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A portfolio study on the safe haven effect of gold for investors in developed and emerging markets

by

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Abstract

A research on the behavior in gold investment is conducted on a selection of developed and emerging markets. To what extent does gold function as a safe haven for stocks and bonds in these markets? The period considered ranges from January 2004 – December 2017. The analysis is done from the perspective of the *Portfolio theorem.* We contribute to the existing literature in two ways. Firstly, we use time-varying variances and dynamic conditional correlations in the portfolio analysis. Secondly, we distinguish the bonds into government and corporate bonds where the corporate bonds are even further distinguished into less risky (investment-grade) and more risky (high-yield) bonds. Results have shown that gold has not lost its traditional property as safe haven asset for portfolios with only stocks and in most cases for portfolios with stocks and bonds.

Keywords: *Gold, safe haven, bonds, stocks, dynamic conditional correlation, financial crisis, Brexit*

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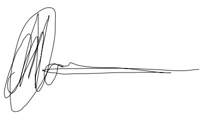

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1 Introduction

Nowadays it is inevitable to state that the gold price has increased enormously apart from the surge to cryptocurrencies, in particular over at least the recent past decade. Investors are in general curious about the financial or political developments that might play a role in this upward surge in demand for gold and how to benefit from it. The literature so far has shown that gold is an extraordinary commodity, that is, gold can also be used as financial asset next to its regular use for industrial purposes or as jewellery. In the past gold used to be a backup for fiat currencies, that is, countries were limited to print their money up to the value of the amount of physical gold they possessed. Gold is also known for its potential to hedge inflation. This is a result of fear, because once there is inflation in a country, investors fear a downward spiral in the value of their national currency. To protect themselves against further devaluation, they flee in gold investments as gold is more likely to retain value compared to another currency. Given the fact that gold is scarce and demand increases, gold prices increase. Due to the low correlation between gold and stocks, gold is in general considered a safe haven asset for stocks. A safe haven asset is on average negatively correlated or uncorrelated with another asset only during extreme periods of financial turmoil. This is not comparable with a hedge in a traditional way where this imposed restriction on correlation should hold on average over the whole time span instead of only during high-volatile periods.

In this study the focus lies on the comparison between gold as a safe haven for investors in developed markets and investors in emerging markets. The reason for this distinction is because previous literature, among others the paper of D. G. Baur and McDermott (2010), showed that gold is more likely to function as a safe haven asset for stocks in major developed markets rather than for stocks in major emerging markets. This is because of heterogeneity in the way investors across markets react on financial turbulence. Although it seems that this subject has already been investigated, we also want to know what the implications are for investors, that is, concrete information on how to invest. For this, the mean-variance portfolio optimization in which we optimally allocate assets to portfolios on the basis of a risk-return trade-off is applied, that is, maximize expected returns given a level of risk in a portfolio and allocate assets with proper weights to the portfolio accordingly.

As far as our knowledge of the vast body of literature regarding gold concerns, the literature dealing with the implications of the inclusion of gold as safe haven in investors' portfolios comprising of stocks and bonds in a mean-variance framework as set out by Markowitz (1952) is scarce. Most empirical studies so far have only tested whether gold might function as a safe haven asset by means of a regression framework on which will be elaborated in the literature review. The majority of the studies that consider gold in the portfolio are rather looking at the diversification or hedging function of gold within a portfolio, for example in the study of Hillier, Draper, and Faff (2006). The paper of Jaffe (1989) proves the diversification benefits of gold as diversification asset in diversified portfolios. The paper of Lean, Wong, et al. (2015) discusses to what extent gold might function as a diversification asset in a stock and in a bond portfolio in a mean-variance framework. There is also another study by Lucey and Tully (2003) that we are aware of that deals with the equity portfolio framework for which gold is an eligible asset to include for diversification purposes. However, they reached an optimal portfolio allocation by applying the mean-variance-skewness framework. That is, next to the regular objectives such as means and variances of returns on which we are focusing, also skewness of returns is subject to investor's decision for an optimal portfolio allocation. Despite the fact that their method falls out of our scope, they also did not consider gold as a potential safe haven asset in their portfolio analysis. That basically leaves us space for being a pioneer in this field.

Returning to this empirical study, the question at hand is rather to what extent an investor should allocate gold to his portfolio in order to benefit from its potential as a safe haven asset by applying the mean-variance asset allocation method prior to comparing developed with emerging markets' portfolios. That is, allocate assets in a portfolio such that expected returns are jointly maximized given a level of variance, say, risk. Secondly, as the aim of this study is to compare the portfolios of the major developed markets with portfolios of the major emerging markets with respect to gold as a safe haven asset, we will compare the differences in weights of gold for each portfolio between periods of financial turmoil and the average period. In case it turns out that this difference is on average significantly different (positive) for either or both the developed markets and emerging markets, then gold functions in either or both markets as a safe haven asset. The vast body of current literature concerning gold thus far mainly focuses on the question whether gold is a hedge or safe haven against different types of commodities, stocks, bonds or exchange rates. Surely, their findings provide useful insights on which this study relies. The aim of this paper is to turn previous general findings into practical implications for investors in terms of portfolio analysis, that is, how an investor optimally can invest gold. In extension to this, the portfolios will not only consist of stocks but also of bonds, where government bonds (less risky) and corporate bonds (more risky) are distinguished which will be a useful addition to the current literature. Finally, we impose dynamic conditional correlations between assets in a portfolio and use time-varying variances, that is, both correlations and variances will be time-varying. This is also an innovative way compared to the traditional way of mean-variance portfolio selection in which a static correlation measure is used. The idea of using dynamic correlation finds support from the fact that during times of financial turmoil correlations between assets are likely to intensify.

Before we can answer the aforementioned question of asset allocation, we first need to figure out whether gold behaves as a safe haven asset. The reason that we do not simply take the previous findings of the literature, which states that gold is more likely to be a safe haven asset for stocks in developed markets rather than for emerging markets, for granted is that now a more recent time span is considered which might give slightly different results. In case gold functions as a safe haven asset for both markets, the comparisons can be done. Altogether, it brings us to the following general research question - ***Does gold function as a safe haven asset for stocks and bonds during periods of financial turmoil?*** - for which we formulated several hypotheses:

Hypothesis 1: Gold does function as a safe haven asset for a portfolio comprising of stocks and bonds for investors in developed markets.

Hypothesis 2: Gold does function as a safe haven asset for a portfolio comprising of stocks and bonds for investors in emerging markets.

1.1 Review of the gold market

Fig. 1: Nominal gold prices in USD/oz between 8 Jan 1998 - 8 Jan 2018 from www.macrotrends.net

As one can notice from the chart of the gold prices per ounce in figure 1, the price was at least doubled in the period 2002-2007, from a value of \$347.20/ounce to \$833.75/ounce. This was mainly the result of the depreciation of about 40% of the U.S.

dollar against the euro. Especially in the period of the global financial crisis, investors wanted to invest in a safe haven asset. That is exactly the reason why investors bought gold in large numbers during that period. As a result, the prices of gold were driven up again. Investors invested in gold due to the crisis in the Eurozone, the consequences of the Obamacare, the Dodd-Frank Wall Street Reform Act and of course the United States debt-ceiling crisis in 2011. As the economy of the United States was about to collapse, many investors tried to protect their investments. Due to the big uncertainty of the economy, investors fled in gold investments. Therefore, the price of gold more than doubled from a value of $869.75 (2008) to $1,895 (2011). Prices reached their record high. Since gold prices were in a rally, investors wanted to take advantage by buying more gold. A momentum effect might be present at this point. However, this was done for direct investment instead of for hedging purposes as was mentioned in the previous part. This is kind of a spiral effect, because it becomes more expensive until a certain point in time. The paper of Białkowski et al. (2015) confirms that the rapid increase of the gold prices in the recent financial crisis can be explained from the desire of investors to flee into safe haven assets. They considered the actual gold prices relative to what the gold prices actually should be based on their fundamentals, which were subjectively chosen by the researchers, in order to discover whether the recent increase in gold price during the GFE-period could be a result of an irrational speculative bubble. They showed among others that the European debt crisis, which they proxied by the sovereign bond yields of the so-called PIIGS-countries, is to a great extent able to track the recent boom in the gold prices. Although the fundamentals were subjectively chosen, the result is nevertheless interesting in the sense that it points on the safe haven characteristic of gold. Investors seem to feel safe in gold investments during turbulent times.

The demand for gold highly increases when economic growth falls, inflation rises and when the monetary policy is unstable. Usually, it rises in times of financial crises and in times the purchasing power of a certain local currency falls. The paper of D. Baur

(2013) shows that the change in inflation, change in interest rate, change in the currency value and change in the policy of the central bank are significant key drivers for the value of gold.

After a long period of inflating gold prices, there seems to be a correction at a certain point in 2012 until somewhere in November, 2015. In 2016 and 2017 it is visible that gold prices are increasing. This is among others due to the Brexit, elections in the US and tensions between the United States and North-Korea. Conclusively, it can be stated that gold prices are mainly driven by sentiments rather than increase in intrinsic value. When times are unstable, gold gains in value. On the other hand, when times are getting stable gold loses on its value.

2 Literature review

This section is laid out as follows. The history of gold as monetary asset will be discussed from the literature. Subsequently, there will be elaborated in detail on the functions of gold in terms of a financial asset from the literature. The functions of gold in a financial framework comprise of a *safe* haven for financial assets in times of financial turmoil - on which this paper will focus on in particular - and finally, a *hedge* against inflation or currency depreciation.

2.1 Gold as special commodity

The burning question relates to why investors consider gold as a special asset to invest in for diversification, hedge or safe haven purposes. In other words, what does especially gold make to be unrelated to other financial assets? The paper of Lawrence (2003) shows based on the US quarterly data of the financial market and macroeconomics over the period 1975-2002 that gold is unrelated to the business cycle. In order to investigate this claim, they break it up in several parts. For gold, they found no significant co-movement between gold's returns and the difference in macroeconomic variables inflation, gross domestic product (GDP) and interest rates. Returns on stock indices and government bonds show correlation with the difference in macroeconomic variables. Moreover, the effect of a difference in macroeconomic variables is stronger for other commodities such as zinc, aluminium and oil than for gold. The returns on the other commodities show a higher correlation with equity and bond indices than returns on gold do. They also pose three major reasons for gold to be different from other commodities. Two reasons relate to the physical aspects of gold, in the sense that gold is indestructible and fungible. The third but most important reason relates to the high liquidity of gold, which makes gold critically different from the other commodities.

2.2 Gold as monetary asset

Gold as monetary asset stems from ancient times. Prior to fiat currencies, people used to pay by commodity money, that is, money made from goods. Usually commodity money was made from precious metals like gold and silver. For a long time paper money has been linked to gold claims, that is, currencies were priced in terms of gold per ounce. The paper of Ciner, Gurdgiev, and Lucey (2013) provides empirical evidence that gold is a safe haven against currency depreciation for the US Dollar as well as for the UK Pond Sterling. This is a confirmation for gold's role as monetary asset.

2.3 Gold as diversification asset

Diversification of a portfolio means that by combining several assets in a portfolio given that the correlations between assets are relatively low, one is able to construct a portfolio with higher returns and lower risk compared to what a position in one specific asset of the portfolio would provide. In terms of gold, it would mean that gold exhibits relatively low correlation with another type of financial asset and as such is not fully exposed to the same risk factors as the other financial asset. The paper of Sherman (1982) shows among others that gold is a good diversification asset in a portfolio consisting of several financial assets in the period of the 1980s.

The paper of Jaffe (1989) investigated the effect of including gold or gold stocks proxied by the returns of the gold stocks on the Toronto Stock Exchange (TSE) and the returns on the gold-mining stocks on the mutual fund of South Africa, in four hypothetical portfolios being different from each other in terms of risk. Their findings were twofold, where on the one hand the result of including gold in the hypothetical portfolios made the average returns increase while the standard deviation of the portfolios decreased, and, where on the other hand the result of including gold stocks in a portfolio made both the average return as well as the standard deviation of the portfolios increase. Noteworthy to mention is that in the latter case, the increase in average returns was relatively higher than the increase in risk proxied by the standard deviation of the portfolio, which implies that also gold stocks induce diversification benefits. Conclusively, they showed that both gold and gold stocks provide diversification benefits in a portfolio consisting of several financial assets.

In the paper of Lean, Wong, et al. (2015) they found for the French portfolios over the period 1949 to 2012 that gold provides diversification benefits in portfolios consisting of only stocks, and, in most of the cases for mixed portfolios where stocks constitute half (50%) of each of the mixed portfolios. Notwithstanding the finding that gold provides diversification benefits for stock and stock-mixed portfolios, it does not so for bond portfolios.

2.4 Gold as a hedge asset

In general gold is able to function as a financial asset in the sense that it can be characterized as either a diversification, hedge or safe haven asset within a portfolio of investments. In this sub-section there will be elaborated on the function of gold as a hedge asset, whilst in the next sub-paragraph the focus mainly lies on gold as a safe haven asset. In the empirical study of McCown and Zimmerman (2006) it is shown that gold can be characterized as a zero-beta asset, because gold is not related to market risk. Moreover, its average returns are more or less equal to those of a Treasury bond. They also provided evidence that gold is a suitable asset to provide hedge against inflation. This assertion is strengthened by the fact that they found the gold prices and the consumption prices to be co-integrated, that is, they are driven by the same stochastic trend, or better said, they exhibit a long-term relation.

The paper of Joy (2011) investigated whether gold functions as a safe haven or rather as a hedge asset for the US dollar. Considering weekly data of 16 more relevant sets of exchange rates denoted in dollars over 23 years on which a dynamic conditional correlation model is used, empirical results showed that gold is an effective hedge asset for the US dollar, even more effective during the financial crisis of 2008. This is an addition to the conclusion of Capie, Mills, and Wood (2005), because even though they also did conclude that gold can function as a hedge asset for the US dollar, they nonetheless did not notice the strengthening of its hedge power over especially the recent years. Finally, among others the paper of D. G. Baur and McDermott (2010) showed that gold might also be a hedge for stocks in some developed markets.

The paper of Coudert and Raymond 2011 investigated whether gold functions as either or both hedge and safe haven against stocks for the United States, United Kingdom, Germany, France and the G7 countries by the use of a conditional covariance analysis between stock and gold returns. Their result was basically threefold. However, as the focus lies on the hedge property, we solely focus on that part of the result. They found that gold properly functions as hedge asset against stocks in most of the cases, however, not in all cases. Similarly, the paper of Pasutasarayut and Chintrakarn (2012) investigated whether gold functions as a hedge or safe haven asset for the Thai stock market (Stock Exchange of Thailand - SET) over the period ranging from 2001 to 2011. Focusing on the hedge part of the study, they did not find the gold of the Thai market to function as a hedge asset for the Thai stock market (TSE).

2.5 Gold as safe haven asset

The recent financial crisis showed that a shift occurred from investing in stocks to investing in gold. More interestingly, financial markets in general faced huge losses. As a consequence, investors were protecting their losses by among others shifting to gold investments in tandem which made gold prices to inflate hugely. Several researchers have therefore dived into the subject of gold being a safe haven in times of financial turmoil, especially since the global financial crisis.

The first paper, as far as it can be made up from the consulted literature, that discussed the role of gold as a safe haven asset in the financial market, was the paper of D. G. Baur and Lucey (2010). In addition, this appeared to be the first paper that investigates the relation between returns of bonds and gold. This paper considered daily returns of stocks, bonds and gold of the United States, United Kingdom and Germany over a period spanning from 1995 to 2005, say, ten years. All of these financial assets' returns were denominated in their local currencies in order to consider the effects of gold investments for investors of all of these countries. For example, if all returns were denoted in USD, then we would basically consider the effects from the perspective of an US investor only, that is whether gold is a hedge or safe haven asset for an US investor. The aim of this paper was to test whether gold was a hedge asset or a safe haven asset. They conducted a dynamic linear regression model with asymmetric GARCH specified error term[1] for each country, in which the daily gold returns were regressed on the daily stock and bond returns. However, in this way it is only possible to test whether gold functions as a hedge asset since we consider the complete interval of asset returns. As they also aimed to know whether gold functions as a safe haven during times of turmoil on the financial markets, they included dummy variables for the lower $5\%, 2.5\%$ and 1% tail[2] of returns of stocks respectively bonds as these returns in the lower tail resemble certain financial losses on stocks or bonds which is needed to check whether gold functions as a safe haven in this case. In principle, if one is able to find a significant adverse relationship between returns of gold and returns of either or both stocks or bonds in their lower tail (in case of losses), then there is evidence to conclude that gold functions as a safe haven asset for either or both assets in case these assets suffer from drastically downward price movements. The definition of gold as safe haven asset implies that there is a shift towards gold when investors face losses on a certain or more financial asset(s), which in turn results in increasing gold prices and decreasing prices of the financial asset(s). The second part of their research is a portfolio analysis

[1] They followed the approach of the paper of Capie, Mills, and Wood (2005) in which a dynamic regression model is used with GARCH specified errors in order to estimate whether gold functioned as a hedge against the USD.

[2] The author mentions that the choice of the quantiles is to a certain extent arbitrary, following the paper of Bae, Karolyi, and Stulz (2003).

which depicts the behaviour of the cumulative returns of portfolios that consist of gold and stocks over 50 consecutive trading days from the moment that extremely negative returns in the stock market occurred. It basically depicts how long the positive returns of gold will last.

The paper provides empirical evidence of gold being a hedge for stocks in only the United States and United Kingdom. However, gold is convincingly a safe haven for stocks during turbulent times, although its effect is only on the short run until a maximum of 15 days of trading. Gold seems not to be a safe haven asset for bonds at all. They also conducted this analysis for different regimes, say bull and bear markets. It appears that gold unanimously behaves as a safe haven asset when prices in the stock markets are falling irrespective of what regime.

The paper of D. G. Baur and McDermott (2010) extends this framework by mainly considering a bigger cross-section sample of stock markets, which now comes from major emerging countries as well in addition to major developed countries which were considered in the paper of D. G. Baur and Lucey (2010), for testing the safe haven hypothesis of gold. The sample period ranges from 1979 to 2009, say, 30 years. Also, different levels in turbulence, on the financial markets are discerned aiming to consider the reaction of investors to these different levels of shocks. Also, a distinction is made whether gold functions as either a weak or strong safe haven asset. The former is defined as no co-movement between the financial asset and gold whereas the latter is defined as an adverse co-movement between the financial asset and gold which can be read as gaining on gold when losing on stocks. In case gold would at times be characterized as a strong safe haven asset, it basically implies that gold provides counterbalance to losses of stock markets by offsetting the suffered losses to a certain extent. Finally, they checked for the influence of global market uncertainty on investment behavior. They found that, in particular when using daily returns, there was a strong effect of gold as a safe haven asset for many stock markets of the major developed countries, especially in times of extreme market movements that were less than one percent to happen. They also showed that the frequency of returns matters, that is, when considering trends of stock returns that are more gradual, such as losses on a monthly or weekly basis, the same impulsive response towards gold investments after extreme losses cannot be confirmed which can be interpreted as short-lived panic shift towards gold. They also found that gold is more likely to function as a safe haven asset for investors in developed markets compared to investors in emerging markets. This result reflects that when investors of emerging markets face losses, they are more likely to shift their investments towards the developed markets rather than to shift to safe haven assets like gold. This finding reflects the finding of the paper of Calvo and Mendoza (2000) that investors also care about their relative performance, next to their absolute performance, with respect to other investors. Finally, they found that an increase in global uncertainty creates in general a shift towards gold investments which basically means an adverse co-movement between stocks and gold as investors withdraw their money from stock investments which in turn makes the stock prices to decrease whilst gold prices increase. However, in times of extreme uncertainty there is nonetheless a positive co-movement between gold and stocks, which basically means that gold does not function as a safe haven asset anymore. The paper of Coudert and Raymond (2011) found gold to be a safe haven asset against stocks for all considered countries, which are the United States, United Kingdom, Germany, France and the G7 countries over the sample period spanning from January 1978 till January 2008. However, it functions as a weak safe haven asset in most of the cases. The empirical finding of Arouri, Lahiani, and Nguyen (2015) stating that the safe haven effect does not hold for major emerging countries that among others comprise of China, however, partly invalidates the finding of D. G. Baur and McDermott (2010) which states that gold does function as a safe haven asset against the stock investments for Chinese investors. Also, the paper of Pasutasarayut and Chintrakarn (2012) shows that gold functions as a safe haven asset for the Thai Stock Exchange (TSE), although not as a strong safe haven asset.

