Gold as a Financial Instrument

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Abstract

In this paper, we explore the effectiveness of gold as a hedging and safe haven instrument for a variety of market risks. Rather than confining the analysis to specific countries, we treat gold as a global asset and apply the novel Phillips, Shi and Yu (2015a,b) methodology to identify extreme price movements. This method accounts for both the level and speed of changes in price dynamics that better characterises periods of abnormally high risks. We find that gold is a strong safe haven for stock, European sovereign, and oil inflation market risks. We also show that gold is a strong hedge to inflationary and currency risks. We demonstrate that gold had exhibited safe haven properties during the 2020 Covid-19 crisis, and highlight the importance of considering explosive behaviour in identifying periods of risk.

Keywords: Gold; Hedge; Safe Haven; Sovereign Debt; Equity Markets.

1 Introduction

In the nineteenth century, the gold standard was the monetary system that predominated in the developed world. Under such an arrangement, countries agreed to convert paper money into a fixed amounts of gold. That fixed price was used to determine the value of the currency. It is not surprising then that gold has commonly been viewed as a hedging asset.[1] Although the prominent role of gold has declined among central banks around the world since the collapse of the Bretton Woods system, it remains an important asset for households' and central banks' portfolios. Gold has traditionally been viewed as a natural store of value and a useful asset for its high liquidity. Thus it is not surprising that gold has often been viewed by investors

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[1] Capie et al. (2005), Tully and Lucey (2007), Sjaastad (2008) and Zagaglia and Marzo (2013), among others, have explored the role of gold as a US dollar hedge.

as a natural hedge to various forms of uncertainty around the globe.[2] In times of financial distress, investors often tilt their portfolios to reduce exposure to risky assets.[3] In particular, the literature has explored the risk-mitigating characteristics of gold as a financial portfolio diversifier (Jaffe (1989); Draper et al. (2006)) and as an inflation hedge (Adrangi et al. (2003); Worthington and Pahlavani (2007); Blose (2010)).

In this paper, we explore the effectiveness of gold as a hedging instrument to a variety of market risks, and whether it serves an important role in forming risk reducing financial strategies. To determine the financial properties of gold, we consider Baur and Lucey (2010) notion's of hedging and safe haven assets. *A hedging asset is one whose return is uncorrelated or negatively correlated with the return of another asset or portfolio. In contrast, a strong (weak) safe haven is defined as an asset whose return is negatively correlated (uncorrelated) with another asset or portfolio only during certain periods.* These definitions allow for testable hypotheses when analysing the financial properties of gold.[4]

Relative to prior literature, rather than confining the analysis to specific countries, we treat gold as a global asset.[5] Thus, we consider extreme events in major developed economies that are likely to affect the composition of investors' portfolio. In addition, we analyze the impact on gold prices from various types of risks. These include European sovereign debt, inflation and stock market risks. Moreover, we employ a novel approach for the identification of extreme episodes to determine what constitutes an abnormal risk period relative to normal market conditions. In particular, we apply the recursive rolling window procedure of Phillips, Shi and Yu (2015a,b) for risk identification, which we hereon refer to as PSY. This is in sharp contrast to what the literature has employed so far, which includes the Hill estimator for the exchange rate as in Reboredo and Rivera-Castro (2014), the copula for the US dollar in Reboredo (2013), the 10%, 5% and 1% quantiles of the return distribution in Baur and McDermott (2010), the 90% (95% and 99%) quantile of the lagged conditional volatility of the world portfolio as in Baur and McDermott (2010), and the Markov switching models of Beckmann and Czudaj (2013).

Relative to previous work, in this paper we analyse multiple risk factors (stock market, Euro sovereign, and inflation risks) in a cohesive and consistent empirical framework by applying the PSY procedure to multiple risk factors. We treat gold as a global asset, and extend the analysis to include the recent Covid-19 crisis. We uncover evidence of gold being a weak hedge (uncorrelated) to the stock market and Euro sovereign bond spreads, and a strong hedge (significant positive correlation) to oil prices which we employ as a proxy for inflation. Gold is a strong

[2]Examples of studies that examine the financial characteristics of gold include Faugere and Van Erlach (2005); Sherman (1982).

[3]This cross-market hedging strategy is sometimes referred as a flight-to-safety (flight-to-quality). This phenomenon may occur in various markets simultaneously as risk-averse investors seek multiple assets to diversify their equity market risks.

[4]These definitions have been employed in subsequent econometric studies of gold behaviour, such as Beckmann et al. (2015) and Baur and McDermott (2010)

[5]Baur and Lucey (2010), Baur and McDermott (2010), Coudert and Raymond (2011) and Beckmann et al. (2015), who study the effectiveness of gold as a hedge instrument against stock market crisis at the global, regional and country levels. The general conclusion of these papers is that gold can serve as both a hedge and a safe haven for US and major European stock markets.

safe haven asset for all three risk categories when extreme risk events are defined by the PSY procedure. We also find a near perfect hedge between gold and the strength of the US dollar. Robustness tests using a quantile method for identifying high risk crisis periods deliver some consistent results; though we posit that the primary driver of these differences is the use of the more advanced PSY bubble detection method in our primary results. When accounting for the Covid-19 crisis, our results indicates that gold has been a safe haven asset during the recent pandemic.

This paper is organised as follows. Section 2 provides a brief review of the existing literature; Section 3 discusses the model specification and data; the results are reported in Section 4; Section 5 contains additional robustness tests (including incorporating the Covid-19 period); and Section 6 offers some concluding remarks.

2 Literature

The effectiveness of gold as a hedge and safe-haven instrument for financial markets has been investigated extensively in the literature (see for example, Baur and Lucey (2010); Baur and McDermott, 2011; Coudert and Raymond (2011); Beckmann et al. (2015); among others). Baur and Lucey (2010) were the first to statistically distinguish between hedging and safe haven properties of gold and conclude that it served both roles during the period of 1995 to 2005 in the US, UK and German equity and bond markets. This allowed subsequent studies to statistically test the properties of gold in various contexts. For example, Choudhry et al. (2015) find evidence that gold acts as a hedge, though not as a safe haven, to various market indices when accounting for bidirectional interdependence. Baur and McDermott (2010) report that gold exhibits strong safe haven properties in developed financial markets, yet only weak safe haven properties in some emerging markets. The consensus within the literature is that there exists some evidence of gold playing the role of both hedge and safe haven, particularly in the US and European stock markets.

