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The relationship between global stock and precious metals under Covid-19 and happiness perspectives

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Abstract

In this paper, we examine the relationship between global stock markets, as respectively represented by the FTSE All-World Series and the MSCI Emerging Markets indexes, and the S&P GSCI Precious Metals index from 01 September 1999 to 03 May 2021. We employ the conditional correlation multivariate generalized autoregressive conditional heteroskedasticity (MGARCH) to investigate this stock-precious metals nexus in terms of return and volatility spillovers. The study assesses impacts of the Covid-19 pandemic on the stock-precious metals nexus and further examine this relationship by supplementing the Twitter’s Daily Happiness Sentiment index to the methodological framework for the period from 01 January 2020 to 03 May 2021. We find that precious metals positively influence stock markets before the Covid-19 outbreak and firmly play a valuable role due to their hedge and safe haven characteristics. In contrast, the bivariate GARCH framework does not provide statistically significant evidence on the stock-precious metals nexus during the Covid-19 pandemic. Meanwhile, the trivariate GARCH approach with stock markets, precious metals, and happiness sentiment indexes reveals sufficiently complicated interactions between these return series. Prominently, past change in the happiness index negatively affects the stock returns but positively drives the performance of precious metals. These findings indirectly demonstrate the stock-precious metals nexus under impacts of the Covid-19 pandemic and reflect the demand of precious metals during crisis periods. Accordingly, we suggest a reasonable method of adjusting the proxies when no interaction effect is significantly found during unprecedented outbreaks.
to the global economy and society. In which, the most vulnerable industries include governments and publics, banking and assurance, financial markets, and capital financing (Goodell, 2020). More specifically, the Covid-19 impacts on financial markets are found to spread beyond geographical and continental boundaries (Ali et al., 2020). The pandemic also implies potential damages to the global financial sector and market centers (Wojcik and Ioannou, 2020). Due to the Covid-19 pandemic, international financial markets are challenged by an increasing level of risks. Accordingly, unexpected losses may occur in short terms despite the quantitative easing policy (Zhang et al., 2020). The pandemic even influences governmental intervention in financial markets, where evidence is found across 77 countries (Ashraf, 2020). More precisely, financial markets are found to contain fractal contagion effects (Okorie and Lin, 2020), where return and volatility is influenced by the pandemic in middle and long term. The financial contagion during Covid-19 is supported with evidence from China and G7 countries (Akhtaruzzaman et al., 2021). The impacts of Covid-19 on capital markets could be employed to predict the stock performance, in terms of a specific consideration of various markets (Ciner, 2020) or health news (Salieu and Vo, 2020). On the other hand, literature has examined impacts of the Covid-19 pandemic on the interactions between stock and alternative investments. As the pandemic influences both demand and supply of financial markets, the pricing overreactions effect is approached in the commodity futures (Borgards et al., 2021). In the markets of natural resources, gold and oil are examined to find the asymmetric multifractality (Mensi et al., 2020). This finding reflects one of the most typical consequences of the Covid-19 crisis, that is, supply chain disruption. Relating to the nexus between stock and cryptocurrency markets, the Covid-19 pandemic is found to cause instability and sequential irregularity (Lahmiri and Bekiros, 2020). Noticeably, the hedge role of gold to stock markets is affirmed in the earlier period of the Covid-19 pandemic (Burdekin and Tao, 2021), compared to previous global financial crisis. Hence, the relationships between stock and precious metals remain an interesting field during an unprecedented event such as the Covid-19 pandemic.

The relationships between stock and precious metals seem to change during the Covid-19 period. Due to the timeseries characteristic of the stock and precious metals indexes, their nexus had been comprehensively examined under multivariate generalized autoregressive conditional heteroskedasticity (MGARCH) models. Under impacts of the pandemic, it is stated that the empirical modeling may not capture the stock-precious metals nexus during Covid-19, for example, the case of Vietnam (Le and Nguyen, 2021). Consequently, there shall be a hidden factor that drives the performance of both stock and precious metals during the outbreak. Since the Covid-19 pandemic contemporaneously affects the mood and behavior of people, we trust that the hidden factor relates to happiness or investor sentiment. Happiness is originally defined by the Greek term “eudaimonia”, which refers to an eternal happiness sentiment in terms of market mechanism and behavior of people’s mind, happiness relates to life satisfaction, psychological health, and mental strain (Blanchflower and Oswald, 2008). Accordingly, the happiness sentiment is a promising factor which can provide interesting perspectives relating to the Covid-19 crisis. The World Happiness Report (Helliwell et al., 2021) indicates that the Covid-19 pandemic enormously the health and trust of people. More specifically, it found that emotional and cognitive balance of people has been changing and happiness decreases accordingly due to the pandemic (Meléndez et al., 2020). The crisis results in considerable changes in the mental health of people, where selected evidence is provided for the case of the United States (Yarrington et al., 2021) and China (Jia et al., 2021). While the Covid-19 occurs in a digital era, it affects the relationships between well-being and other factors, for example, social cultural beliefs in the sharing economy (Alharthi et al., 2021); state of employment, financial concerns, and mental distress (Wolfe and Patel, 2021); and

leisure behavior (Kim, 2021). The role of well-being turns more significant during a difficult period of the Covid-19 pandemic, especially in terms of its relations with the financial wealth. On the perspective of behavioral and experimental finance, the trust in government is stated to increase both financial and general happiness (Barrafrem et al., 2021). The interactions between stock markets and investor sentiment under impacts of Covid-19 pandemic is further explored by the usage of Twitter-based market uncertainty metric (Chatterjee and French, 2019). Thus, literature has investigated the role of happiness in explaining the nexus between stock and precious metals during the Covid-19 period. This finding is an outstanding linkage to the relationship between wealth and happiness (Nguyen and Le, 2021), in which the stock index return is found to increase the well-being and the happiness sentiment mitigates the volatility of financial wealth. Therefore, this study is expected to investigate the nexus between stock and precious metals under the perspectives of Covid-19 and global happiness. Accordingly, we can explain the performance of financial assets during the pandemic by using the happiness sentiment proxy. We shall employ both global and emerging equity market indexes as proxy for the stock investment. This choosing generates comprehensive perception of the results.

Following this introduction, Section 2 presents the related literature, Section 3 presents the framework of methodologies, Section 4 discusses on the results, and Section 5 concludes.

