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Safe haven, hedge and diversification for G7 stock markets: Gold versus bitcoin

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ABSTRACT

We compare gold and Bitcoin for the G7 stock markets, finding that gold and Bitcoin have distinct safe haven and hedging characteristics. Gold is an undisputable safe haven and hedge for several G7 stock indices, whereas Bitcoin takes these two functions in Canada. The out-of-sample hedging effectiveness of gold is much superior to that of Bitcoin. Furthermore, we find that the conditional diversification benefits offered by gold to equity investments in the G7 markets are comparatively much higher and more stable than those of Bitcoin, especially in the lower return quantiles, i.e., when both the stock and gold markets are in a bearish state. Implications are further discussed.

1. Introduction

Throughout its long and rich history, gold has been used as natural money and a store of value. It is a useful portfolio stabilizer and a source of liquidity in times of market turmoil. Gold is a hedge against inflation in the USA and the UK (Van Hoang et al., 2016). It reacts counter-cyclically to macroeconomic news (Elder et al., 2012) and behaves differently than other assets, especially equities. When equity market indices tumble, gold maintains its value or even sometimes increases in value. The empirical literature provides evidence of the traditional role of gold as a hedge against equities in normal times and as a safe haven against equities during stress periods (Baur and Lucey, 2010; Beckmann et al., 2015). However, Baur and Glover (2012) argue that investor behaviour can destroy the hedging property of gold due to the increased investment in gold for speculative or hedging purposes. Klein (2017) uses a dynamic correlation model to show that gold did have a hedging role for the USA and the European stock market indices but this role appears to have dissipated after 2013.

Recently, attention has shifted from gold in favour of a newly emerged asset, Bitcoin, which is often presented as having similar properties to gold, specifically its hedging and safe haven characteristics. On January 3, 2009, Bitcoin debuted as the first decentralized and fully digitalized currency system, based on its blockchain technology and proof of work transaction verification[1]. Not long after becoming a medium of exchange, Bitcoin gained some ground in the investment space, supported by its independence from sovereign authorities and the tradability of its unit on specialized exchanges. Bitcoin investment has since become more accessible[2] with the availability of several Bitcoin-linked funds that are now offered by global investment banks, such as Falcon Private Bank and ARK Investment Management. In December 2017, the

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[1] Blockchain is a shared public ledger that holds all Bitcoin transactions, whereas proof of work is an identity assignment tool that solves the double-spending problem. More detailed explanation of Bitcoin is given by Selgin (2015).

[2] Bitcoin is accessible in most advanced and emerging economies, where most individual and institutional investors can get exposure to the Bitcoin market via online purchase of Bitcoin from leading exchanges (e.g., Bitfinex, Coinbase, Bitstamp, Poloniex). The payment method can be credit or debit card, wire transfer, or hard cash (through Bitcoin-ATM machines).

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Chicago Mercantile Exchange (CME) Group and the Chicago Board Options Exchange (CBOE) launched futures contracts with Bitcoin as an underlying asset. In joining crude oil and gold in futures trading, Bitcoin moved from the margins of the financial world towards the mainstream. This adds legitimacy to Bitcoin and makes it difficult to ignore as an investment option[3]. The weak correlation of Bitcoin with traditional assets makes it a very potent diversification tool (Baur et al., 2018b; Bouri et al., 2017a, 2017b; Brière et al., 2015; Corbet et al., 2018; Guesmi et al., 2019; Ji et al., 2018) and a valuable hedge against equities (Baur et al., 2018b; Bouri et al., 2017a) or the general commodity index (Bouri et al., 2017b)[4]. Notably, Bitcoin was not hit but rather thrived during the European debt crisis of 2010–13[5] and the Cypriot banking crisis of 2012–13 (Kristoufek, 2015; Luther and Salter, 2017), when some investors shed sovereign currencies in favour of non-political and non-sovereign assets. In April 2017, after approximately eight years of existence, one Bitcoin became more valuable than an ounce of gold. As of December 2018, a single Bitcoin is more than three times as valuable as an ounce of gold, and the debate has centred on its ability to mimic or beat the hedging property of gold against stock market returns. Some studies empirically analyze both gold and Bitcoin (Bouri et al., 2017a; Ciaian et al., 2016; Corbet et al., 2018; Ji et al., 2018; Kristoufek, 2015), but there is a lack of evidence on whether Bitcoin and gold share a safe haven or a hedging role against movements in stock market indices during adverse market conditions when hedging benefits are needed most[6]. The empirical literature lacks evidence on the conditional diversification benefits of gold and Bitcoin against stock market returns for various portfolio compositions and probabilities, especially in the lower return quantiles, i.e., when both the stock and gold (Bitcoin) markets are in a bearish state. These issues are relevant to the case of the G7 countries that have some of the most influential institutional investors, the longest history in stock market activities, and the largest market capitalizations and economic outputs.

The aim of this study is to decide whether gold or Bitcoin is a better safe haven, hedge or diversification asset for the G7 (Canada, France, Germany, Italy, Japan, the United Kingdom and the United States) stock markets. We are interested in the comparative study of gold and Bitcoin from the perspective of portfolio management and investment strategies. This is important given that an asset might reduce risk or increase diversification benefits especially in times of market downturn (i.e. when stock prices decrease and price volatility spikes). Our sample period spans July 19, 2010 to December 31, 2018, which makes our analysis interesting as it includes the post-GFC period. During this period, some researchers (e.g., Klein, 2017) questioned the hedge and safe haven ability of gold. Meanwhile, Bitcoin gained substantial ground during the European/Greek debt crisis and the Cypriot banking crisis. The period under study covers a rich time span including booms and busts in the Bitcoin market. Methodologically, we use a combination of methods to analyze the safe haven, hedging and diversification role of Bitcoin and gold for the G7 stock markets. We first examine the safe haven and hedging ability of gold and Bitcoin using the traditional methodology of Baur and McDermott (2010). Next, we comparatively analyze the hedge effectiveness. Then we assess the conditional diversification benefits (CDB) following the method of Christoffersen et al. (2018).

Our focus on the G7 countries is interesting for three notable reasons. First, the G7 group represents the most advanced economies, accounting for almost two-thirds of net global wealth and half of net global output. The literature highlights a heterogeneous role of gold against equity movements in each of the seven countries, which makes the comparative study of equity reactions to gold (Bitcoin) essential. Second, the G7 group comprises the largest and most important stock markets. According to world stock exchange data, the total market value of companies in the G7 stock markets exceeds 41 trillion USD, representing more than two-thirds of the world's market capitalization. Third, the G7 are a heterogeneous set of countries. Although they are all large developed economies, the G7 members often experience differences in their economic states and reactions to global stress periods, such as the European debt crisis, during which gold and Bitcoin might have different reactions. For example, Bitcoin and gold moved in tandem during some periods of the European crisis (see Fig. 1), additionally both gold and Bitcoin gained value after the Brexit vote. Following the bailout announcement for Cyprus, Bitcoin gained value and ground, whereas the gold price continued its downward trend. In addition, Japan is a large player in the Bitcoin market. It has recently adopted digital-friendly rules, suggesting that Bitcoin might play an important role against movements in Japanese stock market returns.

Our main results show that gold is a hedge and a safe haven for most of the G7 stock markets and for the MSCI G7 index, while Bitcoin is a hedge and safe haven for few cases. The out-of-sample hedging effectiveness of gold is comparatively much better than that of Bitcoin. Furthermore, while both Bitcoin and gold appear to offer considerable diversification benefits for investors in G7 stock markets, gold delivers stronger and more stable diversification benefits. Importantly, the diversification benefits are generally larger in the lower tail, compared to the median values, especially for gold. We also discuss several additional caveats. Our empirical analysis is important for the decision making of market participants as it increases the current understanding of the similarities and dissimilarities of the roles of gold and Bitcoin with respect to the stock markets of the G7 countries. Investors and portfolio managers could design better investment strategies by comparing gold and Bitcoin for possible inclusion in the composition of their equity portfolios. Speculators could create spread trades with respect to market conditions. Our analysis is also useful to financial advisors who often seek unconventional assets that can provide protection for stock portfolios against downside risk, especially during stress periods, when protection is rewarding.

We structure the rest of the paper as follows. Section 2 provides an overview of the potential role of Bitcoin as a hedging asset and compares it to gold. Section 3 presents the dynamic correlation methods used to examine the safe-haven and hedging abilities of gold and Bitcoin in adverse market conditions and a framework analysis that includes conditional diversification benefits and hedging effectiveness. Section 4 describes the dataset and discusses the main empirical results providing implications in terms of the conditional diversification benefits and hedging effectiveness. Section 5 provides concluding remarks.

