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Diamonds vs. precious metals: What shines brightest in your investment portfolio?☆

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ABSTRACT

Several studies explore the use of gold and other precious metals for protecting investors' wealth during periods of market turmoil. However, alternative investments, although increasing in popularity, still remain unfamiliar to the majority of investors. We explore the safe haven and hedging properties of diamonds versus precious metals in an international study to evaluate diamonds as a viable investment alternative. Furthermore, we compare the performance between the returns of physical diamonds and diamond indices. Our analysis indicates superior performance by precious metals compared to diamonds. However, investors enjoy greater benefit from directly investing in physical diamonds rather than diamond indices. For investors looking to protect their assets against highly volatile market conditions, precious metals remain a better option. Investors should continue to keep abreast of developments with the evolution of the diamond investments industry and physical diamonds can be included in a portfolio for their downside diversification potential.

1. Introduction

During times of economic distress, investors are observed to exhibit a flight-to-quality effect, where they rebalance their portfolios towards less risky securities such as fixed income and treasury bills (Abel, 1988; Barsky, 1989; Durand et al., 2010). More recently, investors have been examining the role of precious metals as a hedge or safe haven during highly volatile market conditions. Gold has been found to possess safe haven properties during extreme volatility in stock markets (Baur & Lucey, 2010). Other precious metals such as silver, platinum and palladium exhibit safe haven properties during periods that gold does not (Lucey and Li, 2013). Aside from precious metals, investments in precious stones have been shown to be effective diversifiers. Auer and Schuhmacher (2013) show that an investment in a diversified diamond portfolio can outperform a diversified stock market investment in a period of generally lackluster stock market performance. Similar conclusions are drawn by Renneboog and Spaenjers (2012) when applying hedonic regression to a unique data set of auction transactions involving investment-grade diamonds. Our work aims to contrast the respective investment performance of precious metals and diamonds during turbulent market conditions and crises across international stock markets. With diamonds being an increasingly valuable and popular asset choice, we investigate if diamonds possess the similar safe haven qualities as precious metals and the possibility that diamonds could supersede them as a superior alternative investment option due the flight-to-quality effect.

Historically gold has always been associated with adjectives such as valuable, expensive, and long lasting. Besides the application in jewelry fabrication and coins, its versatile and stable properties also make gold a desirable element in technology[1] and medicine[2]. The demand for gold increased drastically after the Global Financial Crisis in 2008, signifying its flight-to-quality characteristics when uncertainty escalates in global markets, and subsequently resulted in a price surge (Biakowski et al., 2015). In 2015, the price of gold has dropped, yet it still remains well above the pre-crisis level. Although demand in jewelry and technology continues to decline, the growth in gold as an investment continues on an upward trend (Street et al., 2015). Diamonds on the other hand, have only been explored as a potential safe haven asset after 2000 (Popper,

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[1] As mentioned by Street et al. (2015), the applications of gold in technology include bonding wires and semiconductors.

[2] Examples of application of gold nanoconjugates in biology and medicine are regulating agents, drug carriers, and intercellular agents (Giljohann et al., 2010).

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1057-5219/

2012). Under promotion by aggressive advertising by various diamond retail brands, it has become a symbol for romance and wealth. The steadily growing demand for diamonds poses a serious challenge to the diamond industry, as no major discoveries of new diamond sites have been made over the past two decades (Fischler et al., 2014). As the wealthy and middle-class population continues to expand in developing countries such as China and India, this will eventually lead to a widened gap between demand and supply. Currently diamonds as an investment only accounts for 5% of the entire diamond demand, as it is hindered by the lack of price transparency and market liquidity (Fischler et al., 2014). However, with the evolution of digitalization and online sales, the transparency of diamond prices will eventually be improved (Goodman et al., 2014), thus encouraging more investors to seek the asset as an alternative investment. Low volatility and stable returns are the safe haven characteristics found in precious metal investments, that make it valuable. Thus for investors who value low downside volatility and stable returns due to the economics of low supply and high demand, do precious metals or diamonds work best? More informed decisions can made when investors understand the dynamics between diamonds, precious metals and international equity markets.

We enhance the analysis introduced by Baur and Lucey (2010) by applying the GJR-GARCH model to capture the asymmetric effects where the market returns exhibit greater volatility in response to bad news as opposed to good news. Our sample spans 8 countries, covering major economies in continents including Americas, Asia-Pacific and Europe. The effect of common precious metals have been tested thoroughly in previous studies, against stock markets, bond markets, currencies, as well as exchange rates (Baur & Lucey, 2010; Baur & McDermott, 2010; Capie et al., 2005; Ciner et al., 2013; Joy, 2011; Lucey & Li, 2013; Pukthuanthong & Roll, 2011; Pullen et al., 2014). The behaviors of diamonds have also been evaluated by several papers (Auer & Schuhmacher, 2013; Renneboog & Spaenjers, 2012). Chong et al. (2012) find long-range dependency in certain diamond categories internationally. Auer (2014) explores the returns of diamond indices and compares their performance against gold and silver. Our work is extensive as it includes four precious metals (i.e., gold, silver, palladium, and platinum) that have appeared in earlier studies, and rhodium[3]. We evaluate a number of diamond indices, and include high quality physical diamond prices as a more comprehensive representation of the diamond asset group. Furthermore this provides additional guidance for investors regarding the benefits of either directly investing in physical diamonds or an indirect investment with diamond indices.

Among the precious metals group, we find that gold and silver present safe haven abilities in countries like the US, Germany, France, and Australia, with the effect being relatively strong in extreme market conditions. Platinum and palladium work in selective countries such as European countries and Australia. Being a lesser-known yet indispensable member of the jewelry world, we find that as an investment choice, rhodium is just as qualified as gold. Furthermore, it is capable of acting as a strong safe haven during highly volatile times to Australia, Americans, and European countries. As the hedge or safe haven properties exerted by diamond indices are fairly limited, we conclude that it is more effective for investors to hold physical high quality diamonds to protect themselves against a volatile market. It is worth noting that although the overall performance of precious metals outperforms diamonds as alternative investments, 1 carat D flawless diamonds stand out as a strong hedge and safe haven.

The novel contribution of this paper lies in the direct performance comparison between precious metals and diamonds across several international country indices. Out study also facilitates the comparison between investing in diamond indices (indirect investment) and physical diamonds (direct investment). Our precious metals data set is more comprehensive as it includes rhodium. Prior studies have not investigated the safe haven and hedge properties of rhodium, thus its correlation properties with different international equities' market remains as of yet unknown. Similarly, diamond prices have yet to undergo an extensive examination. As diamonds are a relatively new addition to the investment field, investors who are interested in diamonds would benefit from understanding the respective interaction between diamond index, diamond price, and the market. By comparing across commodities that share the qualities of being precious and rare assets, investors will have a greater understanding of the best options available when it comes to protect their investment portfolios during periods of market uncertainty and minimizing downside risk exposure.

The paper is organized as follows. Section 2 reviews the literature relevant to our study, including safe haven and hedge characteristics of diamonds and precious metals. Section 3 describes our data set of precious commodities and international equity indices. Research methods and our empirical models are discussed in detail in Section 4, while our analysis across different international indices is presented in Section 5. Section 6 concludes our study.

2. Literature review

Baur and Lucey (2010) describe that the distinction between a hedge and a safe haven rests on the duration of the negative correlation that an asset has with the market. A hedge is defined as an asset that correlates negatively (or uncorrelated if it is a weak hedge) with the market on average, and a safe haven is defined as such asset that correlates negatively (or uncorrelated if it is a weak safe haven) with the market in certain periods only.

McCown and Zimmerman (2006) demonstrate gold's zero-beta property by using the CAPM and find evidence of its inflation-hedging properties. Baur and McDermott (2010), Baur and Lucey (2010) find that gold generally acts as a safe haven against international stock markets, although at varying degrees depending on the country, and generally stronger (weaker) for developed (emerging) markets. Baur and Lucey (2010) explain that due to the influence of exchange rate fluctuations, gold is not a hedge for most indices except North America. Gold proves to be a safe haven during the peak of financial crisis periods, however the effects are exclusive to most developed markets. Similar results are shown under increased world volatility, where gold exhibits hedge as well as safe haven qualities for developed countries. They conclude that evidence suggests that investors in developed and emerging markets react to negative shocks differently. Reboredo (2013) reaches a similar conclusion, that apart from serving as hedge, gold is also an effective safe haven against extreme USD rate movements. When comparing different instruments as investment in gold, it is established that both gold bullion and gold ETFs show support for the safe haven property as opposed to gold stocks and gold mutual funds, which display very little evidence of the safe haven characteristic (Pullen et al., 2014). By analyzing both data from the US and UK market, Ciner et al. (2013) suggest the hedging role of gold against exchange rate fluctuations, and gold is found to be a consistent safe haven in the UK market. Bampinas and Panagiotidis (2015) report that on average, the hedging ability of gold against inflation is stronger in the US as opposed to the UK. For countries with a religion factor such as Malaysia, the domestic Islamic gold account gives inferior performance in comparison to official gold, during extreme market downturns (Ghazali et al., 2015). Joy (2011) states that gold does not act as a safe haven from market stress, no evidence was discovered to suggest that gold has acted as an effective safe haven. As for US dollars in particular, it is found that gold has been a valuable hedge against currency risks associated with the US dollar. Evidences found by Reboredo (2013), Joy (2011), Capie et al. (2005) support the findings that gold can act as a hedge against movements in USD. Pukthuanthong and Roll (2011) extend the research to other currencies and find that US dollars is not the only currency that gold is

[3] Rhodium is an important component in jewelry as it is corrosion resistant and is often used to plate cosmetic jewelry (e.g., engagement rings). The industry demand for rhodium mainly comes from automakers. Rhodium acts as a catalyst, and converts vehicle emissions into substances that are less harmful to the environment.

negatively associated to, the same relationship also applies to Euro, Yen and Pound. Through exclusive study of French portfolios, Hoang et al. (2015) confirm that a difference exists in the diversification role that gold plays with stock and bond. While gold is a good diversifier for stock portfolios, it is not the optimal choice when comes to bond portfolios. As a hedge for traditional assets, Bredin et al. (2015) conclude that the effect of gold can sustain for up to one year.

Other literatures broaden the commodities under study towards other precious metals. Among gold, silver and platinum, gold proves to be the optimal choice for a hybrid portfolio which offers the most efficiency gains (Hillier et al., 2006). Resulting from the popularity of gold as an effective choice for managing risk, Charles et al. (2015) find that the gold market is the most efficient.Conover et al. (2009) conclude that improvements in portfolio performance can be achieved by either investing directly or indirectly in precious metals, with effects found to be more prominent by investing indirectly. Via an analysis of quarterly data, Lucey and Li (2013) find evidence that suggests that at certain times silver, platinum and palladium can act as safe haven when gold does not, and the effect can sometimes be stronger. An example would be the decline of equity market in 1996, where silver maintains a more effective safe haven. In the US stock market, Hood and Malik (2013) show that unlike gold, platinum and silver act as neither hedge nor safe haven. Furthermore, they find that although gold serves as a hedge and a weak safe haven, does not exhibit negative correlation with the US market during periods of extreme negative returns.