2. Literature review

We shall initially present literature relating to the nexus between stock markets and typical precious metals such as gold, silver, platinum, and palladium. In which, the findings are mostly driven by examined markets, period, and quantitative models. Empirical results have revealed that precious metals maybe a diversifier, hedge, or safe haven to equity markets. Next, we shall examine both theory and evidence on the interactions between happiness sentiment and financial assets. Accordingly, our literature review emphasizes the relationships between three key factors, those are, stock markets, precious metals, and happiness sentiment in terms of market mechanism and behavior of investors.

In essence, precious metals are natural resources and therefore reflects unlimited demand compared to scarce supply. Traded on commodity markets, precious metals have become interesting alternative investments compared to traditional stock. As a result, precious metals play an important role in pursuit of portfolio optimization (Conover et al., 2009). The stock-gold nexus has been prominently investigated by using quantile regression (Baur and McDermott, 2010), in which gold is found to be a hedge in the United States and Europe markets and safe haven in emerging regions. This study lays the groundwork for the valuable role of precious metals during crisis periods. The hedges and safe havens are comprehensively examined in a general consideration of stock, bond, gold, oil, and currency exchanges (Ciner et al., 2013), where the results affirm the valuable characteristic of precious metals. The theory is strongly affirmed under various approaches, for example, wavelet analysis (Bredin et al., 2015) and smooth transition method (Beckmann et al., 2015). The theory framework is constantly robust under MGARCH models, where we could explore the interactions between stock and precious metals in terms of return and volatility spillovers. Those findings propose a research question that if the hedge and safe haven role of gold remains consistent with regard to other precious metals. Significant evidence is found in the United States market (Hood and Mallik, 2013), considering safe haven role of gold, silver, and platinum. This finding is consistent with various perspectives, for example, regression market model-type (Cochrane, 2001), complementing oil and copper (Choi and Hammoudeh, 2010), varying the portfolio construction (Emmrich and McGroarty, 2013), exploring more precious metals (Lacey and Li, 2015), multimarket examination (Low et al., 2016), emerging markets assessment (Li and Lucey, 2017), mining industry approach (Umar et al., 2019), boosting the volatility fluctuations.
(Pierdzioch et al., 2016), and comparing to the bond market (Peng, 2020). To generalize the methodologies in terms of market selection, the hedge and safe haven role of precious metals is demonstrated compared to the MSCI World and the S&P 500 equity indexes (Baur and McDermott, 2016). Remarkably, those studies provide firm evidence based on various mechanisms of the MGARCH framework. Moreover, the hedge and safe haven characteristic of precious metals is widely tested compared to cryptocurrency investments. Significant evidence is found in various analyses, for example, economic value of portfolio (Symitsi and Chalvatzi, 2019), tail behavior (Kwon, 2020), and wavelet investigation (Bouri et al., 2020). An extensive revision (Ali et al., 2020) reveals that precious metals are indisputably hedge and safe haven to specific stock markets. Furthermore, this valuable role of precious metals is robustly found in considering external factors. Indeed, precious metals remain their hedging role to stock markets under impacts of exchange rate risk (Iqbal, 2017), inflation (Hussein Shahzad, Mensi, Hammoudeh, Sohail and Al-Yahyae, 2019), oil shocks (Salisu and Adediran, 2020), and currency volatilities (Nguyen et al., 2020). Henceforth, the hedge and safe haven characteristic of precious metals remains unchanged during an unprecedented period of the Covid-19 pandemic. Preliminary evidence confirms our hypothesis, in which gold futures is found to be a strong safe haven during the earlier period of Covid-19 crisis (Ji et al., 2020). In support, complicated assessments (Zhang and Wang, 2021) provide various alternatives on the hedging characteristic of gold and bitcoin to financial markets of the United States and China. This related literature motivates our study, especially when the Covid-19 outbreak is still going and we are supposed to assess its impacts on financial relationships under various perspectives.

The human factor is indisputably an important component of any economic activities, and financial market is not an exception. As the well-being is found to increase productivity (Oswald et al., 2015), it becomes significant in exploring economic activities. Indeed, happiness facilitates to explain people in terms of economic cognition and sentiment, for example, decision making (Ise, 2001), investment behavior (Chuluun and Graham, 2016), management and governance (Fisher, 2010), and asset pricing (Falato, 2009). This lays the groundwork for positive impacts of happiness to particular outcomes, for example, economic growth (Stevenson and Wolfers, 2008), national income (Hagerty and Veenhoven, 2003), and maximizing the utility of consumptions (Kahneman and Thaler, 2006). Regarding the exchange of financial assets, investor sentiment plays a key role due to its affect to demand, supply, and other conditions which determines the price. By the early of 2000s, investor sentiment is found to interact significantly with excess returns and volatility of stock markets (Lee et al., 2002). The study indicates a systematic risk which is represented by the Investors' Intelligence sentiment index. This theoretical framework is extended to find that investor sentiment relates to the near-term stock market (Brown and Cliff, 2004). More evidence on the relations between equity markets and investor behavior are demonstrated based on the cross-sectional approach (Baker and Wurgler, 2006), in which the wave of sentiment could be employed to project the performance of stock returns. Those pioneer findings have been supported by alternative mechanisms of investor sentiment in stock markets, for example, media contents (Tetlock, 2007), response to earning news (Mian and Sankaraguruswamy, 2012), and record status in the global social networks (Dodds et al., 2011). On the eudaimonia perspective, literature has found the relations between health and well-being. The Covid-19 impact assessments facilitate to confirm prior literature on the nexus between health and happiness in terms of, for example, income (Deaton, 2008), inequality (Ryff, 2017), and psychology (Diener et al., 2017). A key issue in studying sentiment and its relationships with economic factors is constructing an appropriate metric (Kahneman & Krueger, 2006), which generates a homogeneous of well-being or happiness. The development of digital era facilitates the quantification of people sentiment, in which the wordiness method (Kramer, 2010) is formulated based on the platform of social networks. The digital revolution is remarked by amazing evidence that happiness could predict the performance of stock markets (Siganos et al., 2014). A further examination with the quantile causality approach reveals that happiness is a determinant of both return and volatility from selected stock markets (Balcilar et al., 2018). Recent literature has been using the Twitter’s daily happiness sentiment index (DHS) as a popular well-being proxy. Due to the timeseries characteristic of DHS, literature has explored amazing linkages between happiness and financial assets. Empirical findings relating to the nexus between the happiness sentiment and international stock markets have been demonstrated under various approaches, for example, Granger’s causality (Zhang et al., 2016), quantile Granger (You et al., 2017), skewness of stock returns (Shen et al., 2018), and causality tests (Zhang et al., 2018). The robustness of the relationship between happiness and stock markets is affirmed by specific countries, for example, the United States (Zhao, 2020), Singapore (Zhao, 2019), and China (Li et al., 2017). Beside its nexus with stock markets, DHS has been widely found to relate with alternative investments. Interestingly, literature has indicated the relationship between happiness and precious metals. These interactions are explored by various approaches, for example, return dynamics (Balcilar et al., 2017), volatility of futures markets (Fang et al., 2018), and geopolitical risks (Gkillas et al., 2020). The relationship between happiness gold price is testified by a variety of modeling, for example, extreme value theory (Byström, 2020) and heterogeneous autoregressive realized volatility (Bonato et al., 2021). The happiness sentiment could be employed to examine mechanisms of other markets, for example, crude oil and gold futures (Asai, 2020) and exchange-traded funds (Lee and Chen, 2020). Thus, literature has constantly affirmed the role of happiness sentiment in explaining market relations. This enhances our study on investigating the nexus between stock markets and precious metals under happiness perspective.