In addition to hedging financial market risks, many researchers have studied gold's ability to hedge inflationary risks. An early study by Chua and Woodward (1982) reports that gold seems to be an effective hedge to US inflation in the short-run. Subsequent studies, such as Wang et al. (2011); Beckmann and Czudaj (2013), have found evidence that gold has inflation hedging properties across various developed countries. However, these results depend on the time horizon considered. This is consistent with an earlier study by Ghosh et al. (2004), who uncover only a long-run hedging ability of gold towards US and world price indices. Consistent with well documented evidence that oil prices are closely linked to inflation (Hooker, 2002; Hunt, 2006), we consider Reboredo (2013) as a relevant study that - using copulas - reports that gold is not a hedge for oil prices but is instead a strong safe haven.

Another important risk considered in this study is that of the Eurozone sovereign debt crisis, with its sudden onset in late 2009 causing a substantial flight-to-quality by investors (Dajcman, 2012; Hong, 2018). Agyei-Ampomah et al. (2014) analyse various precious metals as potential hedges and safe havens to this crisis. The authors find that gold had served as a hedge to the sovereign bonds of Greece, Italy and Portugal, but exhibited mixed results as a safe haven. Białkowski et al. (2015) study whether gold prices were in a bubble and construct a 10-year bond spread between the Portugal, Italy, Ireland, Greece, and Spain relative to German bonds. This bond spread is used as a barometer of default risk in the Eurozone and is a suitable measure of the fundamental value of gold during investors' flight-to-quality.[6]

Finally, there is overwhelming evidence showing the co-movement between the price of gold and the strength of various currencies. Ciner et al. (2013) study the price behaviour of gold and the US dollar and Pound Sterling. These authors find that - for daily data - gold is a strong hedge and safe haven for both currencies. Evidence for gold as a hedge to the US currency is echoed by Reboredo and Rivera-Castro (2014); Reboredo (2013); Joy (2011). Interestingly, Pukthuanthong and Roll (2011) show that, due to the law of one price, an asset whose physical presence is not required for ownership and with no barriers to capital flows - such as gold - can have a strong negative correlation to multiple currencies. This is consistent with prior studies (see, for example, Wang and Lee, (2007); Reboredo (2013), and Joy (2011)).

Fewer studies have analysed the aforementioned risks within a unified framework. An important exception is that of Ciner et al. (2013). These authors study the co-movements of stocks, bonds, gold, oil and exchange rates in the US and UK markets. They find evidence that bonds serve their traditional role as a hedge to the equity markets, and that gold is a strong hedge for exchange rate risk. Białkowski et al. (2015) sought to model the fundamental value of gold to determine if there were price bubbles during 2003 to 2013, and include multiple factors such as equity markets, inflation, risk-free rate, exchange rates, and the Euro sovereign bond spread between Germany and the PIIGS countries.

The current paper builds upon the previous literature by providing a unified framework that considers various types of risks while incorporating the innovative PSY procedure when identifying risky events. The PSY procedure employs a recursive algorithm that tests for the null hypothesis of a random walk against explosive price behaviour. Unlike the traditional methods for extremely events that rely on market returns (i.e., magnitude of price changes), the PSY procedure takes both the price level and speed of changes into consideration. It has been applied to a broad range of markets for bubble identification.[7] Interestingly, this procedure can also been used for other purposes. For example, PSY was able to date-stamp sovereign crises in the European sovereign market (Phillips and Shi, 2019, 2020), credit risk in energy corporations (Figuerola Ferretti Garrigues and Cervera Conte, 2018), stock market crises (Phillips and Shi, 2018), and explosive inflationary behaviour in oil prices (Caspi et al., 2018; Fantazzini, 2016). Additionally, we include the recent Covid-19 crisis to examine whether the safe haven properties of gold were present during the pandemic.

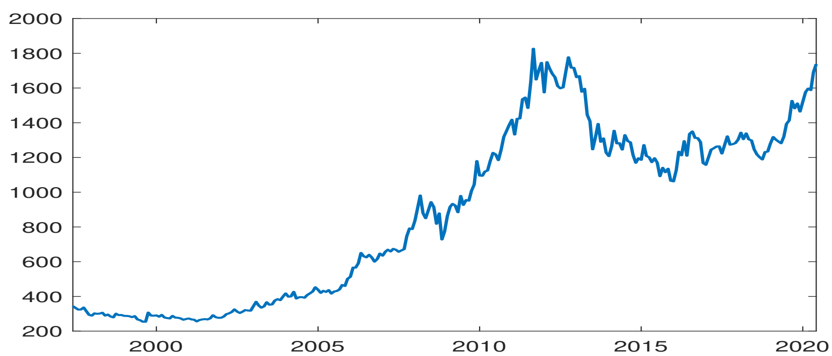
[6]This is an important proxy for the severity of the Euro sovereign debt crisis that will be revisited in the current paper.

[7]See, for example, Bohl (2003); Etienne et al. (2014); Pavlidis et al. (2016); Adämmer and Bohl (2015); Figuerola-Ferretti et al. (2015); Caspi et al. (2018); Caspi (2016); Shi et al. (2016); Greenaway-McGrevy and Phillips (2016); Deng et al. (2017); Milunovich et al. (2019); Hu and Oxley (2017, 2018a,b).

3 Model Specification

Before delving into the econometric model, we first document gold price regularities over the past three decades.[8] We will use these observations to inform key aspects of our study design. As can be observed in Figure 1, since 2001, the price of gold had skyrocketed from US$250 per troy ounce to an all-time high of US$1900 in August 2011, before falling to approximately US$1200 at the end of June 2013. Gold prices steadily declined though experienced a substantial surge in 2020. Not surprisingly, these surges in gold prices coincide with the dot-com boom and bust in the US stock market, the European sovereign debt crisis, the unprecedented global financial crisis and the impact of Covid-19. These episodes have led to large real estate losses, government bailouts, significant corrections in the stock market and a substantial contraction in economic activity. During these episodes we have seen investors' flight to safe assets, such as gold.

Figure 1: Gold London bullion price (US $ per troy ounce) from June 1997 to June 2020.