2. Bitcoin as a hedging asset

2.1. Potential

Although many argue that Bitcoin has virtues making it somewhat comparable to gold, Bitcoin and gold differ in several respects. The main differences between gold and Bitcoin are related to tangibility, history, intrinsic value, volatility, use in the production process, and acceptance as a global monetary reserve. Bitcoin is an intangible asset with a rather short and questionable history (for more detail on the legal issues, please refer to Bhaskar et al., 2019). Its intrinsic value is a topic of ongoing discussion, as it is not backed by any institutionalized entity, but current research suggests that the price of Bitcoin is not solely driven by speculation (Kristoufek, 2015; Ciaian et al., 2016). As a leading cryptocurrency, the volatility of Bitcoin is quite unprecedented in the financial markets, and although it had been on a rather stable downward trend

[3] While Baur et al. (2018b) show evidence that Bitcoin is weakly correlated with equities suggesting a diversification ability in both normal and stress periods, the authors claim that Bitcoin is "mainly used as a speculative investment and not as an alternative currency and medium of exchange".

[4] These roles played by Bitcoin are documented despite its extremely high price return and volatility (Brière et al., 2015).

[5] https://www.cnbc.com/2015/07/01/greece-is-in-crisis-why-no-love-for-gold-commentary.html.

[6] A recent study by Klein et al. (2018) applies a combination of methods and finds that the conditional variance properties of Bitcoin are different from those of gold.

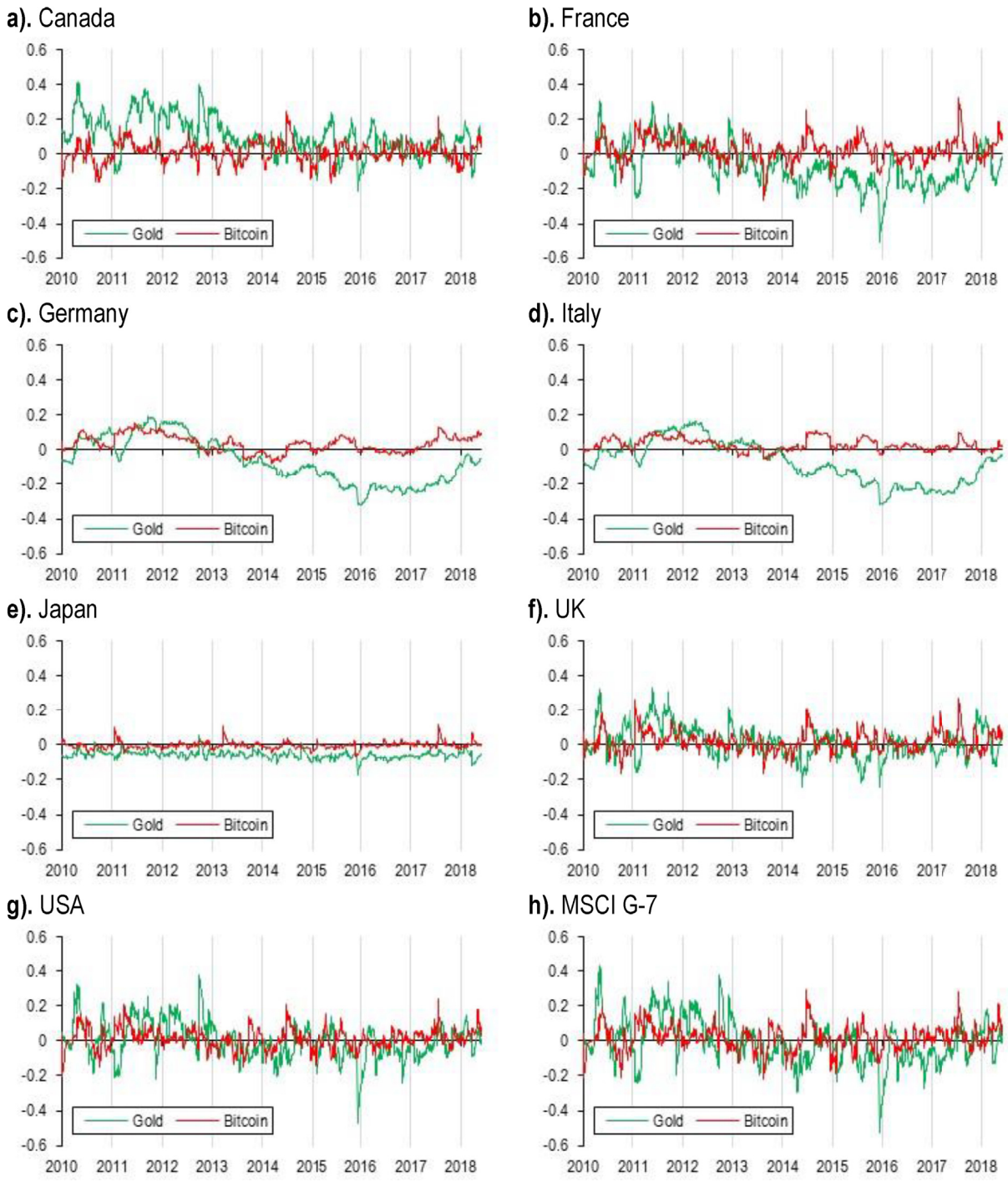

Fig. 1. Evolution of daily dynamic correlations between the returns of Bitcoin (gold) and each of the G7 stock index returns. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

until the end of 2016, it has experienced a strong upswing since the beginning of 2017 (Kristoufek, 2018). Such a change in volatility dynamics is counterintuitive, as the year 2017 was characterized by an influx of new investors and thus increased liquidity. This suggests that although the traded volumes of Bitcoin and other cryptocurrencies and tokens have been steadily increasing, the implied liquidity is still low compared to other standard financial assets and instruments — which is a challenge and an opportunity for further growth and development as well as a warning signal for institutional investors. However, the possibilities for using Bitcoin as a payment method have increased, even though there are geographic specifics, and its acceptance cannot yet be considered global. For most of these factors, we can treat gold as the almost exact opposite. From the perspective of an ideal hedging asset, the most problematic characteristics of Bitcoin are its questionable history (although many investors do appear to trust its reliability) and high volatility (which implies that Bitcoin would ideally need to be negatively correlated with the rest of a portfolio, i.e., the stock index, to be considered a hedge).

In contrast, gold and Bitcoin have many common features that include the classification as a commodity by the US Commodity Futures Trading Commission, production in a process called mining (even though in reality the physical mining of gold is completely different from the CPU-

and GPU-based digital mining of Bitcoin[7]), liberation from sovereign authorities such as central banks, limitation or scarcity of supply[8] a positive return-volatility relationship, the ability to hedge inflation and stock market risks, an inverted asymmetric reaction to positive and negative news, and an inability to generate cash-flows as in conventional assets such as equities and bonds. Of these characteristics, the most important is that both gold and Bitcoin are effective inflation and stock market risk hedges. This assumes that both are deflationary (or at least not inflationary) and are not correlated, or are even negatively correlated, with the stock markets. These aspects are well documented for gold but are not so well-known for Bitcoin which economists consider deflationary, as its circulating supply is known and given by an algorithm, and its amount cannot be artificially increased, i.e., there is no inflationary 'money printing'. In the long term, this leads to an increasing price as long as there is reasonable demand. Several studies show that Bitcoin is very weakly correlated with other financial assets (Dyhrberg, 2016; Bouri et al., 2017a, 2017b; Ji et al., 2018). Interestingly, Kristoufek (2015) suggests that Bitcoin is only mildly correlated with gold and only for very specific periods, which makes it reasonable to consider gold and Bitcoin as good risk diversifiers even in combination.

2.2. Issues and limitations

Cryptocurrencies form a unique class of assets with specific features that are frequently distinct from those of standard financial assets and instruments. Although many of these features are considered advancements in the financial world — such decentralization, little regulation, low transaction fees, and anonymity — there are also features (sometimes connected to the previously listed advancements) that limit Bitcoin and cryptoassets in general from wider acceptance and utility. The most important issues and limitations with respect to a hedge label are liquidity issues, an unclear international tax status, and technical specifics.

Compared to standard financial assets, liquidity is still low in the cryptoworld. Even though the most capitalized cryptocurrencies (the top 5 being Bitcoin, Ethereum, Ripple, Bitcoin Cash, and Litecoin) are considered quite liquid, the total trading volume of all cryptocurrencies is estimated to be approximately 0.1% of the total forex trading volume. This shows room for growth and demonstrates how small the crypto-market currently is. Such illiquidity is reflected in the price differentials between exchanges that, even though sometimes considerable, are not arbitraged away. This is not necessarily solely connected to the low liquidity but rather a combination of unstable transfer and withdrawal times of the exchanges and high volatility. In effect, arbitrageurs do not clear the differential away unless it is considered high enough not to disappear before the transfer between exchanges is complete[9]. Another problematic issue connected to liquidity and potential utility as a hedging asset is the virtual non-existence of many (fiat) currency pairs with Bitcoin. In practice, there are few Bitcoin pairs that economists consider liquid enough, in this case, with sufficient market depth — the US dollar, Euro, Japanese Yen and South Korean Won (historically, the pair with the Chinese Yuan was important until the Chinese government issued such firm restrictions on it)[10]. Of these, the USD pair is the most important, which means that although Bitcoin might be stock market neutral, the exchange rate risk of the US dollar is indirectly transferred to Bitcoin holdings as well (unless hedging against a USD-based portfolio).