Henceforth, prior literature suggests that we assess the nexus between stock markets and precious metals under both Covid-19 and happiness perspectives. Our study is expected to clarify the interactions between popular financial investments before and during a difficult period caused by the pandemic. As the outbreak may cause unexplainable economic relations between equity markets and precious metals, we shall investigate their nexus during the Covid-19 outbreak by employing the proxy of happiness sentiment. In specific, we shall explore the return and volatility transmissions between stock, precious metals, and happiness indexes. This study generates more clarified evidence on the stock-precious metals nexus and the role of well-being in examining financial relationships. This study provides a supportive illustration that happiness could be studied as an economic term (Piekkaliewicz, 2017). Our Covid-19 impact assessment to the nexus between stock and precious metals reveals further implications regarding the relationship between global wealth and happiness (Nguyen and Le, 2021), in which well-being is found to drive financial wealth while happiness remains a preferable objective. On the other hand, this study shall provide empirical findings to the related literature while we employ both global and emerging equity indexes as proxies for stock markets. The research novelty also includes the examination on the timeframe from 1999 to 2021. Accordingly, the study is expected to contribute additional perspectives on the interactions between financial markets and investor happiness sentiment under impacts of the Covid-19 pandemic.
3. Methodologies

3.1. Empirical modeling

We employ the MGARCH framework to explore the relationship between stock markets and precious metals in terms of return and volatility spillovers. In which, proxies of stock markets include the FTSE All-World Series and the MSCI Emerging Markets indexes. The precious metals investment is represented by the S&P GSCI Precious Metals index, which comprises of gold, silver, platinum, and palladium. A remarkable issue of MGARCH modeling is to estimate the conditional variance matrices. Considering the trade-off between feasibility and flexibility of MGARCH models (De Almeida, Hotta and Ruiz, 2018), we use the conditional correlation mechanisms to explore the nexus between stock markets and precious metals in terms of shock transmissions. Modeling specifications are the vector autoregressive moving average (VARMA)-GARCH (Ling and McAleer, 2003), the constant conditional correlation (CCC)-GARCH (Bollerslev, 1990), and the dyadic conditional correlation (DYAC)-GARCH (Engle, 2002). The effectiveness of these models is illustrated in various studies on the relationship between stock and related factors, for example, oil price (Arouri et al., 2011), commodity markets (Mensi et al., 2013), macroeconomic news (Caporale et al., 2016), and air quality (Nyguén & Lê, 2021).

As supported by the Schwarz-Bayes information criterion, we first estimate a one-legged vector autoregressive (VAR) mean equation:

\[
\begin{align*}
    r_t &= \mu + \Phi r_{t-1} + \epsilon_t \\
    \epsilon_t &= H_t^{1/2}\eta_t
\end{align*}
\]

In which, \( r_t \) is the daily return series (\( r_t \) for stock markets and \( r_t \) for precious metals), \( \mu \) is the vector of intercepts, \( \Phi \) is the matrix of coefficients, \( \epsilon_t \) is the vector of error terms, \( H_t^{1/2} \) is the Cholesky factor of the time-varying conditional correlation matrix \( H_t \), and \( \eta_t \) is the vector of independently and identically distributed errors at time \( t \). \( r_{t-1} \) corresponds to the daily return series at time \( t - 1 \), as well as remaining coefficients. Next, we shall respectively present the estimation of \( H_t \) based on the conditional correlation MGARCH mechanism.

Given \( \rho_t \) is the time-varying conditional correlation between returns of stock markets and precious metals. The conditional correlation mechanism of the MGARCH framework is suggested by the following matrix decomposition:

\[
H_t = D_t \Phi D_t = \begin{pmatrix} \sqrt{h_t^s} & 0 \\ 0 & \sqrt{h_t^m} \end{pmatrix} \begin{pmatrix} 1 & \rho_t & 1 \\ \rho_t & 1 & \rho_t \\ 1 & \rho_t & 1 \end{pmatrix} \begin{pmatrix} \sqrt{h_t^s} & 0 \\ 0 & \sqrt{h_t^m} \end{pmatrix}
\]

The school of VARMA-GARCH and CCC-GARCH models assumes that \( \rho_t \) is a constant (denoted by \( \rho \)) and therefore estimates elements of \( H_t \):

\[
\begin{align*}
    h_t^s &= C + A \epsilon_{t-1}^s + B \begin{pmatrix} h_t^{m,1} \\ h_t^{m,2} \end{pmatrix} \\
    h_t^m &= \rho \sqrt{h_t^s h_t^m}
\end{align*}
\]

In which, \( C \) is the vector of intercepts and \( A \) and \( B \) are matrices of coefficients. The superiority of the VARMA-GARCH model is demonstrated through its capturing the return and volatility spillovers:

\[
\begin{align*}
    h_t^s &= c^s + a^s (\epsilon_{t-1}^s)^2 + a^{m,s} (\epsilon_{t-1}^m)^2 + b^s h_{t-1}^s + b^{m,s} h_{t-1}^m \\
    h_t^m &= c^m + a^m (\epsilon_{t-1}^m)^2 + b^m h_{t-1}^s + b^{m,m} h_{t-1}^m \\
    h_{t-1}^m &= \rho \sqrt{h_t^s h_t^m}
\end{align*}
\]

The CCC-GARCH model is a special case where \( A \) and \( B \) are imposed to be diagonal. Accordingly, this model could not comprehensively explore the interdependence and transmissions between return series. Moreover, we are supposed to find eigenvalues \( \lambda \) of the matrix \( (A + B) \) inside the unit circle in compliance with the stationary condition of both VARMA-GARCH and CCC-GARCH models.