Given the features of the data, we consider the European sovereign debt, inflation (oil), equity and the US dollar exchange rate risks. We now outline the methodology to assess the hedging and safe-haven properties of gold against these risks. To measure the effectiveness of gold as a hedging instrument, we consider an investor's portfolio and explore how the different risk factors co-move with gold. More precisely, we consider the following specification:

$$r_{gold,t} \quad = \quad \alpha + \beta_t \, r_{stock,t} + \gamma_t \, r_{sover,t} + \delta_t \, r_{oil,t} + \eta \, r_{usd,t} + e_t \tag{1}$$

where $r_{S,t}$ is the asset return of market $S = \{gold, stock, oil, usd\}$, $r_{sover,t}$ denotes the logarithmic changes of sovereign bond yield spreads (which will be defined later), e_t is the error term, η measures the impact of the US dollar exchange rate risk and β_t, γ_t, and δ_t capture the co-movements associated with stock market returns, sovereign bond yields and oil returns, respectively. These coefficients are modeled as dynamic processes as follows

$$\beta_t \quad = \quad b_0 + b_1 \, D_{stock,t}$$

[8]The gold price data is downloaded from DataStream International.

$$\begin{aligned}\gamma_t &= c_0 + c_1\ D_{sover,t} \\ \delta_t &= d_0 + d_1\ D_{oil,t} \\ e_t &= \sqrt{h}_t\ v_t \quad \text{with} \quad v_t \overset{i.i.d}{\sim} N(0,1) \\ h_t &= \pi_0 + \pi_1\ e_{t-1}^2 + \pi_2\ h_{t-1}\end{aligned}$$

where $D_{j,t}$ denotes dummy variables for periods of abnormal returns associated with the three different risks[9]. Finally, the last two equations present a GARCH(1,1) dynamic of the error term that accounts for potential heterocedasticity in the data.

Table 1: Coefficient interpretations

	Equity	Sovereign	Inflation	Exchange
Strong hedge	$b_0 < 0$	$c_0 > 0$	$d_0 > 0$	$\eta > 0$
Weak hedge	insig. b_0	insig. c_0	insig. d_0	insig. η
Safe haven	sig. b_1	sig. c_1	sig. d_1	
	$b_0 + b_1 \leq 0$	$c_0 + c_1 \geq 0$	$d_0 + d_1 \geq 0$	

Gold is a strong hedging asset for equity risk and exchange rate risk if gold returns are negatively related to stock returns (i.e., $b_0 < 0$) and the USD exchange rate (i.e., $\eta < 0$) during non-crisis periods. Gold serves as a weak hedge if there is no significant relationship during the normal periods. Unlike $r_{stock,t}$ and $r_{usd,t}$, larger values of $r_{oil,t}$ and $r_{sover,t}$ imply higher levels of inflation and Euro sovereign risks. Therefore, one would expect positive relationships between $r_{gold,t}$ and $r_{oil,t}$ ($r_{sover,t}$) should gold serves as a hedging instrument for oil (inflation) and sovereign risks; so that the coefficients c_0 and d_0 are either positive or insignificant. When the risk indicator $D_{stock,t}$ is activated and equal to one, statistically significant values of b_1, c_1 and d_1 denote changes in the relationship between gold and the risk factors during abnormal periods of risk. Furthermore, if $b_0 + b_1 \leq 0$, $c_0 + c_1 \geq 0$, $d_0 + d_1 \geq 0$, then gold is considered a safe haven for the equity, sovereign, and inflation risks.

Key in our analysis is identifying the periods of risk across the different sources examined in this paper. In the next subsection, we outline the identification procedure to achieve this.

3.1 Identifying Risks

To identify abnormal risky periods, the determination of whether a particular observation is consistent with an explosive process (H_A) or with a normal martingale (H_0) is essential. One way of achieving this is to employ the testing algorithm based on a right-tailed unit root test proposed by Phillips et al. (2015a,b): the PSY procedure. The underlying methodology is as follows

$$\Delta y_t = \alpha + \beta\ y_{t-1} + \sum_{i=1}^{K} \gamma_i \Delta y_{t-i} + \varepsilon_t \tag{2}$$

[9]The returns to the USD is not tested for safe haven effects as there are no extreme movements in the USD over the period; and hence, no identified crisis episodes by the PSY test.

where y_t is the relevant time series associated with a particular risk at period t, K is the lag order (set to 1 in the applications), and ε_t is the error term. The ADF statistic is the t-ratio of the OLS estimate of β.

The PSY test requires conducting subsample regressions. Let τ_1 and τ_2 be the starting and ending points of a subsample regression. The algorithm calculates the ADF statistic repeatedly on a sequence of backward expanding samples. The corresponding ADF statistic sequence is denoted by $\left\{ADF_{\tau_2}^{\tau_1}\right\}$. Suppose τ is the observation of interest. We fix the ending points of all samples on τ and let the starting point of the samples vary from the first available observation to $\tau - \tau_0$, where τ_0 is the minimum window size required to initiate a regression. Inference of explosiveness for observation τ is based on the maximum value of the ADF sequence, denoted by PSY_τ and defined as follows

$$PSY_\tau = \max\left\{ADF_{\tau_2}^{\tau_1} : \tau_2 = \tau \text{ and } \tau_1 \in [1, \tau - \tau_0]\right\}.$$

The minimum window size τ_0 is set according the rule of $\tau_0 = (0.01 + 1.8/\sqrt{T}) \times T$ as suggested in Phillips et al. (2015a). To address the potential unconditional heteroskedasticity issue in the error term, we employ a wild bootstrapping procedure proposed by Harvey et al. (2016) for critical values. We refer readers to Harvey et al. (2016) or Milunovich et al. (2019) for details of the bootstrapping procedure.

Using the previous methodology, we can then define the dummy variables in equation (1) as follows

$$D_{j,t} = \mathbf{1}(PSY_{j,\tau} > cv_{j,0.95}),$$

where $\mathbf{1}(.)$ is an indicator function and $cv_{j,0.95}$ is the 95% bootstrapped critical values. This captures instances of explosive (abnormal) behaviour in the time series of the risk measures.

European Sovereign Debt

The sovereign debt crises was a multi-year crisis that took place in the European Union at the end of 2009. This episode was sparked when Greece, Ireland, Italy, Portugal, and Spain (which from now on refer as GIIPS) were unable to repay or refinance their government debt or had to bail out over-indebted banks under national supervision without the assistance of third parties.[10] These events created significant turmoil in global financial markets.