Another essential issue of Bitcoin as a potential useful hedge is its unclear classification, specifically with respect to tax systems and taxes in general. This is a situation where anonymity meets regulation and governments' desire to collect taxes and prevent money laundering[11]. The topic of how to tax cryptocurrencies is still pertinent and of interest to researchers (Gross et al., 2017; Sullivan and Burger, 2017). Until the tax dilemma, which is mainly a financial asset classification dilemma (currencies, stocks and properties are usually taxed differently), is resolved or reasonably harmonized internationally, it is difficult to imagine that large institutional investors would consider Bitcoin (or any other cryptocurrency) as an investment outlet[12].

The last interesting aspect of Bitcoin (and cryptocurrencies in general) that can be considered a barrier to entry for the big players is the technical cryptoworld peculiarities, which are not observed in other financial assets. In addition to blockchain function and transaction/confirmation times, the topic of forks of cryptocurrencies is increasingly popular. All cryptocurrencies are based on a code that must be updated and upgraded over time and as new challenges arise. Upgrades of the code have been controversial in the community, and splits have occurred when one version of the code goes on as the original cryptocurrency while another version forms a new cryptocurrency (each then functions with its own blockchain, whereas the history before the split is the same for both). Such a split is referred to as a (hard) fork. Although forks evoke dividends or stock splits, they are quite different. A fork forms a new currency that must show its utility, and according to its utility and investor interest, its price is attributed. The newly-formed cryptocurrency is generally 'given away' to the holders of the cryptocurrency that has been forked (in some predetermined ratio or under specific conditions). The additional risk connected with forking is the uncertainty of the price effect on the cryptocurrency being forked and whether its possible decline is offset by the price of the newly created cryptocurrency[13]. However, the occurrence of forks is exogenous with respect to the situation of financial markets and should not play a role in the assessment of Bitcoin as a hedging asset.

To summarize, there are several attractive properties of Bitcoin that can make it a useful hedging asset, but there are also several properties that decrease its utility. The current developments in the cryptoworld make it so that the attractive properties should persist and the problematic properties could disappear, although some of the specifics

[7] See Bouri et al. (2017b) for further details on Bitcoin mining.

[8] Bitcoin supply is limited, as dictated by the Bitcoin protocol which puts a ceiling of 21 million on the overall number of mined coins, i.e. the 'money creation' process of Bitcoin is algorithmic and given.

[9] Transaction (confirmation) times vary considerably over time, and at the beginning of 2018 the network congestion was so severe that the average confirmation time of a transaction reached as much as 11,000 min. However, at the time of writing (March 2018), the times are more reasonable, and now fluctuate mostly between 10 and 20 min (where 10 min is the frequency for creating a block of transactions and can be considered a minimum average transaction time).

[10] In most countries, services that offer Bitcoin purchases in local currencies exist, but these are usually very illiquid, with high transaction fees, and mainly focus on small (and inexperienced) retail investors.

[11] Notably, no uniform international approach has been adopted to regulating the Bitcoin market (https://blockonomi.com/bitcoin-money-laundering). For example, the European Commission adopted proposals that ensure Bitcoin exchanges and wallet providers must comply with the European Union's anti-money laundering rules. In the USA, the Internal Revenue Service has issued a ruling regarding how Bitcoin earnings should be taxed, specifically indicating that Bitcoin assets are subject to income taxes once they are converted into non-Bitcoin assets, whereas Bitcoin holdings are still not taxable. South Korea announced, in January 2018, a system that seeks to ban the use of anonymous accounts in Bitcoin transactions. Ultimately, further regulation is almost inevitable in other countries and regions.

[12] Note that the end of 2017 marked an important milestone in making Bitcoin a standard financial instrument as both CME and CBOE launched their Bitcoin futures contracts. As both exchanges are regulated and function in accordance with enforceable laws, this allows institutional investors to enter the market safely.

[13] Two actual hard forks of Bitcoin to date are Bitcoin Cash and Bitcoin Gold. The former can be considered a success but the latter struggles.

Table 1
Hedge and safe haven conditions and conclusions.

Condition	Conclusion
c_1, c_2 or $c_3 \neq 0$	There is a non-linear relationship
c_0, c_1, c_2 and $c_3 \leq 0$	Gold (Bitcoin) is a weak safe haven
c_0, c_1, c_2 and $c_3 < 0$	Gold (Bitcoin) is a strong safe haven
$c_0 = 0$ and $c_0 > \sum_{i=1}^{3} c_i \leq 0$	Gold (Bitcoin) is a weak hedge
$c_0 < 0$ and $c_0 > \sum_{i=1}^{3} c_i \leq 0$	Gold (Bitcoin) is a strong hedge

(mainly proclaimed anonymity) would need to be abandoned[14].

3. Methodology

We analyze the hedge and safe haven roles of Bitcoin and gold for the G7 stock markets using the framework proposed by Baur and McDermott (2010). Next, we assess the hedge effectiveness of the G7 stock markets through gold and Bitcoin in the out-of-sample setting[15]. Finally, we calculate the diversification benefits of Bitcoin (gold) for equity investors via the application of the conditional diversification benefit (CDB) measure of Christoffersen et al. (2018). We discuss these methods only briefly here, and refer interested readers to the original articles for details.

3.1. Safe haven testing

Following Baur and McDermott (2010), we estimate the following three principle regression equations to check the safe haven property of Bitcoin and gold:

$$r_{Gold/BTC,\ t} = a + b_t r_{Stock,\ t} + e_t \tag{1}$$

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

$$h_t = \pi + \alpha e_{t-1}^2 + \beta h_{t-1} \tag{3}$$

Eq. (1) describes the relation between gold (Bitcoin) and the G7 stock returns. The parameters to estimate are a and b_t. The error term is given by e_t. The parameter b_t is modelled as a dynamic process given by Eq. (2). The parameters to estimate in Eq. (2) are c_0, c_1, c_2 and c_3. The dummy variables denoted as $D(.)$ capture extreme stock market movements and are equal to one if the stock market exceeds a certain threshold given by the 10%, 5% and 1% quantile of the return distribution. If one of the parameters c_1, c_2 or c_3 is significantly different from zero, there is evidence of a non-linear relationship between gold (Bitcoin) and the G7 stock market. If the parameters in Eq. (2) are non-positive (including c_0), gold (Bitcoin) acts as a weak safe haven for the market considered. If the parameters are negative and statistically different from zero, gold (Bitcoin) functions as a strong safe haven. Gold (Bitcoin) is a hedge for a specific market if the parameter c_0 is zero (weak hedge) or negative (strong hedge) and the sum of the parameters c_1 to c_3 are not jointly positive exceeding the value of c_0. Table 1 presents a summary of conditions for which gold/Bitcoin is concluded to be a hedge or safe haven. Finally, Eq. (3) presents a GARCH(1,1) model which is used to account for heteroscedasticity in the data. Eqs. (1)–(3) are jointly estimated through likelihood maximization.

3.2. Hedge effectiveness

We compare the hedging ability of gold (Bitcoin) for the G7 stock markets by considering their hedge effectiveness. Specifically, we compute the hedge effectiveness of the hedged positions between the G7 stock markets and gold (Bitcoin) to infer how much gold (Bitcoin) reduces the risk of a combined portfolio. Such a comparison is relevant and represents a very common instrument of portfolio risk assessment. Notably, the analysis is conducted out-of-sample.

Let $R_{H,t}$ be the return on a hedged portfolio that contains a stock and gold (Bitcoin) position:

$$R_{H,t} = R_{S,t} - \phi_t R_{A,t} \tag{4}$$

where $R_{S,t}$ represents the return on the individual G7 stock index, $R_{A,t}$ denotes the return on gold (Bitcoin), and ϕ_t represents the hedge ratio. Accordingly, the variance of the hedged portfolio conditional on the information set $I_t{-}1$ is given by:

$$var\ (R_{H,t}I_{t-1}) = var\ (R_{S,t}I_{t-1}) + \phi_t^2 var\ (R_{A,t}I_{t-1}) - 2\phi_t\ cov\ (R_{A,t}\ ,\ R_{S,t}I_{t-1}) \tag{5}$$

Following Baillie and Myers (1991), the optimal coefficient that minimizes the conditional variance of the hedge portfolio is:

$$\phi_t^* I_{t-1} = \frac{cov\ (R_{S,t}\ ,\ R_{A,t}|I_{t-1})}{var\ (R_{A,t}|I_{t-1})} \tag{6}$$

According to Kroner and Sultan (1993), hedge ratios are computed based on the conditional-volatility and covariance estimates from the asymmetric generalized dynamic conditional correlation version of the generalized autoregressive conditional heteroskedasticity (AGDCC-GARCH) modelling (details are given in the Appendix). Generally, a long position in a stock index is hedged with a short position in gold (Bitcoin) according to the following hedge:

$$\phi_t^* | I_{t-1} = h_{SA,t}/h_{A,t} \tag{7}$$

where $h_{SA,t}$ is the conditional covariance between the stock index and gold (Bitcoin) returns and $h_{A,t}$ is the conditional variance of gold (Bitcoin) returns.