On the other hand, the school of DCC-GARCH model assumes that the conditional correlation is dynamic and therefore further composes:

\[
\begin{align*}
    P_t &= \begin{pmatrix} 1 & \rho_t \\ \rho_t & 1 \end{pmatrix} = (Q_t)^{-1/2} Q_t (Q_t)^{-1/2} \\
    Q_t &= \begin{pmatrix} q_t^s & q_t^{m,s} \\ q_t^{m,s} & q_t^m \end{pmatrix} = (1 - \alpha - \beta) \bar{Q} + \alpha \eta_{t-1} \eta_t + \beta Q_{t-1} \\
    Q_t > 0, \quad Q_t &= \begin{pmatrix} q_t^s & 0 \\ 0 & q_t^m \end{pmatrix} \bar{Q} = E(\eta \eta_t)
\end{align*}
\]

In which, \( \alpha \) and \( \beta \) are non-negative scalars imposed to \( \alpha + \beta < 1 \) and \( \bar{Q} \) is the matrix of unconditional correlations between standardized errors \( \eta_t \).

To assess the portfolio of stock and precious metals before and during the Covid-19 pandemic, we shall respectively consider following ratios:

\[
\begin{align*}
    w_t^p &= \text{median}\left\{ 0, E \left( \frac{h_t^s - h_t^m}{2h_t^s + h_t^m} ; 1 \right) \right\} \\
    \rho_t^m &= E \left( \frac{h_t^m}{h_t^s} \right) \gamma = \frac{\sigma_t^s - \sigma_t^m}{\sigma_t^s}
\end{align*}
\]

In which, \( w_t^p \) is the optimal holding weight (Kroner and Ng, 1998) of precious metals during period \( T \). The median term implies that the holding weight shall be neither greater than 1 nor less than 0. The optimal allocation for stock markets is therefore \( w_t^p = 1 - w_t^p \). The hedge ratio (Kroner and Sultan, 1993) is denoted by \( \rho_t^m \). This ratio reflects the sensitivity between financial assets of the portfolio and represents the amount of unit currency in contrasting (long and short) positions. Besides, ratio \( \gamma \) (Ku et al., 2007) measures the hedging effectiveness of the portfolio. This ratio indicates the strategic diversification and provides supportive evidence on the role of precious metals to stock markets as a diversifier, hedge, or safe haven during a given period.

To assess impacts of the Covid-19 pandemic on the nexus between stock markets and precious metals, we shall investigate their interactions based on the bivariate GARCH framework before (01 September 1999 to 31 December 2019) and during (01 January 2020 to 03 May 2021) the outbreak. To further investigate the stock-precious metals nexus during the Covid-19 period, we adjust the models by employing the DHS index. Consequently, the estimated terms become,
for example, \( r_t = (r_t^1, r_t^2, r_t^3) \), in which \( r_t^j \) represents the happiness return at time \( t \), etc. In other words, the framework becomes a tri-variate GARCH. This approach implies the happiness perspective regarding how the Covid-19 crisis influences the stock-precious metals relationship, in which their interchangeable impacts may not be stated endogenously. The usage of variant proxies for stock markets and empirical models enhances the study significance as well as ensure the robustness check.

3.2. Data and preliminary analysis

As priorly presented, we employ the FTSE All-World Series (FAW), the MSCI Emerging Markets (EMI), and the S&P GSCI Precious Metals (PMI) index series from 01 September 1999 to 03 May 2021 to assess impacts of the Covid-19 pandemic to the nexus between global stock markets and precious metals. In support, we adjust the empirical methods by adding the Twitter’s Daily Happiness Sentiment (DHS) index to further investigate the stock-precious metals relationships during the Covid-19 outbreak (from 01 January 2020 to 03 May 2021).

Table 1 presents descriptive statistics and stochastic properties of the index series. Fig. 1 illustrates the returns of stock markets and precious metals indexes during the whole studied period and Fig. 2 illustrates the DHS return index during the Covid-19 crisis.

The stock indexes tend to grow stably and contemporaneously during the research study. Both FAW and EMI are enormously damaged in the beginning stage of current outbreaks, those are, the global financial crisis in 2008 and the Covid-19 pandemic in 2020. These indexes seem to recover during recent months of the Covid-19 crisis. Besides, the precious metals index increases dramatically at the peak of each crisis. This pattern reflects the high demand of precious metals during outbreaks as well as their role as a hedge or safe haven. On the other hand, the DHS tends to harmonize during the studied period, which indicates the status of mental health. Thus, the happiness sentiment proxy is expected to capture the nexus between stock markets and precious metals during an unprecedented outbreak caused by the Covid-19 pandemic. In addition, stochastic properties provide statistically significant evidence that return series are asymmetric, leptokurtic, normally distributed, autocorrelated, heteroskedastic, and stationary. These preliminary analyses confirm the appropriateness of the MGARCH models in our framework of methodologies.