The study of Beckmann, Berger, and Czudaj (2015) extends the studies of D. G.

Baur and Lucey (2010) and D. G. Baur and McDermott (2010) by considering a non linear, say, smooth transition regression approach of their model. They considered both individual as well as regional markets over a period spanning from 1970 to 2012, say, 42 years. They basically consider two regimes where one regime reflects periods that are associated with average stock returns, whilst the second regime reflects periods that are associated with highly volatile stock returns, that is, when there are extreme market conditions. Clearly, the latter regime allows for testing the safe haven hypothesis of gold. They found accordingly that gold functions as a safe haven asset. However, the results strongly vary over the countries and markets. Finally, they conducted a portfolio analysis in order to show what the benefits of including gold in portfolios are where the weights are also based on the information of the smooth transition function.

The study of Lucey and Li (2015) also considered the safe haven effect of other precious metals besides gold, which are silver, palladium and platinum in the United States. They interestingly found that gold is not always relatively the strongest safe haven at times, which means that at times one of the other precious metals under consideration might be characterized as a stronger safe haven asset. In addition, they found that even in periods that the other precious metals function as a safe haven asset, gold does not. The study of Reboredo and Ugolini (2015) confirms that the behaviour of these four precious metals is not as if they were a single asset class by considering the price spillover effect between these metals. When considering pairs of precious metals, there is lower tail dependency between these precious metals in many cases, although the magnitude of dependency differs across the precious metals. This means that the downside price spillover effect is in general present across precious metals. Moreover, there was in general also upper tail dependency, say, positive price spillover effect between precious metals found although in a smaller magnitude. The paper of Hood and Malik (2013) also considered the VIX next to the precious metals in the sample of US data starting from November 1995 till November 2010. They found no negative correlation between gold and stock returns during times that volatility were extremely high or low. They confirmed that gold functions as a weak safe haven during periods of financial rumour. The VIX, however, has during the whole sample period a negative correlation with even a stronger negative correlation during periods of financial turmoil compared to gold.

The study of Białkowski et al. (2015) investigated the price dynamics of gold. They defined some drivers of gold prices, which are based on the function of gold as a hedge against the depreciation of the dollar, hedge against inflation, diversifier of an portfolio and safe haven. Considering the deviations of gold prices after correcting for the drivers, they showed by the use of a Markov-switching Augmented Dickey-Fuller test that the oil crisis was for a big part able to explain the boom in gold prices around the 1980s, and, that the European sovereign debt crisis was for a big part able to explain the boom in the gold prices in the recent financial crisis. Altogether, this finding signifies that gold is likely to function as a safe haven asset.

There is, however, another strand of literature that proves that the safe haven characteristic of gold is vanishing. The paper of MacDonald and Shumsky (2015) discusses the role of gold as investment asset nowadays. They state that the price of gold has become dependent on investors' expectations when the Federal Reserve Bank of America (FED) will raise the interest rates instead of the threats on the fields of economics, politics and inflation. The paper of D. G. Baur and Glover (2012) shows that the safe haven characteristic of gold is eroded or can even be destroyed nowadays, because many investors as well as institutional investors such as pension funds and hedge funds, treat gold as an investment or hedge asset. That means that a certain fraction of their portfolio consists of gold. As a result, the prices of gold will not solely depend on the supply and demand anymore, but also on the investor's trading strategies. In this way, linkages between stock prices and gold prices will be caused and in turn let the safe haven characteristic of gold be weakened. If investors take this weakened safe haven effect into account and as such change their beliefs regarding gold as an effective safe haven asset, then the safe haven characteristic might be destroyed. They empirically showed that the safe haven effect of gold lasted for a shorter duration in the crisis of 2008 compared to before.

2.6 Summary of literature review

The aforementioned studies show that gold indeed functions as a safe haven asset for the stock markets, although its effect is for a short-term and seems rather to be a short-lived panic investment to the so-called flight-to-safety asset. The short-lived effect can be explained from a behavioural point of view. That is, since investors use gold as an investment asset nowadays rather than as safe haven asset, the effectiveness of the safe haven property will wane. Investors adjust their beliefs on it and are gradually less likely to use gold as safe haven asset anymore. This causes the duration of the gold as safe haven to shrink or might even be destroyed. There is, however, no evidence for gold as safe haven asset for the bond market yet. In addition, it is shown that gold as a safe haven asset is more likely for investors in stock markets of major developed markets rather than for emerging markets. More recent studies also show that gold is not a stand-alone asset within the class of precious metals that can function as a safe haven asset. Instead, other metals such as silver, palladium and platinum also seem to exhibit this feature to a certain extent. Notably, the precious metals cannot be classified as one asset class as each of them generally has its own behavior although there are price spillover effects present between these metals. This means that price shocks in one precious metal has in general, where a few exceptions are left out for the sake of simplicity, a transmission effect on the remaining precious metals. Gold can also function as a hedge or safe haven asset against currency depreciation, e.g. US dollar. In addition, gold can also be used as a hedge against inflation or against stocks in some cases. Finally, gold is an appropriate asset to include in a portfolio for diversification purposes.

3 Data

In this section the data used for this empirical study will be described in detail. Data used for this empirical analysis comes from several sources, that is, *Investing.com, Standard and Poor's, Yahoo Finance, The Wall Street Journal, Datastream and Thomson Reuters*. As already mentioned in the introduction, the effect of gold as a safe haven asset will be investigated for investors of developed markets respectively emerging markets. In our empirical study the emerging markets compose of BRIC countries, that is, Brazil, Russia, India and China. Furthermore, the selection of developed markets that we opted for composes of countries from the Eurozone[3], United Kingdom and United States. Table 1 depicts the classifications[4].

Table 1: Classification of countries into markets according to MSCI standards. Names of their local currencies are between parentheses.

Developed markets (DM)	**Emerging markets (EM)**
Eurozone (EUR)	China (CNY)
UK (GBP)	Brazil (BRL)
US (USD)	India (INR)
	Russia (RUB)

The set of financial assets considered for this portfolio study composes of gold, stocks and bonds where there is a distinction between corporate and government bonds. As we take each country into isolation when analyzing gold as potential safe haven asset, it is necessary that all assets are denoted in local currencies. That basically means that in particular gold prices, which are usually denoted in USD per troy ounce, should be translated into local currencies. In order to avoid potential biases when transforming prices of gold futures, which are denoted in USD per troy ounce, into several local

[3]Eurozone is the collective name for countries within the European Union that adopted the Euro as their domestic currency.

[4]Classification is based on the authentic information of the MSCI website https://www.msci.com/emerging-markets

currencies, we need to take into account the timing of the exchange rates as well as the timing of the prices of the gold futures. When the time sets are not the same, we are most likely to apply wrong exchange rates to the prices of gold futures inducing undesired bias in the gold future prices. For government bonds, the 10-year Treasury bond of each country is preferred. For all assets, we analyze returns rather than absolute prices. The reason is that a series of prices oftentimes contain a unit root implying that moments are varying over time, whilst returns in general are normalized and stationary. Moreover, as returns are in a normalized form, it becomes possible to compare performance of several assets. Returns of assets are calculated in the following way:

$$R_{t+1} = log(\frac{p_{t+1}}{p_t}) \tag{1}$$

Note that we have opted for a logarithmic transformation of returns. This has several benefits over using returns in the standard, that is, in the arithmetic form which is defined as $r_{t+1} = \frac{p_{t+1}-p_t}{p_t}$. The most important reason is that, based on the fact that financial assets are in general log-normally distributed, the logarithmic transformed returns, say, $\log(1 + r_{t+1})$ are[5] approximately normally distributed. In addition, it allows for easier aggregation in the time dimension, whilst still maintaining the normal distribution. This is because each return in the time-dimensions enters in an additive way to the likelihood of the logarithmic function of returns, that is, $\prod_{t=1}^{n} log(1+r_{t+1}) = \sum_{t=1}^{n} log(1+r_{t+1})$ rather than in a multiplicative way as would be the case for the arithmetic returns. This is because the product of logarithms is the sum of logarithms. Recall from the probability theory that the multiplication of random normally distributed variables, say returns, does not result in a normal distribution. However, the sum of random normal variables results again in a normal distribution. An

[5] This formula is mathematically the same as equation (1)

important technical note regarding the latter statement about the normal distribution of the sum of random normally distributed variables is that this is merely the case when all variables are not correlated. Another advantage of the logarithmic transformation is that we now have numerical stability. That is, addition of small return values does not cause unstable values, as would be the case when multiplying small return values. However, the advantage of arithmetic returns over logarithmic returns is that comparing returns in the cross-section is mathematically better feasible for arithmetic returns.

The remainder of the *Data* section will discuss in greater detail the data of stocks, bonds and gold.

3.1 Gold

In this empirical analysis, we opted for prices of 3-month gold per 100 troy ounces futures traded on the Commodity Exchange Inc. (COMEX) as measurement for the price of gold per 100 troy ounces, following among others the paper of Arouri, Lahiani, and Nguyen (2015). The prices are extracted from *Investing.com*, where daily closing prices are used. Closing time of the markets are at 5pm in terms of New York time(NYT). This time is crucial for the exchange rates that we need for converting gold futures USD into several local currencies. Therefore, we need to extract all exchange rates, that is, USD/other currency measured at 4.59pm NYT from Sunday until Friday. Unfortunately, extensive research work showed that there is no exchange rate data available for the desired time, that is, on 4.59pm NYT. We only have the closing exchange rates, which is the average of the bid and ask rates, captured on 5.59pm NYT from Sunday until Thursday and for Friday on 4.59pm NYT. As is visible, this deviation in time from Sunday until Friday lasts just one hour and we take the potential bias that might occur by using different times for gold futures and exchange rates for granted.

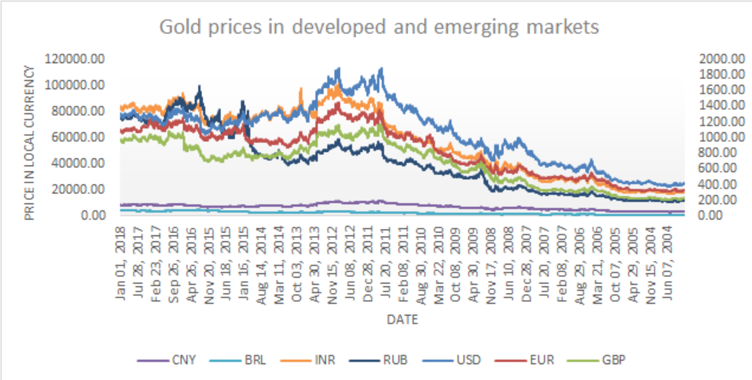


Fig. 2: Gold price expressed in different currencies where the scaling on the left vertical axis is devoted to emerging markets and the scaling on the right vertical axis to the developed markets.

3.2 Stocks

For each country we opted for the most prominent stock markets among all possibilities for that country. That basically means that we opted for the *S&P500* for the United States, the *FTSE100* for the United Kingdom, Eurostoxx 50 for the Eurozone, *Ibovespa* for Brazil, *MOEX* for Russia, *BSE Sensex 30* for India and finally *Shanghai Composite index* for China. Note that we specifically selected the *Eurostoxx 50* instead of the more extensive *Eurostoxx 600* as suitable gauge for the stock market of the Eurozone. That is because the *Eurstoxx 50* only contains stocks of countries that belong to the European Monetary Union, that is, countries within the European Union that adopted the Euro as their local currency. On contrary, the *Eurostoxx 600* also contains stocks of countries within the EU that do not have adopted the Euro as their domestic currency.

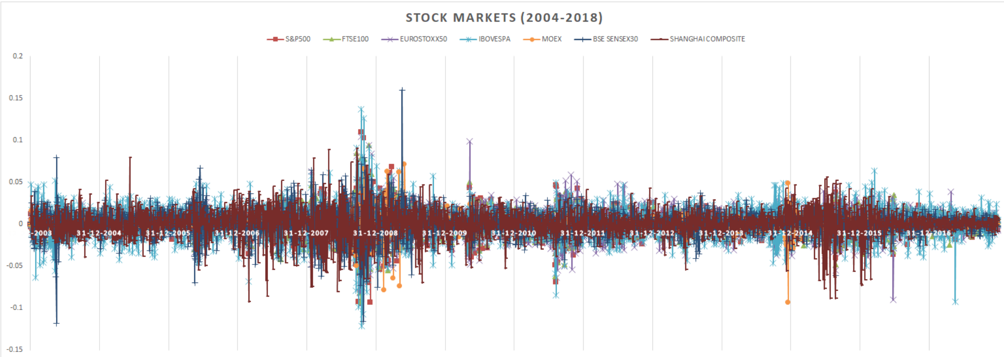


Fig. 3: Time-series graph of the stock markets S&P500, FTSE100, Eurostoxx50, Ibovespa, MOEX, BSE Sensex 30 and Shanghai Composite Index, where the horizontal axis represents the dates scaled by one year and the vertical axis represents the log-return.

Table 2: Descriptive statistics of the stock markets S&P500, FTSE100, Eurostoxx50, Ibovespa, MOEX, BSE Sensex 30 and Shanghai Composite Index.

	Mean	Volatility	Skew	Kurtosis	Min	Max	observations
S&P500	0.0002	0.012	-0.358	12.472	-0.095	0.110	3525
FTSE100	0.0000	0.011	-0.150	8.883	-0.093	0.094	3460
Eurostoxx50	-0.0001	0.014	-0.029	6.388	-0.090	0.104	3493
Ibovespa	0.0001	0.017	-0.052	5.254	-0.121	0.137	3404
MOEX	0.0000	0.006	-1.390	79.381	-0.093	0.072	3346
BSE Sensex30	0.0004	0.014	-0.053	9.893	-0.118	0.160	3368
Shanghai Composite	0.0002	0.016	-0.498	4.341	-0.093	0.090	3291

	S&P500	FTSE100	Eurostoxx50	Ibovespa	MOEX	BSE Sensex30	Shanghai Composite
S&P500	1.00	0.58	0.61	0.65	0.06	0.27	0.08
FTSE100	0.58	1.00	0.88	0.51	0.08	0.42	0.15
Eurostoxx50	0.61	0.88	1.00	0.50	0.09	0.40	0.14
Ibovespa	0.65	0.51	0.50	1.00	0.09	0.29	0.16
MOEX	0.06	0.08	0.09	0.09	1.00	0.07	0.08
BSE Sensex30	0.27	0.42	0.40	0.29	0.07	1.00	0.22
Shanghai Composite	0.08	0.15	0.14	0.16	0.08	0.22	1.00

Fig. 4: Correlation matrix between stock markets S&P500, FTSE100, Eurostoxx50, Ibovespa, MOEX, BSE Sensex 30 and Shanghai Composite Index.

Figure 3 shows the time-series graph of all stock markets that we take into consideration as earlier mentioned. First thing that draws attention is that there is seemingly volatility clustering in the time-series, that is, periods of high volatility are followed up by periods of high volatility and periods of low volatility are followed up by periods of low volatility as is explained in the paper of Cont (2007). During the period of beginning 2008 until amid 2009 the volatility, or better said, the movement in stock returns during that time period seems to exhibit relatively the most excessive pattern. This is clearly due to the global financial crisis. The global financial crisis officially began in September 2008, when the bank Lehman Brothers went bankrupt. The preamble of the global financial crisis is the U.S. credit crisis (2007-2008), as is explained in the paper of Guillén (2009). The second period where there is seemingly clustered high volatility, is between the end of 2014 and amid 2016, loosely speaking, in 2015. This might be due to the international manufacturing growth that was slowing down and the normalization of the U.S. policy that was about to happen. The normalization of the U.S. monetary policy basically encompasses two major elements, that is, firstly returning the interest rates to more normal levels and secondly returning the amount of securities possessed by the FED to somewhat more normal levels as those prior to the global financial crisis (GFE)[6] in a relative sense. The volatility over 2017 seems to be remarkably low when looking at the time-series plot. According to a report presented by UBS[7] even historically low. Noteworthy despite a little out of our chosen time frame is that the volatility in 2018 has increased for several reasons. One of the reasons is that the economy of the United States being the world's largest one, has expanded for almost a decade since the global financial crisis. Now it becomes gradually harder to expand the economy even further, that is, it becomes relatively more difficult for companies to increase production. Also, due to increasingly tightening on the labour market, salaries will be increased which in turn causes inflation to rise. In order to dampen the increase in inflation, central banks others than that of the United States (FED) now have also initialized the process of increasing the interest rates in order to diminish the liquidity in the global financial

[6] The information originates from the Federal Reserve Bank, that is, www.federalreserve.gov/monetarypolicy/policy-normalization.htm.

[7] https://www.ubs.com/content/dam/WealthManagementAmericas/documents/global-financial-markets-volatility-is-back-are-you-prepared.pdf

market. This is because borrowing will become gradually more expensive for companies and households, which will dampen inflation pressures, but will also make the economy grow slower as well as the profit growth of companies. This will be visible in the financial markets by means of less certain returns. Also, protectionism like Donald Trump announced for the United States regarding Chinese goods, will affect global economic growth and as such affect profits for the companies. Several other risks might affect the global economic growth as well, such as the financial situation of Italy increasing the risk of a debt crisis in the Eurozone, big increase of Chinese debts raising the chance of a local credit crisis for China which will negatively affect the global economic growth as well. Finally, several geopolitical tensions such as among others the tension between the United States and North Korea about its nuclear program might badly influence the global economic growth.

Table 2 shows that there is not much difference in the mean of the returns. The BSE SENSEX 30 index of India seems to have on average relatively the highest level of return, the highest maximum return value with respect to all other indices, whilst it has more or less the same level of volatility as the EUROSTOXX50 index of the Eurozone. The Ibovespa index of Brazil seems to exhibit relatively the highest level of volatility, and has also relatively the lowest minimum return value in its range. The statistics of Russia are somewhat counter-intuitive. It has relatively the lowest level of volatility, is relatively the most negatively skewed, has very thick tails with kurtosis value of around 79. This means that deviating observations are far more likely to occur compared to a normal distribution. It seems that the MOEX index has to cope with relatively stronger negative returns compared to its positive returns.

Considering the correlation matrix between stock indices in figure 4, it is remarkable that stock markets of the developed markets are more strongly correlated with each other than with emerging stock markets. That is also reasonable as these countries have similar economies. Interestingly, the emerging stock markets are not strongly correlated with each other. Stock markets of Brazil and India are however reasonably correlated to the developed markets.

3.3 Bonds

Bonds are either issued by the government or company in order to borrow money from investors. The investor gets in turn periodically coupon rent and, in the end of the term, the principal amount. In terms of hierarchy, government bonds bear relatively the lowest risk. This is because the government has more channels to generate cash-inflow when times become hard, for instance by rising taxes. Of course, corporate bonds bear relatively more risk as they usually do not have many financial channels to cover potential losses and debts.

3.3.1 Government bonds

In the quest for government bond of each country, there were different choices regarding the time to maturity. However, we opted for a term of 10 years as far as possible since bonds with this term were available for more countries. Initially, we considered the term of 30 years, but those bonds did not appear to be available for many countries, especially in the field of emerging markets. All prices of the Treasury bonds except for Russia were downloaded from Standard and Poor's. The prices for the Russian government bonds were downloaded from *Moscow Exchange*. All indices from Standard and Poor's are market-value weighted and aim to track the performance of bonds issued by the governments for the domestic markets. Government bond indices used are *S&P U.S. Treasury Bond 10-year index* for the United States, *S&P U.K. Gilt Bond Index* for the United Kingdom, *S&P Eurozone Sovereign Bond 7-10 years index* for the Eurozone, *S&P Brazil Sovereign Inflation-Linked bond index* for Brazil, *RGBI 10Y* for Russia, *S&P BSE India Goverment Bond Index* for India and finally, *S&P China government bond index* for China. Although we are aware of the fact that we have sovereign bond indices for the Eurozone and Brazil, we nonetheless neglect the minor discrepancies that might occur due to the fact that the government bonds, which are issued for the domestic market, are denoted in foreign currencies. As the bond index returns an price index value where the base case is valued as 100, we therefore believe that it does not really matter in which currency the bond is denoted. It is just about the performance, which is in this case measured by returns on an index scale. Unfortunately, we were not able to achieve referring bond indices denoted in local currencies, therefore we adopted the sovereign bond indices as these were available for the Eurozone and Brazil. The point is in fact that most of the sources only provide yields of bonds as historical data, whilst we rather need original prices of those bonds on which returns can be calculated for the sake of portfolio analysis.