The performance of the optimal hedge ratios obtained from AGDCC-GARCH models is measured using the hedging effectiveness (HE) index (Basher and Sadorsky, 2016; Toyoshima et al., 2013)[16] where a higher HE index indicates a higher hedging effectiveness:

$$HE = \frac{var_{unhedged} - var_{hedged}}{var_{unhedged}} \tag{8}$$

Out-of-sample hedge ratios are constructed using a rolling window analysis. At time period t, one-period-ahead conditional volatility and covariance forecasts are made and used to construct a one-period ahead hedge ratio. These forecasted hedge ratios are then used to construct the hedged portfolio.

3.3. Diversification benefits

We assess the diversification benefits arising from combining the individual G7 stock indices and gold (Bitcoin) via the CDB measure of Christoffersen et al. (2018), which is captured in terms of the expected shortfall for a probability q as follows:

[14] It is now almost the norm that new registrations to crypto-exchanges require the so-called KYC ("know your customer") procedure where the registered user provides an ID and relevant identification information. Even though this is not generally true for the wallets where the investor holdings are kept, there are now services which are connected to or even founded by financial institutions providing a connection between the standard financial world and cryptoworld. Such services hold the standard KYC process and usually investigate identification more deeply, as a standard bank would.

[15] In-sample results are available from the authors upon request.

[16] Lin et al. (2014) also conduct hedging effectiveness analysis.

Table 2
Descriptive statistics and unit root tests.

	Mean (%)	Std. Dev. (%)	Sharpe ratio	Skewness	Kurtosis	ADF	KPSS
Canada	0.011	0.773	0.015	−0.314	5.689	−44.62***	0.070
France	0.015	1.206	0.012	−0.268	6.516	−46.32***	0.050
Germany	0.027	1.194	0.022	−0.294	5.832	−44.98***	0.100
Italy	−0.003	1.534	−0.002	−0.468	7.081	−48.78***	0.062
Japan	0.037	1.296	0.028	−0.608	9.369	−49.78***	0.068
UK	0.012	0.914	0.013	−0.212	5.575	−45.82***	0.079
USA	0.039	0.895	0.044	−0.573	8.127	−49.06***	0.120
MSCI G-7	0.031	0.786	0.039	−0.652	7.592	−42.36***	0.097
Gold	0.003	1.003	0.003	−0.773	10.69	−48.92***	0.142
Bitcoin	0.487	6.386	0.076	−0.017	12.17	−44.81***	0.401

Notes: The table presents the descriptive statistics and unit root tests for ten return series. The sample period is July 19, 2010, to December 31, 2018. ADF and KPSS tests present empirical statistics of the augmented Dickey-Fuller (ADF) unit root test and Kwiatkowski–Phillips–Schmidt–Shin (KPSS) stationarity test, respectively. *** indicates significance at the 1% level or better.

$$CDB_t(\omega_t, q) = \frac{\omega_t ES_{i,t}(q) + (1-\omega_t)ES_{g,t}(q) - ES_{p,t}(\omega_t q)}{\omega_t ES_{i,t}(q) + (1-\omega_t)ES_{g,t}(q) - VaR_t(q)} \quad (9)$$

where ω_t represents the weight of the asset i (Bitcoin, gold) in the portfolio p at time t. The expected shortfall (ES) is given by:

$$ES_{z,t}(q) = -E\left[r_{z,t} \middle| r_{z,t} \le F_{z,t}^{-1}(q)\right] \quad (10)$$

where $z = i,g$; $F_{z,t}^{-1}(q)$ represents the inverse of the distribution function of asset z at time t. The upper bound of the expected shortfall $ES_{p,t}(\omega_t q)$ is given by $\omega_t ES_{i,t}(q) + (1-\omega_t)ES_{g,t}(q)$; $VaR_t(q) = -F_{p,t}^{-1}(q)$ and represents the value-at-risk (VaR) of the combined portfolio as given by the qth quantile setting the lower bound on the expected shortfall. Accordingly, the value of diversification measure ranges in the [0,1] interval where diversification benefits increase with an increasing value of the CDB.

Given that diversification benefits may vary with the composition of the portfolio and the probability q, we compute the conditional diversification benefits for various portfolio weights. These portfolio weights are selected at the probability values of 5% and 50% corresponding to the lower tail and the median values of the distribution. The ES is given by:

$$ES_{z,t}(q) = -\mu_{z,t} + \frac{\sigma_{z,t}}{q} h\left(H^{-1}(q)\right)\left[\frac{\upsilon + H^{-1}(q)^2}{\upsilon - 1}\right] \quad (11)$$

where H and h show a cumulative distribution function with υ degrees of freedom and standard Student's t density function, respectively. The VaR is given by $VaR_t(q) = -\mu_{p,t} - \sigma_{p,t}H^{-1}(\alpha)$.

4. Empirical results

4.1. The dataset

In this study, we use the prices of gold, Bitcoin, and the individual stock market indices of the G7 countries (Canada, France, Germany, Italy, Japan, the United Kingdom and the United States) as well as an overall weighted index for all G7 countries (MSCI G7). Gold and Bitcoin prices are denominated in USD. This is also the case for the individual G7 stock indices and the MSCI G7, which are computed by Morgan Stanley Capital International (MSCI), the provider of the most widely used international equity indices for institutional investors. We extract the daily data from Thomson Reuters Datastream, except for the Bitcoin price series, which we obtain from CoinDesk (https://www.coindesk.com). We conduct our empirical analysis with the natural logarithmic first differences of the daily data from July 20, 2010 to December 31, 2018. Notably, the beginning of the sample period is dictated by the availability of Bitcoin price data. Interestingly, the sample period covers a rich time span including booms and busts in the Bitcoin market. Table 2 gives the summary statistics and unit root tests of daily returns. Bitcoin has the highest average return and standard deviation, which is in agreement with previous studies (Brière et al., 2015) and suggests that the higher expected profits are partially balanced by higher volatility. Importantly, the Bitcoin Sharpe ratio is also the highest, which suggests that even after controlling for the higher volatility, Bitcoin's returns are the highest. The mean returns are negative for Italy, whereas they are positive for the rest of the G7 countries and for gold. Bitcoin and gold have the highest excess kurtosis. Negative skewness values are present in all cases with a lower magnitude for Bitcoin. While Bitcoin has the most extreme movements in

Table 3
The estimation results for the role of gold/Bitcoin as a hedge and safe haven asset - Baur and McDermott (2010).

	A. Gold				B. Bitcoin			
	Hedge (c_0)	0.1 (c_1)	0.05 (c_2)	0.01 (c_3)	Hedge (c_0)	0.1 (c_1)	0.05 (c_2)	0.01 (c_3)
Canada	0.075**	0.044	0.050***	0.151***	−0.037***	−0.073***	0.000	−0.049***
	(0.036)	(0.933)	(0.003)	(0.006)	(0.001)	(0.001)	(0.000)	(0.001)
France	−0.053***	−0.063***	−0.062	−0.195***	0.000	0.000	0.000	−0.055***
	(0.016)	(0.006)	(0.067)	(0.005)	(0.000)	(0.000)	(0.000)	(0.000)
Germany	−0.057***	−0.065**	−0.118***	−0.143***	0.032***	0.066***	0.010***	−0.058***
	(0.008)	(0.030)	(0.018)	(0.004)	(0.001)	(0.001)	(0.000)	(0.000)
Italy	−0.035***	−0.024	−0.047***	−0.187***	0.000	−0.063***	−0.116***	0.102***
	(0.009)	(0.314)	(0.004)	(0.005)	(0.000)	(0.001)	(0.002)	(0.000)
Japan	0.000	−0.028***	−0.024***	−0.013	−0.032***	0.000	−0.105***	0.053***
	(0.000)	(0.001)	(0.002)	(0.210)	(0.000)	(0.000)	(0.001)	(0.001)
UK	−0.002	−0.025***	−0.023***	−0.025***	0.000	0.052***	0.229***	0.396***
	(0.237)	(0.001)	(0.002)	(0.000)	(0.000)	(0.003)	(0.034)	(0.008)
USA	−0.036***	−0.112***	−0.131***	−0.053***	0.000	0.062***	0.020***	0.196
	(0.013)	(0.010)	(0.009)	(0.001)	(0.000)	(0.004)	(0.000)	(0.000)
MSCI G-7	−0.030	−0.148***	−0.185***	−0.065***	0.000	0.056***	0.121***	0.241
	(0.027)	(0.018)	(0.007)	(0.001)	(0.000)	(0.002)	(0.001)	(0.002)

Table 4
Summary statistics of hedge ratio and hedging effectiveness (HE).