As is common in the literature, we account for the degree of sovereign risk in the euro zone by measuring the spread between the GDP weighted of the 10-year government bond yield between GIIPS and Germany.[11] The German bond yield is used as a proxy for economic fundamentals in the euro zone.[12] To identify an upsurge in European sovereign risk, we apply the PSY procedure

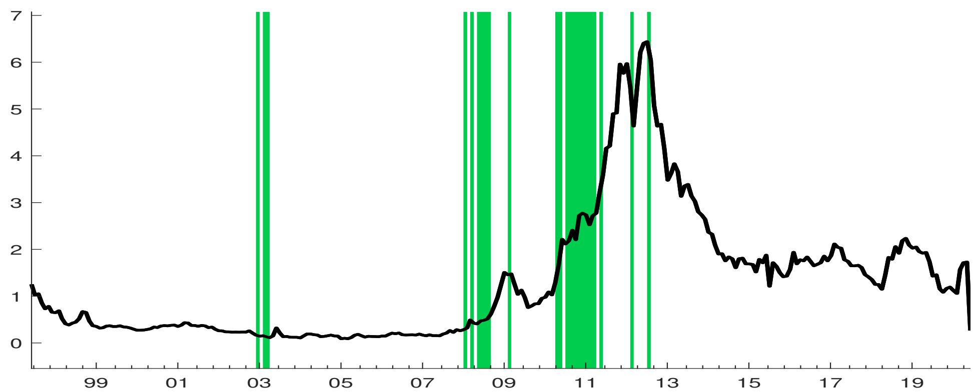
[10] These third parties include other eurozone countries, the European Central Bank (ECB), or the International Monetary Fund (IMF).

[11] All data are obtained from Datastream. The GDP data are downloaded quarterly and converted to a monthly frequency by assuming constant. The June 2020 quarter GDP was not available at the time of download due to the delay of data release. We assume the weights in 2020Q2 is the same as those in 2020Q1.

[12] This methodology has been used in several other papers including Phillips and Shi (2020); Białkowski et al. (2015).

to the aforementioned bond yield spread. Figure 2 plots the data series with the shaded regions identified as periods of crisis (i.e. $D_{sover,t} = 1$). The procedure identifies three major episodes of sovereign crisis. The first episode is detected in January of 2003. The second episode overlaps with the global financial crisis period, from February 2008 to March 2009 - though the indicator switches from one to zero within that period. This result is consistent with the findings of Phillips and Shi (2020) who report that the debt crisis in 2008 emerged before the bank bailouts in Europe (September - November 2008). The third episode identified has a starting date in May 2010, six-month after Greece announced a 300 billion euro debt.[13] The end date of the sovereign debt crisis is found to be in September 2012.

Figure 2: The GDP-weighted 10-year government bond yield spread between the GIIPS countries and Germany (line) and the identified crises periods at 10% significance level (shaded areas).



Oil Prices

There is a long and well established literature linking oil price movements to changes in inflation.[14] Researchers have found that the oil price contributes significantly to the extreme dynamics in inflation and inflationary expectations.[15] Moreover, the volatile nature of oil price dynamics will facilitate a more accurate identification of extreme movements in price levels with the PSY technique. Thus, rather than exploring the link between gold and CPI inflation as in Wang et al. (2011) and Beckmann and Czudaj (2013), we examine whether gold is a hedge for the explosive dynamics in oil prices. Specifically, we employ the crude oil Brent spot price (dollars per barrel) as reported by the US Energy Information Administration. We use a monthly

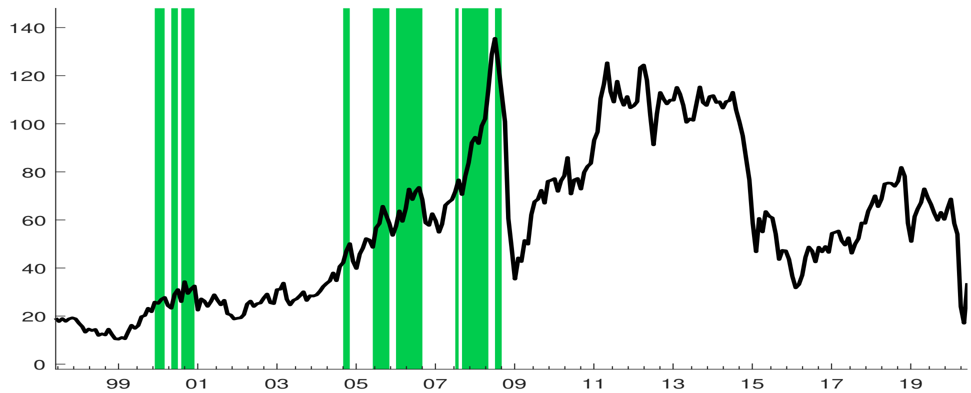
[13] This what is typically referred as the European debt crisis period.

[14] By estimating augmented Phillips curves on quarterly data from the US, UK, France, Germany, and Japan on the period 1980Q12001Q4, LeBlanc and Chinn (2004) find that a 10% increase in oil price leads to direct inflationary increases of about 0.10.8 percentage points in these countries. Alvarez et al. (2011) find that the direct effects of oil price increases on inflation have increased over time in the Euro area.

[15] We refer the reader to Arora et al. (2013); Neely and Rapach (2011); Wong (2015) for excellent discussions on this topic.

frequency from June 1997 to June 2020 and apply the PSY procedure. Figure 3 plots the data series with the shaded regions corresponding to identified periods of crises (i.e. $D_{oil,t} = 1$).

Figure 3: The crude oil price (line) and the identified explosive inflationary periods at 10% significance level (shaded areas).



As can be observed in Figure 3, the price of crude oil experienced a rapid increase starting from 2004, followed by a mild downturn in October of 2006. Upward momentum continued in 2007. It rose at an even faster rate between 2007 and 2008 but collapsed dramatically in June of 2008. The market began to recover in 2009 and reached a plateau (with minor fluctuations) in 2011-2014. The oil price then fell again in late 2014 and the price has remained low until the end of the sample period. The PSY test suggests that the oil price has experienced several episodes of explosiveness during the sample period. The most significant explosive price increase is observed from August 2007 to September 2008. The PSY test also captures the substantial and rapid crude oil price drop in 2015; though this has been omitted in the current study as we are concerned only with rapid explosive price rises (inflation) in oil.