4. Results

4.1. Covid-19 perspective

Table 2 presents the nexus between stock markets and precious metals indexes before and during the Covid-19 outbreak under conditional correlation MGARCH modeling. In the 1999–2019 period, we find that past return of precious metals positively affects the performance of

| Table 1 |
| --- |
| Descriptive statistics and stochastic properties of return series. |
| **All-World Series Index** | **Emerging Market Index** | **Precious Metals Index** | **DHS** |
| **1999-2019** | **2020-2021** | **1999-2019** | **2020-2021** | **1999-2019** | **2020-2021** | **2020-2021** |
| Obs. | 5305 | 349 | 5305 | 349 | 5305 | 349 | 322 |
| Mean | 0.01% | 0.06% | 0.02% | 0.05% | 0.03% | 0.04% | -0.01% |
| SD | 0.96% | 1.52% | 1.16% | 1.40% | 1.14% | 1.36% | 0.69% |
| Skew | -0.3852*** | -1.4832*** | -0.5007*** | -1.0620*** | -0.2621*** | -0.3922*** | -1.4002*** |
| Kurt | 18.734*** | 18.571*** | 18.741*** | 18.288*** | 18.697*** | 18.643*** | 18.639*** |
| LB | 18.741*** | 18.643*** | 18.571*** | 18.288*** | 18.697*** | 18.643*** | 18.639*** |
| ML | 156.17*** | 137.51*** | 156.17*** | 137.51*** | 156.17*** | 137.51*** | 156.17*** |
| ADF | -62.242*** | -21.633*** | -62.242*** | -21.633*** | -62.242*** | -21.633*** | -62.242*** |
| PP | -62.17*** | -21.453*** | -62.422*** | -21.633*** | -62.720*** | -21.453*** | -62.422*** |

Notes: *, **, and *** indicate statistical significance of 10%, 5%, and 1%, respectively. Descriptive statistics include number of observations (Obs.), mean, standard deviation (SD), skewness (Skew), and kurtosis (Kurt). Stochastic properties include normality with the Jarque-Bera (JB) test, the autocorrelation effect with 15-lagged Ljung-Box (LB) and McLeod-Li (ML) tests, heteroskedasticity with a 15-lagged ARCH test, and stationary conditions with augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) unit-root tests.

![Fig. 1. FTSE All-World Series (FAW), Emerging Market Index (EMI), and Precious Metals Index (PMI) series from 01 Sep 1999 to 03 May 2021.](https://www.investing.com/)

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1 Source: Investing retrieved from [https://www.investing.com/](https://www.investing.com/).
the global stock market index. Meanwhile, past performance of emerging stock and precious metals indexes positively influence to each other. These results are robust regardless of model specifications. In support, the estimated mean equations indicate the autocorrelation effect in return series, positive for the stock markets and negative for the precious metals. The VARMA-GARCH model further explores the nexus between two assets that past shock and volatility of the global stock proxy influences such patterns of precious metals. The co-movement between emerging market and precious metals indexes is clarified in terms of interchangeable shock and volatility transmissions. A specific interaction between stock markets and precious metals is testified due to the significant evidence of the constant conditional correlation, which supports VARMA-GARCH and CCC-GARCH. The proper estimation under the DCC-GARCH model provides supportive evidence on the relationships between stock markets and precious metals. Regarding model selection, both log likelihood and information criteria demonstrate the superiority of the VARMA-GARCH model. Diagnostic tests of residuals reveal the suitability of the MGARCH framework, while the DCC-GARCH model provides significant evidence of stochastic properties, which include normality, autocorrelation, and heteroskedasticity. The stationary condition is found appropriate under all models.

During the Covid-19 pandemic, only the DCC-GARCH model provides significant evidence on the interactions between emerging stock and precious metals in the mean equation. However, the impact of past change in emerging stock on precious metals becomes negative. In other words, this effect illustrates the implication of the pandemic to the relationship between the two financial assets. The dynamic conditional correlation mechanism is elaborately confirmed by the coefficient of unconditional standardized errors. Besides, the constant conditional correlation approach does not provide sufficiently empirical findings on the stock-precious metals in terms of return and volatility transmissions. Although the Covid-19 outbreak results in the disappearance of significant interactions between stock markets in terms of mean equation and covariance estimations, the constant conditional correlation remains positive. Matching our hypothesis development, bivariate GARCH models provide statistically significant evidence on the nexus between global stocks and precious metals from 1999 to 2019, which is considered a period of relatively stable economic conditions compared to the Covid-19 outbreak. In contrast, the financial assets could not interchangeably explain themselves during the occurring crisis, using the identical framework. These findings suggest that we investigate the nexus between stock markets and precious metals during the Covid-19 crisis under an alternative perspective, for instance, employing the happiness sentiment proxy.

The portfolio assessments reveal that the optimal holding weight of precious metals increase, regardless of stock market proxies and model specifications. This finding affirms that precious metals remain their role as a hedge and safe haven to equity markets. These characteristics of precious metals are consistent to priorly prominent literature with various empirical evidence, for example, multimarket investigation (Low et al., 2016), equity indexes (Baur and McDermott, 2016), and emerging markets (Li and Lucey, 2017). Following the safe haven role of precious metals, the portfolio performance dramatically improves despite the Covid-19 outbreak. In specific, the portfolio becomes more achievable and less volatile during the crisis. The optimal hedge ratio slightly increases, which recommends effective strategic investments during an unprecedented crisis. These patterns contribute to the impressive performance of the risk-adjusted return and the hedging effectiveness ratio. Due to the valuable role of precious metals, the portfolio performance turns amazing during the crisis, even though the Covid-19 pandemic has been causing enormous economic and financial damages.

4.2. Happiness perspective

Table 3 presents the relationships between stock markets, precious metals, and happiness sentiment indexes during the Covid-19 outbreak under tri-variate GARCH models. Information criteria of the vector autoregressive selection suggest 6 lags for the global stock proxy and 4 lags for the emerging market index, respectively. Since the CCC-GARCH model excludes the past shock and volatility transmissions between return series, we employ the VARMA-GARCH and the DCC-GARCH models to explore the relationships between stock markets, precious metals, and global happiness indexes. When the All-World Series represents the global stock market index, the log likelihood favors the VARMA-GARCH model while information criteria prefer the DCC-GARCH model. When the Emerging Market index represents the stock investment, the VARMA-GARCH model is favorable by both the log likelihood and information criteria. The appropriateness of MGARCH approach is ensured by stochastic properties which include the normality of residuals and the disappearance of autocorrelation and heteroskedasticity effects. In addition, the VARMA-GARCH mechanism is stationary, as eigenvalues of matrices estimated in the conditional covariance are inside the unit circle.

The estimated equations state that the happiness sentiment significantly influences both stock markets and precious metals indexes. Indeed, the two-lagged return of DHS negatively affects stock returns and positively influences the performance of precious metals. This relationship is robust regardless of stock market proxies and model specifications. As the nexus between stock markets and precious metals

![Twitter's daily happiness sentiment index](http://www.hedonometer.org/timeseries/en_all/)

Fig. 2. Daily Happiness Sentiment (DHS) index series from 01 Jan 2020 to 03 May 2021.