	Gold				Bitcoin			
	Mean	Min	Max	HE	Mean	Min	Max	HE
Canada	0.017	−0.251	0.325	−0.001	0.001	−0.046	0.035	−0.012
France	−0.210	−1.328	0.068	**0.062**	0.004	−0.060	0.068	0.000
Germany	−0.207	−1.003	0.107	0.048	0.007	−0.041	0.077	−0.002
Italy	−0.264	−1.623	0.076	0.055	0.010	−0.055	0.103	−0.003
Japan	−0.129	−0.723	0.093	0.016	−0.005	−0.041	0.100	−0.003
UK	−0.069	−0.395	0.198	0.018	0.002	−0.038	0.044	−0.003
USA	−0.068	−0.680	0.298	0.008	−0.002	−0.051	0.034	−0.015
MSCI G-7	−0.087	−0.859	0.231	0.021	−0.002	−0.059	0.039	−0.014

Notes: Hedge ratios calculated from fixed width rolling analysis which produces 1000 one-step forecasts. Models are refit every 20 observations. AGDCC-GARCH estimated using a multivariate t (MVT) distribution. All specifications include a constant and an AR(1) term in the mean equation.

its price, they are basically symmetrical, i.e., the highest losses are of the same level as the highest gains. The return series of all analyzed assets are considered stationary given that the unit roots are strongly rejected by the augmented Dickey–Fuller (ADF) unit root test and stationarity is not rejected by the Kwiatkowski–Phillips–Schmidt–Shin (KPSS) test.

4.2. Results of safe haven and hedge testing

The estimated results on the role of gold and Bitcoin as a safe-haven and hedge are reported in Table 3. The results indicate that gold is a strong safe haven for the stock markets of Germany and the USA, given the evidence that all parameters are statistically significant and negative. Gold also acts as a weak safe haven for France, Italy, Japan and the UK. Comparably, Bitcoin is only a weak safe haven for the stock markets of Canada and France. Furthermore, gold is a strong hedge for the stock markets of France, Germany, Italy and the USA, and a weak hedge for Japan and the UK. Comparably, Bitcoin is a strong hedge for Canada and Japan and a weak hedge for France and Italy. We also consider the aggregate stock market index of the G7 countries (MSCI G-7), and the related results show that gold is a weak safe haven for the MSCI G7 index whereas Bitcoin has no such ability for the MSCI G7 index. Based on the results above, it appears that gold and Bitcoin do not share the same safe haven and hedging characteristics against falling stock markets in the G7 countries, with gold showing superior virtues against most of the G7 countries, both on average and in times of large stock market downturns.

4.3. Results of hedging effectiveness

Fig. 1 presents the evolution of the daily dynamic correlations between the returns of Bitcoin (gold) and each of the G7 stock indices for

Table 5
Summary statistics of hedge ratio and hedging effectiveness (HE) – various model specifications.

	Gold				Bitcoin			
	Mean	Min	Max	HE	Mean	Min	Max	HE
A). Model refit every 10 observations								
Canada	0.017	−0.231	0.309	−0.002	0.001	−0.047	0.036	−0.013
France	−0.209	−1.391	0.073	**0.061**	0.003	−0.056	0.067	0.001
Germany	−0.205	−1.031	0.117	0.049	0.007	−0.038	0.087	0.000
Italy	−0.268	−1.852	0.079	0.056	0.010	−0.055	0.107	−0.002
Japan	−0.122	−0.755	0.142	0.014	−0.005	−0.054	0.092	−0.002
UK	−0.071	−0.402	0.195	0.019	0.002	−0.036	0.045	−0.002
USA	−0.071	−0.756	0.284	0.007	−0.002	−0.050	0.043	−0.019
MSCI G-7	−0.090	−0.890	0.209	0.022	−0.002	−0.059	0.038	−0.016
B). Model refit every 30 observations								
Canada	0.017	−0.211	0.316	−0.001	0.001	−0.046	0.035	−0.012
France	−0.210	−1.282	0.070	**0.061**	0.004	−0.059	0.068	0.000
Germany	−0.206	−0.968	0.109	0.046	0.007	−0.040	0.083	−0.001
Italy	−0.265	−1.623	0.084	0.053	0.010	−0.055	0.103	−0.003
Japan	−0.130	−0.723	0.084	0.015	−0.005	−0.041	0.091	−0.003
UK	−0.070	−0.384	0.198	0.017	0.002	−0.037	0.044	−0.003
USA	−0.071	−0.655	0.298	0.008	−0.002	−0.048	0.034	−0.013
MSCI G-7	−0.089	−0.842	0.231	0.019	−0.002	−0.058	0.038	−0.013
C). Forecast length of 500 days								
Canada	0.022	−0.139	0.166	−0.005	0.003	−0.019	0.032	−0.011
France	−0.182	−0.409	0.044	**0.036**	0.004	−0.024	0.034	−0.004
Germany	−0.188	−0.423	−0.001	0.025	0.008	−0.016	0.038	−0.002
Italy	−0.275	−0.590	−0.054	0.015	0.002	−0.020	0.025	−0.010
Japan	−0.138	−0.497	−0.067	0.012	0.001	−0.013	0.037	−0.006
UK	−0.034	−0.200	0.114	0.007	0.003	−0.022	0.027	0.006
USA	−0.028	−0.352	0.198	0.006	0.004	−0.018	0.076	−0.034
MSCI G-7	−0.052	−0.315	0.083	0.007	0.004	−0.016	0.052	−0.012

Notes: Hedge ratios calculated from fixed width rolling analysis which produces one-step forecasts and models are refitted for specific daily observations. AGDCC-GARCH estimated using a multivariate normal (MVNORM) distribution. All specifications include a constant and an AR(1) term in the mean equation.

alternative market regimes as well the daily dynamic correlations between the returns of Bitcoin (gold) and the MSCI G7 index. Notably, the correlation between Bitcoin and the stock markets is weaker and more stable than that between gold and stock markets. For the Bitcoin-stock pairs, the correlation is generally between +0.2 and −0.2, except for the Bitcoin-France pair for which the correlation reaches 0.4. Thus, Bitcoin is almost uncorrelated with the stock markets during the whole examined period, which suggests promising diversification opportunities. Conversely, for the gold-stock pairs, the correlation varies between +0.45 and −0.40, except for the gold-Japan pair, for which the correlation is much weaker. However, the dynamics of gold-stocks correlation is more complex than for the Bitcoin-stock pairs. For practically all stock indices, even though the strength of the statement varies across countries, the gold-stocks correlation is positive for the first part of the analyzed period, mostly up to 2013, and then becomes either very close to zero (for Canada, the UK and the USA) or negative (for France, Germany, Italy and Japan). For France, Germany and Italy, the conditional correlation gets as low as −0.4 in the later part of the studied sample.