3.3.2 Corporate bonds

For each country, we consider the bonds issued by the companies in the country itself. This analysis will be twofold. On the one hand, we consider less risky bonds, the so-called investment grade corporate bonds. On the other hand, we consider the more risky, that is, the higher yielding corporate bonds. In terms of credit rating, all bonds within the spectrum of Aaa (upper boundary) - Baa3 (lower boundary) according to Moody's credit rating method and within the spectrum of AAA (upper boundary) - BBB (lower boundary) according to Standard and Poor's credit rating method, fall within the category of investment-grade bonds. All bonds that fall within the remainder set of credit ratings, belong to the category of high-yield corporate bonds. Since the sources are very limited, we were only able to retrieve from Standard and Poor's indices for the investment grade bonds as well as for the high-yield corporate bonds of the United States. The investment-grade and high-yield corporate bond indices for the countries with emerging markets were extracted from Datastream. Investment grade corporate bond indices for the United Kingdom and Eurozone were extracted from Standard and Poor's. The high-yield corporate bond index for the Eurozone was extracted from the official source of *Bank of America Merrill Lynch*. Although, high-yield corporate bond data for the UK was unavailable, we still continue the analysis for the remaining financial securities in the portfolio of the UK investor. The availability of the data for corporate bond indices for investment-grade respectively high-yield bonds was very divergent. For some countries data from Jan 2004 was available, for some from 2008 and for others from July 2012. As the analysis should be consistent, it is important that we compare portfolios for countries over the same time span. Therefore, when considering the corporate bonds as two separate categories, that is, investment-grade and high-yield corporate bonds, we run the analysis from July 2012 until December 2017.

The aforementioned analysis of course goes along with a tremendous loss of data from our initial sample (2004-2018), since we neglect loosely eight years (2004-2012) of data and simply use the data from 2012 onwards. Therefore, we also run the portfolio analysis where we do not assume the corporate bond to be classified and simply assume it to be one class *Corporate bonds*, which is loosely speaking an aggregated corporate bond index. For this analysis, a lot more data is available for the aggregated corporate bond indices. In this case, we managed to acquire data from July 2008 until December 2017. Standard and Poor's provided general corporate bond indices, that is without distinction of credit worthiness, for the United States (*S&P500 corporate bond index*), India (*S&P BSE India corporate bond index*) and China (*S&P China corporate bond index.* The Russian Moscow exchange provided a general corporate bond index for Russia, which is called *MICEX Corporate bond index.* Datastream provided the corporate bond indices for the remaining countries. For the United Kingdom and Eurozone, Datastream provided data originating from the *Bank of America Merill Lynch* for maturity buckets of 7-10 years. Finally, Datastream provided corporate bond data for Brazil which originates from *Barclays.*

3.4 Descriptive statistics

In this subsection, we show the descriptive statistics of gold, stocks and bonds for all countries. The analysis will be split up in three parts. The fist part we consider, encompasses the whole time span from January 2004 until December 2017 for analyzing stocks and gold. The second part consists of the time span from July 2008 until December 2017 for analyzing gold, stocks, government bonds and general corporate bonds. The third part, finally, encompasses the time span from July 2012 until December 2017 for analyzing gold, stocks, government bonds, investment grade corporate bonds and high yield corporate bonds.

3.4.1 Sample period 2004-2018

Developed countries

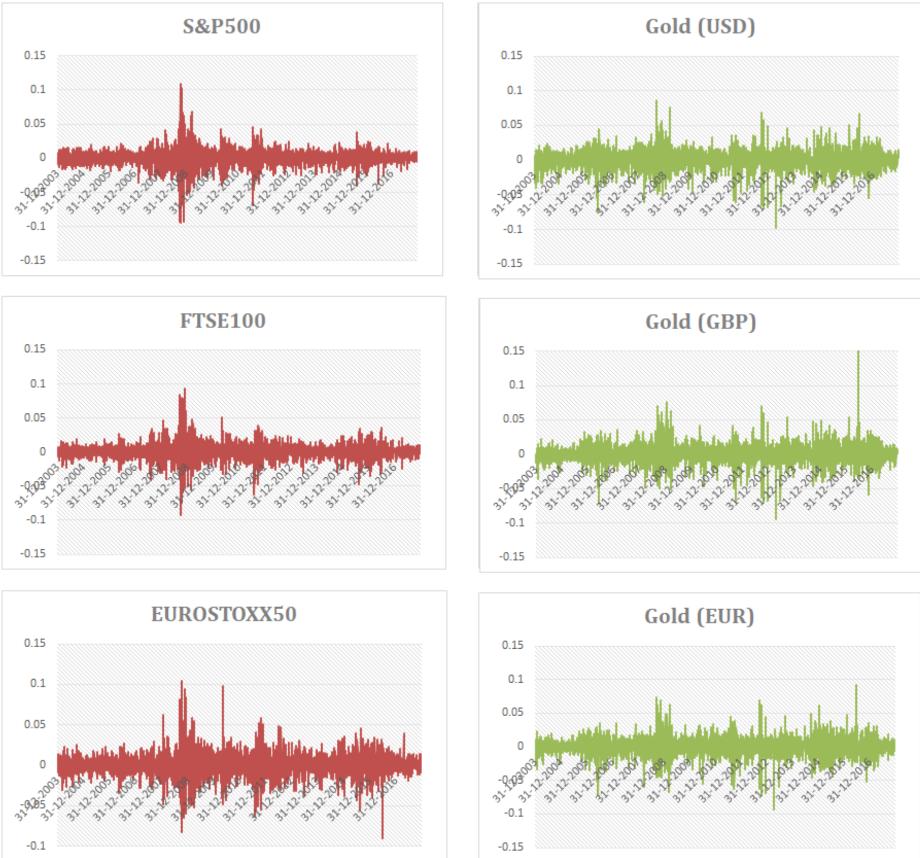
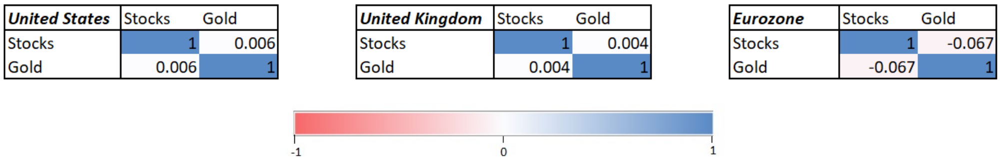


Fig. 5: Time-series plot of stock markets and gold over the period Jan 2004 - Dec 2017 for developed countries.



United States	Stocks	Gold
Stocks	1	0.006
Gold	0.006	1

United Kingdom	Stocks	Gold
Stocks	1	0.004
Gold	0.004	1

Eurozone	Stocks	Gold
Stocks	1	-0.067
Gold	-0.067	1

Fig. 6: Correlation matrix of stock markets and gold over the period Jan 2004 - Dec 2017 for developed countries. The bar below the graph is the colour legend.

Table 3: Descriptive statistics of stocks and gold of developed countries *United States*, *United Kingdom and Eurozone* over Jan 2004 - Dec 2017.

	S&P500	*Gold (USD)*	*FTSE100*	*Gold (GBP)*	*EUROSTOXX50*	*Gold (EUR)*
mean	0.0002	0.0004	0.0001	0.0004	0.0000	0.0003
median	0.0006	0.0005	0.0005	0.0005	0.0002	0.0005
stdev	0.0116	0.0132	0.0113	0.0134	0.0136	0.0130
skewness	-0.3571	-0.2706	-0.1497	0.2128	-0.0278	-0.1718
kurtosis	12.4530	4.8298	8.8676	9.0148	6.3756	5.8093
min	-0.0947	-0.0982	-0.0926	-0.0950	-0.0901	-0.0935
max	0.1096	0.0864	0.0938	0.1515	0.1044	0.0918
observations	3518	3518	3452	3452	3486	3486

Emerging countries

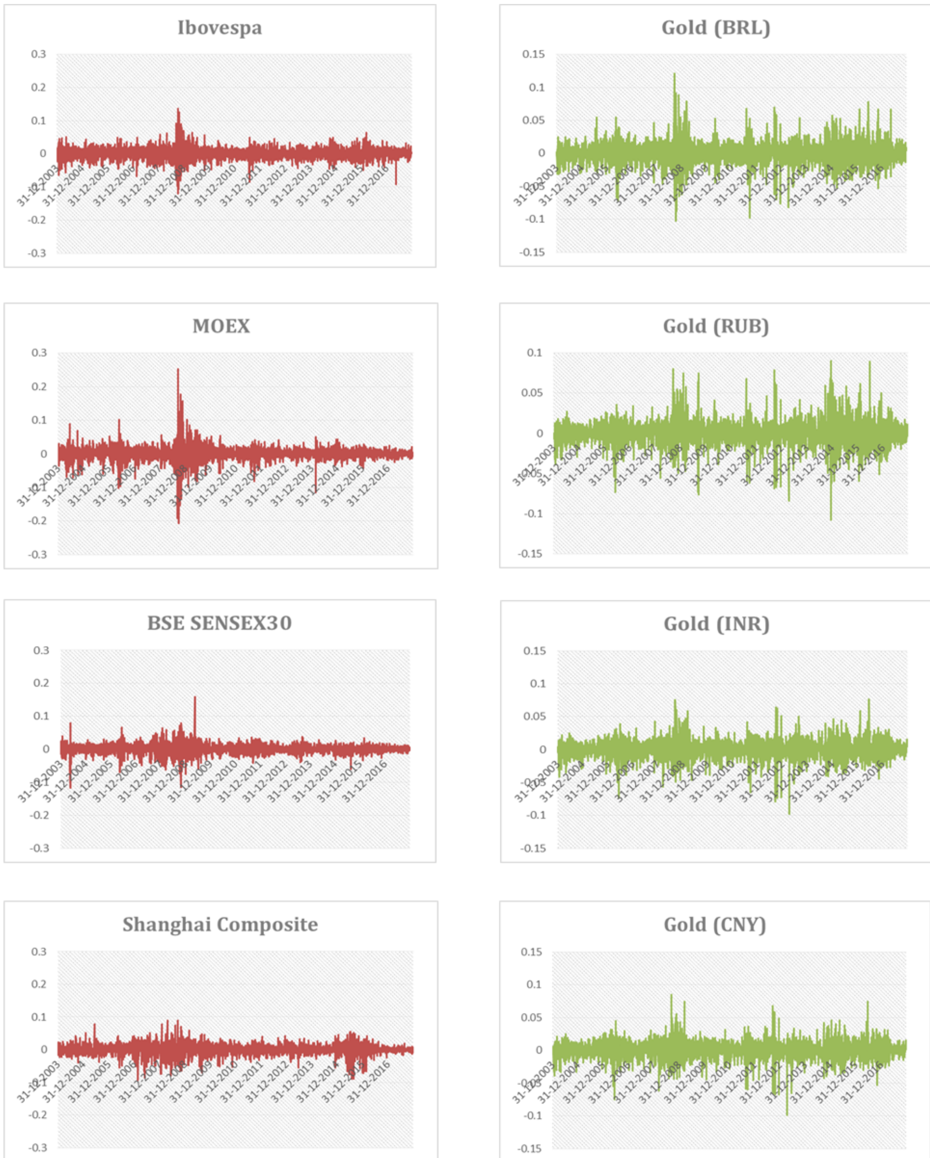


Fig. 7: Time-series plot of stock markets and gold over the period Jan 2004 - Dec 2017 for emerging BRIC countries.

Brazil	Stocks	Gold
Stocks	1	-0.261
Gold	-0.261	1

Russia	Stocks	Gold
Stocks	1	-0.018
Gold	-0.018	1

India	Stocks	Gold
Stocks	1	-0.050
Gold	-0.050	1

China	Stocks	Gold
Stocks	1	0.020
Gold	0.020	1

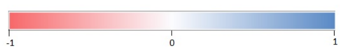


Fig. 8: Correlation matrix of stock markets and gold over the period Jan 2004 - Dec 2017 for emerging BRIC countries. The bar below the graph is the colour legend.

Table 4: Descriptive statistics of stocks and gold of emerging countries *Brazil, Russia, India and China* over Jan 2004 - Dec 2017.

	Ibovespa	*Gold (BRL)*	*MOEX*	*Gold (RUB)*	*BSE Sensex30*	*Gold (INR)*	*Shanghai Composite*	*Gold (CNY)*
mean	0.0003	0.0004	0.0003	0.0005	0.0005	0.0005	0.0002	0.0002
median	0.0007	0.0004	0.0006	0.0006	0.0008	0.0007	0.0007	0.0004
stdev	0.0175	0.0162	0.0205	0.0152	0.0146	0.0132	0.0165	0.0131
skewness	-0.0557	0.0573	-0.1775	0.0135	-0.0534	-0.2810	-0.4981	-0.2772
kurtosis	5.1375	5.2863	20.4499	5.2663	9.7099	4.9310	4.3431	5.1487
min	-0.1210	-0.1028	-0.2066	-0.1081	-0.1181	-0.0977	-0.0926	-0.0990
max	0.1368	0.1215	0.2523	0.0901	0.1599	0.0765	0.0903	0.0848
observations	3340	3340	3346	3346	3315	3315	3283	3283

3.4.2 Sample period 2008-2018

Developed countries

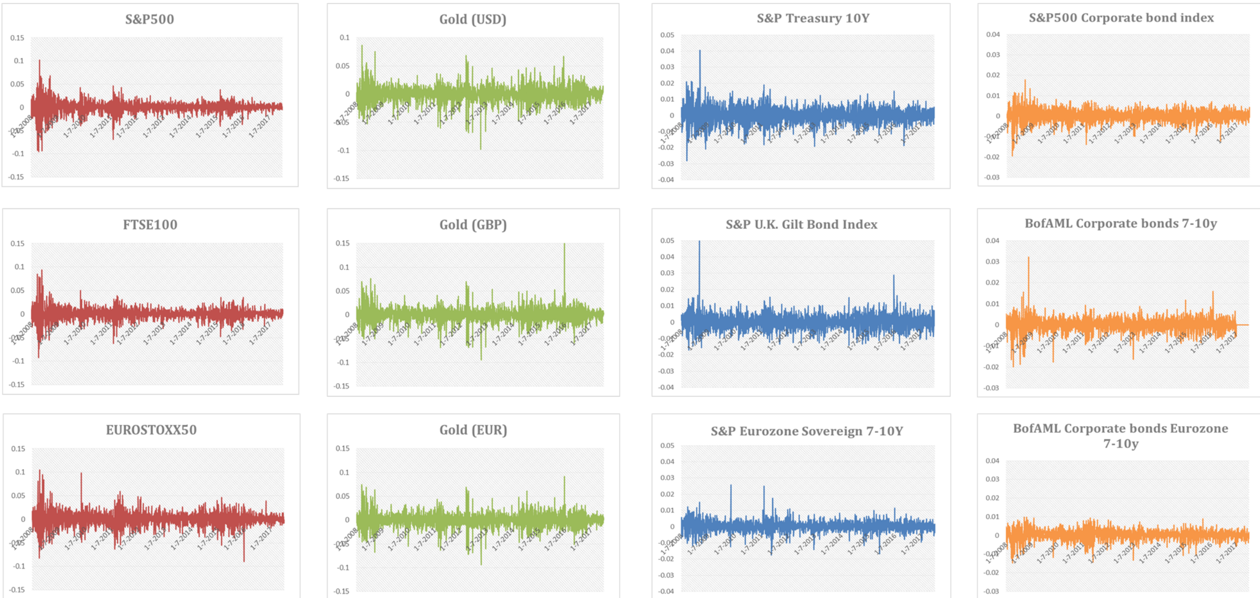


Fig. 9: Time-series plot of stock, gold, government bond and general corporate bond markets over the period Jul 2008 - Dec 2017 for developed countries.

United States	Stocks	Gold	Government bond	Corporate bond
Stocks	1	0.002	-0.410	-0.256
Gold	0.002	1	0.098	0.101
Government bond	-0.410	0.098	1	0.818
Corporate bond	-0.256	0.101	0.818	1

Eurozone	Stocks	Gold	Government bond	Corporate bond
Stocks	1	-0.114	-0.030	-0.209
Gold	-0.114	1	0.091	0.168
Government bond	-0.030	0.091	1	0.595
Corporate bond	-0.209	0.168	0.595	1

United Kingdom	Stocks	Gold	Government bond	Corporate bond
Stocks	1	-0.043	-0.314	-0.212
Gold	-0.043	1	0.225	0.172
Government bond	-0.314	0.225	1	0.714
Corporate bond	-0.212	0.172	0.714	1

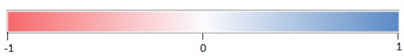


Fig. 10: Correlation matrix of stock, gold, government bond and corporate bond markets over the period Jul 2008 - Dec 2017 for developed countries. The bar below the graph is the colour legend.

Table 5: Descriptive statistics of stocks, gold, government bonds and corporate bonds of developed countries *United States, United Kingdom and Eurozone* over Jul 2008 - Dec 2017.