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2 Source: Hedonometer retrieved from [http://www.hedonometer.org/timeseries/en_all/](http://www.hedonometer.org/timeseries/en_all/).
| Table 2 |
| Relationship between global stock and precious metals index under conditional correlation MGARCH models. |

**All-World Series and Precious Metals Indexes**

|                | VARMA-GARCH | CCC-GARCH | DCC-GARCH |
|----------------|-------------|-----------|-----------|
|                | 1999-2019   | 2020-2021 | 1999-2019 | 2020-2021 | 1999-2019 | 2020-2021 |
| \( r^i \)       | 0.0005***   | 0.0014*** | 0.0004*** | 0.0013*** | 0.0004*** | 0.0015*** |
| \( \rho^i \)    | (0.0001)    | (0.0004)  | (0.0001)  | (0.0005)  | (0.0001)  | (0.0001)  |
| \( r^i_{-1} \)  | 0.1550***   | 0.0444    | 0.1584*** | 0.0267    | 0.1613*** | -0.0154** |
| \( \rho^i_{-1} \) | (0.0139)    | (0.0632)  | (0.0127)  | (0.0657)  | (0.0140)  | (0.0002)  |
| \( r^i_{-2} \)  | -0.0044     | 0.0092    | -0.0066   | 0.0024    | -0.0036   | 0.0109*** |
| \( \rho^i_{-2} \) | (0.0110)    | (0.0414)  | (0.0106)  | (0.0395)  | (0.0090)  | (0.0003)  |
| \( r^i_{-3} \)  | 0.0003**    | 0.0007    | 0.0003**  | 0.0006    | 0.0003*   | 0.0007    |
| \( \rho^i_{-3} \) | (0.0002)    | (0.0007)  | (0.0001)  | (0.0007)  | (0.0001)  | (0.0006)  |
| \( r^i_{-4} \)  | 0.0488***   | -0.0194   | 0.0528*** | 0.0113    | 0.0521*** | 0.0247    |
| \( \rho^i_{-4} \) | (0.0172)    | (0.0672)  | (0.0160)  | (0.0671)  | (0.0114)  | (0.0195)  |
| \( r^i_{-5} \)  | -0.0228**   | -0.0689   | -0.0225*  | -0.0742   | -0.0227*  | -0.0203   |
| \( \rho^i_{-5} \) | (0.0136)    | (0.0615)  | (0.0134)  | (0.0634)  | (0.0117)  | (0.0402)  |
| \( r^i_{-6} \)  | 0.0011      | 0.0067    | 0.0272**  | 0.0067    | 0.0011    | 0.0067    |
| \( \rho^i_{-6} \) | (0.0017)    | (0.0117)  | (0.0030)  | (0.0083)  | (0.0016)  | (0.0087)  |
| \( r^i_{-7} \)  | 0.0277***   | 0.1479**  | 0.0297*** | 0.2061*** | 0.0304*** | 0.2225*** |
| \( \rho^i_{-7} \) | (0.0031)    | (0.0655)  | (0.0029)  | (0.0688)  | (0.0032)  | (0.0177)  |
| \( b^r \)       | 0.8839***   | 0.7167*** | 0.8920*** | 0.7105*** | 0.8918*** | 0.7110*** |
| \( \rho^b \)    | (0.0090)    | (0.0455)  | (0.0086)  | (0.0493)  | (0.0094)  | (0.0254)  |
| \( b^x \)       | 0.0013      | -0.0531   | 0.0013    | -0.0531   | 0.0013    | -0.0531   |
| \( \rho^b \)    | (0.0027)    | (0.0372)  | (0.0027)  | (0.0372)  | (0.0027)  | (0.0372)  |
| \( b^y \)       | -0.0272**   | 0.0258    | -0.0272** | 0.0258    | -0.0272** | 0.0258    |
| \( \rho^b \)    | (0.0065)    | (0.0660)  | (0.0065)  | (0.0660)  | (0.0065)  | (0.0660)  |
| \( b^z \)       | 0.9649***   | 0.9563*** | 0.9636*** | 0.6993*** | 0.9637*** | 0.5296*** |
| \( \rho^b \)    | (0.0039)    | (0.1103)  | (0.0036)  | (0.0742)  | (0.0038)  | (0.0323)  |
| \( r^x \)       | 0.1146***   | 0.1281**  | 0.1101*** | 0.1291*** | 0.1623*** | 0.1252**  |
| \( \rho^\alpha \) | (0.0107)    | (0.0516)  | (0.0110)  | (0.0524)  | (0.0132)  | (0.0513)  |
| \( \alpha \)    | 0.0434***   | -0.0061***| 0.0434*** | -0.0061***| 0.0434*** | -0.0061***|
| \( \beta \)     | 0.9493***   | 0.9894*** | 0.9493*** | 0.9894*** | 0.9493*** | 0.9894*** |

**Emerging Markets and Precious Metals Indexes**

|                | VARMA-GARCH | CCC-GARCH | DCC-GARCH |
|----------------|-------------|-----------|-----------|
|                | 1999-2019   | 2020-2021 | 1999-2019 | 2020-2021 | 1999-2019 | 2020-2021 |
| AIC            | 12.1450     | 13.2370   | 12.7730   | 12.7870   | 13.2190   | 12.1350   |
| HQ             | 13.1870     | 13.1850   | 12.0880   | 12.0730   | 12.1730   | 12.1450   |
| JB             | 602.6***    | 140.87*** | 616.63*** | 146.07*** | 615.83*** | 141.02*** |
| LB             | 4925***     | 98.78***  | 5548***   | 94.59***  | 5781***   | 113.65*** |

(continued on next page)
during the Covid-19 outbreak is not supported by sufficient evidence under the bivariate GARCH models, the happiness sentiment index tremendously explains interactions between the two financial assets. In return, the happiness sentiment could be explained by past performance of both stock markets and precious metals. We find that the global happiness is positively affected by the statistically significant estimator of the lowest-lagged stock return. The past financial changes influence the status of sentiment in complicated mechanisms. In addition, the relationship between asset returns and happiness sentiment is clarified by the past shock and volatility spillovers in the estimation of the conditional covariance matrix. In which, both VARMA-GARCH and DCC-GARCH models support significant evidence on the interactions between return series in terms of residuals and conditional correlations. At the same time, these findings ensure the suitability of the tri-variate GARCH framework during the Covid-19 period.