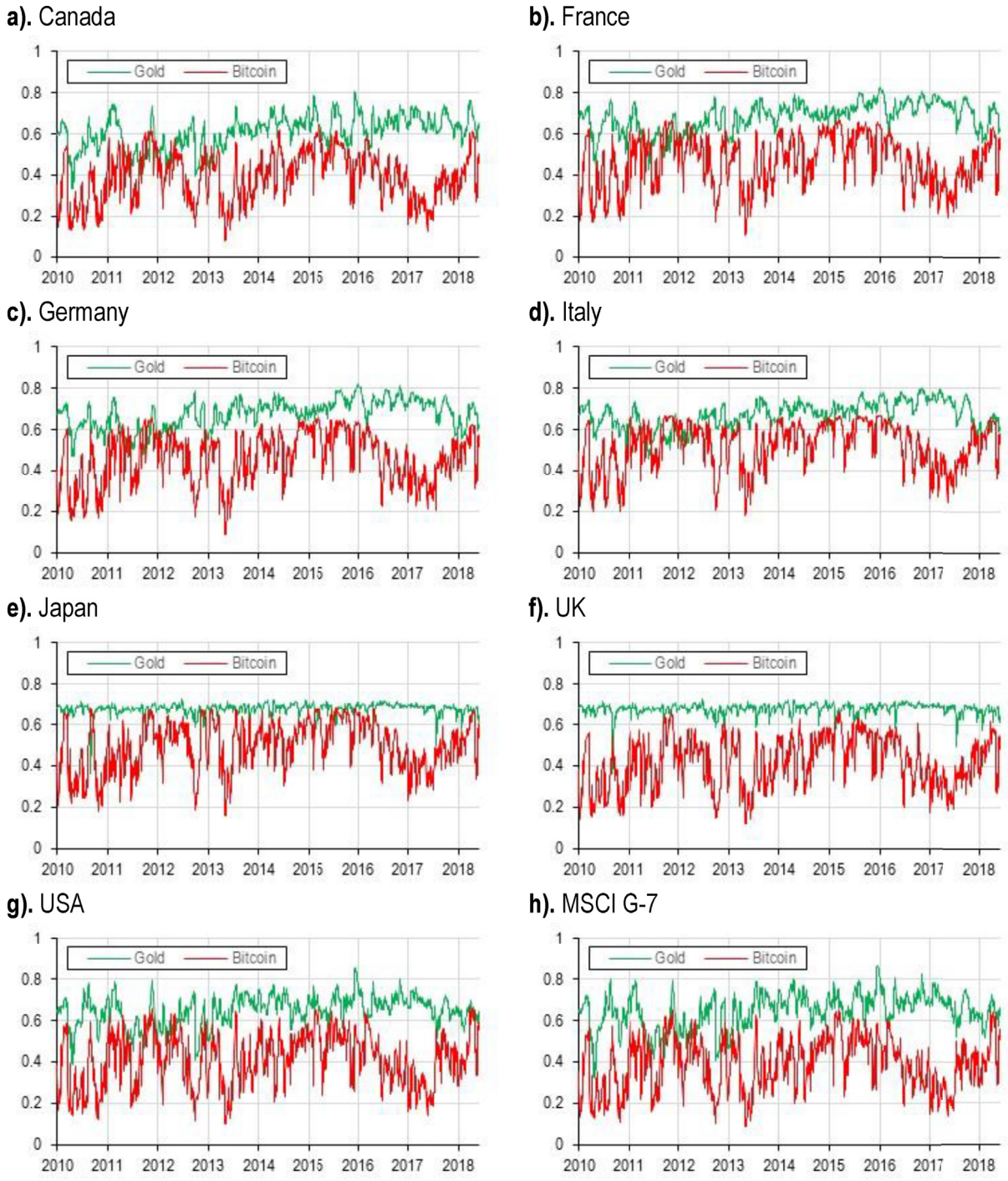

Fig. 2. Time series plot of the conditional diversification benefits (CDB) of gold and Bitcoin for G7 stock markets – equally weighted portfolios, 5% quantile. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

From the other side, Bitcoin-stocks conditional correlation is dynamic as well, but the range is much narrower suggesting that the positions of Bitcoin and gold in the hedging competition are likely different and distinguishable.

Table 4 presents the results of the hedge ratios and the hedge effectiveness (HE). The average values of the hedge ratios are negative for gold and the G7 stock indices, except for Canada. The negative values arising from the inverse relationship between gold and stock indices suggest that the hedge is formed by taking either long or short positions for both assets (i.e. gold and stock indices). For example, a $1000 long position in Italian stocks is hedged by taking another long position for $264 in the gold market. For the case of Bitcoin, the picture is quite different given that the average values are very close to zero, although many are positive while only a few are negative. This finding suggests that a much smaller amount of US dollars in Bitcoin is needed to hedge G7 equity investments. For example, the (positive) average value of the

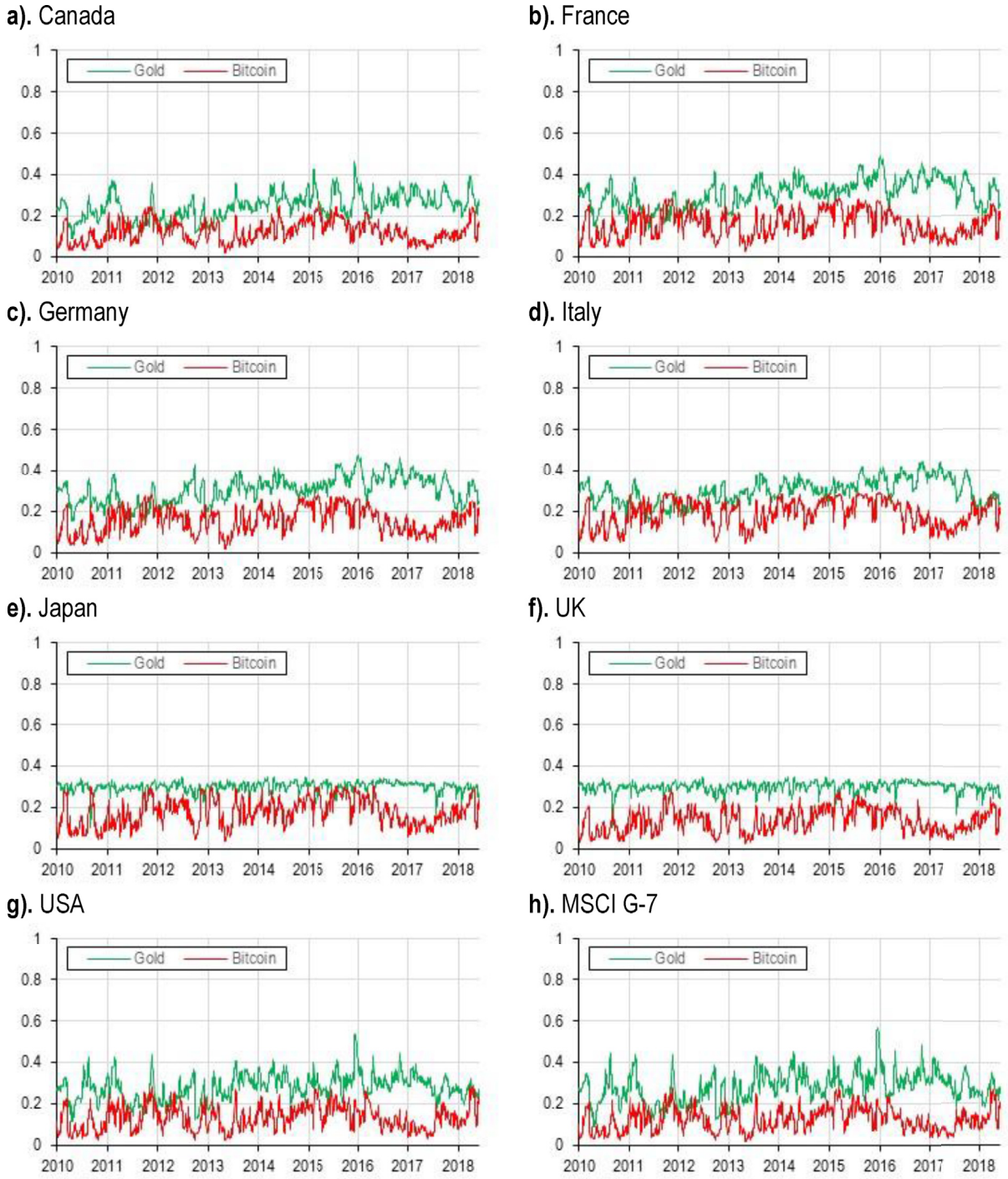

Fig. 3. Time series plot of the conditional diversification benefits (CDB) of gold and Bitcoin for G7 stock markets – equally weighted portfolios, 50% quantile. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

hedge ratio between France and Bitcoin is 0.004 indicating that a $1000 long position in French stocks is hedged by taking a short position in the Bitcoin market of $4.

Moving to the HE results, where a higher HE index indicates a higher hedging effectiveness, we see that, except for Canada, gold produces higher HE values than Bitcoin for each of the G7 countries and for the MSCI G7 index, suggesting that gold is a more valuable hedge for stocks than Bitcoin.

As the HE values presented in Table 4 are estimated under specific assumptions related to the number of model refits and the forecast length, we assess the robustness of those HE values to changes in the assumptions. Table 5 shows that the results for the HE are not altered by a change in the number of model refits or the forecast length, supporting the robustness of our earlier results.

4.4. Results of conditional diversified benefits

Given the above evidence (mainly from Fig. 1) that the correlation between the G7 stock indices and gold (Bitcoin) is time-varying, we assess the diversification benefits using a measure that accounts for this feature. Considering the time series plots of the CDB for equally weighted portfolio of the G7 stock market indices and gold (Bitcoin), the CDB results are reported for the extreme lower tail (Fig. 2) and the middle quantile of the distribution (Fig. 3). The diversification benefits of gold for a portfolio with the G7 markets are generally stable across the sample period. Furthermore, they are much larger for the lower tail (5% quantile) than the median values (50%) of the distribution. In contrast, more variability is observed in the CDB for Bitcoin across the G7 markets, especially at some points during the second half of 2012 and the first half of 2013. The CDB decreases from mid-2016 till mid-2017, before it exhibits a slight uptrend that fails to last till the end of the sample period. Still, the CDB for gold and G7 are much larger than the CDB of Bitcoin and G7. These results hold when we consider the MSCI G7 index.