Stock Market Risk

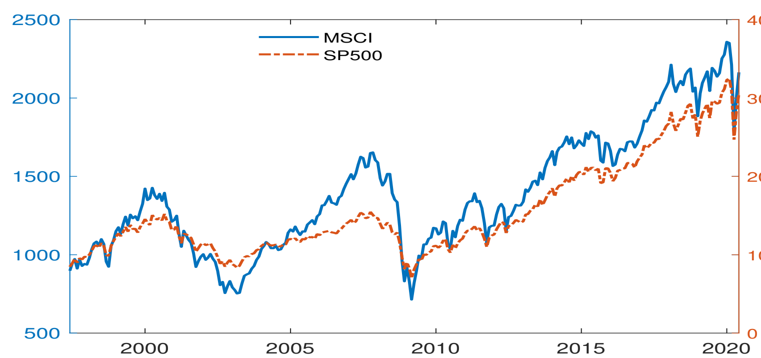
Starting from the turn of the century, global stock market volatility has been dominated by two extremes events originating in the US market, namely the dot-com bubble collapse in the early 2000s and the subprime mortgage crisis. To capture the abnormal crisis periods in the stock market, we employ the cyclically adjusted price earning (CAPE) ratios of the S&P stock market as a measure of market sentiment relative to fundamentals. This variable is obtained from Robert Shiller's website.[16]. In the asset pricing literature, Lleo and Ziemba (2016) and Siegel (2016) demonstrate that CAPE has been shown to predict future stock returns, and importantly, it has also predicted crashes over the long term. A rise in CAPE suggests that equity is overpriced and returns are expected to be lower than average in the long-term. In

[16]The web address is: `www.econ.yale.edu/~shiller/data.htm`.

contrast, we apply the PSY procedure to the inverse of the CAPE ratio to identify periods of explosive market price falls relative to fundamentals that signify abnormal price corrections.

CAPE is calculated by Shiller using the S&P500 index. Though this study examines gold as a global hedging and safe-haven asset, the S&P500 index closely tracks the global MSCI index.[17] It has been shown that global equity markets are highly correlated (Swanson, 2003) and there is evidence that the S&P500 is the leader of global equity markets (Cheung et al., 2010). Moreover, in abnormal negative return periods when gold may be considered a safe-haven, movements across global equity markets converge Markwat et al. (2009). See Figure 4 for the dynamics of these two data series over the sample period. As such, the S&P500 index is used as the measure of global market risk in this study. This also ensures the CAPE calculation is consistent with prior studies (Lleo and Ziemba, 2016; Siegel, 2016).

Figure 4: The dynamics of the global MSCI and the S&P500 composite indexes. Both data series are obtained from DataStream.

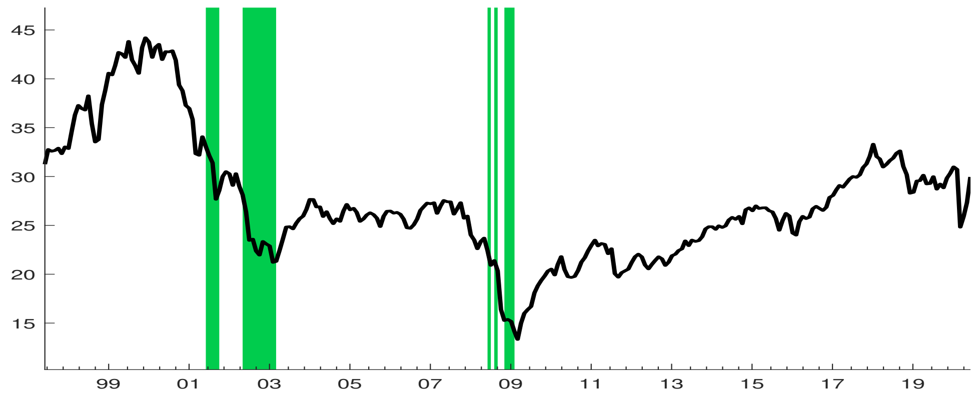


As observed in Figure 5, episodes of equity market turmoil - as identified by PSY in the CAPE time series - are concentrated around two major market downturns. The first coincides with the early 2000s' bursting of the dot-com bubbles, which witnessed the fall of the S&P500 index from a high of 1270 in May of 2001 to 837 in February of 2003. During this time, the CAPE ratio fell from 33.07 to 21.21, which represents a substantial correction in equity prices towards their fundamentals. In fact, the NASDAQ rose from less than 1000 to over 5000 in the 5 years preceding the crash. The PSY procedure identifies this period of July 2001 to March 2003 as periods of explosive movements in the S&P500 index.

The second identified period of abnormal market movement coincides with the sub-prime mortgage crisis of mid-2008 to early 2009. During this period, the S&P500 shrank by 50% from 1539 in late 2007 to 757 in March of 2009. This downfall in market values corresponds to a

[17]The MSCI World Index captures large and mid cap representation across 23 Developed Markets countries and index covers approximately 85% of the free float-adjusted market capitalization in each country. The countries included are: Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Hong Kong, Ireland, Israel, Italy, Japan, Netherlands, New Zealand, Norway, Portugal, Singapore, Spain, Sweden, Switzerland, United Kingdom and the US

Figure 5: The cyclically adjusted price earning ratios of the S&P stock market (line) and the identified crisis periods in the S&P 500 market at 10% significance level (shaded areas).



44.5% drop in CAPE to 13.32. Similarly, this rapid destruction in market value triggers the PSY statistic at the 10% level.

4 Hedging Results

Recall that equation (1) includes the return of the US dollar exchange rate, which we proxy by the Trade-Weighted Value of US dollar against major currencies and obtained from DataStream.[18] As we can see from Figure 6, the US dollar exchange rate generally moves in the opposite direction to the price of gold. For instance, the price of gold is at its peak in 2011-2012, which coincides with the lowest point in of the exchange rate proxy. Similarly, as the value of gold declines from 2012 to 2016, we see the value of the US dollar increase substantially against major currencies. However, this broad inverse relationship deteriorates from the mid-2018 onward as both the prices of gold and the trade-weighted value of the US currency increase.

Before estimating the effectiveness of gold as a hedging instrument for various risks, we examine the data and report some descriptive statistics. In particular, Figure 7 presents the price of gold and the identified high risk periods. These relate to the four risk factors considered and are defined as instances where the p-values of the PSY test statistic are below 10%.

As we can see from Figure 7, our methodology identifies several abnormal periods. Some of these episodes coincide with substantial (and upward) movements in gold prices. For example, in 2010 to early 2011, we see substantial upward momentum in gold prices that coincide with the period of sovereign risk. Similarly, in late 2007 and 2008, we see the price of gold rise substantially during the market meltdown of the US sub-prime mortgage crisis, the sovereign crisis in the euro zone, and the surge in oil prices. We also observe shorter and sporadic episodes of abnormal sovereign and stock market risk in the first half of the sample (1999 to 2007). These

[18]The last observation available at the time of collection for this data series is December 2019. As such, the sample period for estimation results in this section is from June 1997 to December 2019.