Only a handful of studies investigate the characteristics of diamonds as an alternative investment asset. Renneboog and Spaenjers (2012) find evidence of relatively superior performance of diamonds compared to the global equities market. Contrasting evidence was presented by Auer (2014), the effect of diamonds as diversifier against international stock market downturns is actually weak. Chong et al. (2012) utilize modified rescaled range (R/S) statistic and show that diamond daily returns do not have long memory in volatility.

Auer and Schuhmacher (2013) establish the potential diversifier role of diamonds in the world portfolio. They apply a correlation analysis using dynamic conditional correlation GARCH (DCC-GARCH) model, and find that all 10 diamond indices studied exhibit low correlations with each of the three components of the world portfolio (i.e. stock, bond, and commodity). Thus, they conclude that diamonds are at best a hedge and a weak safe haven, and close-to-zero correlations with traditional asset classes may signify diversification potential. They apply a further step to directly compare the risk-adjusted performance between world market portfolio that contains a certain diamond index and the original world portfolio. They find that incorporation of a diamond index within the investment portfolio can indeed increase portfolio performance. They find that among all indices, the best risk-reducing performance is given by the 1.0 carat mixed diamond index. With an investment proportion of 30%, the mixed index can increase the mean return of portfolio by 12% comparing to a portfolio with no investment in diamond index. However, these promising results come at a price, whereby a high proportion (i.e. 30%) of diamonds is required to achieve these performance outcomes. In contrast, such considerable effects can be achieved using gold at weight of 5%-10% within the investment portfolio.

Auer (2014) compares the investment performance of diamond indices with that of gold and silver. He reports that the two precious metals clearly offer a better performance than the former based on the Sharpe ratio of weekly returns as a simple measure. The author further verifies that 1.0 carat class is the most profitable. He finds that lower risks are found in a diversified diamond portfolio compared to investments in precious metals.

3. Data

The data set consists of daily returns of 5 precious metals (gold, silver, platinum, palladium and rhodium), 2 diamond prices (D Flawless grade, 1 carat and 3 carat respectively), and 6 PolishedPrices diamond indices. A total of 7 country indices (Australia, China, US, UK, France, Germany, and Brazil) are also included. All data are sourced from Datastream. Data covers a period from Aug 4, 2003 to Aug 2, 2013, a total sample size of 2610 observations. The major market turmoils encompasses during the period are Global Financial Crisis (GFC) in 2008 and more recently the downgrade of US credit ratings for the first time from AAA to AA+ in 2011. The duration of crisis periods are set be 20 days after each crisis starts, which is consistent with the crisis periods defined in Baur and McDermott (2010). The explicit crisis period is set from September 12, 2008 to October 2, and July 23, 2011 to August 12 for US credit downgrade. The start and end points of metal data are selected to equal the diamond group to facilitate a robust comparison between both commodities classes and ensuring the integrity of our empirical analysis.

Diamond indices are a group of 10 indices published by PolishedPrices since 2002. Apart from the overall diamond index, the remaining 9 indices are constructed based on different weights, namely 0.3 carat, 0.5 carat and 1 carat. Each weight category is classified further based on quality threshold. Quality classifications are fine, commercial, and mixed to reflect the grade and applications of diamonds in the class.

Table 1 exhibits descriptive statistics of our data and it is shown that precious metals generally have lower standard deviation than diamonds. The diamond group exhibits more extreme maximum and minimum returns, with two diamond prices having the highest maximum and lowest minimum. A closer look at risk-adjusted ratios reveals that precious metals offer higher returns, which is consistent with the previous analysis of Auer (2014). Gold unsurprisingly proves to be the most profitable. While the mean return of gold is among the highest in precious metals, it is found that returns of gold on weekends are significantly lower than on weekdays. The return would have resulted in an even higher figure without the influences from the uneven performance of returns (Blose & Gondhalekar, 2013). The results of 3 carat D flawless diamonds are the exemplar of all assets investigated.

Fig. 1 shows the prices of precious metals and we find that the prices of silver, platinum, palladium, and rhodium all suffered during the 2008 GFC. Rhodium exhibits the largest price drop. After a dramatic surge in price prior to 2008, rhodium lost well over half its value from the highest point of over $10,000 per ounce in late June, 2008 to $1,000 per ounce in late November. In contrast, the price of gold dropped from a high of $900 per ounce to a low of $720, suggesting that it is the most stable commodity within the group. The gentle upward trend of the price of gold is evident throughout the entire length of data set. Seeing an end to the post-crisis recovery in rhodium price in 2010, it continued its downward trend through rest of the data period. Silver however, continues its recovery until reaching a peak price in early 2011. The fluctuation of diamond indices is greatly influenced by 1 carat fine index as shown in Fig. 2. From Fig. 3, it is clear that the 3 carat D flawless price responded fiercely to world portfolio turbulence and tends correlate well with the world index. In contrast, the price of 1 carat diamonds experienced less volatility. As the world index dived in early 2008, the price of 1 carat D flawless diamonds moved in the opposite direction thus exhibiting negative correlation with the market under stressful conditions. Similarly, when the world index plunged from 1350 to around 1150, conversely the 1 carat D flawless rose in price.

4. Research method

The initial stage of our analysis utilizes the following model which was first proposed and used by Baur and Lucey (2010):

$$r_{asset,t} = a + b_t r_{stock,t} + \varepsilon_t \quad (1)$$

$$b_t = c_0 + c_1 D(r_{stock} q_{10}) + c_2 D(r_{stock} q_5) + c_3 D(r_{stock} q_1) \quad (2)$$

Table 1
Descriptive statistics of all asset returns in local currencies and all index returns in US dollars.
This table shows the descriptive statistics of daily returns data for all assets explored from Aug 2003 to Aug 2013. Thereby yielding 2610 observations for each asset explored. 9 types of descriptive statistics are calculated for each asset (namely mean return, Standard deviation, skewness, kurtosis, minimum return, maximum return, Sharpe ratio, value at risk, and mean return divide by conditional value at risk). In Panel A, the returns for each country index is denominated in the local currency. In Panel B and Panel C, the returns for the precious metals and diamonds are denominated in US dollars.

Assets	Mean	Std. Dev.	Skew	Kurt	Min	Max	Sharpe	VaR	Mean/CVaR
Panel A: Countries									
Australia	0.020	0.011	−0.383	8.526	−0.087	0.061	0.018	−0.018	−0.007
Brazil	0.046	0.017	−0.150	7.124	−0.141	0.134	0.027	−0.027	−0.011
China	0.044	0.019	−0.052	9.504	−0.128	0.140	0.023	−0.029	−0.010
France	0.012	0.014	0.009	9.917	−0.093	0.104	0.009	−0.022	−0.004
Germany	0.023	0.014	0.015	9.740	−0.074	0.111	0.017	−0.022	−0.007
US	0.022	0.127	−0.351	14.440	−0.095	0.110	0.017	−0.019	−0.007
UK	0.018	0.012	−0.162	11.851	−0.092	0.093	0.015	−0.018	−0.006
Panel B: Precious metals									
Gold	0.051	0.012	−0.624	8.113	−0.102	0.069	0.041	−0.021	−0.016
Silver	0.053	0.022	−0.611	7.439	−0.130	0.137	0.024	−0.037	−0.009
Platinum	0.029	0.015	−1.003	13.573	−0.173	0.084	0.019	−0.023	−0.007
Palladium	0.054	0.022	−0.505	8.122	−0.179	0.109	0.024	−0.035	−0.010
Rhodium	0.024	0.020	−1.307	37.185	−0.248	0.198	0.012	−0.020	−0.005
Panel C: Diamonds									
1ct Comm.	0.014	0.031	0.092	6.655	−0.168	0.163	0.005	−0.052	−0.002
1ct Fine	0.016	0.037	−0.007	7.073	−0.189	0.199	0.004	−0.059	−0.002
0.5ct Comm.	0.005	0.028	0.793	17.010	−0.246	0.256	0.002	−0.037	0.00
0.5ct Fine	0.006	0.038	0.530	8.052	−0.206	0.198	0.002	−0.059	0.00
0.3ct Comm.	0.009	0.022	−0.075	20.941	−0.222	0.199	0.004	−0.027	−0.002
0.3ct Fine	0.005	0.040	0.570	11.751	−0.251	0.279	0.001	−0.056	0.00
3ct D Flawless	0.044	0.037	0.636	125.976	−0.607	0.598	0.012	0.00	−0.176
1ct D Flawless	0.022	0.067	−0.357	20.614	−0.624	0.553	0.003	−0.089	−0.001

$$h_t = \omega + \alpha\varepsilon_{t-1}^2 + \beta h_{t-1}. \quad (3)$$

Eq. (1) models the relation of each metal (gem) and stock returns. The parameters b_t are modeled as a dynamic process given by Eq. (2). D(…) are dummy variables to capture extreme stock market movements, taking a value of one if stock market return at time t exceeds a certain threshold given by the 10%, 5% and 1% quantiles of the return distribution, and zero otherwise. The residual term e_t is modeled as a GJR-GARCH process Glosten et al. (1993). All equations are jointly estimated with Maximum Likelihood methods.

If any of the parameters c_1, c_2 or c_3 is significantly different from zero, then this suggests a relationship between the asset in question and the stock market. If the parameters in Eq. (2) are non-positive, the asset acts as a weak safe haven. If the parameters are negative and statistically different from zero, the asset becomes a strong safe haven. In the event c_0 equals zero or negative, and the sum of the parameters c_1 to c_3 are not jointly positive exceeding the value of c_0, the asset serves as a hedge, where negative c_0 suggests strong hedge and a value of zero indicates weak hedge.

Choosing the conditional volatility of the world portfolio as a proxy for uncertainty, we can change the model under the assumption that as the uncertainty of the market changes, the asset–stock relation also varies. If the conditional volatility of the world index is estimated with a GJR-GARCH process, an alternative to Eq. (2) can be specified in equation as below:

$$b_t = c_0 + c_1 D(h_{world} q_{90,t-1}) + c_2 D(h_{world} q_{95,t-1}) + c_3 D(h_{world} q_{99,t-1}) \quad (4)$$

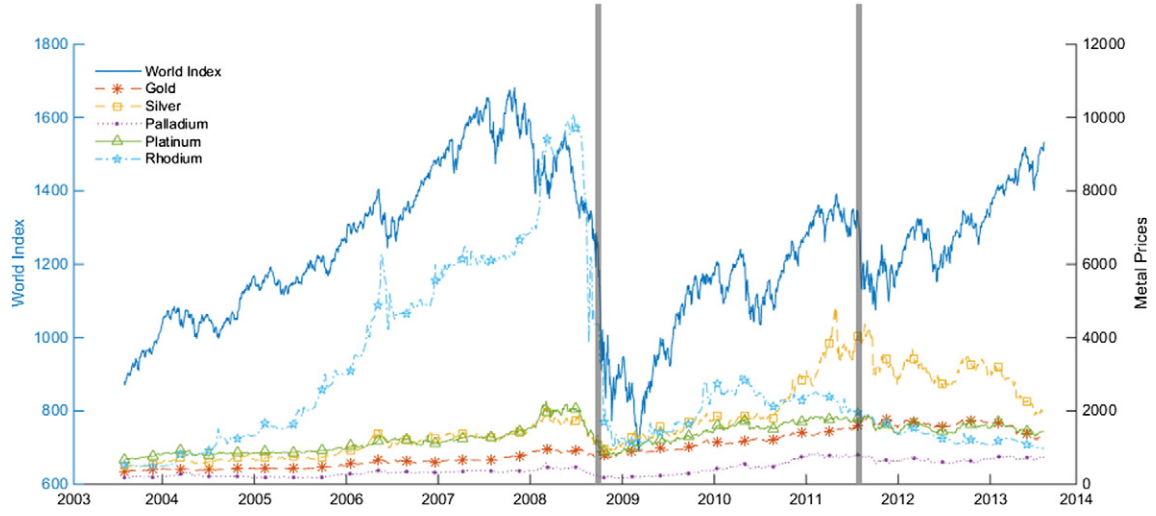

Fig. 1. Evolution of prices of precious metals. The figure exhibits data spanning the entire sample period from Aug 4, 2003 to Aug 2, 2013. Silver price is showed in a different unit (cent per troy ounce) than gold, platinum, palladium and rhodium (dollar per troy ounce). The world index is measured on the left vertical axis while metal prices are measured on the right vertical axis.