	S&P500	*Gold (USD)*	*S&P Treasury 10y*	*S&P500 Corp. Bond*	*FTSE100*	*Gold (GBP)*	*S&P U.K. Gilt Bond*	*BofAML C.bonds 7-10y*	*EUROSTOXX50*	*Gold (EUR)*	*S&P Eurozone sov. 7-10y*	*BofAML Corp. 7-10y*
mean	0.0003	0.0002	0.0002	0.0002	0.0001	0.0003	0.0002	0.0001	0.0000	0.0002	0.0002	0.0002
median	0.0006	0.0003	0.0003	0.0003	0.0005	0.0003	0.0002	0.0000	0.0001	0.0004	0.0003	0.0003
stdev	0.0127	0.0139	0.0051	0.0030	0.0122	0.0145	0.0045	0.0032	0.0151	0.0141	0.0032	0.0028
skewness	-0.6527	-0.0934	0.0956	-0.4195	-0.1480	0.3756	0.6240	-0.1317	-0.0154	-0.0394	0.2282	-0.6230
kurtosis	10.3971	5.0123	3.1056	3.4637	8.9207	8.9505	7.5554	7.5511	5.6337	5.2973	5.5608	2.6660
min	-0.0947	-0.0982	-0.0283	-0.0195	-0.0926	-0.0950	-0.0170	-0.0199	-0.0901	-0.0935	-0.0177	-0.0147
max	0.1025	0.0864	0.0405	0.0178	0.0938	0.1515	0.0501	0.0322	0.1044	0.0918	0.0257	0.0098
observations	2373	2373	2373	2373	2346	2346	2346	2346	2371	2371	2371	2371

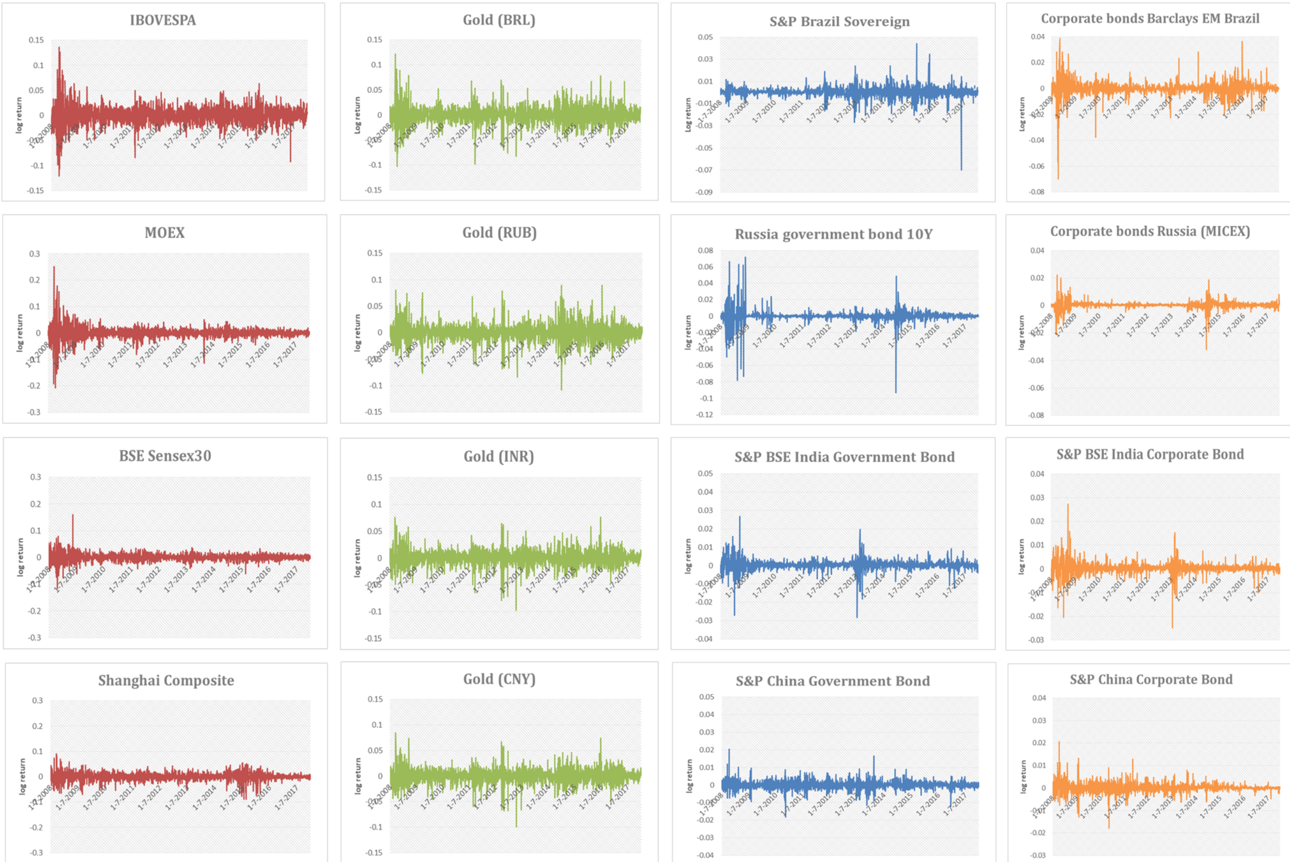


Fig. 11: Time-series plot of stock, gold, government bond and general corporate bond markets over the period Jul 2008 - Dec 2017 for the emerging BRIC countries.

Brazil	Stocks	Gold	Government bond	Corporate bond
Stocks	1	-0.289	0.178	0.179
Gold	-0.289	1	-0.097	-0.049
Government bond	0.178	-0.097	1	0.211
Corporate bond	0.179	-0.049	0.211	1

Russia	Stocks	Gold	Government bond	Corporate bond
Stocks	1	-0.089	0.087	0.064
Gold	-0.089	1	-0.120	0.003
Government bond	0.087	-0.120	1	0.178
Corporate bond	0.064	0.003	0.178	1

India	Stocks	Gold	Government bond	Corporate bond
Stocks	1	-0.116	0.125	0.100
Gold	-0.116	1	-0.045	-0.046
Government bond	0.125	-0.045	1	0.916
Corporate bond	0.100	-0.046	0.916	1

China	Stocks	Gold	Government bond	Corporate bond
Stocks	1	0.018	-0.001	0.005
Gold	0.018	1	0.021	0.024
Government bond	-0.001	0.021	1	0.832
Corporate bond	0.005	0.024	0.832	1

Fig. 12: Correlation matrix of stock, gold, government bond and corporate bond markets over the period Jul 2008 - Dec 2017 for the emerging BRIC countries. The bar below is the colour legend.

Table 6: Descriptive statistics of stocks, gold, government bonds and corporate bonds of the emerging BRIC countries over Jul 2008 - Dec 2017.

	Ibovespa	*Gold (BRL)*	*S&P Brazil Sov. Bond*	*Corp. Bond Barclays*	*MOEX*	*Gold (RUB)*	*Russia gvrn. Bond 10y*	*Corporate bond (MICEX)*	*BSE Sensex30*	*Gold (INR)*	*S&P BSE India gvrn. Bond*	*S&P BSE gvrn. Bond*	*Shanghai Composite*	*Gold (CNY)*	*S&P China gvrn. Bond*	*S&P China corp. Bond*
mean	0.0001	0.0005	0.0005	0.0000	0.0001	0.0005	0.0001	0.0003	0.0003	0.0004	0.0003	0.0004	0.0001	0.0001	0.0001	0.0002
median	0.0002	0.0005	0.0005	0.0002	0.0000	0.0004	0.0001	0.0003	0.0004	0.0004	0.0003	0.0003	0.0007	0.0003	0.0002	0.0002
stdev	0.0177	0.0174	0.0045	0.0051	0.0209	0.0168	0.0067	0.0023	0.0139	0.0140	0.0026	0.0022	0.0156	0.0138	0.0023	0.0020
skewness	0.0194	0.1135	-1.3782	-2.0230	-0.0624	0.1184	-1.2165	-1.6936	0.3599	-0.1511	-0.6928	-0.1449	-0.5340	-0.1196	0.1164	0.3835
kurtosis	6.9026	5.2441	35.2243	34.5878	26.6346	4.5538	56.4631	41.0448	13.3914	5.0797	24.7177	27.9537	4.8646	5.3575	8.0488	13.8505
min	-0.1210	-0.1028	-0.0699	-0.0698	-0.2066	-0.1081	-0.0933	-0.0322	-0.1160	-0.0977	-0.0282	-0.0249	-0.0887	-0.0990	-0.0182	-0.0178
max	0.1368	0.1215	0.0440	0.0386	0.2523	0.0901	0.0716	0.0222	0.1599	0.0765	0.0267	0.0274	0.0903	0.0848	0.0203	0.0206
observations	2282	2282	2282	2282	2277	2277	2277	2277	2248	2248	2248	2248	2235	2235	2235	2235

3.4.3 Sample period 2012-2018

Developed countries

United States	Stocks	Gold	Government bond	Corporate bond (IG)	Corporate bond (HY)
Stocks	1	-0.044	-0.357	-0.261	0.428
Gold	-0.044	1	0.181	0.179	-0.015
Government bond	-0.357	0.181	1	0.897	-0.082
Corporate bond (IG)	-0.261	0.179	0.897	1	0.128
Corporate bond (HY)	0.428	-0.015	-0.082	0.128	1.000

United Kingdom	Stocks	Gold	Government bond	Corporate bond (IG)	Corporate bond (HY)
Stocks	1	-0.051	-0.232	-0.139	
Gold	-0.051	1	0.262	0.226	
Government bond	-0.232	0.262	1	0.902	
Corporate bond (IG)	-0.139	0.226	0.902	1	
Corporate bond (HY)					

Eurozone	Stocks	Gold	Government bond	Corporate bond (IG)	Corporate bond (HY)
Stocks	1	-0.085	0.165	-0.047	0.514
Gold	-0.085	1	0.111	0.169	-0.009
Government bond	0.165	0.111	1	0.731	0.278
Corporate bond (IG)	-0.047	0.169	0.731	1	0.292
Corporate bond (HY)	0.514	-0.009	0.278	0.292	1

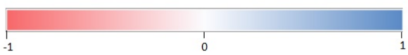


Fig. 13: Correlation matrix of stock, gold, government bond and corporate bond markets over the period Jul 2012 - Dec 2017 for the developed countries. Recall that the high-yield corporate bond data was not available for the United Kingdom. The bar below the graph is the colour legend.

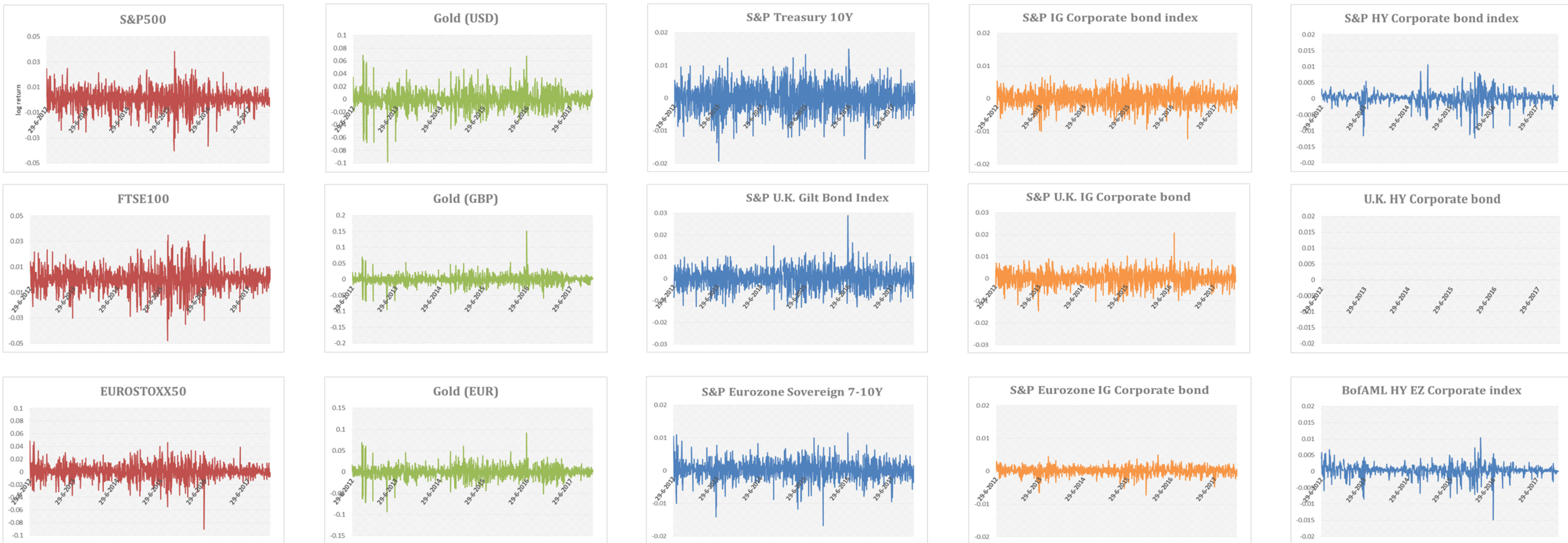


Fig. 14: Time-series plot of stock, gold, government bond and Investmet Grade/High-Yield corporate bond markets over the period Jul 2012 - Dec 2017 for the developed countries.

Table 7: Descriptive statistics of stocks, gold, government bonds and corporate bonds of the developed countries over Jul 2012 - Dec 2017.

	S&P500	*Gold (USD)*	*S&P Treasury 10y*	*S&P IG Corp. Bond*	*S&P HY Corp. Bond*	*FTSE100*	*Gold (GBP)*	*S&P U.K. Gilt Bond*	*S&P U.K. IG Corp. Bond*	*Corporate bond (HY)*	*EUROSTOXX50*	*Gold (EUR)*	*S&P Eurozone Sov. 7-10y*	*S&P Eurozone IG Corp. Bond*	*BofAML HY Eur. Corp. Bond*
mean	0.0005	0.0000	0.0000	0.0001	0.0002	0.0002	0.0000	0.0001	0.0002	?	0.0003	-0.0001	0.0002	0.0001	0.0003
median	0.0004	-0.0003	0.0003	0.0002	0.0004	0.0005	-0.0002	0.0002	0.0003	?	0.0004	-0.0001	0.0003	0.0001	0.0004
stdev	0.0075	0.0137	0.0040	0.0024	0.0020	0.0085	0.0145	0.0042	0.0033	?	0.0117	0.0139	0.0027	0.0012	0.0017
skewness	-0.3272	-0.2030	-0.2597	-0.4005	-0.9621	-0.1982	0.5421	0.1045	-0.0985	?	-0.3650	-0.1273	-0.4325	-0.6608	-1.0688
kurtosis	2.7065	6.0654	0.8897	1.2196	7.3942	2.5413	13.0684	2.0201	1.7862	?	4.2425	6.7813	3.2093	3.0645	9.1292
min	-0.0402	-0.0982	-0.0192	-0.0123	-0.0122	-0.0478	-0.0950	-0.0142	-0.0146	?	-0.0901	-0.0935	-0.0168	-0.0072	-0.0148
max	0.0383	0.0689	0.0150	0.0075	0.0105	0.0351	0.1515	0.0288	0.0207	?	0.0484	0.0918	0.0114	0.0049	0.0104
observations	1374	1374	1374	1374	1374	1361	1361	1361	1361	?	1363	1363	1363	1363	1363

Emerging countries

Brazil	Stocks	Gold	Government bond	Corporate bond (IG)	Corporate bond (HY)
Stocks	1	-0.289	0.178	0.161	0.044
Gold	-0.289	1	-0.097	-0.017	-0.058
Government bond	0.178	-0.097	1	0.295	0.104
Corporate bond (IG)	0.161	-0.017	0.295	1	0.319
Corporate bond (HY)	0.044	-0.058	0.104	0.319	1

Russia	Stocks	Gold	Government bond	Corporate bond (IG)	Corporate bond (HY)
Stocks	1	-0.121	0.191	0.035	0.013
Gold	-0.121	1	-0.247	-0.067	0.030
Government bond	0.191	-0.247	1	0.332	0.178
Corporate bond (IG)	0.035	-0.067	0.332	1	0.111
Corporate bond (HY)	0.013	0.030	0.178	0.111	1

India	Stocks	Gold	Government bond	Corporate bond (IG)	Corporate bond (HY)
Stocks	1	-0.151	0.215	0.050	0.265
Gold	-0.151	1	-0.045	0.132	-0.024
Government bond	0.215	-0.045	1	0.074	0.029
Corporate bond (IG)	0.050	0.132	0.074	1	0.214
Corporate bond (HY)	0.265	-0.024	0.029	0.214	1

China	Stocks	Gold	Government bond	Corporate bond (IG)	Corporate bond (HY)
Stocks	1	-0.026	0.012	0.019	0.206
Gold	-0.026	1	0.026	0.178	0.046
Government bond	0.012	0.026	1	0.040	-0.014
Corporate bond (IG)	0.019	0.178	0.040	1	0.246
Corporate bond (HY)	0.206	0.046	-0.014	0.246	1

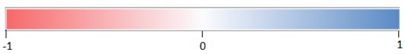


Fig. 15: Correlation matrix of stock, gold, government bond and corporate bond markets over the period Jul 2012 - Dec 2017 for the emerging countries. The bar below the graph is the colour legend.

Table 8: Descriptive statistics of stocks, gold, government bonds and corporate bonds of the emerging countries Brazil and Russia over Jul 2012 - Dec 2017.

	Ibovespa	*Gold (BRL)*	*S&P Brazil Sov.*	*BofAML IG Corp. Brazil*	*BofAML HY Corp Brazil*	*MOEX*	*Gold (RUB)*	*Russia gvrn. Bond 10y*	*Mosc. Corp. Bond BBB (IG)*	*Mosc. Corp. Bond B (HY)*
mean	0.0001	0.0005	0.0005	0.0000	-0.0001	0.0003	0.0002	0.0000	0.0004	0.0003
median	0.0002	0.0005	0.0005	0.0002	0.0002	0.0000	-0.0001	0.0001	0.0004	0.0004
stdev	0.0177	0.0174	0.0045	0.0039	0.0121	0.0114	0.0176	0.0049	0.0023	0.0047
skewness	0.0194	0.1135	-1.3782	-1.1164	-1.0306	-0.6381	0.0627	-4.7851	-1.3822	-4.2758
kurtosis	6.9026	5.2441	35.2243	10.8293	94.5010	8.6244	4.4244	111.4512	45.1528	60.2172
min	-0.1210	-0.1028	-0.0699	-0.0323	-0.1484	-0.1142	-0.1081	-0.0933	-0.0289	-0.0689
max	0.1368	0.1215	0.0440	0.0269	0.1525	0.0512	0.0901	0.0488	0.0265	0.0321
observations	2282	2282	2282	2282	2282	1321	1321	1321	1321	1321

Table 9: Descriptive statistics of stocks, gold, government bonds and corporate bonds of the emerging countries India and China over Jul 2012 - Dec 2017.

	BSE Sensex30	*Gold (INR)*	*S&P BSE India Gov. Bond*	*BofAML IG Corp. India*	*BofAML HY Corp. India*	*Shanghai Composite*	*Gold (CNY)*	*S&P China Gvrn. Bond*	*BofAML IG China Corp. Bond*	*BofAML HY China*
mean	0.0005	0.0000	0.0003	0.0001	0.0001	0.0003	0.0000	0.0001	0.0000	0.0001
median	0.0005	-0.0002	0.0003	0.0001	0.0001	0.0007	-0.0002	0.0001	0.0001	0.0001
stdev	0.0089	0.0141	0.0023	0.0015	0.0035	0.0144	0.0137	0.0020	0.0019	0.0025
skewness	-0.3553	-0.3049	-1.8408	-0.5146	-0.0056	-1.1000	-0.2901	0.0734	-0.4215	-1.8720
kurtosis	2.9957	6.4059	30.1449	5.1182	14.4682	7.2879	6.5788	7.4387	4.0925	17.8585
min	-0.0612	-0.0977	-0.0282	-0.0096	-0.0248	-0.0887	-0.0990	-0.0121	-0.0128	-0.0264
max	0.0370	0.0765	0.0197	0.0085	0.0307	0.0560	0.0743	0.0165	0.0096	0.0108
observations	1297	1297	1297	1297	1297	1295	1295	1295	1295	1295

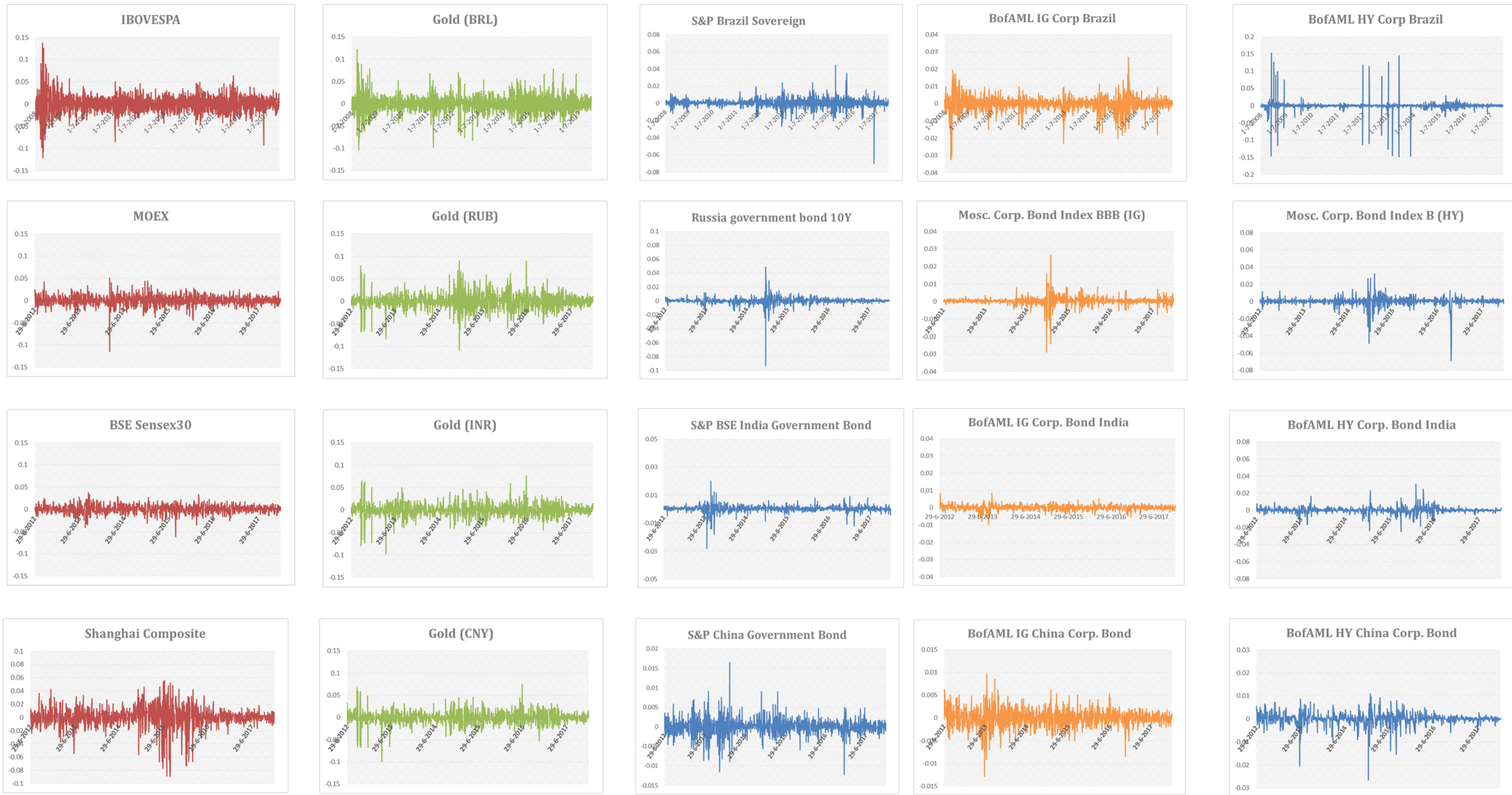


Fig. 16: Time-series plot of stock, gold, government bond and Investmet Grade/High-Yield corporate bond markets over the period Jul 2012 - Dec 2017 for the emerging countries.