In economic sense, these findings imply the interactions between happiness and financial investment outcome during an unprecedented outbreak caused by the Covid-19 pandemic. During the crisis, past stock returns positively affect the well-being. This relation is consistent to recent literature on the nexus between wealth and happiness, for example, in terms of return transmissions (Nguyen and Le, 2021). In contrast, the past change in happiness negatively influence the stock performance during the Covid-19 outbreak. This is a unique finding on the relationship between stock return and change in happiness compared to prior periods with stable economic conditions. In other words, the stock-happiness nexus becomes negative under impacts of the Covid-19 pandemic. This fact implies a trade-off between wealth and happiness during such a difficult period caused by the pandemic. On the other hand, the past change in happiness positively influences the performance of precious metals. This finding reflects the mind of investors who prefer precious metals during crises such as the Covid-19 outbreak. In the end, people tend to favor precious wealth such as gold, silver, platinum, and palladium when economic conditions turn unstable. This relation further reaffirms the hedge and safe haven characteristic and supports prior literature regarding the interactions between happiness and precious metals, in terms of, for example, gold price (Byström, 2020) and futures market (Asai, 2020). Henceforth, the happiness perspective reveals interesting findings on the nexus between stock markets and precious metals under implications of the Covid-19 pandemic.

5. Conclusion

We have examined the relationships between stock markets and precious metals during the first 20 years of the 21st Century. In which, we employ the conditional correlation MGARCH framework to investigate the return and volatility spillovers between index series. The study assesses performance of the FTSE All-World Series, the MSCI Emerging Markets, and the S&P GSCI Precious Metals indexes from 01 September 1999 to 03 May 2021. Main findings indicate that the precious metals index is firmly a hedge and safe haven to both global and emerging equity market indexes. The stock-precious metals nexus is emphasized due to impacts of the Covid-19 pandemic, which occurs in 2020 and is still going. Therefore, we employ the Twitter’s Daily Happiness Sentiment index to examine its relationships with stock markets and precious metals indexes, especially during an unprecedented crisis caused by the Covid-19 outbreak. We find that the well-being index significantly explains the patterns of both stock markets and precious metals during the Covid-19 period. In other words, the happiness proxy facilitates to explore the nexus between stock markets and precious metals during the Covid-19 period under the MGARCH framework, whilst the bivariate approach does not provide sufficiently empirical evidence. Accordingly, we have assessed the stock-precious metals nexus under Covid-19 and happiness perspectives. These empirical findings suggest economic implications on the role of psychological and behavioral aspects in exploring financial relationships.

Table 2 (continued)

| All-World Series and Precious Metals Indexes | VARMA-GARCH | DCC-GARCH |
|--------------------------------------------|-------------|-----------|
| Indexes                                   | 1999-2019   | 2020-2021 |
| Emerging Markets                          | 7.5590      | 7.5690    |
| Stocks                                    | 13.8950     | 14.0000   |
| Gold                                      | 6.3950      | 6.4100    |
| Silver                                    | 15.9850     | 16.0000   |
| Platinum                                  | 16.4050     | 16.4300   |
| Palladium                                 | 16.3200     | 16.3400   |
| Happiness                                 | 0.9879      | 0.9970    |
| Notes: Standard deviations are in parentheses. *, **, and *** indicate statistical significance of 10%, 5%, and 1%, respectively. Log likelihood is denoted by LogL. Information criteria include Akaike (AIC), Schwarz-Bayes (SBC), Hannan-Quinn (HQ), and the natural logarithm of the final prediction error (LFPE). The Jarque-Bera (JB) test is for normality of residuals. The autocorrelation effect is checked with 15-lagged Ljung-Box (LB) and McLeod-Li (ML) tests. The ARCH (15 lags) test is a heteroskedasticity check. Portfolio (PF) assessments include stock weight (w), hedge ratio (β), return (R), and hedging effectiveness ratio (γ). Estimation with the Broyden-Fletcher-Goldfarb-Shanno (BFGS) algorithm. |
|                      | All-World Series and Precious Metals Indexes | Emerging Markets and Precious Metals Indexes |
|----------------------|---------------------------------------------|-------------------------------------------|
|                      | FAW-GARCH | PMI | DHS | DCC-GARCH | FAW | PMI | DHS | DCC-GARCH | FAW | PMI | DHS | DCC-GARCH |
| $\mu$                |          |     |     |           |     |     |     |           |     |     |     |           |
| (0.0005)             | 0.0003   | 0.0002 | 0.0000*** | (0.0000) | 0.0000*** | (0.0000) | 0.0000*** | (0.0000) | 0.0000*** | (0.0000) | 0.0000*** | (0.0000) |
| r$^{-1}$,           | 0.0013*** | 0.0007*** | 0.0006 | 0.00001 | 0.0017*** | 0.0006 | 0.0001 | 0.0009 | 0.00001 | 0.00001 | 0.00001 | 0.00001 |
| (0.0005)             | (0.0007) | (0.0000) | (0.0000) | (0.0000) | (0.0000) | (0.0000) | (0.0000) | (0.0000) | (0.0000) | (0.0000) | (0.0000) | (0.0000) |
| r$^{-2}$,           | 0.0002   | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 |
| (0.0005)             | (0.0007) | (0.0000) | (0.0000) | (0.0000) | (0.0000) | (0.0000) | (0.0000) | (0.0000) | (0.0000) | (0.0000) | (0.0000) | (0.0000) |
| $\sigma$             | 0.1115*** | 0.0906*** | 0.0583 | 0.0703** | 0.0544** | 0.0509** | 0.0544** | 0.0583 | 0.0906*** | 0.0583 | 0.0703** | 0.0544** |
| (0.0006)             | (0.0006) | (0.0006) | (0.0006) | (0.0006) | (0.0006) | (0.0006) | (0.0006) | (0.0006) | (0.0006) | (0.0006) | (0.0006) | (0.0006) |
| $\rho$               | 0.1115*** | 0.0906*** | 0.0583 | 0.0703** | 0.0544** | 0.0509** | 0.0544** | 0.0583 | 0.0906*** | 0.0583 | 0.0703** | 0.0544** |
| (0.0007)             | (0.0007) | (0.0007) | (0.0007) | (0.0007) | (0.0007) | (0.0007) | (0.0007) | (0.0007) | (0.0007) | (0.0007) | (0.0007) | (0.0007) |
| $\phi$               | 0.0442   | 0.0366 | 0.0266 | 0.0133 | 0.0207 | 0.0079 | 0.0442 | 0.0366 | 0.0266 | 0.0133 | 0.0207 | 0.0079 |
| (0.0849)             | (0.0441) | (0.0632) | (0.0716) | (0.0865) | (0.0540) | (0.0849) | (0.0441) | (0.0632) | (0.0716) | (0.0865) | (0.0540) | (0.0849) |
| $\alpha$             | 0.0000*** | 0.0000*** | 0.0000*** | 0.0000*** | 0.0000*** | 0.0000*** | 0.0000*** | 0.0000*** | 0.0000*** | 0.0000*** | 0.0000*** | 0.0000*** |
| (0.0000)             | (0.0000) | (0.0000) | (0.0000) | (0.0000) | (0.0000) | (0.0000) | (0.0000) | (0.0000) | (0.0000) | (0.0000) | (0.0000) | (0.0000) |
| $\beta$              | 0.0617*** | 0.0583 | 0.0583 | 0.0583 | 0.0583 | 0.0583 | 0.0617*** | 0.0583 | 0.0583 | 0.0583 | 0.0583 | 0.0583 |
| (0.0006)             | (0.0006) | (0.0006) | (0.0006) | (0.0006) | (0.0006) | (0.0006) | (0.0006) | (0.0006) | (0.0006) | (0.0006) | (0.0006) | (0.0006) |