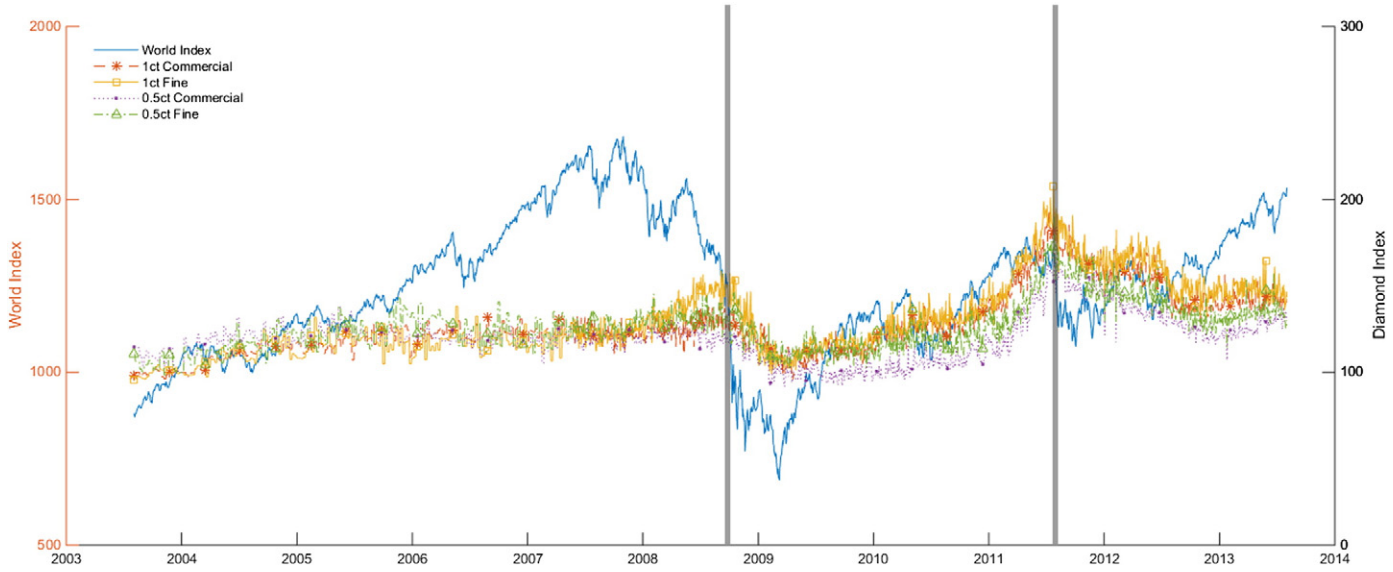

Fig. 2. Evolution of diamond indices. The figure exhibits data spanning the entire sample period of diamonds from Aug 4, 2003 to Aug 2, 2013. The world index is measured on the left vertical axis while diamond indices are measured on the right vertical axis.

where the dummy variable is equal to one if the lagged conditional volatility of the world index exceeds the 90%, 95%, and 99% quantiles and zero otherwise.

Finally, we identify certain periods such as economic or financial crises. Time dummies are equal to one if the returns fall within the predefined period and zero otherwise. Our data encompasses two major crisis periods, the Global Financial Crisis (GFC) and the downgrade of the US credit rating. The model would be specified as follows:

$$b_t = c_0 + c_1 D(\text{GFC}, 2008) + c_2 D(\text{US credit downgrading}, 2011). \quad (5)$$

If the parameters c_1 or c_2 are zero or negative, the asset is a safe haven in the respective crisis period. Alternatively, a positive parameter means that the asset co-moves with the market and is not a safe haven.

5. Results

5.1. Daily conditional volatility

The volatility level of precious metals and diamonds in the periods of study are presented in Figs. 4, 5, and 6. Within the diamond assets, diamond prices volatility is showed in Figs. 5 and 6 contains only diamond indices.

5.1.1. Precious metals

Fig. 4 displays the daily conditional volatility of precious metals against world index. Among all metal assets, rhodium fluctuated with the greatest magnitude. During 2008 GFC, the volatility of rhodium spiked along with world index, while others exhibited a comparatively flat trend. Gold revealed its safe haven quality by being the least volatile during the crisis period. Post 2008 crisis period, the 5 metals form two general trends, as distinguished by their

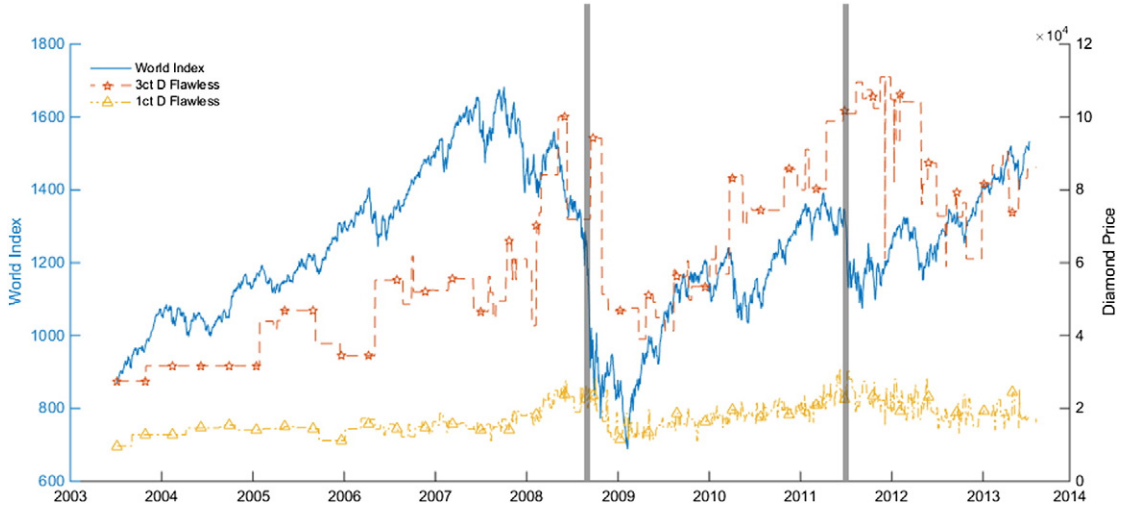

Fig. 3. Evolution of diamond prices. The figure exhibits data spanning the entire sample period of diamonds from Aug 4, 2003 to Aug 2, 2013. Evolution of prices of diamond prices. The world index is measured on the left vertical axis while diamond prices are measured on the right vertical axis.

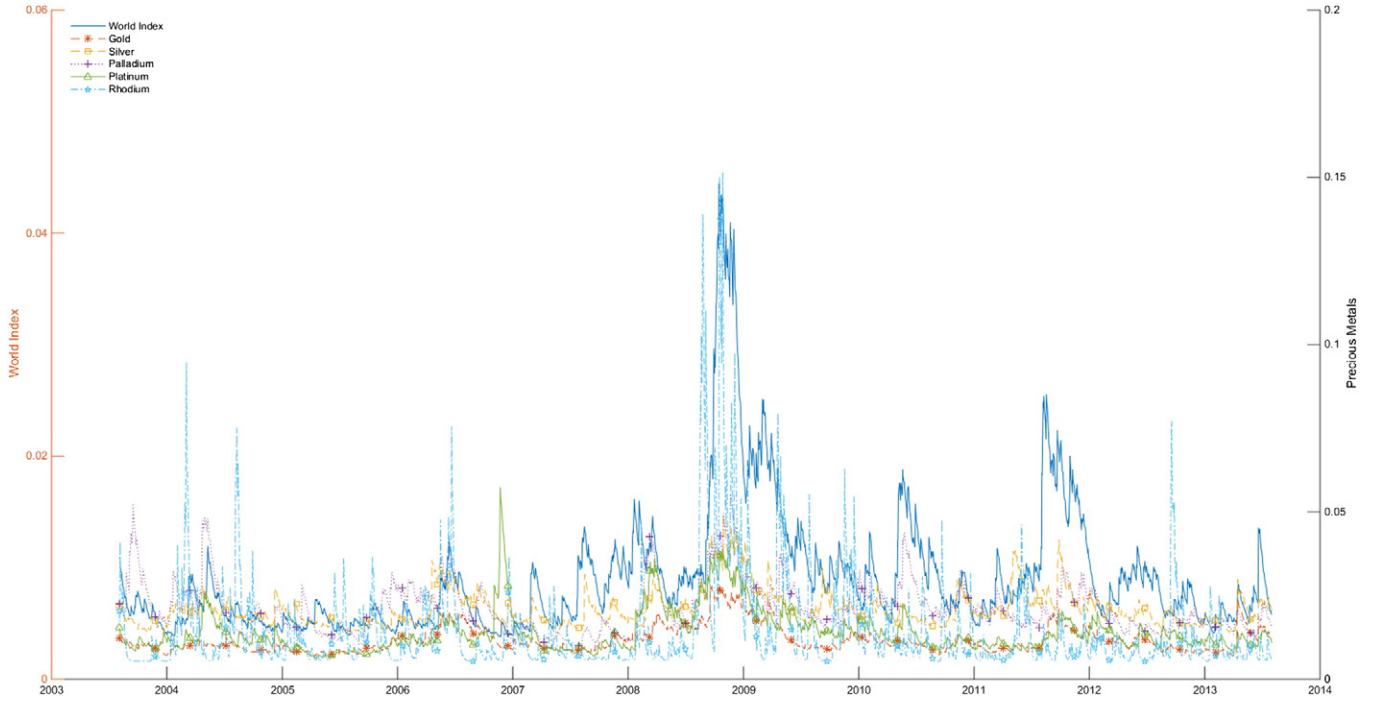

Fig. 4. Daily conditional volatility of precious metals and the World Index. GARCH GJR estimates of the World index return and the return on precious metals assets from Aug 4, 2003 to Aug 2, 2013.

respective magnitudes of volatility. The volatility of gold, silver, and rhodium is lower whereas platinum and palladium exhibit higher volatility. During the 2011 US credit rating downgrade crisis, in contrast to the sudden surge in world index volatility, all precious metals maintain a low level of volatility.