Taken together, the results indicate that gold provides higher and more stable diversification benefits for the G7 stock markets than Bitcoin, especially for the lower tail (5% quantile) of the distribution when the benefits of diversification are most needed by investors. This is likely due to larger fluctuations in Bitcoin prices than gold prices but also reflects the fact that the conditional correlations between gold and stock indices decreased much more than between Bitcoin and stock indices during the later part of the period studied when the differences between diversification benefits were most pronounced.

Table 6 presents the mean values and standard deviations of the CDB for varying portfolio weights using 5% and 50% probability levels for the expected shortfall. The results show that the CDB is higher at the 5% level (see Panel A) than the 50% level (see Panel B) for both gold and Bitcoin. However, the CDB decreases with the weight of gold in the portfolio, peaking for equally weighted portfolios for all the G7 countries and the MSCI G7 index. In fact, the CDB is much higher for gold than Bitcoin at the 50% level, regardless of the weight of gold (Bitcoin) in the portfolio. Furthermore, the CDB is much higher for gold than Bitcoin at the 5% level only for equally weighted portfolios (i.e., 50%–50% portfolios). However, for Bitcoin, the peak is shown for portfolios composed of 80% stocks and 20% Bitcoin, and, exceptionally, the CDB is much higher in Canada for the Bitcoin-stock portfolio. Interestingly, for gold, France and Japan offer the highest benefits at the 5% level and Germany and France offer the highest benefits at the 50% level. For Bitcoin, Japan and Italy offer the highest benefits at both the 5% and 50% levels. For the cases of Canada, the UK and the MSCI G7, the CDB is higher for the portfolio composed of 5% gold than the one composed of 95% gold, for both 5% and 50% probability levels. For Bitcoin, like the case of gold, the CDB is higher at the 5% level (Panel A) than the 50% level (Panel B). While, like for gold, the CDB decreases with the weight of Bitcoin, the highest benefits being reported for portfolios composed of 80% stocks and 20% Bitcoin, as opposed to 50%–50% portfolios for gold and stocks.

While the CDB results confirm that both gold and Bitcoin offer

Table 6
Diversification benefits of gold and Bitcoin for various portfolio compositions and probabilities.

	Canada		France		Germany		Italy		Japan		UK		USA		MSCI G-7	
Panel A: at the 5% level																
A). Gold																
0.05	0.147	(0.053)	0.239	(0.079)	0.236	(0.076)	0.287	(0.078)	0.253	(0.064)	0.183	(0.061)	0.177	(0.075)	0.162	(0.069)
0.20	0.410	(0.096)	0.550	(0.098)	0.546	(0.098)	0.599	(0.087)	0.567	(0.062)	0.474	(0.090)	0.460	(0.105)	0.440	(0.109)
0.50	0.609	(0.082)	0.681	(0.072)	0.675	(0.070)	0.670	(0.066)	0.676	(0.030)	0.653	(0.061)	0.648	(0.071)	0.647	(0.085)
0.80	0.525	(0.079)	0.506	(0.091)	0.499	(0.085)	0.447	(0.075)	0.481	(0.069)	0.531	(0.075)	0.545	(0.093)	0.567	(0.093)
0.95	0.235	(0.059)	0.201	(0.061)	0.197	(0.058)	0.159	(0.041)	0.181	(0.044)	0.228	(0.059)	0.244	(0.072)	0.265	(0.074)
B). Bitcoin																
0.05	0.041	(0.022)	0.061	(0.036)	0.060	(0.034)	0.078	(0.042)	0.070	(0.041)	0.047	(0.026)	0.046	(0.027)	0.041	(0.024)
0.20	0.160	(0.074)	0.218	(0.100)	0.217	(0.098)	0.265	(0.107)	0.243	(0.106)	0.179	(0.082)	0.174	(0.084)	0.159	(0.078)
0.50	0.392	(0.119)	0.465	(0.124)	0.462	(0.124)	0.519	(0.112)	0.498	(0.119)	0.419	(0.121)	0.410	(0.127)	0.388	(0.126)
0.80	0.610	(0.069)	0.619	(0.047)	0.614	(0.051)	0.628	(0.040)	0.639	(0.044)	0.615	(0.059)	0.613	(0.068)	0.604	(0.075)
0.95	0.558	(0.088)	0.479	(0.118)	0.473	(0.116)	0.435	(0.121)	0.475	(0.119)	0.527	(0.099)	0.541	(0.099)	0.558	(0.091)
Panel B: at the 50% level																
A). Gold																
0.05	0.034	(0.015)	0.062	(0.028)	0.061	(0.025)	0.078	(0.030)	0.066	(0.022)	0.044	(0.018)	0.043	(0.024)	0.039	(0.021)
0.20	0.129	(0.047)	0.208	(0.070)	0.205	(0.067)	0.241	(0.069)	0.213	(0.043)	0.160	(0.051)	0.155	(0.061)	0.145	(0.061)
0.50	0.247	(0.062)	0.310	(0.068)	0.304	(0.065)	0.299	(0.061)	0.299	(0.026)	0.281	(0.053)	0.279	(0.062)	0.280	(0.073)
0.80	0.188	(0.048)	0.178	(0.052)	0.174	(0.049)	0.144	(0.037)	0.161	(0.035)	0.191	(0.045)	0.202	(0.058)	0.218	(0.062)
0.95	0.060	(0.018)	0.049	(0.018)	0.048	(0.017)	0.037	(0.011)	0.043	(0.012)	0.057	(0.018)	0.063	(0.023)	0.070	(0.024)
B). Bitcoin																
0.05	0.009	(0.005)	0.013	(0.008)	0.013	(0.008)	0.017	(0.010)	0.015	(0.010)	0.010	(0.006)	0.010	(0.006)	0.009	(0.005)
0.20	0.038	(0.021)	0.057	(0.032)	0.056	(0.031)	0.072	(0.037)	0.065	(0.036)	0.044	(0.024)	0.043	(0.025)	0.038	(0.022)
0.50	0.123	(0.053)	0.159	(0.064)	0.158	(0.063)	0.189	(0.063)	0.178	(0.066)	0.135	(0.056)	0.132	(0.058)	0.122	(0.055)
0.80	0.245	(0.047)	0.250	(0.034)	0.247	(0.035)	0.256	(0.030)	0.266	(0.034)	0.248	(0.041)	0.248	(0.046)	0.242	(0.050)
0.95	0.211	(0.056)	0.167	(0.064)	0.163	(0.062)	0.144	(0.061)	0.164	(0.064)	0.192	(0.059)	0.201	(0.061)	0.211	(0.058)

Notes: The table reports the conditional diversification benefit as described in Eq. (10) for portfolios composed of the alternate assets (gold and Bitcoin) and G7 stock markets indicated in columns 2–6. Portfolio weights for G7 stock markets are indicated in the first column. The diversification benefit is computed by considering expected shortfall values at the 5% (Panel A) and 50% (Panel B) probability levels. For each portfolio, the table reports the time-average of the conditional diversification benefit and, in brackets, the standard deviation.

particular value to investors in the G7 stock markets, gold evidently offers higher diversification benefits, mainly in an equally weighted portfolio and when both the stock and gold markets are in bearish states, i.e., in the lower return quantiles.

5. Discussion and conclusions

We conduct a comparative analysis of the potential roles of gold and Bitcoin for the stock markets of the G7 countries from July 20, 2010 to December 31, 2018. As a starting point, we apply the approach of Baur and McDermott (2010) that covers the safe haven and hedge roles against stock market downturns. Then, we analyze the out-of-sample hedging effectiveness of gold and Bitcoin for the G7 stock indices. We also assess the conditional diversification benefits for various portfolio compositions and probabilities (Christoffersen et al., 2018). Such a rich analysis is particularly important for investors who seek to minimize the likelihood of extreme losses. Importantly, it adds to previous studies that limit their scope to testing the hypothesis that Bitcoin is a safe haven without capturing practical implications in terms of hedging effectiveness and the conditional benefits of diversification (Bouri et al., 2017a, 2017b). It also adds to embryonic findings that generally compare the virtues of gold and Bitcoin for stock indices (e.g., Klein et al., 2018).

Our main results indicate that gold and Bitcoin exhibit large dissimilarities in their safe haven, hedging and diversifying abilities for the stock markets of the G7 countries. Gold shows an indisputable (strong or weak) safe haven property for most of the individual G7 stock indices[17] and for the MSCI G7 index. In terms of the hedging effectiveness, results show that gold is the most effective hedge for the stock indices of France, Germany, Italy, Japan, the United Kingdom, the United States and the MSCI G7 index, whereas Bitcoin is most effective for the Canadian stock index. The practical implications for investors in terms of the conditional diversification benefits arising from adding Bitcoin (gold) to G7 equity investments are that both Bitcoin and gold provide valuable diversification benefits. However, gold offers higher and more stable benefits, especially in the lower return quantiles, i.e., when both the stock and gold markets are in a bearish state.