Firstly, we discuss the sample period 2004-2018 where we compare the stock markets with the gold markets for a selection of developed markets as well as emerging markets. In general, it is remarkable from Table 3 and Table 4 that returns on stock markets are more likely to be higher for emerging countries, except for China, compared to the developed countries. That is also reasonable since the creditworthiness of those emerging countries are in general worse compared to that of the developed markets, which means that those countries are more risky in terms of default risk. Expected returns of gold seem to be in general bigger than the expected returns for stocks, except for India and China where they seem to be more or less similar to their expected stock returns. The standard deviation, which is in our case a proxy for volatility, of stock returns appear to be slightly smaller than for gold in the developed markets except for the Eurozone, whilst for the emerging markets it is more likely to find the reverse pattern, that is, slightly higher volatility on the stock markets. This basically points that for this time span, gold might render generally higher returns on average for relatively less risk. Interesting to note is that for the emerging markets, the min-max range is wider for stock returns compared to gold returns. That basically means that minimum values are lower respectively maximum values are higher for stock returns compared to gold returns. However, a similar pattern is not visible for the developed markets although it is remarkable that the minimum values of gold returns attain lower values than those of stocks. By visual inspection, we might note that volatility clustering is present for stock as well as for gold returns in all cases. Considering the correlation matrices in Figure 6 and Figure 8, the correlation between stocks and gold seem to be either close to zero or negative. More specifically, the correlation appears to be positive for the developed markets US, UK and the emerging market China although close to zero.

Secondly, we discuss the sub-period ranging from mid 2008 to 2018 where government bond and general corporate bond indices are added to the analysis since we only managed to acquire data of general corporate bond indices for most of the countries during that period. Even tough it goes along with a partly loss of data from our initial sample i.e. the mortgage crisis, which is the run-up to the global financial crisis, in the US prior to the global financial crisis in 2008, we still fully capture the global financial crisis as we take the sample starting from amid 2008 (Jul, 2008) onwards. The aim of this research is namely to consider gold as safe haven and for that, this sub-period would suffice as it contains the financial crisis, Brexit, tensions regarding the American elections, tensions in the European Union regarding the countries that wanted to leave the European Union. In addition to the previous finding, the correlation between stocks and gold has shrunk with even a negative correlation for the United Kingdom now. Notable is that for countries in the developed markets in Figure 10, the correlation between the stock market and government bond is negative, whereas for the emerging markets in Figure 12 it seems to be positive except for China. In most cases, gold returns were again on average higher than those of stocks. We see it in Table 5 for the UK and Eurozone, and, in Table 6 for Brazil, Russia and India. Gold and government bonds except for Russia show loosely similar mean returns and volatility, which sounds logical from a certain point of view as both share safe haven characteristics. Interesting to note is that the skewness of government bonds is positive for the developed economies, and, negative for emerging economies, except for China having a positive skewness as well. Corporate bonds and government bonds are positively correlated. A controversial finding between developed respectively emerging markets is that for developed markets, stocks and corporate bonds seem to be negatively correlated whilst for emerging markets, stocks and corporate bonds are positively correlated. Point of annotation hereby is that the correlation for China is close to zero. In addition, Table 10 shows that correlation between bonds and gold is positive for the developed markets and Table 12 shows them to be negative for the emerging markets except for China. Probably, the aforementioned patterns might point that China is in a kind of transition stage from emerging to developed market, since it shows to a certain extent similarities with developed markets. Only for the US it seems that gold investment might be worse than an investment in the stock index, because mean and median returns are one-third respectively two times lower, standard deviation is slightly higher and the minimum value is slightly lower as well. A somewhat more counter-intuitive finding is, however, that government bonds seem to exhibit in general more volatility than corporate bonds.

Finally, we discuss the sub-period ranging from amid 2012 to 2018 where the general corporate bond index is replaced by two subdivisions, an Investment Grade corporate bond index and an High Yield corporate bond index. The reason for the choice of this time-span is that we were only able to consistently acquire data of the referring corporate bond indices for all countries over this time-span. The point that makes this time-span also interesting is that it does not include the Global Financial Crisis anymore but rather moderate to tranquil periods, and as such might give different expected returns, correlations, standard deviations and other statistics. Starting with the developed markets in Table 7, it is notable that stocks are performing relatively the best compared to the other assets. Gold has relatively the lowest average and median return, which is different from previous samples. Mean returns of gold are for the US and UK close to zero, and, for the Eurozone slightly below zero (negative). In addition, gold and stocks seem to exhibit negative correlation, which was not the case for the US and UK in the full sample (2004-2018). Correlation between stocks and government bonds is relative the most negative, except for the Eurozone where it is surprisingly positive. Also, it is notable that for the United States and the Eurozone the correlation between stocks and investment-grade corporate bonds is negative, while the correlation between stocks and high-yield corporate bonds is positive. Overall, the relative safer assets such as gold, government bonds and investment-grade corporate bonds are positively correlated with each other. Also, there exists a relative strong correlation between the government bonds and investment-grade corporate bonds. For the emerging markets in Table 15, it is notable that stocks are positively correlated with bonds in general and negatively correlated with gold. Also, gold and government bonds are negatively correlated except for China.

To conclude, it is visible that for the full sample period (2004-2018) of the developed markets gold is on average weakly positively correlated with stocks. The average returns of gold are at least two times as big compared to average returns of stocks, while there is relatively not much risk, which is gauged by volatility, added for gold. In the case of emerging markets, the average returns of gold are at least equal or bigger but less than two times bigger compared to the average returns of stocks. The volatility is in all cases lower for gold compared to stocks.

For the sub-sample spanning from July 2008 - Dec 2017, it is visible for the developed markets that gold is hardly to negative correlated with stocks and positively correlated with bonds. Also, gold shows positive average returns. For emerging markets except for China, it is notable that gold is on average negatively correlated with stocks and government bonds. The correlation of gold with corporate bonds varies from hardly correlation (Russia) to negative correlation (Brazil and India). For China, the correlation between gold and the remaining assets are all positive. Average returns of gold are in all cases relatively higher than the average returns of stocks, but not necessarily higher than the average returns of bonds. For both the developed markets as well as the emerging markets, the volatility of gold is relatively higher than the volatility of government respectively corporate bonds.

For the final sub-sample, spanning from July 2012 - Dec 2017, it is visible for the developed markets that gold is negatively correlated with stocks on average, and, on average positively correlated with government bonds and investment-grade corporate bonds. Gold is hardly to negatively correlated with high-yield corporate bonds. Now, gold has on average relatively the lowest average return varying from negative to loosely nihil, whilst its volatility is relatively the highest. For the emerging markets, gold returns are in all cases, on average, negatively correlated with stock returns. Except for China, gold returns are also on average negatively correlated with government bond returns. In the case of China, gold returns are on average positively correlated with all bond returns.

4 Methodology

In this section we define the mean-variance portfolio analysis, as is introduced by Markowitz (1952). This analysis is commonly used by investors. In addition to this portfolio framework, in which we use means and (co-)variances of assets' returns to come up with an optimal portfolio, we use the *Exponential Weighted Moving Average* (EWMA) for the means of returns, and replace the classical correlation matrix by a time-varying, whilst more accurate correlation matrix, namely the *Dynamic Conditional Correlation* (DCC) matrix.

4.1 Mean-variance portfolio

4.1.1 General framework

The concept of mean-variance analysis, as is developed by Markowitz (1952), finds its fundamental in three different, yet related, hypotheses. The first (1) hypothesis states that portfolios are evaluated by its expected return and risk. The second hypothesis (2) states that investors are risk-averse, whilst the third (3) hypothesis states that given a certain return, the investor chooses that portfolio having the lowest risk or given a specific risk, the investor chooses for the portfolio containing the highest return.

We can express the mathematical problem as follows: Consider k securities over a time-period of n months (gold, stocks and bonds in our case, so k=*3*. Nonetheless, we still work with k in describing the mathematical problem. A comprehensive proof of the weights can be found in Appendix A). The idea is basically that a portfolio is formed by combining the k assets in a simplistic linear way, where weights are attached to each asset subject to the constraint that the individual weights should sum to unity. Firstly, we consider returns respectively expected returns for k assets for each time period in a

1xk vector

$$r'_t = (r_{1t}, r_{2t}, ..., r_{kt}) \tag{2}$$

$$\mu'_t = (\mu_{1t}, \mu_{2t}, ..., \mu_{kt}) \tag{3}$$

The covariance matrix of assets can be expressed as:

$$\Sigma_t = \begin{bmatrix} \sigma_{1t}^2 & \cdots & \rho_{1,kt}\sigma_{1t}\sigma_{kt} \\ \vdots & \ddots & \vdots \\ \rho_{k,1t}\sigma_{kt}\sigma_{1t} & \cdots & \sigma_{kt}^2 \end{bmatrix} \tag{4}$$

In terms of combining assets in a portfolio, the time-varying weight vector is introduced as

$$w'_t = (w_{1t}, w_{2t}, ..., w_{kt}) \tag{5}$$

The expected return and co-variance matrix of the portfolio π is therefore defined as follows:

$$\mu_{\pi,t} = w'_t \mu_t \tag{6}$$

$$\sigma_{\pi,t}^2 = w'_t \Sigma_t w_t \tag{7}$$

In order to find the optimal portfolio, say π_{opt}, we should look for the portfolio with the maximum Sharpe Ratio with respect to the weights w_t, which is defined as:

$$argmax_{w_t} SR_t = \frac{\mu_{\pi,t-r_{f,t}}}{\sigma_{\pi,t}} \tag{8}$$

where $r_{f,t}$ represents the time-varying risk-free rate. For practical reasons, we decided to omit the risk-free rate from our analysis by truncating it to a zero-value, as we solely want to focus not on how to optimally invest over the Capital Allocation Line (CAL) but rather on - the behaviour of gold with respect to stocks and bonds during roaring times - (dynamics). We therefore considered the government bonds (from sub-samples 2008 onward) separately as investment asset rather than as provided risk-free rate what it is normally used to be. In this way, we only consider assets on the efficient frontier. In addition, data for government bonds of all considered countries was not always available for all different sub-samples (i.e. especially prior to 2008), which would make it infeasible as well to consistently consider the risk-free rate in the process of portfolio optimization. Two restrictions are imposed on the weights, which are firstly no short-selling allowed, and secondly the maximum weight of an asset within a portfolio to be 50% which is arbitrarily chosen. The latter one is desired in terms of asset allocation performed by professionals, because a portfolio should normally be diversified in order to spread the risk and hence an upper boundary should be specified, which must not be exceeded. Otherwise, the portfolio is completely exposed to the risk faced by one asset.

4.1.2 Time-varying expected returns

As this study involves determining dynamic portfolio weights based on dynamic (time-varying) correlation and dynamic co- variance matrix, it is also important to have a dynamic mean vector of the assets for consistent estimation.

For simplicity reasons, we assume equal weights for all returns. This means that relative reasonable as well as seemingly aberrant returns are equally important in determining the mean of the asset returns. We apply a rolling window of 100 trading days prior to the current trading date until the trading date, which amounts to 101 observations. As this is of course not possible for the first 100 trading days, we apply on this part an expanding window from the beginning of the sample until time $t \leq 100$ for determining the average returns. The calculation is as follows:

$$\mu_{t^*} = \begin{cases} \frac{1}{t^*} \sum_{t=1}^{t^*} r_t & \text{if } t^* \leq 100 \\ \frac{1}{101} \sum_{t=(t^*-100)}^{t^*} r_t & \text{if } t^* > 100 \end{cases} \tag{9}$$

where μ_t and r_t are kx1 vectors. In this way, we allow for a time-varying mean.

4.1.3 Time-varying covariance and correlation of assets

Besides the time-varying expected returns, we also need the time-varying variance-covariance matrix of asset returns to determine the optimal portfolio weights. Highlighting an element of the Σ_t matrix in equation (4), it is notable that this term is composed of a crossproduct between the standard deviations of asset i (σ_{iit}) and asset j (σ_{jjt}), and, the correlation between asset i and asset j, which is denoted by $\rho_{i,jt}$. Firstly, the focus lies on estimating the time-varying volatility for each asset i on time t, which is denoted by σ_{iit}. We apply the GARCH(1,1) model for determining the time-varying variances, which provides one-step ahead forecasts of the variances, say, $\sigma_{iit|t-1}$. We rephrase this conditional volatility as h_{iit}. Secondly, the focus lies on estimating the $\rho_{i,jt}$ (DCC).

In order to make the conditional correlation between assets and conditional variances of assets in a portfolio (see equation 4) time-varying in contrast to the classical covariance matrix which is presumed to be time-constant, we apply the concept of *Dynamic Conditonal Correlation* (DCC) which is proposed by Engle (2002). This method is a generalization of the somewhat more restrictive *Constant Conditional Correlation* (CCC) of Bollerslev (1990) in the sense that, despite that both models allow for conditional variances to be time-varying, now conditional correlations between assets are allowed to be time-varying(dynamic) as well instead of constant over time which was the case for the CCC model. In order to delve further into this concept, we first have to introduce some notations.

$$r_t = E(r_t|\mathcal{I}_{t-1}) + \epsilon_t \tag{10}$$

$$Var(\epsilon_t|\mathcal{I}_{t-1}) = H_t \tag{11}$$

The return is a function of the current expected return at time t given the information set in the previous period, say *t-1*, and a disturbance term ϵ. The conditional variance of the returns, or more specifically the disturbance terms, given the information set in the previous period, is denoted by matrix H. In order to model each element of the conditional variance matrix H, say, h_{iit}, we use GARCH(1,1) models separately. The GARCH (1,1) model looks as follows:

$$h_{ii,t} = \omega_i + \delta_i \epsilon_{i,t-1}^2 + \gamma_i h_{ii,t-1} \tag{12}$$

where ω_i represents the unconditional variance for asset i, δ_i represents to what extent a volatility shock remains in the next period, whereas the parameter γ_i measures the persistence of volatility. The sum of δ_i and γ_i measures the rate at which the effect of volatility shocks for asset i would erode over time. To ensure stationary time-series for asset i, the sum of δ_i and γ_i should be < 1.

The big matrix H can be decomposed as follows:

$$H_t = D_t R_t D_t \tag{13}$$

$$D_t = diag(\sqrt{h_{ii,t}})$$

Matrix D_t contains the conditional time-varying volatilities, whereas matrix R_t contains the conditional time-varying correlations. The matrix representation takes the following form:

$$\mathrm{H}_t = \begin{bmatrix} \sqrt{h_{11t}} & \cdots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \cdots & \sqrt{h_{kkt}} \end{bmatrix} \begin{bmatrix} 1 & \cdots & \rho_{1,kt} \\ \vdots & \ddots & \vdots \\ \rho_{k,1t} & \cdots & 1 \end{bmatrix} \begin{bmatrix} \sqrt{h_{11t}} & \cdots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \cdots & \sqrt{h_{kkt}} \end{bmatrix}$$

For notational simplicity, we parametrize the diagonal elements $\sqrt{h_{ii,t}}$ of matrix D_t by a vector θ such that we can write $\mathrm{D}_t = D_t(\theta)$. The dynamics of the conditional correlation

R_t are such that it depends on lagged standardized residuals and an AR(1) term. One big drawback of the DCC method, as is pointed out among others in the paper of Hafner and Reznikova (2012), is that if the cross-sectional dimension approaches the sample size, the maximum likelihood estimator, which is used for the DCC model, will be strongly biased. In the paper of Hafner and Reznikova (2012) they pose as major reason that this bias is due to an estimator of the sample covariance matrix that is ill-behaved.

In general we can define the DCC model as follows:

$$H_t = D_t R_t D_t \tag{14}$$

$$R_t = diag(Q_t)^{-1/2} Q_t diag(Q_t)^{-1/2}$$

$$Q_t = (1 - \alpha - \beta)S + \alpha \epsilon_{t-1}\epsilon'_{t-1} + \beta Q_{t-1}$$

We parametrize the matrix R_t=$R_t(\phi,\ \theta,\ S)$, where ϕ = $(\alpha,\ \beta)$ and S is a parameter matrix being positive definite, whereas diag(Q_t) consists of diagonal elements of matrix Q_t. Clearly, there are many parameters to be estimated. For estimating these parameters we apply the quasi-maximum likelihood method, henceforth referred as to QML, in three steps with the assumption that there are Gaussian innovations. To begin with, consider the joint likelihood of the model:

$$\begin{aligned}\mathcal{L}(\theta, \phi, S) &= -0.5 \sum_{t=1}^{T} (Klog(2\pi) + log|H_t| + r'_t H_t^{-1} r_t) \\ &= \mathcal{L}_v(\theta) + \mathcal{L}_c(\theta, \phi, S) \end{aligned} \tag{15}$$

where

$$\mathcal{L}_v(\theta) = -0.5 \sum_{t=1}^{T} (Klog(2\pi) + log|D_t|^2 + r'_t D_t^{-2} r_t),$$

$$\mathcal{L}_c(\theta, \phi, S) = -0.5 \sum_{t=1}^{T} (log|R_t| + \epsilon'_t R_t^{-1} \epsilon_t - \epsilon'_t \epsilon_t). \quad (16)$$

where $\mathcal{L}_v$ represents the likelihood function for the model that contains parameters of the volatility process, whereas $\mathcal{L}_c$ represents the likelihood function for the model that contains parameters for the correlation process. The parameters for the volatility process, denoted by θ, can be estimated by

$$\hat{\theta} = \underset{\theta}{argmax}\ \mathcal{L}_v(\theta)$$

When parameter $\hat{\theta}$ is obtained, the next step is to estimate matrix S, which is needed for estimating the parameters of the correlation process, as $\hat{S} = \frac{1}{T} \sum_t^T \hat{\epsilon}_t \hat{\epsilon}'_t$ where the vector of standardized returns is estimated as $\hat{\epsilon}_t = D_t(\hat{\theta})^{-1} r_t$. Therefore, the optimization of the likelihood function for the model that contains parameters of the correlation process is now only dependent on parameter ϕ as parameters θ and S are now given. This facilitates the optimization process which we can denote as follows:

$$\hat{\phi} = \underset{\phi}{argmax}\ \mathcal{L}_c(\hat{\theta}, \phi, \hat{S})$$

4.2 Preliminary analysis

Prior to applying the dynamic conditional correlation analysis on the returns, we should first make sure that the returns are stationary, that there is an ARCH effect which means that there is heteroskedasticity meaning volatility clustering present in our case, and, finally that the order of the ARIMA model is well-specified such that it is able to capture the underlying dynamics of the returns in order to get proper residuals without serial correlation. Stationarity of a time-series is one assumption for using the ARIMA model to capture the dependence structure in the time series. If the returns contain serial correlation of order p, which reduces the amount of independent returns, then the returns can be modelled using an AR(P) model as in equation (17).

$$r_t = \Phi_0 + \Phi_1 r_{t-1} + ... + \Phi_p r_{t-p} + \epsilon_t \tag{17}$$

First of all, we check whether the time-series is stationary by the use of the Augmented-Dickey Fuller test, and, by the use of the famous KPSS test. Both tests are a complement to each other. The ADF test states as null hypothesis that there is a unit-root present against an alternative hypothesis of (trend-) stationarity. The KPSS, on contrary, states as null hypothesis that the time-series exhibits trend-stationarity. Stationarity means that the returns exhibit a constant average over time, where shocks have a transitory property and as such revert back to the constant mean. Trend-stationary means that the mean of the time-series might be growing or declining over time, but that shocks occurring over time are transitory and revert back to the trend mean. The presence of unit root, however, means that shocks have a permanent effect on the shift in the average of the time-series over time.