5.1.2. Diamonds

The conditional volatility of diamond prices is presented in Figs. 5 and 6 shows the conditional volatility of diamond indices. During the study period, the 1 carat fine index fluctuated with the highest amplitude. In contrast, the conditional volatility of 0.3 carat commercial index, shifted downward since 2006 and sustained a level of low volatility through the subsequent market turmoils. As the 2008 GFC struck the world market, both 1 carat fine index responded strongly by hitting a new high as measured by volatility. The 0.5 commercial index exhibits an upward trend in the later half of the 2008 crisis period. As for diamond prices, the volatility of 1 carat D flawless rose dramatically during GFC, a new high on volatility level was also recorded by 3 carat D flawless during that period. All diamond indices moved along in similar directions in the post-crisis times. An all-time high in volatility was

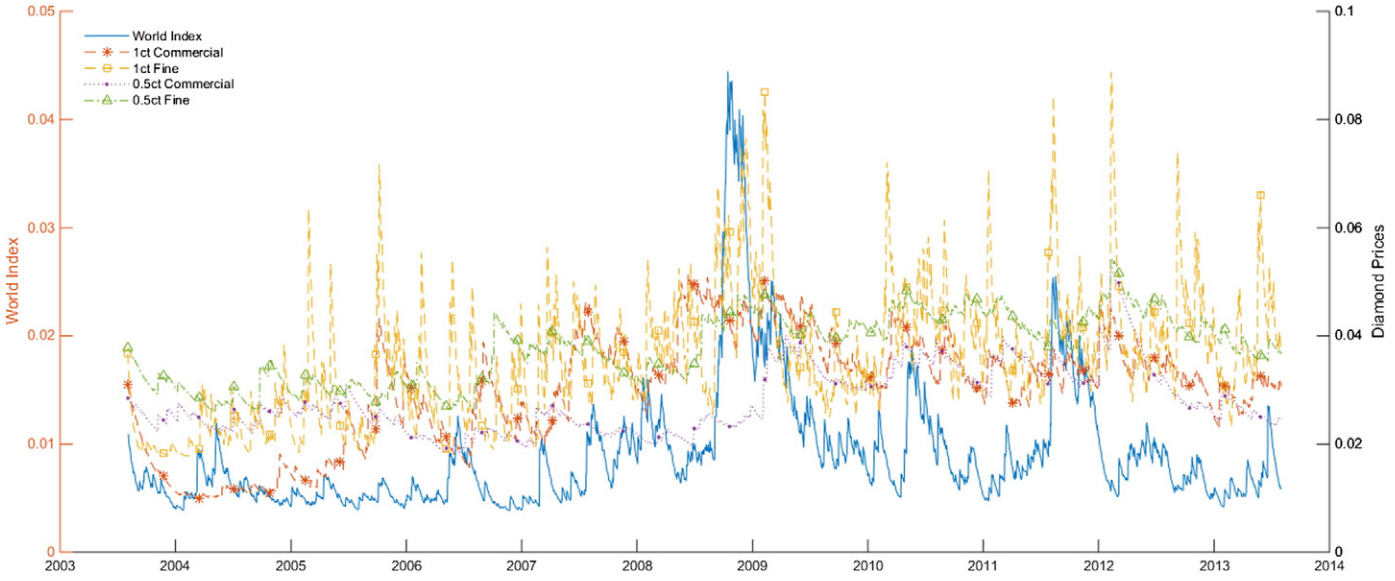

Fig. 5. Daily conditional volatility of diamond indices and the World Index. GARCH GJR estimates of the World index return and the return of diamond assets from Aug 4, 2003 to Aug 2, 2013.

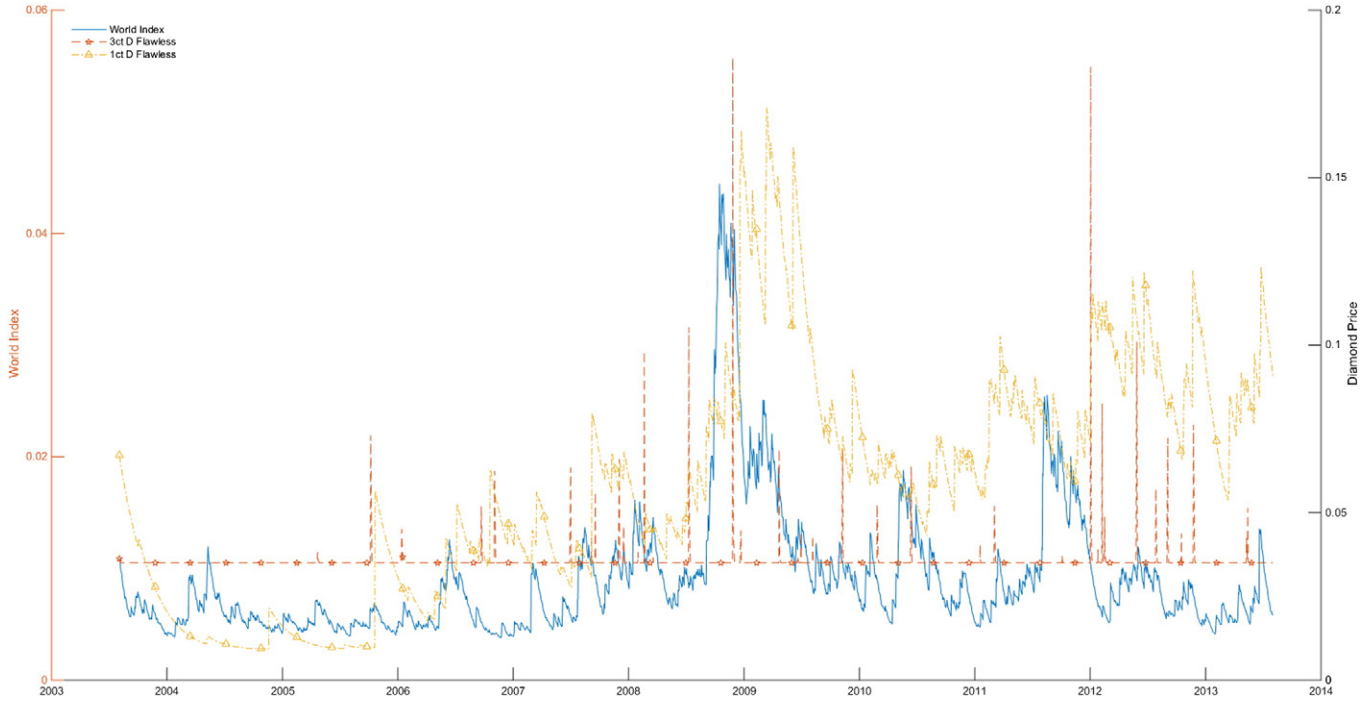

Fig. 6. Daily conditional volatility of diamond prices and the World Index. GARCH GJR estimates of the World index return and the return of diamond assets from Aug 4, 2003 to Aug 2, 2013.

achieved by 1 carat fine index, 0.5 commercial index, and 3 carat D flawless prices after the market turbulence in 2011 due to the downward change in US credit ratings.

5.1.3. Summary

Conditional volatility of precious metals show smaller magnitudes of oscillation compared to diamonds. While diamond prices and indices

Table 2
Hedge and safe haven properties of precious metals vs. diamonds (Americas: United States, Brazil).
This table presents the estimation results for precious metals, diamond indices, and prices for daily returns modeled by Eqs. (1), (2), and (3). The sample period dates from Aug 4, 2003 to Aug 2, 2013. Panels A and B represent results for the US and Brazil market index, respectively. Negative coefficients in the hedge column (c_0) signifies that the asset is a hedge against stocks. Zero (negative) coefficients in extreme market conditions, namely quantile 10% (c_1), 5% (c_2), and 1% (c_3) indicate that the asset is a weak (strong) safe haven. Each t-statistics column is associated with the coefficient column to the left, as an indication of the significance level.

		Hedge	t-Stats	Safe haven quantiles					
				10%	t-Stats	5%	t-Stats	1%	t-Stats
Panel A: United States									
Metals	Gold	0.094	3.793	−0.079	−1.271	0.129	1.989	−0.247***	−4.733
	Silver	0.321	7.407	−0.231*	−1.979	0.469	3.979	−0.423***	−3.866
	Platinum	0.165	5.424	−0.125*	−1.710	0.211	2.849	−0.180***	−2.695
	Palladium	0.218	4.843	−0.138	−1.174	0.303	2.660	−0.088	−1.035
	Rhodium	−0.043***	−2.475	0.112	2.350	−0.023	−0.490	0.249	9.488
Diamonds	3ct D Flawless	−0.020	−0.540	−0.302*	−1.909	0.242	0.648	0.076	0.005
	1ct D Flawless	0.006	0.050	−0.165	−1.009	−0.078	−0.218	−0.873**	−2.254
	1ct Fine	0.017	0.222	−0.364*	−1.926	0.573	2.715	0.467	2.486
	1ct Commercial	−0.110**	−2.055	−0.092	−0.488	0.277	1.164	0.048	0.222
	0.5ct Fine	0.098	1.251	−0.148	−0.503	0.028	0.091	0.284	1.482
	0.5ct Commercial	0.089	1.836	−0.099	−0.441	−0.064	−0.263	0.035	0.223
	0.3ct Fine	0.098	1.434	−0.077	−0.247	0.031	0.094	0.096	0.454
	0.3ct Commercial	0.027	0.626	−0.054	−0.407	0.090	0.658	0.008	0.082
Panel B: Brazil									
Metals	Gold	0.096	5.252	0.080	1.995	0.022	0.529	−0.032	−0.882
	Silver	0.308	10.350	0.112	1.626	0.036	0.469	−0.136*	−1.970
	Platinum	0.104	5.830	0.083	1.833	−0.039	−0.771	0.051	1.053
	Palladium	0.175	6.148	0.057	0.717	−0.043	−0.514	0.191	2.747
	Rhodium	0.021	1.816	−0.001	−0.037	−0.033	−0.749	0.174	6.033
Diamonds	3ct D Flawless	−0.065**	−2.131	−0.246**	−2.331	0.347	1.706	−0.027	−0.048
	1ct D Flawless	−0.054	−0.700	0.036	0.299	−0.998***	−9.706	0.756	6.702
	1ct Fine	0.018	0.366	−0.037	−0.246	0.109	0.587	0.317	1.828
	1ct Commercial	−0.006	−0.148	−0.113	−1.027	0.116	0.745	0.023	0.116
	0.5ct Fine	0.008	0.153	0.083	0.460	−0.029	−0.142	0.105	0.592
	0.5ct Commercial	0.019	0.526	0.097	0.667	−0.130	−0.662	0.028	0.178
	0.3ct Fine	0.01	0.183	−0.017	−0.089	0.162	0.705	−0.069	−0.289
	0.3ct Commercial	−0.007	−0.210	−0.068	−0.749	0.116	1.128	−0.024	−0.218

*, **, *** indicates statistical significance at the 10, 5, and 1 percent levels, respectively.

fluctuate at a higher amplitude than world index, volatility of metals hovers at a lower level. These higher volatilities reflect price changes, but do not reflect if these are upward or downward movements. It is likely that the higher volatilities as captured in our model are indications of upward changes in the prices of these precious assets due to market turbulence on the world equities index. Thus, our study continues to analyze the direction of the volatility by analyzing hedge and safe haven characteristics.