Figure 6: The dynamics of gold prices and the US dollar exchange rate.

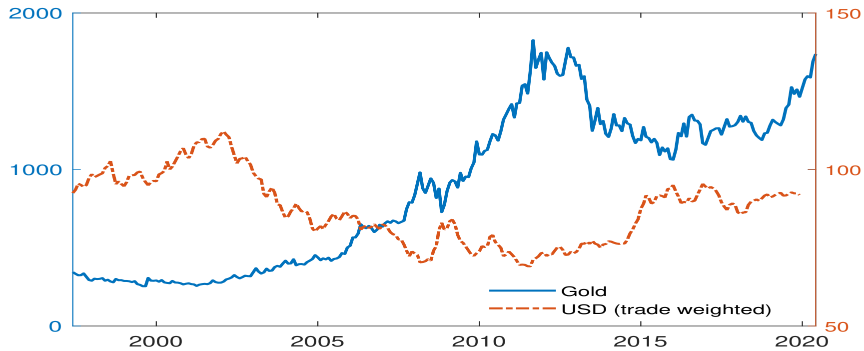
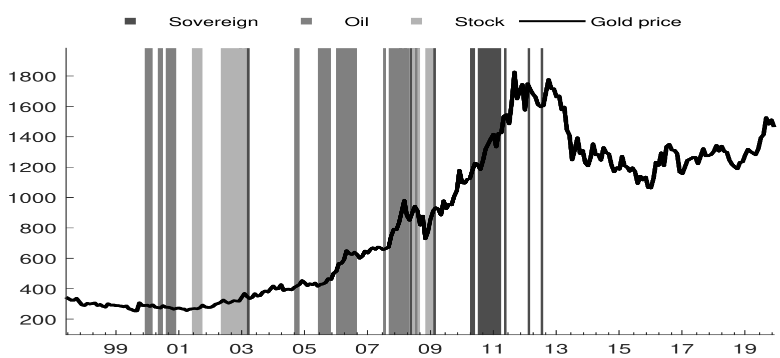


Figure 7: The gold price and the identified sovereign, inflation and stock market risk periods (shaded areas).



are associated with stable movements in gold prices. Visually, Figure 7 illustrates the possibility of gold serving as a safe haven for sovereign, oil and stock market risks. In many occasions, we observe an increase in the value of gold during high risk periods as identified by the PSY statistic. For example, the period of 2007 to 2011 coincides with crises (as identified by PSY) in all three risk factors and the sustained price increase in gold. Notably, from 2013 to 2016 when the price of gold falls, there are no identified risk crises in the euro bond spread, market risk measure, or oil price.

Table 2 present some summary statistics of the returns included in the regression analysis. The average monthly returns are roughly equivalent to zero for all assets except for gold at 1% monthly return. We see that most of the variation in returns is in the sovereign spreads and oil prices. In contrast, the proxy for the US dollar exchange rate, equity (S&P500 composite index), and gold markets exhibit the most stable returns. Over the sample period, they exhibit standard deviations of 2%, 5%, and 5%, respectively. The PSY test identifies 19, 24, and 35 months of extreme risk, many of these periods overlapping and of substantially different duration. For example, the period of the US sub-prime mortgage crisis witnessed simultaneous abnormal risk periods in the both the stock market and inflation, with sporadic months of sovereign risk. This highlights the linkages in financial risks and the importance of a suitable safe haven in times of multiple crises. Table 2 also reports sporadic and less persistent periods of abnormal risk, such as the one associated with euro zone sovereignty in March and August of 2012. Similarly, oil prices also exhibit a short crisis period in October to November of 2004.

Table 2: Summary statistics: Returns of various assets.

r_t	Gold	Spread	Oil	S&P500	USD
Mean	0.01	-0.00	0.00	0.00	-0.00
Std. dev	0.05	0.14	0.11	0.05	0.02
Skewness	-0.05	0.40	-0.68	-0.76	-0.04
Kurtosis	4.22	6.61	5.12	4.84	3.71
Min	-0.19	-0.49	-0.51	-0.18	-0.05
Max	0.19	0.76	0.28	0.15	0.06
# of extreme risk	N/A	24	35	19	0
# of obs	270	270	270	270	270

Having examined the raw data, we now determine the hedging properties of gold by estimating the benchmark model, given by equation (1). We do so by Maximum Likelihood. The resulting estimates are reported in Table 3 along with several likelihood ratio tests.

Table 3: Maximum likelihood estimates from June 1997 to December 2019.

Benchmark Model				
Intercept	Stock market β_t	Sovereign Debt γ_t	Oil price δ_t	US dollar
α 0.004***	b_0 0.024	c_0 0.0023	d_0 0.028*	η -0.954***
	b_1 -0.198*	c_1 0.197***	d_1 0.095**	
Volatility Parameters				
π_0 0.0004**	π_1 0.179***	π_2 0.645***		
log lld. 1431.4				
Likelihood Ratio Tests				
H_0	LR stat.	H_0	LR stat.	
$\beta_t = 0$	2.58	$\eta = 0$	65.95***	
$\gamma_t = 0$	1.15***	$\delta_t = \eta = 0$	81.60***	
$\delta_t = 0$	8.53***	$b_1 = c_1 = d_1 = 0$	21.717***	
$\gamma_t = \beta_t = 0$	31.76***			

Note: *,**, and *** indicates significance at the 10%, 5%, and 1% level, respectively.

Our results suggest that there is no significant relationship between gold and the equity[19] and

[19]Note that the PSY procedure is applied to CAPE to identify crisis episodes in the equity markets, though

European sovereign markets during normal market conditions (b_0 and c_0 are insignificant). This provides evidence that gold is a weak hedge for these asset markets. Nevertheless, during periods of extreme risk, gold can serve as a safe haven for both equity and European sovereign bonds (significant $b_1 < 0$ and $c_1 > 0$) markets. We also find significant and positive co-movements between oil and gold. This is observed during both abnormal and normal market conditions, and is an indication that gold is both a strong hedge and safe haven financial asset for inflation. It is worth highlighting that the effect of hedging is strong during periods of extreme risks relative to normal periods ($d_1 > d_0$). Furthermore, as expected, gold is inversely related to the US dollar, displaying a coefficient close to -1.