(continued on next page)
### Table 3 (continued)

|                           | All-World Series and Precious Metals Indexes | Emerging Markets and Precious Metals Indexes |
|---------------------------|---------------------------------------------|---------------------------------------------|
|                           | VARMA-GARCH DCC-GARCH                       | VARMA-GARCH DCC-GARCH                       |
|                           | FAW  PMI  DHS                               | EMI  PMI  DHS                               |
|                           | 0.0015 (0.0022) 0.0149** (0.0006) 0.5697*** (0.0175) | 0.0025** (0.0004) 0.0303** (0.0005) 0.5382*** (0.0247) |
| ρ Stock                   | 0.1375*** (0.0394) 0.0766 (0.0568)          | 0.1514*** (0.0372) 0.0713 (0.0584)          |
|                           | 0.0454 (0.0545)                             | 0.0215 (0.0247)                             |
| DCC Info                  | α 0.1033*** (0.0317) β 0.7794*** (0.0601)  α + β 0.8827 | α 0.0393** (0.0175) β −0.0500 (0.2912)  α + β −0.0107 |
| Obs.                      | 317                                         | 319                                         |
| LogL                      | 3197.81 3161.22 N/A                         | 3197.81 3161.22 N/A                         |
| AIC                       | −19.6640 −19.4250 N/A                       | −19.6640 −19.4250 N/A                       |
| SBC                       | −18.7040 −18.6810 N/A                       | −18.7040 −18.6810 N/A                       |
| HQ                        | −19.2810 −19.1280 N/A                       | −19.2810 −19.1280 N/A                       |
| LFPE                      | −19.6530 −19.4190 N/A                       | −19.6530 −19.4190 N/A                       |
| JB Tests                  | 61.11*** 74.11*** 107.41***                 | 27.02*** 81.71*** 111.38***                 |
| LB                        | 18.9310 9.4698 25.0775**                    | 16.8855 19.8001 27.1431**                   |
| ML                        | 8.0457 13.2176 46.3183**                    | 23.9064* 17.5425 50.8186**                  |
| ARCH                      | 7.8500 12.4040 37.3650**                    | 21.1590 16.7250 41.7920**                   |
|                           | 0.8921 0.7011 0.0616                        | 0.7688 0.6347 0.6347                        |

Notes: Standard deviations are in parentheses. *, **, and *** indicate statistical significance of 10%, 5%, and 1%, respectively. Log likelihood is denoted by LogL. Information criteria include Akaike (AIC), Schwarz-Bayes (SBC), Hannan-Quinn (HQ), and the natural logarithm of the final prediction error (LFPE). The Jarque-Bera (JB) test is for normality of residuals. The autocorrelation effect is checked with 15-lagged Ljung-Box (LB) and McLeod-Li (ML) tests. The ARCH (15 lags) test is a heteroskedasticity check. Estimation with the Broyden-Fletcher-Goldfarb-Shanno (BFGS) algorithm.
Consequently, investors shall consider their own emotions as well as market behaviors to optimize investment strategies. On the other hand, policymakers are recommended to assess alternative social aspects of financial markets to regulate them efficiently. The participation of happiness sentiment in financial investments turn more significant during difficult times such as the Covid-19 pandemic. Therefore, the happiness perspective of financial markets becomes a valuable source of information for related parties, from investors to policymakers.

This study is designed by the integration of various factors, which include proxies, timeframe, modeling, and particular adjustments. Besides findings which are consistent and supportive to prior literature, we expect to construct a practice of methodologies relating to the investigation of an unprecedented event such as the Covid-19 pandemic. In specific, we have thought about the happiness sentiment proxy when stock markets and precious metals indexes do not sufficiently explain each other during the Covid-19 outbreak. And interestingly, the happiness index provides statistically significant explanation regarding the stock-precious metals index during the Covid-19 crisis. The proxy adjustment facilitates to examine the co-movements between stock markets and precious metals during the Covid-19 outbreak without changing the framework of methodologies considerably. In accordance with metaphysical finance (Nguyen and Le, 2021), a dialectic relationship could be dualistic, materialist, idealistic, or monistically neutral. Our finding coincidentally indicates that the nexus between wealth and happiness turn idealistic during an extreme crisis caused by the Covid-19 pandemic. Furthermore, our practice of employing the happiness proxy is a reasonable solution for the occurrence of monistically neutral circumstances, those are, neither stock markets nor precious metals have an interaction effect. This approach is recommended for studies that we are supposed to find a significant impact factor, especially in unprecedented events such as the Covid-19 pandemic.

Author statements

There is NO conflict of interests.

Data availability

Data will be made available on request.

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