5.2. Hedge and safe haven: daily returns

The estimated results of the regression model given by Eqs. (1), (2), and (3) are reported in Tables 2, 3, and 4. The table contains the estimates of c_0 and the total effects for extreme market conditions, which is the sum of c_0 and c_1 for the 10% quantile, the sum of c_0, c_1, and c_2 for the 5% quantile, and the sum of c_0, c_1, c_2 and c_3 for the 1% quantile.

5.2.1. Precious metals

Under the GJR-GARCH model silver outperforms gold based upon the number of countries that it is an effective safe haven in, namely 6 out of 7 countries. Gold exhibits safe haven qualities for Australia, US, Germany, and France. Among all precious metals, rhodium is the only asset that functions as a strong hedge in the US. In most cases, all metals exhibit a safe haven quality when markets are at the 1% quantile. Looking at Australia, US, and France specifically, the safe haven effects of precious metals are relatively stronger. A closer analysis of the Australian market would reveal that all 5 metals correlate negatively with the market at the lowest quantile. As a previous study by Chan and Faff (1998) points out, a widespread sensitivity of Australian industry returns is associated with gold returns. For US, 4 out of 5 metals are effective safe havens or a hedge against the market, with the exception of palladium. As for France, all metals except for rhodium appear to be a strong safe haven at the lowest quantile. There exists at least one asset that acts as either a hedge or safe haven for rest of the countries in our study.

Table 3
Hedge and safe haven properties of precious metals vs. diamonds (Europe: UK, Germany, France).
This table presents the estimation results for precious metals, diamond indices, and prices for daily returns modeled by Eqs. (1), (2), and (3). The sample period is from Aug 4, 2003 to Aug 2, 2013. Panel A, B, and C represent results for the UK, Germany and France market index, respectively. Negative coefficients in the hedge column (c_0) signifies that the asset is a hedge against stocks. Zero (negative) coefficients in extreme market conditions, namely quantile 10% (c_1), 5% (c_2), and 1% (c_3) indicate that the asset is a weak (strong) safe haven. Each t-statistics column is associated with the coefficient column to the left, as an indication of the significance level.

		Hedge	t-Stats	Safe haven quantiles					
				10%	t-Stats	5%	t-Stats	1%	t-Stats
Panel A: United Kingdom									
Metals	Gold	0.134	5.176	0.092	1.519	−0.053	−0.862	−0.047	−0.836
	Silver	0.500	11.150	0.089	0.788	0.108	0.934	−0.003	−0.039
	Platinum	0.243	8.661	0.174	2.424	−0.125*	−1.670	−0.018	−0.227
	Palladium	0.410	10.660	0.169	1.573	−0.171	−1.507	0.178	2.044
	Rhodium	−0.02	−0.893	0.035	0.700	0.028	0.520	0.124	3.110
Diamonds	3ct D Flawless	0.020	0.259	−0.259	−1.293	0.188	0.946	0.044	0.005
	1ct D Flawless	0.102	0.873	−1.921***	−13.000	1.788	10.400	−1.195***	−6.371
	1ct Fine	0.063	0.796	0.051	0.223	0.128	0.551	0.390	1.681
	1ct Commercial	−0.078	−1.327	0.125	0.587	0.029	0.114	−0.034	−0.147
	0.5ct Fine	−0.020	−0.236	0.149	0.657	−0.296	−1.136	0.476	2.094
	0.5ct Commercial	0.060	1.259	−0.138	−0.795	0.077	0.379	0.005	0.029
	0.3ct Fine	−0.040	−0.511	0.156	0.608	−0.228	−0.858	0.312	1.561
	0.3ct Commercial	0.006	0.133	0.061	0.582	−0.041	−0.318	0.076	0.538
Panel B: Germany									
Metals	Gold	0.100	4.720	0.091	1.934	−0.091*	−1.912	−0.010	−0.214
	Silver	0.348	9.216	0.258	3.020	0.014	0.157	−0.313***	−3.587
	Platinum	0.186	8.285	0.083	1.345	0.020	0.290	−0.053	−0.956
	Palladium	0.290	8.520	0.165	2.011	0.051	0.520	−0.150*	−1.846
	Rhodium	−0.012	−0.799	0.011	0.258	0.043	0.882	0.024	0.472
Diamonds	3ct D Flawless	0.076	1.604	−0.126	−0.286	−0.144	−0.314	0.185	0.011
	1ct D Flawless	0.098	1.035	−0.473**	−2.015	0.368	1.710	−0.360*	−1.730
	1ct Fine	0.037	0.586	−0.054	−0.308	0.293	1.569	0.154	0.789
	1ct Commercial	−0.092*	−1.885	0.135	1.046	−0.008	−0.047	−0.012	−0.058
	0.5ct Fine	0.018	0.263	−0.042	−0.215	−0.074	−0.322	0.221	1.118
	0.5ct Commercial	0.076	1.681	−0.159	−0.992	−0.084	0.459	−0.023	−0.168
	0.3ct Fine	0.022	0.328	−0.286	−1.360	0.197	0.897	0.094	0.538
	0.3ct Commercial	0.019	0.476	0.049	0.468	−0.045	−0.367	−0.040	0.364
Panel C: France									
Metals	Gold	0.084	3.795	0.016	0.279	0.087	1.518	−0.101***	−2.040
	Silver	0.341	9.200	−0.018	−0.180	0.448	4.651	−0.468***	−5.950
	Platinum	0.188	8.451	−0.010	−0.160	0.204	3.003	−0.173***	−2.780
	Palladium	0.309	8.993	−0.030	−0.290	0.367	3.409	−0.255***	−3.320
	Rhodium	−0.007	−0.510	−0.009	−0.190	0.065	1.246	0.021	0.416
Diamonds	3ct D Flawless	0.062	1.394	−0.062	−0.100	−0.038	−0.060	0.028	0.009
	1ct D Flawless	0.093	0.897	−0.046	−0.190	−0.032	−0.170	−0.292	−1.310
	1ct Fine	0.034	0.549	0.096	0.594	0.138	0.794	0.268	1.434
	1ct Commercial	−0.059	−1.190	0.086	0.603	−0.059	−0.320	0.119	0.608
	0.5ct Fine	0.010	0.141	−0.001	−0.010	−0.149	−0.630	0.292	1.616
	0.5ct Commercial	0.074	1.700	−0.205	−1.280	0.162	0.891	−0.110	−0.82
	0.3ct Fine	0.018	0.281	−0.107	−0.480	0.019	0.080	0.119	0.706
	0.3ct Commercial	0.019	0.502	−0.063	−0.670	0.065	0.636	0.00	0.002

*, **, *** indicates statistical significance at the 10, 5, and 1 percent levels, respectively.

Table 4
Hedge and safe haven properties of precious metals vs. diamonds (Asia-Pacific: Australia, China).
This table presents the estimation results for precious metals, diamond indices, and prices for daily returns modeled by Eqs. (1), (2), and (3). The sample period is from Aug 4, 2003 to Aug 2, 2013. Panels A and B represent results for the Australia and China market index, respectively. Negative coefficients in the hedge column signifies (c_0) that the asset is a hedge against stocks. Zero (negative) coefficients in extreme market conditions, namely quantile 10% (c_1), 5% (c_2), and 1% (c_3) indicate that the asset is a weak (strong) safe haven. Each t-statistics column is associated with the coefficient column to the left, as an indication of the significance level.

		Hedge	t-Stats	Safe haven quantiles					
				10%	t-Stats	5%	t-Stats	1%	t-Stats
Panel A: Australia									
Metals	Gold	0.129	4.771	0.104	1.306	−0.027	−0.340	−0.240***	−2.920
	Silver	0.308	6.346	0.180	1.397	−0.062	−0.470	−0.179*	−1.850
	Platinum	0.338	11.750	0.070	1.011	0.046	0.629	−0.209***	−3.040
	Palladium	0.466	11.410	0.105	0.883	0.089	0.716	−0.155**	−2.140
	Rhodium	−0.023	−1.250	0.081	1.532	0.003	0.044	−0.172***	−3.310
Diamonds	3ct D Flawless	−0.087	−0.690	0.227	0.822	0.216	1.029	−1.302***	−11.000
	1ct D Flawless	−0.031	−0.240	0.006	0.014	−2.832***	−6.550	2.183	12.000
	1ct Fine	0.034	0.437	0.029	0.143	−0.267	−1.230	0.261	1.093
	1ct Commercial	0.115	1.760	0.059	0.244	−0.046	−0.160	−0.253	−1.180
	0.5ct Fine	−0.047	−0.520	0.381	1.458	−0.276	−0.920	−0.247	−0.880
	0.5ct Commercial	−0.095	−1.390	0.207	1.082	−0.135	−0.620	−0.075	−0.520
	0.3ct Fine	−0.072	−0.850	−0.056	−0.250	0.284	1.048	−0.349	−1.230
	0.3ct Commercial	−0.029	−0.540	0.064	0.521	0.068	0.537	−0.186*	−1.880
Panel B: China									
Metals	Gold	0.119	7.083	−0.032	−0.797	0.050	1.170	−0.013	−0.351
	Silver	0.238	8.011	−0.126*	−1.697	0.233	3.293	−0.057	0.949
	Platinum	0.225	13.390	0.001	0.038	−0.018	−0.420	−0.003	−0.071
	Palladium	0.254	10.640	0.046	0.710	0.028	0.414	−0.057	0.993
	Rhodium	−0.002	−0.187	−0.019	−0.575	0.016	0.389	0.017	0.291
Diamonds	3ct D Flawless	−0.020	−0.554	0.176	1.233	−0.158	−0.815	0.006	0.000
	1ct D Flawless	0.005	0.070	−1.118***	−11.650	1.051	6.998	−0.052	−0.239
	1ct Fine	0.024	0.529	−0.074	−0.623	0.058	0.444	0.141	0.901
	1ct Commercial	−0.003	−0.074	−0.007	−0.043	0.052	0.286	−0.033	0.238
	0.5ct Fine	0.070	1.421	−0.171	−1.252	0.026	0.167	0.119	0.870
	0.5ct Commercial	0.00	0.019	−0.172	−1.361	0.124	0.868	0.066	0.590
	0.3ct Fine	−0.034	−0.663	0.077	0.558	−0.071	−0.447	0.042	0.242
	0.3ct Commercial	−0.010	−0.336	−0.043	−0.500	0.065	0.707	−0.017	−0.205

*, **, *** indicates statistical significance at the 10, 5, and 1 percent levels, respectively.

Table 5
Hedge and safe haven properties of precious metals vs. diamonds during different levels of world volatility (Americas: US, Brazil).
This table presents the estimation results for precious metals, diamond indices, and prices in periods of increased (90% and 95%) or extreme world volatility (99%) modeled by Eq. (4). Panels A and B represent results for the US and Brazil market index, respectively. Negative coefficients in the hedge column (c_0) signifies that the asset is a hedge against the market. Negative coefficients in subsequent columns show that it is a safe haven when the world volatility exceeds 90% (c_1), 95% (c_2), and extreme level 99% (c_3). Each t-statistics column is associated with the coefficient column to the left, as an indication of the significance level.

