms of the full sample nor in terms of subsample analysis. The bond issuer seems to be the main driver of that effect in the countries more impacted by the European sovereign debt crisis. When we focus on specific periods, we find some in which gold served as a safe haven for all bonds (except German and French bonds), such as the Irish and Portuguese bailouts, and the Brexit referendum. Overall, our results imply that gold's effectiveness as a risk mitigator for a portfolio depends on the type and issuer of assets that compose the portfolio, the type of events that may influence the financial markets and, inevitably, the investment goals and risk aversion level of the portfolio manager.

In our analysis, we compute structural breaks in terms of levels to define each of the subsamples. Future research could use a different approach by determining these structural breaks in terms of assets' volatility, which might lead to different subsamples lengths and/or periods. The analysis could also be extended by comparing gold's hedging and safe haven ability to those of other precious metals, such as silver, platinum or palladium, as well as other asset classes such as volatility indices, and cryptocurrencies. It might also be interesting for portfolio risk management to extend the analysis to specific sectorial indices or the components of an index, instead of analysing the country equity index itself.

CRediT author statement

Duarte Saldanha Vieira: Conceptualization, Methodology, Software, Data Curation, Formal analysis, Investigation, Writing - Original Draft.

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Declaration of competing interest

Duarte Saldanha Vieira, Paulo Viegas de Carvalho, José Dias Curto, and Luís Laureano, Authors of the manuscript "Gold's Hedging and Safe Haven Properties for European Stock and Bond Markets", confirm they have no conflict of interest to declare.

Moreover, the Authors certify that they have seen and approved the manuscript being submitted to Resources Policy and warrant that the article is the Authors' original work. We warrant that the article has not received prior publication and is not under consideration for publication elsewhere. On behalf of all Co-Authors, the corresponding Author shall bear full responsibility for the submission.

Acknowledgement

We gratefully acknowledge the constructive comments and suggestions of two anonymous reviewers that helped us improve the quality of the paper. Any remaining errors are our own. This work was supported by Fundação para a Ciência e Tecnologia, grant UIDB/00315/2020.

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