To gain a deeper insight on the hedging properties of gold, we test whether different combinations of individual risk factors alter the previous results. Table 3 reports various likelihood ratio tests. We find that, at the 1% level, all risk factors (tested individually) are statistically significant in their co-movement with gold. The only exception is the stock market which is insignificant but very close to the 10% significance level. To determine if only equity and sovereign bond markets have an impact on gold's hedging properties, we impose the following restriction: $\delta_t = \eta = 0$. We find that at the 1% level, we reject that internal and external currency risks are not relevant. Similarly, we examine whether just internal and external currency risks are related to gold prices by constraining $\gamma_t = \beta_t = 0$. We find that at the 1% level, equity and sovereign bond markets risk factors are relevant. Finally, we explore the role of gold as a safe haven asset by restricting $b_1 = c_1 = d_1 = 0$. These joint restrictions are rejected at the 1% level.

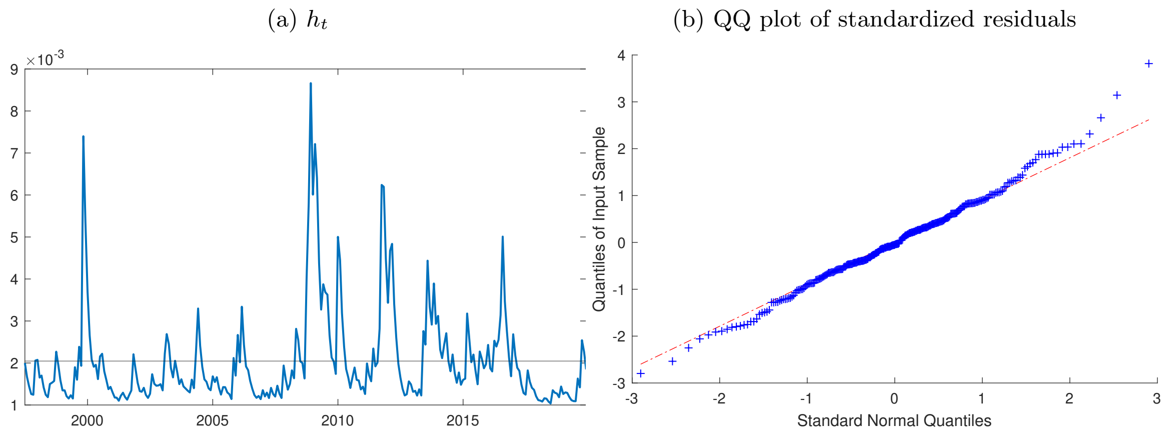
Our result that gold is a strong safe haven for equity markets is consistent with prior studies, such as Baur and Lucey (2010), Baur and McDermott (2010), Beckmann et al. (2015). Though Agyei-Ampomah et al. (2014) reported some mixed results regarding gold's role as a safe haven for the European sovereign bonds, we posit that differences in our results are likely due to the novel use of the PSY test statistic in identifying periods of high risk. Consistent with our results for oil prices, gold has been shown in the literature to be an effective hedge for oil/inflation (Worthington and Pahlavani, 2007; Beckmann and Czudaj, 2013), and safe haven during extreme price movements (Reboredo, 2013). The strong correlation between gold prices, as seen in in Table 3, and the strength of the US dollar supports the law of one price argument put forth by Pukthuanthong and Roll (2011), and the empirical findings of prior studies (see, for example, Reboredo (2013)).

Having described the hedging properties, we now explore the potential for heterocedasticity in the data by considering a GARCH(1,1) model. The volatility structure proposed in our benchmark model, GARCH(1,1), is suited to describe the data as all relevant coefficient are statistically different from zero (Table 3). To complement these results, Figure 8 also displays the estimated conditional volatility of gold returns and the QQ-plot of the standardized residuals. Figure 8(b) suggests that the residuals are approximately standard normal. This is consistent with our model assumption.

In addition, Figure 8(a) also finds several episodes of high volatility in the gold market.

it is the returns of the S&P500 that is used as a regressor in (1). In unreported results, the inverse of CAPE is inputted in (1) as the regressor for equity returns and produced consistent (almost identical) results.

Figure 8: Estimated conditional volatility of gold returns and the Quantile-Quantile plot of the standardized residuals The horizontal line in panel (a) is the mean of h_t over the sample period.



The two most dramatic episodes are related to the stock market crises. One is before the burst of the dot-com bubble (from October 1999 to February 2000) and the other one is at the peak of the subprime mortgage crisis (from October 2008 to April 2009). These are extreme volatility episodes as they are in orders of magnitude larger than the mean value (depicted by the horizontal line).

5 Robustness Checks

5.1 Covid-19

Since the beginning of 2020, there has been uncertainty regarding the effects of COVID-19 on many aspects of the economy, ranging from health, labor to financial markets. To capture the uncertainty in financial markets, Baker et al. (2020) developed an infectious disease equity market volatility tracker.[20] Not surprisingly, this index coincides with the Covid-19 period.

To study this recent source of uncertainty, we consider the following specification

$$r_{gold;t} \quad = \quad \alpha_0 + \alpha_1\, D_{Covid19,t} + \beta_t\, r_{stock,t} + \gamma_t\, r_{sover,t} + \delta_t\, r_{oil,t} + e_t \qquad (3)$$

where $D_{Covid19,t}$ is a dummy variable that is equal to one from January 2020 to the end of the sample period (June 2020), and α_1 accounts for the impact of Covid-19. β_t, γ_t, δ_t, and e_t are specified as in the benchmark model. It is important to highlight that in this latter specification

[20] The authors identify three indicators: stock market volatility, newspaper-based economic uncertainty, and subjective uncertainty in business expectation surveys that provide real-time forward-looking uncertainty measures. The authors use these indicators to document and quantify the enormous increase in economic uncertainty in the past several weeks.

we do not consider exchange rate risk as - at the time of writing - data on the trade weighted US dollar for 2020 is not yet available. The resulting estimates using the maximum likelihood procedure are reported in Table 4.

Table 4: Maximum Likelihood Estimation: from June 1997 to June 2020.

			Mean Equation				
Intercept		Stock market β_t		Sovereign γ_t		Oil δ_t	
α_0	0.004**	b_0	0.061	c_0	0.009	d_0	0.033***
α_1	0.031***	b_1	-0.278***	c_1	0.140***	d_1	0.138***
			Volatility Equation				
π_0	0.0004***	π_1	0.123***	π_2	0.707***		
log lld.			14354.1				

Note: *,**, and *** indicates significance at the 10%, 5%, and 1% level, respectively.