Asset		Hedge		Volatility > 90%		Volatility > 95%		Volatility > 99%	
		Coeff.	t-Stats	Ttl. eff.	t-Stats	Ttl. eff.	t-Stats	Ttl. eff.	t-Stats
Panel A: United States									
Metals	Gold	0.12	5.86	−0.04***	−3.49	0.14	0.42	0.02	−1.31
	Silver	0.39	10.50	0.20**	−2.44	0.37	−0.22	0.20	−1.41
	Platinum	0.20	8.30	0.09**	−2.16	0.18	−0.29	0.29	0.71
	Palladium	0.24	6.41	0.29	0.65	0.17	−0.81	0.20	−0.33
	Rhodium	0.00	0.09	−0.21***	−13.20	0.16	5.25	0.40	9.30
Diamonds	3ct D Flawless	−0.24***	−5.01	0.00	0.59	−0.22	0.02	1.36	3.06
	1ct D Flawless	−0.03	−0.32	0.04	0.23	−0.96**	−2.46	2.13	13.60
	1ct Fine	0.03	0.41	0.15	0.77	0.10	0.34	0.10	0.33
	1ct Comm.	−0.12**	−2.01	0.05	1.30	−0.22	−0.63	0.09	0.94
	0.5 ct Fine	0.06	0.73	0.03	−0.16	0.08	0.06	0.45	1.95
	0.3 ct Fine	−0.01	−0.12	0.18	0.90	−0.18	−0.68	1.01	5.45
	0.3 ct Comm.	0.04	0.88	0.05	0.12	−0.03	−0.59	0.18	1.48
Panel B: Brazil									
Metals	Gold	0.15	11.93	0.03***	−3.49	0.14	−0.18	0.14	−0.16
	Silver	0.37	15.58	0.24**	−2.06	0.34	−0.26	0.40	0.29
	Platinum	0.13	8.45	0.09	−1.36	0.10	−0.50	0.37	2.03
	Palladium	0.19	7.96	0.28	1.56	0.10	−0.85	0.43	1.57
	Rhodium	0.01	0.86	−0.21***	−16.42	0.25	6.89	0.24	5.46
Diamonds	3ct D Flawless	−0.13***	−3.42	−0.01	0.28	−0.09	0.09	1.05	4.56
	1ct D Flawless	−0.12**	−2.43	−0.31	−0.76	−0.39	−0.82	0.18	0.83
	1ct Fine	0.03	0.58	0.11	0.65	0.22	1.09	−0.04	−0.35
	1ct Comm.	−0.02	−0.43	−0.03	−0.06	−0.11	−0.55	0.18	0.97
	0.5 ct Fine	0.03	0.65	0.09	0.29	−0.06	−0.37	0.17	0.79
	0.5 ct Comm.	0.02	0.59	0.08	0.49	−0.23**	−2.09	0.29	2.89
	0.3 ct Fine	0.00	0.07	0.18	0.84	−0.16	−0.54	0.32	1.48
	0.3 ct Comm.	0.00	−0.05	0.03	0.26	−0.05	−0.41	0.02	0.21

*, **, *** indicates statistical significance at the 10, 5, and 1 percent levels, respectively.

5.2.2. Diamonds

Within the diamond category, the 1 carat with flawless clarity is the most influential asset, acting as a safe haven at different quantiles against 6 countries (only France is excluded). It is however, not a hedge. Their pricier version, the 3 carat flawless diamonds, is also a safe haven in Australian, US, and Brazilian markets. The hedging characteristics of 3 carat diamonds is only apparent in the Brazilian market. In terms of diamond indices, in the 1 carat category, the commercial index exerts hedging capability in both US and Germany while the fine index works as a safe haven at the 10% quantile in the US. The only effect of 0.3 category is within the commercial category as a safe haven against the Australian market. The 0.5 carat group, however, is ineffective as a hedge or safe haven in all markets explored in our study.

5.2.3. Summary

Precious metals act as safe haven at the lowest quantile in most circumstances. There exists a tendency that for countries with more precious metals acting as safe havens, there is an higher likelihood for more categories within the diamond group in demonstrating hedge or safe haven characteristics. This observation is not applicable to France, as no diamond index or physical diamond asset proves to be a hedge or safe haven for this market.

5.3. Hedge and safe haven: world Volatility

Tables 5, 6, and 7 presents the estimation results of the model specified in Eq. (4). Three levels of volatility (90%, 95%, and 99%) are chosen as a proxy for global financial market uncertainty. To ensure consistency, the GJR-GARCH model is applied in calculating the conditional volatility of the world index.

5.3.1. Precious metals

Rhodium offers the best protection against all markets, in periods of volatility surpassing 90% or 95%, but not under extreme volatility (99%). The negative correlation between rhodium and the markets are significantly strong, signifying its reliable safe haven quality when the world index fluctuates at a high level. Gold acts as a safe haven for China, US, Germany, and France, with the effect being stronger for the latter

Table 6
Hedge and safe haven properties of precious metals vs. diamonds during different levels of world volatility (Europe: UK, Germany, France).
This table presents the estimation results for precious metals, diamond indices, and prices in periods of increased (90% and 95%) or extreme world volatility (99%) modeled by Eq. (4). Panels A, B, and C represent results for the UK, Germany, and France market index, respectively. Negative coefficients in the hedge column (c_0) signifies that the asset is a hedge against the market. Negative coefficients in subsequent columns show that it is a safe haven when the world volatility exceeds 90% (c_1), 95% (c_2), and extreme level 99% (c_3). Each t-statistics column is associated with the coefficient column to the left, as an indication of the significance level.

Asset		Hedge		Volatility > 90%		Volatility > 95%		Volatility > 99%	
		Coeff.	t-Stats	Ttl. eff.	t-Stats	Ttl. eff.	t-Stats	Ttl. eff.	t-Stats
Panel A: United Kingdom									
Metals	Gold	0.16	8.25	0.13	−0.48	0.03	−1.61	0.37	2.49
	Silver	0.58	20.30	0.51	−0.81	0.48	−0.80	0.89	2.27
	Platinum	0.27	10.90	0.32	0.85	0.13*	−1.68	0.23	−0.26
	Palladium	0.43	13.10	0.74	4.07	0.00***	−4.59	0.78	2.26
	Rhodium	0.01	0.45	0.19	8.83	−0.30***	−7.81	0.53	7.27
Diamonds	3ct D Flawless	−0.10**	−2.30	−0.07	0.15	−0.23	−0.30	1.81	20.80
	1ct D Flawless	0.10	0.71	−0.37	−1.10	0.56	1.11	1.63	5.57
	1ct Fine	0.07	0.94	0.26	1.14	0.16	0.41	0.22	0.51
	1ct Comm.	−0.10	−1.24	0.23	1.83	−0.20	−0.55	−0.20	−0.58
	0.5ct Fine	0.00	−0.20	0.00	0.00	0.10	0.40	0.11	0.64
	0.5ct Comm.	0.00	0.31	0.02	0.00	−0.10	−0.90	0.34	2.69
	0.3ct Fine	0.00	−0.40	0.15	0.73	−0.30	−1.00	0.40	2.41
	0.3ct Comm.	0.00	1.14	−0.01	−0.50	0.09	0.32	0.00	−0.50
Panel B: Germany									
Metals	Gold	0.12	7.20	0.10	−0.46	−0.08***	−2.92	0.36	3.37
	Silver	0.45	15.10	0.42	−0.38	0.25*	−1.67	0.49	0.35
	Platinum	0.22	10.90	0.30	1.75	0.02***	−2.90	0.50	2.28
	Palladium	0.34	11.80	0.59	4.36	−0.06***	−4.91	0.76	1.66
	Rhodium	0.01	0.57	0.02	0.41	−0.06*	−1.70	0.43	5.77
Diamonds	3ct D Flawless	−0.06	−1.03	−0.10	−0.20	0.02	0.16	1.54	3.69
	1ct D Flawless	0.05	0.54	−0.16	−0.54	0.31	0.57	1.59	5.09
	1ct Fine	0.05	0.89	0.17	0.76	0.15	0.49	0.08	0.11
	1ct Comm.	−0.06	−1.29	0.06	0.92	−0.09	−0.14	−0.15	−0.41
	0.5ct Fine	−0.02	−0.26	0.00	0.10	−0.03	−0.06	0.27	1.59
	0.5ct Comm.	0.04	0.71	0.05	0.06	−0.13	−1.24	0.32	2.68
	0.3ct Fine	−0.02	−0.28	−0.03	−0.04	−0.15	−0.58	0.55	3.56
	0.3ct Comm.	0.05	1.36	−0.02	−0.78	0.11	0.46	−0.01	−0.55
Panel C: France									
Metals	Gold	0.11	6.68	0.09	−0.46	−0.06**	−2.53	0.34	3.16
	Silver	0.43	16.30	0.39	−0.57	0.35	−0.77	0.76	2.89
	Platinum	0.21	10.60	0.28	1.30	0.00***	−2.74	0.47	1.99
	Palladium	0.36	12.90	0.58	3.62	0.02***	−4.17	0.76	2.53
	Rhodium	0.01	0.45	0.08	3.37	−0.14***	−4.62	0.49	6.58
Diamonds	3ct D Flawless	−0.10	−0.88	−0.10	−0.24	0.04	0.22	1.58	4.19
	1ct D Flawless	0.08	0.88	−0.16	−0.68	0.20	0.30	1.63	6.42
	1ct Fine	0.06	1.07	0.21	1.01	0.17	0.58	0.13	0.28
	1ct Comm.	−0.10	−1.13	0.07	0.99	−0.05	0.01	−0.19	−0.63
	0.5ct Fine	0.00	−0.28	0.00	0.12	−0.01	0.07	0.12	0.90
	0.5ct Comm.	0.04	0.70	0.08	0.33	−0.19*	−1.74	0.30	2.71
	0.3ct Fine	0.00	−0.19	0.12	0.63	−0.29	−1.20	0.38	2.74
	0.3ct Comm.	0.04	1.07	−0.03	−0.89	−0.08	0.43	−0.05	−0.94

*, **, *** indicates statistical significance at the 10, 5, and 1 percent levels, respectively.

Table 7
Hedge and safe haven properties of precious metals vs. diamonds during different levels of world volatility (Asia-Pacific: Australia, China).
This table presents the estimation results for precious metals, diamond indices, and prices in periods of increased (90% and 95%) or extreme world volatility (99%) modeled by Eq. (4). Panels A and B represent results for the Australia and China market index, respectively. Negative coefficients in the hedge column (c_0) signifies that the asset is a hedge against the market. Negative coefficients in subsequent columns show that it is a safe haven when the world volatility exceeds 90% (c_1), 95% (c_2), and extreme level 99% (c_3). Each t-statistics column is associated with the coefficient column to the left, as an indication of the significance level.