The test that we opt for analyzing whether serial correlation is present in the time-series, is the Ljung-Box test where the null hypothesis state that the time-series has an independent distribution against an alternative hypothesis of no independent distribution (i.e. serial correlation). Serial correlation means that the data is correlated over time.

For checking whether there are ARCH effects present in the time-series, we use the ARCH-LM test. An ARCH effect is present when there is auto-correlation in the squared time series, or put it differently, when there is heteroskedasticity present.

5 Results

In this subsection, the summary tables are presented for each country over all considered time periods as well as the sub-periods such that the reader grasps the key findings at one catch. From a portfolio perspective, we consider gold as safe haven asset for an investor if the weight of gold increases for a mean-variance-optimized portfolio in a high-volatile period relative to the average positions held in gold over the whole time frame.

Sub-periods are selected as volatile periods from the perspective of the complete time span 2004-2018. If clustered periods' conditional volatility exceeds the average conditional volatility over this time span, then they were marked as volatile periods. In appendix 3, the selected sub-periods are discussed in more detail. Along the different time sets 2004-2018, 2008-2018 and 2012-2018 that we are analyzing, we make consistently use of the same volatile sub-periods as established in the first time span 2004-2018.

The time span from 2004 till 2018 considers portfolios that only consist of stocks and gold, whereas the time span from 2008 till 2018 considers portfolios that consist of stocks, government bonds, general corporate bonds and gold. The time span from 2012 till 2018 considers portfolios that consist of stocks, government bonds, investment-grade corporate bonds, high-yield corporate bonds and gold.

For the sake of clarity, all time spans are taken *until* the end of December 2017. However, for notational simplicity we consider it as *till* January 2018, which practically means the same. Therefore, in the remainder of this paper the notation *start year - 2018* means the period from the start till 2018, implying until the end of December 2017.

The correlation between the weight of gold in the portfolio and the volatility on the stock market index represents to what extent gold reacts as function of the volatility on the stock market index. The volatility on the stock market index proxies the market risk. In our belief, the stronger the correlation is, the more likely it is that it signifies on gold as a safe haven asset.

In section 4, we proposed to restrict short-selling from a practical point of view, which means that the weight of assets within a portfolio should be within the interval [0,1]. In order to make sure that a portfolio will not only consist of one asset, we opted for an upper boundary of 50%. This means that an asset's weight should be within interval [0,0.50]. Exception is the complete sample ranging from January 2004 until December 2017, as the portfolio allocation is only between two assets, as was already mentioned in section 3. Applying the upper bound to be 50%, it provides an exact 50-50 distribution between gold and stocks for all considered countries in the sample of 2004-2018. Therefore, the asset allocation restriction has been adjusted towards 75% for this sample period in order to get results that make sense. In other words, this means that the weight of an asset can take values within the interval [0,0.75] for the period 2004-2018.

For the sake of simplicity, we refer to assets just by their types instead of their local names. For instance, the term 'stocks' for the United States simply refers to the S&P500. In section 3, an extensive explanation of the names of the indices used for the analysis can be found.

The correlation vector presented for each country in the results shows the correlation between the weight of gold attached in a portfolio and the weight of stocks or bonds in the portfolio. The intuition is that in case there is a negative correlation, it might be an indication that gold functions as a safe haven asset for that asset when conditioned on the positive correlation between gold weight and market risk proxied by the volatility of the country's referring stock market. In simple words, a negative correlation between the weight of gold in a portfolio and the weight of another asset shows that the addition of gold in a portfolio goes to a certain extent at the cost of that specific asset. Notwithstanding the fact that the correlation vectors represent the average correlation over the whole time span, it would be better to examine the correlation vectors for each sub-volatile period in order to acquire a better picture of the weights' behaviour over the volatile periods. However, as this goes a bit out of the scope with regards to the main research question, we decided to stay with the analysis based on the whole time span for a more general impression.

The discussion of the conditional input parameters' results needed for estimating the optimal dynamic portfolio weights based on the mean-variance framework, such as the conditional mean $\hat{\mu_t}$, conditional volatility $\hat{\sigma_t}$ and the dynamic conditional correlation $\hat{\rho}_t$, are discussed in appendix 3. The estimated underlying parameters' results for modeling the conditional volatility $\hat{\sigma_t}$ and the dynamic conditional correlation $\hat{\rho}_t$, can be found in appendix 2. Finally, in appendix 3 the analysis of gold as safe haven asset will be highlighted from the traditional perception, in which (dynamic conditional) correlations will argue whether gold functions as safe haven asset for a portfolio or not.

5.1 United States

Table 10: Summary table of the average gold positions over the complete periods 2004-2018, 2008-2018 & 2012-2018 (vertical axis) and the different volatile sub-periods (horizontal axis). *Country: United States.*

United States		whole period	sep 2008 - aug 2009	aug 2011 - jan 2012	jun 2015 - jun 2016
	average weight of gold	0.434	0.656	0.727	0.504
	average weight of stocks	0.566	0.344	0.273	0.496
2004-2018	average conditional volatility stock	0.010	0.025	0.018	0.010
	correlation (gld_weight, vol stock)	0.501			
	average weight of gold	0.063	0.179	0.117	-
	average weight of stocks	0.266	0.083	0.060	-
2008-2018	average weight of gov. bonds	0.236	0.331	0.483	-
	average weight of corp. bonds	0.435	0.406	0.341	-
	average conditional volatility stock	0.010	0.025	0.019	-
	correlation (gld_weight, vol stock)	0.307			
	average weight of gold	0.014	-	-	0.043
	average weight of stocks	0.174	-	-	0.148
	average weight of gov. bonds	0.107	-	-	0.311
2012-2018	average weight of IG corp. bonds	0.314	-	-	0.308
	average weight of HY corp. bonds	0.391	-	-	0.190
	average conditional volatility stock	0.007	-	-	0.009
	correlation (gld_weight, vol stock)	0.048			

In Table 10 it becomes clear that gold functions as a safe haven asset in a stock portfolio in the period 2004-2018, where the average position in gold was about 43% (0.434) and the allocation of gold in all volatile sub-periods exceeds this level. This pattern is strengthened by the relative high correlation of approximately 50% (0.501) between the weight of gold in the stock portfolio and the volatility on the stock market. For the period 2008-2018, it is visible that the average allocation of gold in a portfolio of stocks, government bonds and general corporate bonds is approximately 6.3% (0.063), and, that the average allocation of gold in the volatile sub-periods[8] exceeds this benchmark level. Also, this pattern can be strengthened by the relative moderate correlation between gold

[8]The sub-period jun 2015-jun 2016 has been deleted as volatile sub-period from the time span 2008-2018, because its referring average conditional volatility was lower than the average conditional volatility over the whole period 2008-2018. Therefore, it was not applicable for our analysis anymore.

and the stock market's volatility of about 30.7% (0.307). Finally, for the period 2012-2018 it is visible that the average allocation of gold is approximately 1.40% (0.014), and, that the allocation in the volatile sub-period *jun 2015 - jun 2016* with 4.30% (0.043) exceeds this benchmark. Figure 17 shows the dynamic weights of the assets in the portfolios.

Table 11: Correlation vector of weights for stocks, government bonds and corporate bonds of the United States over the period July 2008 - December 2017.

	S&P500	S&P T-10Y	S&P Corp.
gold	-0.328	-0.007	-0.307

For the time span 2008-2012, it is notable that the weight of gold in a portfolio is negatively correlated (-0.328) with the weight of the stock market index S&P500 and the S&P Corporate bond index (-0.307) in the portfolio. In simple words, to some extent it seems that the inclusion of gold comes partly at a cost of the investment in corporate-related assets such as corporate bonds and stocks. This might point on a safe haven characteristic of gold, since it would be logical to decrease the proportion of stocks in the portfolio when it is turbulent on the stock market. There is almost no relation between the amount of gold possessed in the portfolio and the amount of government bonds held in the portfolio, as these are seemingly hardly correlated (-0.007).

A closer investigation during volatile periods in the time span 2008-2012 gives us the following results in Table 10. Interesting is that the average weight of gold held in a portfolio increases in the period September 2008 - August 2009 and in the period August 2011 - January 2012. The average weight of stocks is lower in the sub-periods compared to the average percentage. The average weight held in government bonds is in all sub-periods higher than the average held over the whole period. Similar as for stocks, the average level of corporate bonds held in the sub-periods is lower than on average over the whole sample period. Not unsurprisingly, government bonds also seem to exhibit to some extent the safe haven characteristic.

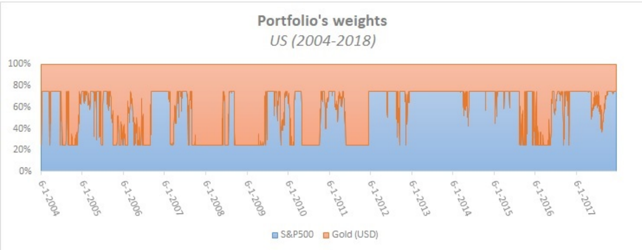
Table 12: Correlation vector of weights for stocks, government bonds and corporate bonds of the United States over the period July 2012 - December 2017.

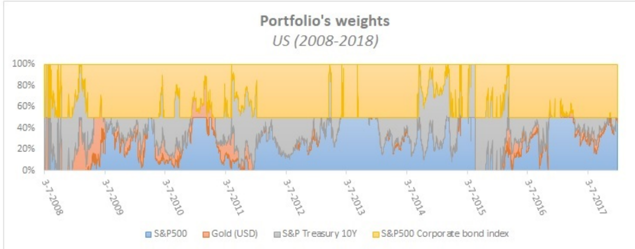
	S&P500	S&P T-10Y	S&P U.S. IG Corp. Bond	S&P U.S. HY Corp. Bond
gold	-0.031	0.104	-0.043	-0.247

For the time span 2012-2018 it is notable in Table 12 that the the weight of gold is negatively correlated to the weight of the S&P500 stocks (-0.031) in the portfolio. Moreover, it is also positively correlated to the weights of the S&P Treasury 10Y government bonds (0.104), and, negatively correlated to the S&P Investment Grade (-0.043) as well as the High-Yield corporate bonds (-0.247).

The negative relation with the weight of gold and the weight of corporate-related assets such as stocks and bonds in a portfolio might signify on the safe haven characteristic of gold in the portfolio conditioned on the fact that the weight of gold in a portfolio and the market risk are positively related. To an investor, it simply means that when there is uncertainty on the financial market, then it would be wise to flee into gold investments where it is wiser to acquire gold at the cost of corporate assets such as stocks and bonds.

Based on the portfolio analysis, the conclusion for an US investor is that gold functions as a safe haven asset for portfolios composed of only stocks, but also for portfolios composed of stocks, government bonds and corporate bonds.





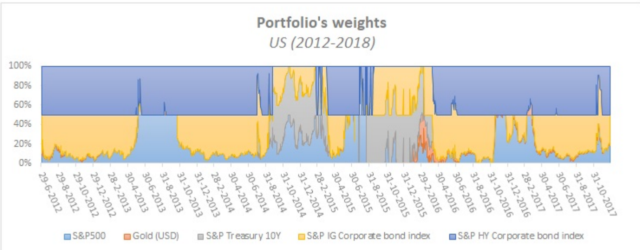


Fig. 17: Portfolio compositions over all time-periods. Period 2004-2008 encompasses portfolios with stocks, period 2008-2018 encompasses portfolios with stock, government bonds and general corporate bonds, and, period 2012-2018 encompasses portfolios with stocks, government bonds, investment-grade corporate bonds and high-yield corporate bonds. *Country: United States.*

5.2 United Kingdom

Table 13: Summary table of the average gold positions over the complete periods 2004-2018, 2008-2018 & 2012-2018 (vertical axis) and the different volatile sub-periods (horizontal axis). *Country: United Kingdom.*

United Kingdom		whole period	18 May 2006- 19 Jun 2006	1 Aug 2007 - 1 Sep 2008	15 Sep 2008 - 15 May 2009	1 May 2010 - 1 Aug 2010	1 Aug 2011 - 1 Dec 2011	1 Aug 2015 - 1 Sep 2016
	average weight of gold	0.450	0.638	0.669	0.741	0.736	0.750	0.614
	average weight of stocks	0.550	0.362	0.331	0.259	0.264	0.250	0.386
2004-2018	average conditional volatility stock	0.010	0.015	0.014	0.025	0.015	0.012	0.012
	correlation (gld_weight, vol stock)	0.531						
	average weight of gold	0.129	-	-	0.469	0.212	0.400	0.218
	average weight of stocks	0.216	-	-	0.036	0.042	0.042	0.076
2008-2018	average weight of gov. bonds	0.334	-	-	0.483	0.396	0.500	0.436
	average weight of corp. bonds	0.321	-	-	0.011	0.350	0.058	0.269
	average conditional volatility stock	0.011	-	-	0.025	0.015	0.018	0.012
	correlation (gld_weight, vol stock)	0.543						
	average weight of gold	0.068	-	-	-	-	-	0.189
	average weight of stocks	0.261	-	-	-	-	-	0.080
	average weight of gov. bonds	0.213	-	-	-	-	-	0.331
2012-2018	average weight of IG corp. bonds	0.458	-	-	-	-	-	0.400
	average weight of HY corp. bonds	NA*	-	-	-	-	-	NA*
	average conditional volatility stock	0.008	-	-	-	-	-	0.011
	correlation (gld_weight, vol stock)	0.187						

In Table 13 it is notable that gold functions as a safe haven asset for a portfolio of stocks in the time period 2004-2018. The average allocation of gold is about 45% (0.450), and, the allocations of gold over all volatile sub-periods exceed this benchmark allocation. This finding can be strengthened by the relative high correlation of about 53% (0.531) between the weight of gold and the volatility on the stock market index in this period. In the second time frame of 2008-2018, it is visible that gold functions as a safe haven asset for a portfolio of stocks, government bonds and corporate bonds. The average gold allocation was about 13% (0.129), where this value is exceeded during the volatile sub-periods. Again, this finding goes along with the relative high correlation of about 54% (0.543) between gold allocation and volatility. In the final time frame of 2012-2018, it is visible that gold functions as a safe haven asset for a portfolio of stocks, government bonds and investment-grade corporate bonds[9]. The average allocation of gold took a value of about 6.8% (0.068), where this value is exceeded in the volatile sub-period 01 Aug 2015 - 01 Sep 2016. The dynamic weights in the portfolio are depicted in Figure 18.

Table 14: Correlation vector of weights for stocks, government bonds and corporate bonds of the United Kingdom over the period July 2008 - December 2017.

	FTSE100	S&P U.K. Gilt	BofAML Corp. 7-10y
gold	-0.265	0.095	-0.720

In Table 14 it is visible for the time span 2008-2018 that the weight of gold is negatively correlated with the weight of the FTSE100 and the weight on the corporate bond index BofAML Corp 7-10Y in a portfolio. On the other hand, the weight of gold is positively correlated with the weight of the government bond S&P U.K. Gilt in a portfolio. The negative relation of gold with the corporate assets, such as stocks and bonds, might signify on the safe haven characteristic of gold in a portfolio conditioned on the moderate positive relation between the weight of gold in a portfolio and the risk

[9]Recall that the data of the high-yield corporate bonds was not available for the UK, as mentioned in section 3.

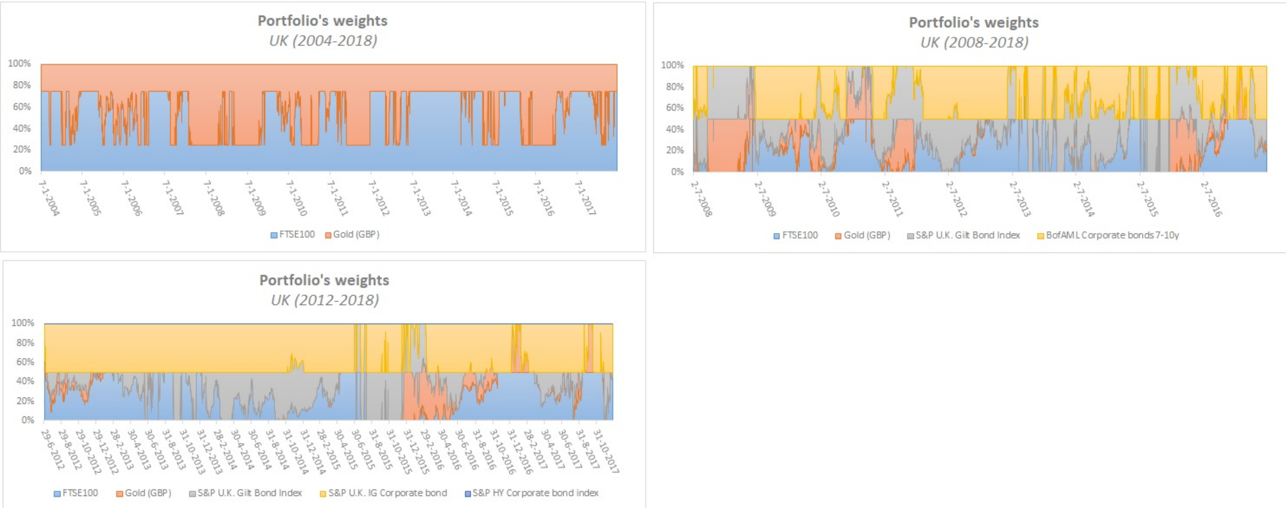


Fig. 18: Portfolio compositions over all time-periods. Period 2004-2008 encompasses portfolios with stocks, period 2008-2018 encompasses portfolios with stock, government bonds and general corporate bonds, and, period 2012-2018 encompasses portfolios with stocks, government bonds, investment-grade corporate bonds and high-yield corporate bonds. *Country: United Kingdom.*

on the market (0.543).

Table 15: Correlation vector of weights for stocks, government bonds and corporate bonds of the United Kingdom over the period July 2012 - December 2017.

	FTSE100	S&P U.K. Gilt	S&P U.K. IG Corp. Bond	S&P U.K. HY Corp. Bond
gold	-0.157	-0.111	-0.661	NA

In Table 15, it is visible that the weight of gold is negatively correlated with the weights of all assets considered in the portfolio, even with the government bonds (-0.111). This might be a biased result due to the lack of the data on the high-yield corporate bond.

On the basis of the portfolio analysis, the conclusion for an UK investor is that gold functions as a safe haven asset for portfolios composed of only stocks, but also for portfolios composed of stocks, government bonds and corporate bonds.