These results are not generally in line with previous research arguing that Bitcoin has some of the virtues of gold due to the logic of its hedging properties, i.e., specifically hedging against stocks and the US dollar (Dyhrberg, 2016), and diversification benefits (Baur et al., 2018b; Brière et al., 2015; Bouri et al., 2017a, 2017b; Dyhrberg, 2016; Corbet et al., 2018; Guesmi et al., 2019; Ji et al., 2018). However, the hedging effectiveness of gold is dominant and the conditional diversification benefits offered by gold to investments in the G7 equity markets are comparatively much higher and more stable than those of Bitcoin. This is somewhat in concord with previous studies that dispute the diversification benefits of Bitcoin (Chowdhury, 2016; Klein et al., 2018) and argue that Bitcoin's statistical properties (Baur et al., 2018a) and conditional variance properties (Klein et al., 2018) might be different from those of gold.

However, Bitcoin also provides unprecedented profit opportunities. During the period analyzed, the price of one Bitcoin increased from less than 1 USD to more than 10,000 USD, while an ounce of gold held its relatively stable price of approximately 1300 USD. This leads to doubts and uncertainty about Bitcoin's true underlying value and the possibilities of an irrational bubble (Kristoufek, 2013; Bouoiyour et al., 2016; Fry and Cheah, 2016; Li and Wang, 2017). Even though both the G7 stock markets and Bitcoin price generally increased markedly during the period analyzed, they remain virtually uncorrelated, which is tightly connected to the fact that Bitcoin price has been increasing super-exponentially. The stock market price inflation can be partially attributed to the various waves of quantitative easing (factual quantitative easing of the US Federal Reserve or practical easing of the European Central Bank), but this is not the case for Bitcoin, as most new money has been issued to banks and financial institutions that do not invest in Bitcoin due to various legal, taxation and accounting issues (Tan and Low, 2017). Thus, the pools of Bitcoin and stock market investors are quite different (Filtz et al., 2017), and their price driving factors are also different (Kristoufek, 2015; Bouoiyour et al., 2016). Their lack of correlation is thus not surprising.

What distinguishes our analysis from previous studies is its focus on the relationship between Bitcoin (and gold) and the stock markets and potential safe haven abilities under adverse market conditions as well as the detailed and practical analyses of hedging effectiveness and conditional diversification benefits. Although some of the results have far-reaching practical consequences for investors, it should not be taken as a given that investors in some G7 stock markets (i.e., Canada) will consider or make use of Bitcoin as a fully-fledged alternative to gold in their portfolios or investment strategies. This is connected to the not-yet-solved status of Bitcoin in the international financial markets. Although some financial institutions have begun considering it, they are more interested in the blockchain technology than Bitcoin itself, which might complicate further expansion of the cryptocurrency. With the launch of the CME and CBOE futures contracts based on Bitcoin in December 2017, Bitcoin has moved closer to the centre of the financial world, making it harder for policy-makers, institutional investors and bankers to ignore its role as an investment. This has pushed Bitcoin towards legitimacy and should help manage its price volatility.

Several issues must be considered when interpreting the results for more general policy and investment considerations. First, the Bitcoin market was very shallow until approximately 2013, when trading volumes began to increase, and Bitcoin became more well-known to the public. Second, the biggest Bitcoin losses do not necessarily occur during rallies of the stock markets but are rather independent. Bitcoin price decreases occur for two main reasons — Bitcoin exchange closures, and political decisions and restrictions. The highest losses of Bitcoin and stock indices occur at different times, which improves Bitcoin's diversification ability. However, these independent events of Bitcoin seem to have so high an impact on Bitcoin price that the diversification benefits are overshadowed by the resulting losses in the cryptocurrency. Third, the exchange rate of the G7 countries plays a role, as discussed, mainly in the case of the Eurozone members of the G7 group. However, both gold and Bitcoin are generally purchased in US dollars, which erases potential bias. Fourth, the period of Bitcoin's existence coincides with mostly bullish stock markets after recovery from the global financial crisis. Even though this is not universally true for all G7 members (specifically Italy and Japan), the results need to be verified after some severe future turmoil in the stock markets, which would give the opportunity to both gold and Bitcoin to show their true safe haven and hedging potentials. Research into the interplay among Bitcoin, gold, stock markets and foreign exchange is thus far from complete.

Our findings are important for investors and traders who now have empirical evidence that gold is unbeatable by Bitcoin as a safe haven asset against stock movements in many G7 markets and that gold's hedging effectiveness and diversification benefits are also much higher than those of Bitcoin. Furthermore, Bitcoin still has a long way to go to catch gold in terms of price stability, which might be the subject of future research.

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[17] The Canadian stock index contains more natural resource companies than the other G7 stock indices (Beckmann et al., 2015), which could undermine the ability of gold to act as a safe haven in Canada. Still, this does not seem to have affected the results for Bitcoin-Canadian stock index and therefore does not fortify the role of Bitcoin as a hedge or safe haven in Canada. Future research using sectoral analysis could give a more detailed explanation.

Appendix

A.1. AGDCC-GARCH model

To obtain the dynamics of asymmetric time-varying correlations between gold (Bitcoin) and each of the G7 stock indices, we employ the AGDCC-GARCH model proposed by Cappiello et al. (2006), which represents an extension of the standard dynamic conditional correlation (DCC) model of Engle (2002).

The estimation of the AGDCC-GARCH process consists of two steps. First, we fit univariate GARCH models for each series. Next, we model the conditional correlation by using the AGDCC model process. In the framework of our study, the model is given by[18]

$$r_t|I_{t-1}\tilde{}N(0,H_t) \tag{1.A}$$

$$H_t = D_t R_t D_t \tag{2.A}$$

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

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

where $r_t = [r_{1t}, r_{2t}]$' is a *2x1* vector of returns including the G7 stock market returns (r_{1t}) and gold/Bitcoin returns (r_{2t}), H_t denotes the conditional covariance matrix of r_t, D_t is the diagonal matrix containing the conditional standard deviations from the univariate GARCH models, and R_t represents the time-varying conditional correlation matrix. $\varepsilon_t = [\varepsilon_{1t}, \varepsilon_{2t}]$' is a *2x1* vector of residuals conditional on the information set at time *t-1*, z_t denotes a *2x1 i.i.d.* vector of the standardized residuals, and Q_t is the conditional correlation matrix of the standardized residuals.

Following Cappiello et al. (2006), we derive the elements of H_t from the asymmetric univariate GARCH (1,1) model of Glosten et al. (1993), the so-called GJR-GARCH:

$$h_{i,t} = \omega_i + \alpha_i \varepsilon_{i,t-1}^2 + \beta_i h_{i,t-1} + d_i \varepsilon_{i,t-1}^2 I(\varepsilon_{i,t-1}) \tag{5.A}$$

where $h_{i,t}$ is the conditional variance of the return series, ω_i is a constant term, α_i captures the ARCH effect, β_i measures the persistence of the volatility process, and d_i is the asymmetric term. $I(\varepsilon_{i,t-1})$, is an indicator function that is equal to one if $\varepsilon_{i,t-1} < 0$, and zero otherwise. To ensure positivity and stability, the following two constraints must be satisfied: $\alpha_i > 0$ and $\alpha_i + \beta_i < 1$. Following the estimation of the univariate GARCH models, we use the standardized residuals z_t in computing the conditional correlation parameters.

The dynamics of Q in the AGDCC-GARCH model are presented as:

$$Q_t = (1-\theta_1-\theta_2)Q - \varphi N + \theta_1\left(z_{t-1}z_{t-1}^{'}\right) + \theta_2 Q_{t-1} + \varphi\left(\eta_{t-1}\eta_{t-1}^{'}\right) \tag{6.A}$$

where θ_1, θ_2 and φ are parameter matrices, $\eta_t = I(z_t < 0) \circ z_t$ is an indicator function that takes the value of one if the argument is true and zero otherwise, " $\circ$ " indicates the Hadamard product and $Q_j = E[z_t, z_t^{'}]$ and $N_j = E[\eta_t, \eta_t^{'}]$ are the unconditional correlation matrices of z_t and η_t, respectively. φ is the parameter of correlation asymmetry. If $\varphi = 0$, then AGDCC-GARCH is reduced to a standard DCC-GARCH model with no asymmetric effect in the conditional correlation.

The time-varying correlation matrix of the AGDCC-GARCH model is presented as:

$$R_t = Q_t^{*-1} Q_t Q_t^{*-1} \tag{7.A}$$

where Q_t^* is a diagonal matrix with a square root of the ith diagonal of Q_t in its ith diagonal position.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.econmod.2019.07.023.

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[18] We check for other distributions, such as student's t and GED, and the overall conclusions remain the same.

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