Asset		Hedge		Volatility > 90%		Volatility > 95%		Volatility > 99%	
		Coeff.	t-Stats	Ttl. eff.	t-Stats	Ttl. eff.	t-Stats	Ttl. eff.	t-Stats
Panel A: Australia									
Metals	Gold	0.15	6.39	0.12	−0.32	0.07	−0.69	0.21	0.52
	Silver	0.34	9.48	0.42	0.76	0.20	−0.85	0.45	0.54
	Platinum	0.36	16.20	0.58	3.68	0.09***	−2.75	0.80	2.67
	Palladium	0.48	15.70	0.80	3.90	0.24**	−2.16	0.80	1.37
	Rhodium	0.02	1.11	−0.20***	−7.36	−0.10	−1.30	1.21	7.71
Diamonds	3ct D Flawless	−0.58***	−14.90	0.06	1.07	−0.90	−0.63	1.19	18.90
	1ct D Flawless	−0.18	−1.45	−0.10	0.19	−1.30**	−2.33	0.85	3.19
	1ct Fine	0.03	0.43	−0.20	−1.00	0.04	0.06	0.25	0.65
	1ct Comm.	0.12	2.01	−0.20*	−1.71	0.51	1.96	−0.30	−0.85
	0.5ct Fine	−0.07	−0.83	0.15	0.93	−0.10	−0.13	−0.10	−0.09
	0.5ct Comm.	−0.04	−0.65	−0.20	−0.88	0.02	0.29	0.12	0.69
	0.3ct Fine	−0.09	−1.07	0.32	1.56	−0.50	−1.31	−0.10	0.12
	0.3ct Comm.	0.00	−0.09	0.00	−0.14	0.06	0.50	−0.20	−1.20
Panel B: China									
Metals	Gold	0.13	10.40	0.02**	−2.54	.22	1.32	−0.01*	−1.83
	Silver	0.25	12.50	0.17	−1.25	0.46	2.15	−0.04**	−2.31
	Platinum	0.22	16.60	0.24	0.71	0.17	−0.73	0.40	1.66
	Palladium	0.26	13.80	0.38	2.89	0.20	−0.80	0.29	0.30
	Rhodium	0.00	−0.15	0.04	1.90	−0.25***	−9.55	0.78	8.05
Diamonds	3ct D Flawless	−0.18***	−7.27	0.04	1.21	−0.21	−0.08	1.01	3.85
	1ct D Flawless	−0.04	−0.70	−0.36	−1.09	0.51	1.46	0.72	2.55
	1ct Fine	0.04	0.91	−0.06	−0.90	0.04	0.03	0.20	0.81
	1ct Comm.	0.01	0.30	−0.24**	−2.30	0.34	2.23	0.00	−0.06
	0.5ct Fine	0.02	0.32	0.11	0.67	−0.07	−0.50	0.00	−0.12
	0.5ct Comm.	0.00	−0.10	−0.12	−1.23	0.03	0.31	0.10	1.14
	0.3ct Fine	−0.03	−0.48	0.07	0.70	−0.22	−1.15	0.15	1.23
	0.3ct Comm.	−0.01	−0.19	0.00	0.15	−0.02	−0.14	−0.05	−0.47

*, **, *** indicates statistical significance at the 10, 5, and 1 percent levels, respectively.

three countries. Platinum and palladium offer impressive performance in the majority of all countries. Palladium in particular, shows comparatively strong safe haven qualities in all three European markets. For countries in North and South America, precious metals are only effective when volatility is greater than 90%. In Europe, the effects only emerge when volatility is within the 90% and 95% range. China is the only market in which precious metal assets exhibit a safe haven property when the market volatility level reaches our chosen maximum (99%).

5.3.2. Diamonds

Among diamond indices, apart from the 1 carat commercial index and 0.5 commercial index, others prove to be ineffective in any given market. The 1 carat exhibits safe haven potential against Australia and China at the 90% volatility level and hedging potential against the US, while the 0.5 commercial index is a safe haven against the US, France, and Brazil at the 95% volatility level. Strong hedging capability is exhibited by 3 carat flawless diamonds against 5 markets, excluding Germany and France. Their effects register particularly strongly with negative correlations in relation to the US, China, and Australia. While 1 carat flawless diamonds exhibit safe haven qualities with the American and Australian markets when the world volatility elevates above 95%, they also act as a hedge in the Brazilian market. When comparing the diversification abilities of physical diamonds, the 1 carat flawless diamonds are generally a less valuable asset under global finance turbulence than 3 carat ones.

5.3.3. Summary

Using the world index volatility as a proxy, when there is an increase in financial turbulence globally, precious metals are a better choice for investors attempting to protect their investment portfolios from losses. All precious metals show great potential in functioning as a safe haven and rhodium proves to be the most effective. By comparison, the performance by the diamond asset group is lackluster. The superior quality of 3 carat flawless diamonds make it possible for the asset class to withstand adverse market conditions, thus making it an overall hedge. In terms of indices, 0.3 carat category offers no improvement on portfolios as the small weight of the diamond may not be considered to be of sufficient economic value. The only diamond index that moves in an opposite trend than the markets in both 1 carat and 0.5 carat categories is the commercial index, suggesting that for retail investors, diamonds with moderate quality and prices are the best option.

5.4. Hedge and safe haven: periods of financial distress

Eq. (5) analyzes crisis sub-sample periods explicitly and the start date and duration of each period are defined prior to estimation of the model. Two major financial events occurred in the sample period of our investigation, namely the Global Financial Crisis in 2008 (Sept. 12, 2008–Oct. 2, 2008), and the US credit downgrade in 2011 (Jul. 23, 2011–Aug. 12, 2011). Tables 8, 9, and 10 present the results of estimation. For the 3 carat D flawless diamond, we apply a GARCH(1,1) model for convergence of the model estimates.

5.4.1. Precious metals

Gold and silver provide downside protection for all American and European countries against volatile market conditions during both crisis periods under study. While both assets correlate negatively with those markets, the correlation between gold tends to be stronger than silver. Palladium and platinum work in selective countries in the Americas and Europe, however their safe haven properties emerge during the GFC, and the positive correlations with the markets during the US credit rating downgrade signify the co-movement with the markets. Similarly,

Table 8
Hedge and safe haven properties of precious metals vs. diamonds during periods of financial stress (Americas: US, Brazil).
This table presents the estimation results for precious metals, diamond indices, and prices during periods of financial distress (2008 Global Financial Crisis and 2011 US credit rate downgrade) modeled by Eq. (5). Panels A and B represent results for the US and Brazil market index, respectively. The duration of crisis periods are set be 20 days after each crisis starts (i.e. GFC starts from September 12, 2008 and ends October 2, 2008. US credit downgrade starts from July 23, 2011 and ends August 12, 2011). Negative coefficients in the hedge column (c_0) signifies that the asset is a hedge against the market. Negative coefficients in subsequent columns show that it is a safe haven during the GFC (c_1) or US credit downgrade (c_2). Each t-statistics column is associated with the coefficient column to the left, as an indication of the significance level.

Asset		Hedge		GFC		US downgrading	
		Coeff.	t-Stats	Ttl. eff.	t-Stats	Ttl. eff.	t-Stats
Panel A: United States							
Metals	Gold	0.09	5.26	−0.24***	−4.15	−0.16***	−4.40
	Silver	0.35	11.36	−0.02**	−2.50	−0.23**	−2.54
	Platinum	0.17	7.84	−0.07*	−1.78	0.04	−1.40
	Palladium	0.26	9.10	0.02*	−1.82	0.07	−1.14
	Rhodium	0.00	0.16	0.33	8.61	−0.06	−1.13
Diamonds	3ct D Flawless	−0.05	−1.45	0.05	0.00	0.06	0.01
	1ct D Flawless	−0.04	−0.40	−0.34	−1.11	−1.03**	−2.46
	1ct Fine	0.06	0.95	0.57	1.22	1.10	2.79
	1ct Comm.	−0.08	−1.59	−0.02	0.17	0.07	0.82
	0.5ct Fine	0.11	1.72	−0.16	−0.40	−0.19	−1.14
	0.5ct Comm.	0.05	1.15	−0.24*	−1.71	−0.12	−0.69
	0.3ct Fine	0.11	1.82	0.00	−0.10	−0.10	−0.71
	0.3ct Comm.	0.05	1.48	−0.06	−0.34	−0.02	−0.32
Panel B: Brazil							
Metals	Gold	0.14	11.3	−0.16***	−5.32	−0.13***	−4.98
	Silver	0.35	17.3	0.04***	−2.88	−0.23***	−3.12
	Platinum	0.14	9.50	−0.01	−1.39	0.03	−1.25
	Palladium	0.20	9.39	0.02*	−1.66	0.16	−0.22
	Rhodium	0.01	0.96	−0.38***	−9.45	−0.05	−1.26
Diamonds	3ct D Flawless	−0.06**	−2.19	0.06	0.00	0.07	0.01
	1ct D Flawless	−0.13***	−2.66	−0.17	−0.20	−0.94**	−2.28
	1ct Fine	0.05	1.16	0.33	1.41	0.71	1.59
	1ct Comm.	−0.02	−0.42	−0.04	−0.11	−0.21	−0.69
	0.5ct Fine	0.05	1.25	−0.13	−0.38	−0.01	−0.22
	0.5ct Comm.	0.04	1.13	−0.24**	−2.22	0.07	0.10
	0.3ct Fine	0.04	0.86	−0.21	−0.78	0.09	0.10
	0.3ct Comm.	0.01	0.18	−0.08	−0.52	−0.05	−0.19

*, **, *** indicates statistical significance at the 10, 5, and 1 percent levels, respectively.

Table 9
Hedge and safe haven properties of precious metals vs. diamonds during periods of financial stress (Europe: UK, Germany, France).
This table presents the estimation results for precious metals, diamond indices, and prices during periods of financial distress (2008 Global Financial Crisis and 2011 US credit rate downgrade) modeled by Eq. (5). Panels A, B, and C represent results for the UK, Germany and France market index, respectively. The duration of crisis periods are set be 20 days after each crisis starts (i.e. GFC starts from September 12, 2008 and ends October 2, 2008. US credit downgrade starts from July 23, 2011 and ends August 12, 2011). Negative coefficients in the hedge column (c_0) signifies that the asset is a hedge against the market. Negative coefficients in subsequent columns show that it is a safe haven during the GFC (c_1) or US credit downgrade (c_2). Each t-statistics column is associated with the coefficient column to the left, as an indication of the significance level.