5.3 Eurozone

Table 16: Summary table of the average gold positions over the complete periods 2004-2018, 2008-2018 & 2012-2018 (vertical axis) and the different volatile sub-periods (horizontal axis). *Country: Eurozone.*

urozone		whole period	18 May 2006- 23 Jun 2006	13 Aug 2007 - 13 Sep 2007	24 Jan 2008 - 24 Apr 2008	5 Sep 2008 - 5 Aug 2009	28 Apr 2010 - 8 Aug 2010	12 Jul 2011 - 18 Jan 2012	5 Apr 2012 - 11 Jun 2012	16 Oct 2014 - 26 Jan 2015	23 Jun 2015 - 29 Jul 2016
	average weight of gold	0.500	0.593	0.564	0.750	0.750	0.750	0.715	0.627	0.632	0.638
	average weight of stocks	0.500	0.407	0.436	0.250	0.250	0.250	0.285	0.373	0.368	0.362
004-2018	average conditional volatility stock	0.012	0.015	0.015	0.017	0.029	0.019	0.021	0.015	0.015	0.016
	correlation (gld_weight, vol stock)	0.470									
	average weight of gold	0.106	-	-	-	0.306	0.205	0.400	0.000	0.012	0.046
	average weight of stocks	0.123	-	-	-	0.042	0.015	0.038	0.001	0.003	0.066
008-2018	average weight of gov. bonds	0.354	-	-	-	0.443	0.295	0.404	0.499	0.485	0.455
	average weight of corp. bonds	0.416	-	-	-	0.209	0.485	0.158	0.500	0.500	0.433
	average conditional volatility stock	0.014	-	-	-	0.025	0.020	0.022	0.015	0.015	0.016
	correlation (gld_weight, vol stock)	0.563									
	average weight of gold	0.011	-	-	-	-	-	-	-	0.004	0.036
	average weight of stocks	0.040	-	-	-	-	-	-	-	0.000	0.062
	average weight of gov. bonds	0.084	-	-	-	-	-	-	-	0.378	0.227
012-2018	average weight of IG corp. bonds	0.443	-	-	-	-	-	-	-	0.500	0.381
	average weight of HY corp. bonds	0.421	-	-	-	-	-	-	-	0.119	0.294
	average conditional volatility stock	0.011	-	-	-	-	-	-	-	0.015	0.016
	correlation (gld_weight, vol stock)	0.367									

In Table 16 it is notable that gold functions as a safe haven asset for a portfolio of stocks in the time period of 2004-2018. The average allocation of gold was approximately 50% (0.500), where the volatile periods show a relative higher gold allocation up to 75% (0.750). This finding can be strengthened by a relative moderate correlation of 47% (0.470) between the allocation of gold and the volatility of the stock market index. In the time span of 2008-2018, it is remarkable that in three out of the six cases the allocation of gold was even less than the average allocation of gold of 10.60% (0.106). This means that by the inclusion of government bonds and corporate bonds in the portfolio, the safe haven effect seems to vanish to a certain extent. This is also visible in Table 16, where we notice that government and corporate bonds almost occupy the whole portfolio in these three sub-periods 5 Apr 2012 - 11 Jun 2012, 16 Oct 2014 - 26 Jan 2015 and 23 Jun 2015 - 29 Jul 2016. Nevertheless, the period around the financial crisis unanimously shows that gold functions as a safe haven asset for a portfolio of stocks, government bonds and general corporate bonds for the sample over the period 2008-2018. Gold allocation varies roughly between 20 and 40% in these sub-periods 5

Sep 2008 - 5 Aug 2009, 28 Apr 2010 - 8 Aug 2010 and 12 Jul 2011 - 18 Jan 2012. The correlation between gold allocation and the volatility of the stock market is, however, relatively high with a value of 56% (0.563) implying that attaching gold in a portfolio has a moderate positive relation with the market risk. The final period 2012-2018 shows an average allocation of gold of approximately 1.10 % (0.011). Again, we find an ambivalent result, where one sub-period Oct 2014-Jan 2015 shows a decrease in gold allocation to 0.40% (0.004), and, the other sub-period Jun 2015-Jul 2016 an increase in gold allocation to 3.60% (0.036). The graphical depiction of the assets' weights can be found in Figure 19. Altogether, the results in Table 19 make clear that when the market volatility increases, European investors flee into gold investments for stock portfolios. When also bonds are considered in the portfolios, the results are ambivalent where some cases show an increase in gold allocation and other cases show a decrease in gold allocation compared to the average. For cases where the gold allocation decreases, we noticed that the majority of the portfolio consists of government and corporate bonds. When the corporate bonds were distinguished between investment-grade and high-yield corporate bonds, we noticed that the majority of the portfolio consists of government and investment-grade corporate bonds for the case in which gold allocation decreased compared to the time span's average. This suggests that at times investing in bonds can even be safer compared to investing in gold during volatile periods, where government and investment-grade corporate bonds are prominent.

Table 17: Correlation vector of weights for stocks, government bonds and corporate bonds of the Eurozone over the period July 2008 - December 2017.

	EUROSTOXX50	S&P Eurozone Sov. 7-10Y	BofAML Corp. Eurozone 7-10y
gold	0.007	-0.189	-0.785

Considering Table 17, it is remarkable that the weight of gold has a nihil to a slight positive correlation with the weight of the stock market index Eurostoxx50, whilst the correlation with the weights of the bonds, in particular the corporate bonds, is negative for the time span July 2008 - December 2017. This implies that the the investor is more likely to acquire positions in gold at the cost of bonds. From the perspective of the portfolio analysis, this might imply that gold is a safe haven for bonds, especially for corporate bonds in this case conditioned on the moderate positive correlation of 0.563 (56.30%) between the weight of gold and the market risk.

Table 18: Correlation vector of weights for stocks, government bonds and corporate bonds of the Eurozone over the period July 2012 - December 2017.

	EUROSTOXX50	S&P Eurozone Sov. 7-10Y	S&P Eurozone IG Corp. Bond	BofAML HY Eurozone Corp. index
gold	-0.085	0.244	0.024	-0.385

Table 18 shows that the weight of gold is negatively correlated to the weights of the stock market index EUROSTOXX50 and the high-yield corporate bonds over the period July 2012 - December 2017. On the other hand, the weight of gold is positively correlated with the weights of the government bonds and the relative safe investment-grade corporate bonds. This implies that an investor is likely to sell stocks and high-yield corporate bonds for a position in gold. Conditioned on the correlation of 0.367 (36.70%) between the weight of gold in the portfolio and the market risk, this result might imply that gold is a safe haven asset for stocks and high-yield corporate bonds.

Table 16 shows a positive correlation between the weight of gold and the volatility on the stock market index EUROSTOXX50 for all three sample periods. However, in terms of the average weight of gold held, we do not see that a high volatile period is always accompanied by a higher weight than the average over the whole sample periods 2008-2018 and 2012-2018 where bonds are involved.

From the perspective of the portfolio analysis, we can conclude that gold functions as a safe haven asset for a portfolio encompassing only stocks (2004-2018), but we are not able to infer that gold unanimously functions as a safe haven asset for a portfolio composing of stocks and bonds (2008-2018 and 2012-2018).

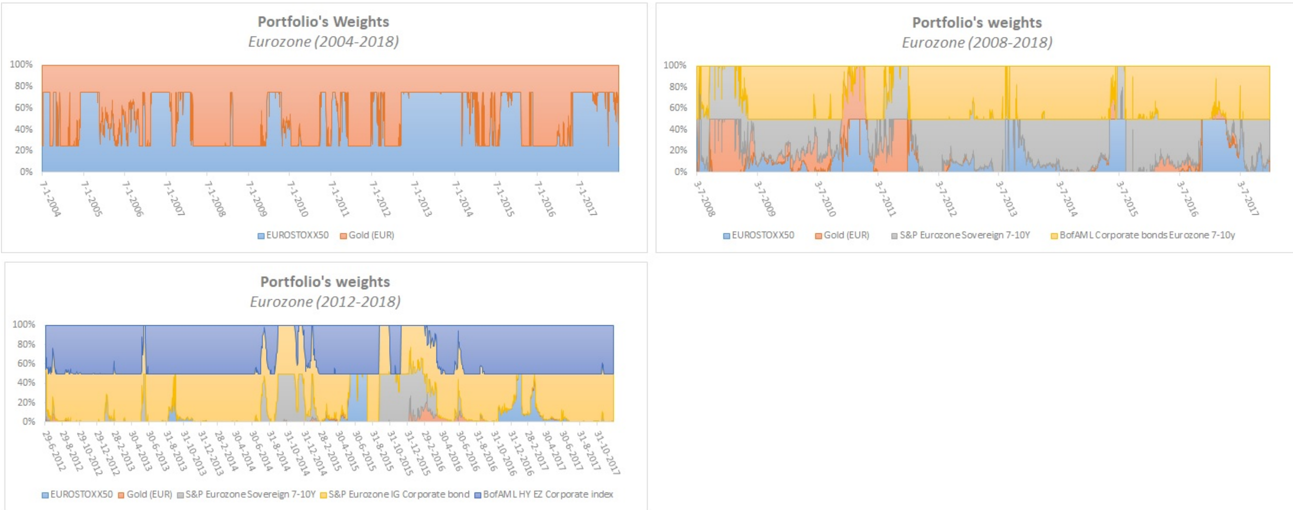


Fig. 19: Portfolio compositions over all time-periods. Period 2004-2008 encompasses portfolios with stocks, period 2008-2018 encompasses portfolios with stock, government bonds and general corporate bonds, and, period 2012-2018 encompasses portfolios with stocks, government bonds, investment-grade corporate bonds and high-yield corporate bonds. *Country: Eurozone.*

5.4 Brazil

Table 19: Summary table of the average gold positions over the complete periods 2004-2018, 2008-2018 & 2012-2018 (vertical axis) and the different volatile sub-periods (horizontal axis). *Country: Brazil.*

Brazil		whole period	30 Jan 2004 - 30 Jun 2004	07 Oct 2005 - 09 Nov 2005	26 May 2006 - 01 Aug 2006	28 Feb 2007 - 03 Apr 2007	27 Jul 2007 - 10 Apr 2008	05 Sep 2008 - 02 Jul 2009	29 Oct 2009 - 30 Nov 2009	11 May 2010 - 15 Jun 2010	05 Aug 2011 - 16 Nov 2011	30 Sep 2014 - 26 Jan 2015	01 Feb 2016 - 20 May 2016	19 May 2 09 Jun 2
	average weight of gold	0.505	0.747	0.405	0.726	0.506	0.518	0.622	0.395	0.749	0.750	0.631	0.501	0.605
	average weight of stocks	0.495	0.253	0.595	0.275	0.494	0.482	0.378	0.605	0.251	0.250	0.369	0.499	0.395
2004-2018	average conditional volatility stock	0.016	0.021	0.019	0.020	0.021	0.019	0.031	0.021	0.019	0.021	0.021	0.020	0.022
	correlation (gld_weight, vol stock)	0.290												
	average weight of gold	0.159	-	-	-	-	-	0.289	0.048	0.178	0.246	0.269	0.276	0.316
	average weight of stocks	0.054	-	-	-	-	-	0.035	0.056	0.001	0.012	0.013	0.148	0.096
2008-2018	average weight of gov. bonds	0.463	-	-	-	-	-	0.494	0.424	0.500	0.500	0.477	0.499	0.101
	average weight of corp. bonds	0.324	-	-	-	-	-	0.182	0.472	0.321	0.241	0.241	0.077	0.486
	average conditional volatility stock	0.016	-	-	-	-	-	0.031	0.021	0.019	0.021	0.021	0.020	0.022
	correlation (gld_weight, vol stock)	0.409												
	average weight of gold	0.166	-	-	-	-	-	-	-	-	-	0.321	0.205	0.213
	average weight of stocks	0.061	-	-	-	-	-	-	-	-	-	0.030	0.079	0.062
	average weight of gov. bonds	0.332	-	-	-	-	-	-	-	-	-	0.500	0.448	0.098
2012-2018	average weight of IG corp. bonds	0.253	-	-	-	-	-	-	-	-	-	0.149	0.158	0.156
	average weight of HY corp. bonds	0.189	-	-	-	-	-	-	-	-	-	0.000	0.110	0.471
	average conditional volatility stock	0.014	-	-	-	-	-	-	-	-	-	0.019	0.019	0.020
	correlation (gld_weight, vol stock)	0.302												

In Table 19 it is notable that for the sample period 2004-2018, the average weight of gold in a portfolio encompassing stocks is 50.50% (0.505). Among all volatile sub-periods only three out of twelve do not show an increase but rather a decrease in the level of gold. This holds for sub-periods 7 Oct 2005 - 9 Nov 2005, 29 Oct 2009 - 30 Nov 2009 and 1 Feb 2016 - 20 May 2016. This can be aligned with the relatively weak positive correlation of 29% (0.29) between the weight of gold in a portfolio and market risk. For the sample period 2008-2018, where the government bonds and general corporate bonds are included, it is visible that the average gold allocation is 15.90% (0.159), where only one sub-period 29 Oct 2009 - 30 Nov 2009 shows a decrease in the gold allocation to 4.80% (0.048). In the last sample period 2012-2018, where the corporate bonds are distinguished between investment-grade and high-yield ones, it is visible that the average weight of gold is 16.60% (0.166) where all sub-periods show an increase in the level of gold. Interesting is that for sub-period 01 Feb 2016 - 20 May 2016, the inclusion of bonds in a portfolio transforms gold to function as a safe haven asset for such a portfolio compared to the situation of a portfolio composed of only stocks. This can be aligned with the negative correlation between the weight of gold in a portfolio and the weight of bonds as depicted in the correlation vector in Table 20 and Table 20. The correlation vector in Table 20 reflects on a relatively strongly negative correlation between the weight of gold and the weight of general corporate bonds in a portfolio (-0.893). The weight of general corporate bonds in sub-period 01 Feb 2016 - 20 May 2016 (0.077) is much lower than the average shows over the whole time span (0.324), because of which the level of gold (0.276) is higher compared to the average (0.159). Similar situation is also visible for the time span 2012-2018 where the correlation vector of Table 21 reflects on a negative correlation between the weight of gold and the weight of investment-grade and high-yield corporate bonds in a portfolio. We indeed notice for the sub-period 01 Feb 2016 - 20 May 2016 that the weight of the corporate bonds are lower than their average values, which among others reflects in a higher allocation of gold in the portfolio compared to its average. The correlation vectors mainly induce a potential safe haven effect of gold for corporate bonds. Furthermore, Figure 20 shows the dynamic portfolio weights over the different time periods.

Table 20: Correlation vector of weights for stocks, government bonds and corporate bonds of the Brazil over the period July 2008 - December 2017.

	Ibovespa	S&P Brazil Sov.	Corp. bond Barclays EM Brazil
gold	0.021	-0.114	-0.893

In Table 20, we see a marginal positive correlation between the weight of gold and the weight of the Ibovespa (0.021), and, a negative correlation between the weights of gold and the weights of the government and corporate bond indices over the time span 2008-2018.

Table 21: Correlation vector of weights for stocks, government bonds and corporate bonds of Brazil over the period July 2012 - December 2017.

	Ibovespa	S&P Brazil Sov. 7-10Y	BofAML IG Corp. Brazil	BofAML HY Corp. Brazil
gold	0.088	0.232	-0.604	-0.535

Table 21 shows that the weight of gold is positively correlated with the weights on of the stocks and government bonds, but negatively correlated with the weights of the corporate bonds over the time span 2012-2018.

Based on the majority of the results of the portfolio analysis, we can deliberately conclude that gold functions as a safe haven asset for Brazilian investors with portfolio investments in stocks, government bonds and corporate bonds.

Fig. 20: Portfolio compositions over all time-periods. Period 2004-2008 encompasses portfolios with stocks, period 2008-2018 encompasses portfolios with stock, government bonds and general corporate bonds, and, period 2012-2018 encompasses portfolios with stocks, government bonds, investment-grade corporate bonds and high-yield corporate bonds. *Country: Brazil.*

5.5 Russia

Table 22: Summary table of the average gold positions over the complete periods 2004-2018, 2008-2018 & 2012-2018 (vertical axis) and the different volatile sub-periods (horizontal axis). *Country: Russia.*

Russia		whole period	22 Apr 2004 - 25 Aug 2004	04 Oct 2004 - 21 Jan 2005	28 Sep 2005 - 18 Nov 2005	11 Jan 2006 - 17 Oct 2006	24 Jan 2008 - 31 Mar 2008	18 Jul 2008 - 09 Dec 2009	05 May 2010 - 16 Jul 2010	09 Aug 2011 - 23 Dec 2011	04 Mar 2014 - 09 Apr 2014
	average weight of gold	0.505	0.564	0.731	0.598	0.552	0.750	0.616	0.750	0.750	0.750
	average weight of stocks	0.495	0.436	0.269	0.402	0.448	0.250	0.384	0.250	0.250	0.250
2004-2018	average conditional volatility stock	0.017	0.025	0.023	0.024	0.024	0.022	0.038	0.022	0.022	0.027
	correlation (gld_weight, vol stock)	0.385									
	average weight of gold	0.126	-	-	-	-	-	0.252	0.095	0.380	0.500
	average weight of stocks	0.063	-	-	-	-	-	0.022	0.001	0.000	0.000
2008-2018	average weight of gov. bonds	0.341	-	-	-	-	-	0.324	0.404	0.120	0.000
	average weight of corp. bonds	0.470	-	-	-	-	-	0.402	0.500	0.500	0.500
	average conditional volatility stock	0.017	-	-	-	-	-	0.038	0.022	0.022	0.027
	correlation (gld_weight, vol stock)	0.484									
	average weight of gold	0.055	-	-	-	-	-	-	-	-	0.238
	average weight of stocks	0.044	-	-	-	-	-	-	-	-	0.000
	average weight of gov. bonds	0.156	-	-	-	-	-	-	-	-	0.000
2012-2018	average weight of IG corp. bonds	0.455	-	-	-	-	-	-	-	-	0.500
	average weight of HY corp. bonds	0.290	-	-	-	-	-	-	-	-	0.262
	average conditional volatility stock	0.011	-	-	-	-	-	-	-	-	0.022
	correlation (gld_weight, vol stock)	0.576									

From the perspective of the asset allocation as depicted in Table 22, it is notable that for the time period 2004-2018 the average allocation of gold in the portfolio composed of stocks was approximately 50.50% (0.505). In all referring volatile sub-periods it is visibly higher than the average over the whole sample period, which implies that gold functions as a safe haven asset for the Russian investor with a portfolio of stocks. This finding is strengthened by the moderate correlation of approximately 0.385 between the weight of gold and the volatility of the MOEX. For the sample period 2008-2018 where the government bonds and general corporate bonds are included, however, it is notable that the sub-period 5 May 2010 - 16 Jul 2010 shows a smaller allocation of gold of 9.50% (0.095) compared to the referring time sample's average of 12.60% (0.126). This might be explained from the negative correlation between the weight of gold and the weight of bonds as depicted in Table 23 in combination with a roughly 90% allocation of bonds to the portfolio in this volatile sub-period. In the final sample period, it is visible that the sub-period *04 Mar 2014 - 09 Apr 2014* shows a higher level of gold in the portfolio compared to the time span's average level of gold of 5.50% (0.055). Similar result regarding this sub-period can be found as well for the other time spans. Remarkable for this sub-period is that when bonds are considered in the time spans 2008-2018 and 2012-2018, that the portfolios only consist of gold and corporate bonds. Furthermore, for the time span 2004-2018 where only stocks are considered, it is also visible that the weight of gold reaches the maximum boundary of 75%. Combining the results for the volatile sub-period 04 Mar 2014 - 09 Apr 2014 over all time spans, it can be stated that neither stocks nor government bonds were good investments for portfolios in this period. This might be due to the involvement of the Russian Federation regarding the annexation of the Crimea. Considering the correlation vector in Table 23, it is visible that the weight of gold has a positive correlation with the weights of the Russian stock index MOEX of about 0.183, and, a negative relation with the weights on the corporate and government bond indices in a portfolio over the time span 2008-2018. The relative strongest negative correlation is with the Russian government bond index with a value of -0.754. This implies that a position in gold is for largely 75% at the cost of a position in the government bonds, which might be an indication for gold as safe haven asset for Russian government bonds.

Table 23: Correlation vector of weights for stocks, government bonds and corporate bonds of the Russia over the period July 2008 - December 2017.

	MOEX	S&P Russia government bond 10Y	Corp. bond Russia (MICEX)
gold	0.183	-0.754	-0.543

Table 24 shows that the weight of gold in a portfolio is positively correlated (0.648) with the weight of stocks, but in general negatively correlated with the weight of bonds over the time span 2012-2018. Remarkable is that the correlation between the weight of gold and the weight of the stocks is relatively high.

Altogether, the portfolio analysis shows that gold functions as a safe haven asset for Russian investors with portfolio investments in stocks, government bonds and corporate bonds.