The results are qualitatively similar to the PSY benchmark model of Table 3. When considering the uncertainty associated with the Covid-19 global pandemic, gold can still serve as a hedging instrument for equity and sovereign markets and sudden oil price changes. The estimated volatility and QQ plot are similar to those from the benchmark model. It is worth highlighting that the estimate for α_1 is statistically positive. This suggests that gold has been a safe haven for investors during the Covid-19 crisis.

5.2 A Threshold Approach to Risk Identification

An important contribution of this paper is to propose a novel methodology to identify risks. As a robustness check, we now consider the conventional threshold approach to identifying extreme market episodes. This has been commonly employed in the literature.[21] To implement this methodology, let us now consider a risk indicator that is equal to one if the following condition is satisfied

$$I_{s,t} = 1(r_{s,t} > \mu_{s,t} + 1.645\ \sigma_{s,t}),$$

where $s = \{spread, oil, market\}$, $\mu_{s,t}$ and $\sigma_{s,t}$ are the rolling window estimation of the sample mean and standard deviations over the past 5 years. The threshold is chosen to be 1.645, which corresponds to a 10% significance level for a right-tailed test. The identified risk periods according to the different risk sources are illustrated in Figure 9. The identified periods are not consistent with our previous PSY identification results nor the common view of most market analysts.

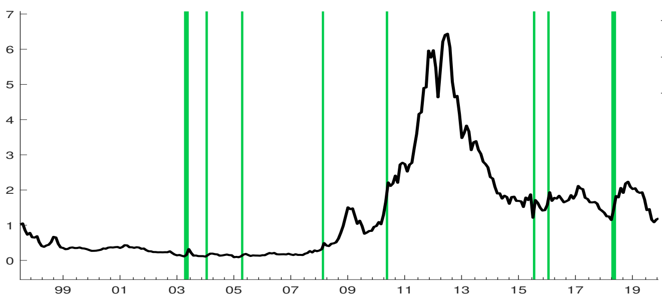
Having identified the risk periods, we can now determine the hedging properties of gold by estimating the benchmark model, as defined in equation (1). The corresponding estimates are reported in Table 5.

As presented in Table 5, none of the three coefficients b_1, c_1, d_1 that account for abnormal times are statistically significant. During normal periods, only the coefficients corresponding

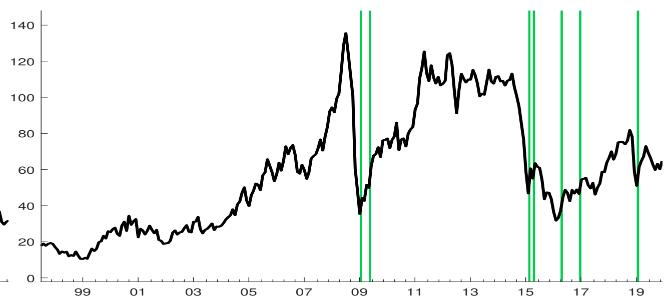
[21] Some prominent examples of this approach are Baur and Lucey (2010); Baur and McDermott (2010).

Figure 9: The identified extremely risky periods in the sovereign, oil, and stock market using the threshold approach.

(a) Sovereign Debt



(b) Oil price



(c) Stock market

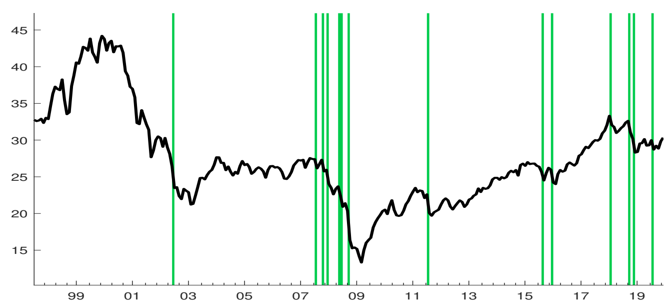


Table 5: Maximum likelihood estimation using the threshold approach for risk identification.

					Benchmark Model						
Intercept		Stock market β_t		Sovereign debtγ_t		Oil price δ_t		US dollar	
α	0.005***	b_0	-0.007	c_0	0.011	d_0	0.033**	η	-0.90***
		b_1	0.037	c_1	0.004	d_1	0.025		
				Volatility Equation					
π_0	0.0003***	π_1	0.186***	π_2	0.660***				
log lld.	1420.9								

Note: *,**, and *** indicates significance at the 10%, 5%, and 1% level, respectively.

to oil prices and exchange rate risk are statistically significant. These results indicate that gold serves only as a strong hedge for all inflation and exchange rate risk. It is also worth highlighting that the log likelihood value is substantially smaller than in the PSY benchmark model reported in Table 3. These differing results indicate that the PSY indicator is crucial in correctly identifying extreme (abnormal) risk periods. This in turn is critical in assessing the hedging properties of gold. The PSY methodology seems to be appropriate as it accounts for the explosiveness of price dynamics that the literature has previously identified when studying the different markets separately. This is a phenomenon that the threshold/quantile approach to risk identification is unable to do. This is the case as high risk periods are defined not just by changes in price movements, but also the level and speed (explosiveness) of those movements.

6 Conclusions

This paper examines the hedging and safe haven properties of gold by simultaneously allowing various sources of risk in a unified framework, by treating gold as a global asset and considering the recent Covid-19 crisis. Furthermore, we apply the novel PSY procedure to identify times of crisis or high risk. These episodes are critical in determining gold's hedging properties. The PSY test is particularly suited to capture the hedging properties of gold as it accounts not only for the lower tail of the returns distribution, but also the explosive dynamics in the return series.

We find compelling evidence that gold is a universal hedge and safe haven. In our benchmark model, we show that gold is a weak hedge to the stock market and Euro sovereign bond spreads. However, gold is a strong hedge to oil prices (a proxy for extreme movements in inflation). Gold is also a strong safe haven asset when investors are confronted with all three risks considered in this paper. Moreover, we report that gold is a near perfect hedge to the US dollar. Our results are consistent with prior literature that analyze these various sources of risk separately and that employ alternative procedures to identify periods of high risk. Robustness tests using the conventional threshold (quantile) method corroborate some our main results. With this different procedure, we find that gold is a weak safe haven to all three risk categories. Finally, employing recent data that includes the Covid-19 period, we find that gold has exhibited safe haven properties during the pandemic crisis. Our results highlight the importance of gold as a stabilizing instrument across multiple markets and its role in risk reduction strategies.

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