Asset		Hedge		GFC		US downgrading	
		Coeff.	t-Stats	Ttl. eff.	t-Stats	Ttl. eff.	t-Stats
Panel A: United Kingdom							
Metals	Gold	0.17	9.63	−0.43***	−3.55	−0.15***	−3.98
	Silver	0.58	22.69	−0.23***	−3.11	0.10**	−2.56
	Platinum	0.28	12.92	0.31	0.14	0.12	−1.50
	Palladium	0.45	17.74	0.10	−1.56	0.42	−0.21
	Rhodium	0.01	0.66	0.59	8.98	0.00	−0.12
Diamonds	3ct D Flawless	−0.02	−0.47	0.02	0.00	0.03	0.00
	1ct D Flawless	0.06	0.69	0.10	1.42	−1.60***	−2.98
	1ct Fine	0.11	1.93	1.05	2.38	1.57	2.73
	1ct Comm.	−0.05	−0.91	0.40	0.53	0.53	2.01
	0.5ct Fine	0.04	0.64	−0.13	−0.25	−0.61	−1.43
	0.5ct Comm.	0.03	0.71	−0.26	−1.35	0.33	0.72
	0.3ct Fine	0.01	0.17	−0.56*	−1.65	−0.16	−0.37
	0.3ct Comm.	0.04	1.09	−0.08	−0.51	0.05	0.03
Panel B: Germany							
Metals	Gold	0.12	7.75	−0.49***	−3.21	−0.27***	−4.69
	Silver	0.43	16.98	−0.45***	−2.63	0.07**	−2.29
	Platinum	0.22	11.99	0.42	0.53	0.10	−1.51
	Palladium	0.36	16.00	0.16	−0.61	0.27	−0.60
	Rhodium	0.01	0.61	−0.89***	−9.76	0.02	0.17
Diamonds	3ct D Flawless	0.00	−0.05	0.00	0.00	0.01	0.00
	1ct D Flawless	0.06	0.70	1.66	1.83	−0.93**	−2.18
	1ct Fine	0.07	1.50	1.58	3.07	1.20	2.63
	1ct Comm.	−0.06	−1.33	0.56	0.56	0.37	2.21
	0.5ct Fine	0.01	0.21	−0.19	−0.21	−0.12	−0.47
	0.5ct Comm.	0.03	0.94	−0.34	−1.35	0.43	2.10
	0.3ct Fine	−0.01	−0.23	−0.92**	−2.12	−0.11	−0.33
	0.3ct Comm.	0.03	1.05	−0.08	−0.41	0.06	0.17
Panel C: France							
Metals	Gold	0.10	6.41	−0.49***	−3.87	−0.26***	−3.91
	Silver	0.44	18.87	−0.44***	−3.68	−0.09**	−2.27
	Platinum	0.22	11.59	0.09	−0.50	0.12	−1.02
	Palladium	0.38	17.04	−0.06*	−1.92	0.22	−0.89
	Rhodium	0.01	0.74	0.63***	−11.23	−0.01	−0.34
Diamonds	3ct D Flawless	0.03	0.71	−0.02	0.00	−0.02	0.00
	1ct D Flawless	0.07	0.88	1.14	1.57	−1.23**	−2.85
	1ct Fine	0.09	1.84	1.13	2.85	1.49	2.83
	1ct Comm.	−0.05	−1.12	0.47	0.60	0.35	1.90
	0.5ct Fine	0.01	0.22	−0.16	−0.24	−0.21	−0.74
	0.5ct Comm.	0.04	1.14	−0.44*	−1.77	0.52	2.33
	0.3ct Fine	0.01	0.17	−0.53	−1.28	−0.14	−0.48
	0.3ct Comm.	0.01	0.55	−0.06	−0.36	0.06	0.21

*, **, *** indicates statistical significance at the 10, 5, and 1 percent levels, respectively.

rhodium exhibits exceedingly strong safe haven properties against 5 markets during the GFC, and its effects recede in the second crisis period. For Asia-Pacific countries, gold still functions as a safe haven, yet the effects of silver, platinum, and palladium are not present in Australia or China. None of the precious metals investigated serve as a general hedge under this model.

5.4.2. Diamonds

In the Brazilian and Australian markets, the 3 carat flawless diamonds act as a hedge, suggesting that diamond mining industry has substantial influence in the mining interests of both countries. For the remaining 5 countries, the correlation between 3 carat diamonds and markets appear as negligible, as they tend not to be investors' choice for asset protection due to exorbitant pricing. The 1 carat flawless diamonds act as a safe haven to all European and American countries during the US credit downgrade in 2011 but not in 2008 GFC, potentially indicating the shift in its role as an investment. Additionally their hedging properties in both Australia and Brazil could again be attributed to diamond mining where the Argyle Diamond Mine in Australia is the largest diamond producer in the world by volume (Zimnisky, 2013). Among the diamond indices, it can be found that their effects on the markets are region-specific. For Asia-Pacific countries, a number of

Table 10
Hedge and safe haven properties of precious metals vs. diamonds during periods of financial stress (Asia-Pacific: Australia, China).
This table presents the estimation results for precious metals, diamond indices, and prices during periods of financial distress (2008 Global Financial Crisis and 2011 US credit rate downgrade) modeled by Eq. (5). Panels A and B represent results for the Australia and China market index, respectively. The duration of crisis periods are set be 20 days after each crisis starts (i.e. GFC starts from September 12, 2008 and ends October 2, 2008. US credit downgrade starts from July 23, 2011 and ends August 12, 2011). Negative coefficients in the hedge column (c_0) signifies that the asset is a hedge against the market. Negative coefficients in subsequent columns show that it is a safe haven during the GFC (c_1) or US credit downgrade (c_2). Each t-statistics column is associated with the coefficient column to the left, as an indication of the significance level.

Asset		Hedge		GFC		US downgrading	
		Coeff.	t-Stats	Ttl. eff.	t-Stats	Ttl. eff.	t-Stats
Panel A: Australia							
Metals	Gold	0.14	6.76	−0.03	−0.91	−0.04**	−2.13
	Silver	0.34	10.38	0.60	0.72	0.46	0.70
	Platinum	0.35	17.95	0.79	1.76	0.31	−0.43
	Palladium	0.50	18.65	0.84	1.22	0.79	1.32
	Rhodium	0.01	0.56	−0.44***	−9.11	−0.04	−0.79
Diamonds	3ct D Flawless	−0.76***	−15.87	0.76	0.08	0.78	0.11
	1ct D Flawless	−0.20**	−2.06	−0.16	0.07	−0.48	−0.30
	1ct Fine	0.01	0.14	0.23	0.34	−1.77***	−2.99
	1ct Comm.	0.10	1.87	0.44	0.58	−0.59*	−1.96
	0.5ct Fine	−0.02	−0.27	0.09	0.16	0.02	0.11
	0.5ct Comm.	−0.05	−0.93	−0.32	−0.91	−0.76**	−2.13
	0.3ct Fine	−0.06	−0.91	−0.07	−0.01	0.32	0.69
	0.3ct Comm.	0.00	0.09	−0.13	−0.36	−0.26	−0.91
Panel B: China							
Metals	Gold	0.12	10.50	−0.28***	−4.31	−0.05**	−2.34
	Silver	0.24	13.49	0.25	0.05	0.49	1.30
	Platinum	0.22	18.71	0.57	3.23	0.13	−1.00
	Palladium	0.27	16.60	0.24	−0.16	0.51	1.83
	Rhodium	0.00	−0.51	0.44	10.29	0.22	3.54
Diamonds	3ct D Flawless	0.00	0.09	0.00	0.00	0.00	0.00
	1ct D Flawless	−0.05	−0.92	0.02	0.25	0.12	0.11
	1ct Fine	0.03	0.84	0.08	0.24	−1.18***	−2.62
	1ct Comm.	0.01	0.19	0.11	0.24	−0.22	−0.86
	0.5ct Fine	0.03	0.75	−0.17	−0.28	0.04	0.02
	0.5ct Comm.	−0.01	−0.27	−0.23	−1.11	−0.37	−0.85
	0.3ct Fine	−0.02	−0.45	−0.19	−0.46	0.01	0.07
	0.3ct Comm.	0.00	−0.10	−0.14	−0.61	−0.19	−0.59

*, **, *** indicates statistical significance at the 10, 5, and 1 percent levels, respectively.

indices play a safe haven role during the US credit downgrade. Alternatively, for countries in Europe and both North and South America, the effects only emerge during 2008 GFC.

5.4.3. Summary

Precious metals provide better protection in times of global financial distress. Gold and silver, while having strong negative correlation to a majority of the markets, are an all-time safe haven that give stable performance in both crisis periods being examined. While no metal shows the character of being a hedge, this role is fulfilled by diamond assets, although in a limited number of markets. The relationship between diamond prices and the market is likely to be affected by the diamond mining industry. With the existence of the industry in Brazil and Australia, both superior quality diamonds exhibit properties as a hedge. A shift can be identified when inspecting 1 carat D flawless diamonds specifically, to markets excluding China, and the weak negative or weak positive correlation during GFC transitioned towards being a strong safe haven during US credit downgrade.

6. Conclusion

During times of economic distress, Abel (1988) and Barsky (1989) present models where by relatively risk averse agents reduce investment allocations to assets with higher expected returns such as equities, and increase their allocations to bonds as 'precautionary savings'. Durand et al. (2010) find evidence of the flight-to-quality effect from equities to bonds during extreme falls in equity prices. As a result of global economic uncertainty, ultra-low interest rates and sluggish growth, investments in hard assets (e.g., real estate, infrastructure, and commodities) are starting to have a significant and increasing presence in institutional investment portfolios. An industry technical report, commissioned by BlackRock (Economist, 2014) shows that as an alternative investment to bonds, 45% of the institutions surveyed have increased the allocations in commodities to boost portfolio returns. Rare commodities such as precious metals have shown to improve risk-adjusted returns of investment portfolios (Conover et al., 2009; Reboredo, 2013; Hood & Malik, 2013; Michis, 2014). Other strategies that should be considered to protect investment portfolios from downside risk exposure include investing in diamond indices or physical diamonds.

Employing a sample period from Aug 4, 2003 to Aug 2, 2013, we compare the role of precious metals and diamonds in various international equities markets and their safe haven and hedge properties. Our study applies the GJR-GARCH model, that allows for asymmetric effects of volatility clustering with daily equities indices data spanning the Americas (US, Brazil), Europe (UK, Germany, France), and the Asia-Pacific (Australia, China) regions. Overall, we find evidence that investing in precious metals rather than diamonds works better to insulate investment portfolios against periods of market crisis and excessive volatility. Upon further analysis of the diamonds category, we compare the performance between investing in diamonds as a physical asset versus diamond indices. We find that only physical diamonds provide satisfactory performance and then only when markets are most volatile. However, diamond indices tend not to function well as safe havens and hedges against international financial markets. A strong negative correlation is evident between top quality diamonds (i.e., flawless) and international equities markets. Thus one of the strongest advantages of holding top-quality physical diamonds is that they continue to preserve their value, and provide price stability during market turmoil.

Analyzing the results country-wise, precious metals are shown to be more effective hedges and safe havens in Europe, the Americas, and

Australia. Rhodium, as a minor investment choice proves to be a viable alternative. For China, gold works well as a safe haven asset during the 2007–2009 GFC and 2011 US credit downgrade. For Australia and Brazil, (where interestingly diamond mining industries exist), only flawless diamonds appear to serve as a hedge. Diamonds with the same quality but lighter weight function better in the remaining countries.

Although our analysis indicates the current dominant advantage of precious metals over diamonds as a safe haven and hedge, diamonds should still be included within a portfolio as an effective diversifier. The diamond investment industry continues to evolve with increasing transparency, coupled with the steady accumulation of wealth within emerging markets, the value of a diamond as a rare commodity will make it a more attractive investment and a potentially valuable addition to any investment portfolio.

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