Table 24: Correlation vector of weights for stocks, government bonds and corporate bonds of Russia over the period July 2012 - December 2017.

	MOEX	Russia government bond 10Y	Mosc. Corp. Bond Index BBB (IG)	Mosc. Corp. Bond Index B (HY)
gold	0.648	-0.307	-0.491	-0.407

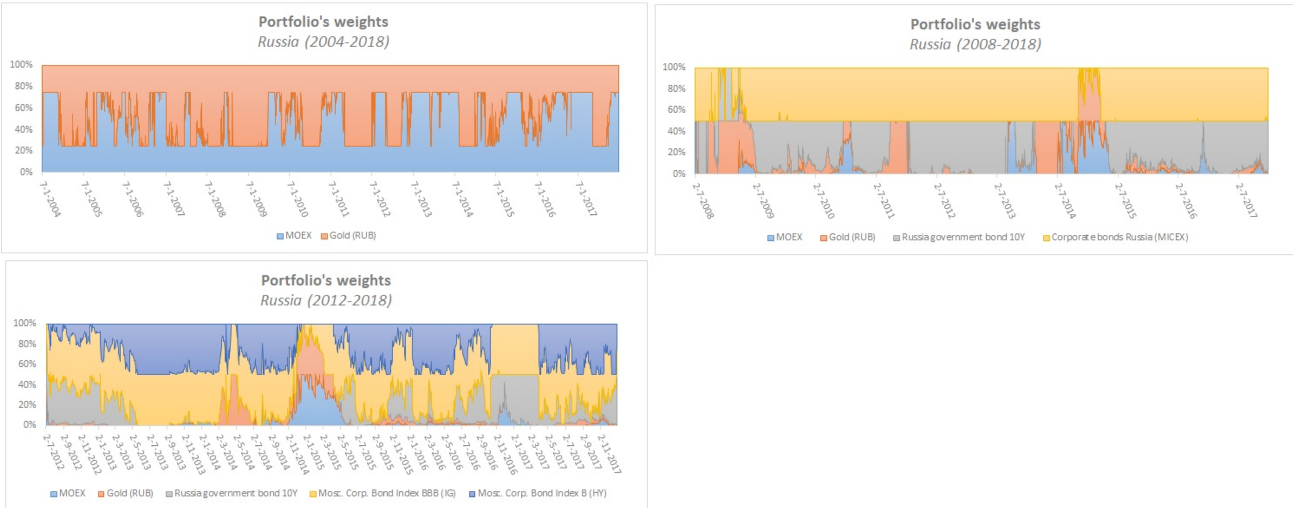


Fig. 21: Portfolio compositions over all time-periods. Period 2004-2008 encompasses portfolios with stocks, period 2008-2018 encompasses portfolios with stock, government bonds and general corporate bonds, and, period 2012-2018 encompasses portfolios with stocks, government bonds, investment-grade corporate bonds and high-yield corporate bonds. *Country: Russia.*

5.6 India

Table 25: Summary table of the average gold positions over the complete periods 2004-2018, 2008-2018 & 2012-2018 (vertical axis) and the different volatile sub-periods (horizontal axis). *Country: India.*

India		whole period	28 Jan 2004 - 24 Mar 2004	12 May 2004 - 15 Jul 2004	27 Apr 2006 - 10 Aug 2006	1 Mar 2007 - 25 Apr 2007	2 Aug 2007 - 17 Nov 2009	30 Aug 2011 - 03 Nov 2011	19 Aug 2013 - 04 Oct 2013	25 Aug 2015 - 15 Sep 2015
	average weight of gold	0.481	0.741	0.741	0.669	0.733	0.621	0.750	0.647	0.750
	average weight of stocks	0.519	0.259	0.259	0.331	0.267	0.379	0.250	0.353	0.250
2004-2018	average conditional volatility stock	0.013	0.018	0.026	0.024	0.019	0.023	0.016	0.017	0.018
	correlation (gld_weight, vol stock)	0.519								
	average weight of gold	0.060	-	-	-	-	-	0.076	0.413	0.006
	average weight of stocks	0.069	-	-	-	-	-	0.000	0.178	0.000
2008-2018	average weight of gov. bonds	0.398	-	-	-	-	-	0.424	0.029	0.494
	average weight of corp. bonds	0.473	-	-	-	-	-	0.500	0.380	0.500
	average conditional volatility stock	0.012	-	-	-	-	-	0.016	0.016	0.017
	correlation (gld_weight, vol stock)	0.360								
	average weight of gold	0.035	-	-	-	-	-	-	0.469	0.064
	average weight of stocks	0.064	-	-	-	-	-	-	0.268	0.000
	average weight of gov. bonds	0.401	-	-	-	-	-	-	0.264	0.500
2012-2018	average weight of IG corp. bonds	0.322	-	-	-	-	-	-	0.000	0.436
	average weight of HY corp. bonds	0.178	-	-	-	-	-	-	0.000	0.000
	average conditional volatility stock	0.009	-	-	-	-	-	-	0.015	0.015
	correlation (gld_weight, vol stock)	0.529								

From the perspective of asset allocation as depicted in Table 25, it is notable that the average level of gold possessed in a portfolio is approximately 48% (0.48) for the sample period 2004-2018. It is visible that in all volatile sub-periods of this sample period, the level of gold lies relatively higher than the benchmark. This finding is strengthened by the relative moderate correlation of 51.90% (0.519) between the volatility of the BSE SENSEX30 and the weight of gold attached in a portfolio. Judging from the asset allocation point of view, we can unanimously infer that gold functions as a safe haven asset for Indian portfolios consisting of stocks. For the sample period 2008-2018, however, the sub-period 25 Aug 2015 - 15 Sep 2015 shows a decrease of the level of gold relative to the average to almost nihil (0.006). This might be the result of the inclusion of bonds in the portfolio. This thought is confirmed by a negative correlation between the weight of gold and the weight of corporate bonds in a portfolio as depicted in Table 26.

In Table 26, it is notable that the correlation between the weight of gold in a portfolio and the weight of stocks in a portfolio is positive with a value of 0.183. The correlation with the weights of bonds is, however, negative where the relative strongest negative relation is with the weights of the Indian government bond (-0.537).

Table 26: Correlation vector of weights for stocks, government bonds and corporate bonds of the India over the period July 2008 - December 2017.

	BSE SENSEX30	S&P BSE India Government Bond	S&P BSE India Corporate Bond
gold	0.183	-0.537	-0.493

Table 27 shows that the weight of gold is positively correlated with the weights of the Indian stock market, but negatively related with the weights in bonds. This might indicate that gold functions as a safe haven asset for bonds.

The majority of the portfolio results shows that gold functions as a safe haven asset for Indian investors with investments in stocks and bonds.

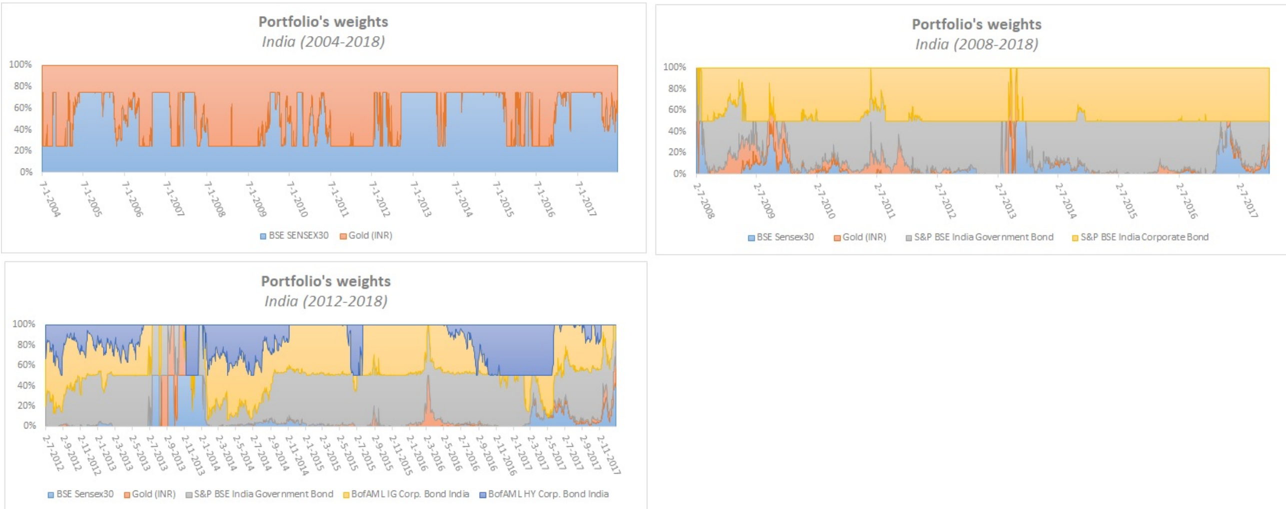


Fig. 22: Portfolio compositions over all time-periods. Period 2004-2008 encompasses portfolios with stocks, period 2008-2018 encompasses portfolios with stock, government bonds and general corporate bonds, and, period 2012-2018 encompasses portfolios with stocks, government bonds, investment-grade corporate bonds and high-yield corporate bonds. *Country: India.*

Table 27: Correlation vector of weights for stocks, government bonds and corporate bonds of India over the period July 2012 - December 2017.

	BSE Sensex30	S&P BSE India Gvrn. Bond	BofAML IG Corp. Bond India	BofAML HY Corp. Bond India
gold	0.648	-0.307	-0.491	-0.407

5.7 China

Table 28: Summary table of the average gold positions over the complete periods 2004-2018, 2008-2018 & 2012-2018 (vertical axis) and the different volatile sub-periods (horizontal axis). *Country: China.*

China		whole period	16 Sep 2004 - 16 Nov 2004	09 Jun 2005 - 01 Aug 2005	15 May 2006 - 26 Jul 2006	04 Jan 2007 - 22 May 2009	30 Jul 2009 - 31 Dec 2009	18 May 2010 - 23 Jul 2010	15 Nov 2010 - 03 Dec 2010	09 Dec 2014 - 06 Mar 2015	17 Apr 2015 - 22 Apr 2016
	average weight of gold	0.5221	0.7500	0.7500	0.2693	0.5794	0.6225	0.7500	0.3791	0.2500	0.5622
	average weight of stocks	0.4779	0.2500	0.2500	0.7307	0.4206	0.3775	0.2500	0.6209	0.7500	0.4378
2004-2018	average conditional volatility stock	0.0152	0.0170	0.0185	0.0175	0.0245	0.0203	0.0168	0.0177	0.0185	0.0249
	correlation (gld_weight, vol stock)	0.1995									
	average weight of gold	0.1070	-	-	-	-	0.3840	0.0560	0.2400	0.0020	0.0090
	average weight of stocks	0.1170	-	-	-	-	0.2520	0.0000	0.4480	0.0760	0.0440
2008-2018	average weight of gov. bonds	0.3570	-	-	-	-	0.3230	0.4440	0.0000	0.4290	0.4500
	average weight of corp. bonds	0.4190	-	-	-	-	0.0410	0.5000	0.3120	0.4920	0.4970
	average conditional volatility stock	0.0142	-	-	-	-	0.0202	0.0167	0.0177	0.0184	0.0240
	correlation (gld_weight, vol stock)	-0.1383									
	average weight of gold	0.0200	-	-	-	-	-	-	-	0.0010	0.0100
	average weight of stocks	0.0960	-	-	-	-	-	-	-	0.0930	0.0480
	average weight of gov. bonds	0.3130	-	-	-	-	-	-	-	0.5000	0.4720
2012-2018	average weight of IG corp. bonds	0.2850	-	-	-	-	-	-	-	0.4060	0.2550
	average weight of HY corp. bonds	0.2860	-	-	-	-	-	-	-	0.0000	0.2150
	average conditional volatility stock	0.0126	-	-	-	-	-	-	-	0.0185	0.0247
	correlation (gld_weight, vol stock)	-0.1895									

In terms of asset allocation, the average weight of gold held in the portfolio is approximately 52.20% (0.522) for the time span 2004-2018. Controversial here is that in some volatile periods, there is even a lower weight of gold in the portfolio. Although gold functions as safe haven asset for portfolios composed of stocks in the majority of the cases, there are also sub-periods where gold does not function as a safe haven asset for stocks of the Shanghai Composite index. This finding can be explained from the pretty low correlation of approximately 0.20 between the weight of gold and the volatility on the stock market, because of which it seems logical that gold will not always function as a safe haven asset.

For sample periods 2008-2018 and 2012-2018, we see a negative correlation between gold's weight and the volatility on the stock market, implying that in volatile periods it is to a certain extent more likely to sell gold rather than to buy. This also reflects in the weight of gold in volatile periods of these sample periods. It is indeed visible that in more than half of the volatile periods, the average weight of gold is lower than the total average weight of gold over the whole sample period.

Here we can conclusively state that gold is certainly not a safe haven asset for portfolios comprising of stocks and bonds for Chinese investors.

Table 29: Correlation vector of weights for stocks, government bonds and corporate bonds of the China over the period July 2008 - December 2017.

	Shanghai Composite	S&P China Government Bond	S&P China Corporate Bond
gold	0.199	-0.436	-0.760

Both correlation vectors in Table 29 and in Table 30 show that the weight of gold is positively correlated with the weight of the stocks, but negatively correlated with the weights on bonds.

Table 30: Correlation vector of weights for stocks, government bonds and corporate bonds of China over the period July 2012 - December 2017.

	Shanghai Composite	S&P China Gvrn. Bond	BofAML IG Corp. Bond China	BofAML HY Corp. Bond China
gold	0.222	-0.308	-0.103	-0.039

Fig. 23: Portfolio compositions over all time-periods. Period 2004-2008 encompasses portfolios with stocks, period 2008-2018 encompasses portfolios with stock, government bonds and general corporate bonds, and, period 2012-2018 encompasses portfolios with stocks, government bonds, investment-grade corporate bonds and high-yield corporate bonds. *Country: China.*

6 Conclusion

In the quest for answering the research questions whether gold functions as a safe haven asset for a portfolio comprising of stocks and bonds for developed and emerging markets over the period January 2004 until December 2017, we formulated two hypotheses. The first hypothesis states that gold functions as a safe haven asset for a portfolio comprising of stocks and bonds for investors in developed markets, while the second states that gold functions as a safe haven asset for a portfolio comprising of stocks and bonds for emerging markets.

In order to solve our quest, we have invented a novel approach in order to consider the implications for the investor himself. This approach has combined the standard mean-variance portfolio optimization techniques, which is used to find the optimal asset allocation in a portfolio by maximizing the Sharpe Ratios (standardized excess returns), with the standard concept of gold as safe haven asset which is usually defined as no or negative correlation with another asset during periods of turmoil. Combining these two concepts gave us the opportunity to re-define gold as a safe haven asset, but now in terms of a portfolio framework, which is inventive and to our knowledge has not been discussed before in the literature. We argued that gold functions as a safe haven asset if the allocation of gold in a portfolio is higher in volatile periods than that it would be in average periods.

In our analysis we considered three types of portfolios, whereby the first type encompasses portfolios with stocks, the second type a portfolio with stocks, government bonds and general corporate bonds, and, the third type a portfolio with stocks, government bonds and a distinction in corporate bonds between investment-grade and high-yield corporate bonds. Analyzing these combinations of portfolios has also not been discussed in terms of gold as safe haven asset yet, and, as such provided new insights for further research.

We found for the developed markets that the safe haven property of gold applies for portfolios of bonds and stocks in the United States and United Kingdom, but not convincingly for the Eurozone. We found for the emerging BRIC-countries that the safe haven property of gold holds for portfolios of bonds and stocks in Brazil, Russia and India. However, it does not hold for China where we even noted an inverse relationship between gold investments and market turmoil. As the majority of the results for both the developed markets as well the emerging markets points on the safe haven characteristic of gold for portfolios consisting of stocks and bonds, we do not reject both hypotheses. As such, we can conclude that gold does function as a safe haven asset for a portfolio of stocks and bonds for both developed and emerging markets.

7 Limitations and Future research

In this research we manually marked periods as high-volatile periods based on the criterion that the volatility of referring period should exceed the average volatility of the total period. As this threshold value is to some extent arbitrary, it might give biased results. As the traditional definition of safe haven states that an asset should provide shelter during roaring times, we first need to make sure how to define the roaring period. Therefore, it could be interesting if a higher threshold value for the volatility is specified such that we only consider the behaviour in extreme times of the market.

Another view would also be interesting, that is, considering the direction of movement of the gold allocation in a portfolio as continuous function of the volatility on the stock market (proxy for market risk). This might provide viable results for traders. The relation between the gold allocation and the allocation of each individual asset's allocation in the portfolio during turbulent periods, might be interesting for further research as well.

Finally, it would be interesting to add more assets in a portfolio such as cryptocurrenncies, real estate and derivatives in order to simulate the portfolio of a real investor. From this angle, we might get interesting results on how gold could protect these portfolios.

1 Appendix A - Proof of optimal weights

In this paper I will examine the following assets or markets:

- Stocks
- Bonds
- Gold

For each of these assets, I will examine whether it is possible to hedge with gold and whether the hedge power of gold is period-dependent.

First of all, I give an introduction to the Markowitz mean-variance theorem. In the paper of Box (2009), it is explained that the mean-variance analysis is a good way to allocate assets to a portfolio. Given a certain return, the investor goes for the portfolio with the minimum variance.

In this paper a portfolio consisting of several assets will be analyzed; stocks, bonds and gold. As all models are based on some assumptions, therefore I will mention some important ones.

- Investors are optimizers, $max[mean|variance]$
- The covariance matrix and the mean-vector are available and known
- Investors can go long or short in any amount of an asset
- Investors have no influence on the price, they are simply *price takers*
- Investors do not face transaction costs

Lagrange multiplier

This is a method that is used to find a minimum or maximum of a function given certain constraints, see the paper of Box (2009).

The two fund theorem

As aforementioned one needs to use the Langrage multiplier for an optimization subject to certain constraints. For an efficient portfolio, it is important that the variance should be minimized given a fixed expected return and a fixed total wealth. The formula below shows how to calculate the mean and variance of the portfolio.

$$\mu_p = \sum_{i=1}^{N} X_i \mu_i$$

$$\sigma_p^2 = \sum_{i=1}^{N} \sum_{j=1}^{N} \sigma_i \sigma_j X_i X_j \rho_{12}$$

X_i is the weight in asset i.

For finding the optimal portfolio, it boils down to maximizing the Sharpe Ratio. See formula below.

$$S_p = \frac{\mu_p - r_f}{\sigma_p}$$

(Sharpe Ratio)

I applied some constraints for optimizing the portfolio. The first constraint is not to go short, while the second constraint is not to take extreme long positions. The last constraint is that the total weight, summed up over all assets, must be one.

$$x_i \geq 0, \qquad \forall\, i = 1,2,..,N \qquad (1)$$

$$X_i \leq 1, \qquad \forall\, i = 1,2,..,N \qquad (2)$$

$$\sum_{i=1}^{N} X_i = 1 \qquad (3)$$

The point is to calculate the expected values of the assets and the covariance matrix of those assets. As we examine a large time period, we should take into account a time-varying covariance matrix. For this, I will use the *dynamic conditional correlation model* (DCC) or assymetric DCC, see Engle (2002).

Regarding the expected returns, it will not be wise to base our expected return solely on past data of returns. In order to calculate expected returns, I will use the EWMA

(Exponentially Weighted Moving Average) model. This method gives more weight to recent information which seems to be more logical.

I will create a portfolio consisting of gold(gld), stocks(stk), corporate bond(bnd) and treasuries(trs). Note that I just considered the general corporate index.

$$E[\mathbf{R}] = E\left(\begin{bmatrix} R_{bnd} \\ R_{trs} \\ R_{stk} \\ R_{gld} \end{bmatrix}\right) = \begin{pmatrix} E[R_{bnd}] \\ E[R_{trs}] \\ E[R_{stk}] \\ E[R_{gld}] \end{pmatrix} = \begin{pmatrix} \mu_{bnd} \\ \mu_{trs} \\ \mu_{stk} \\ \mu_{gld} \end{pmatrix} = \boldsymbol{\mu}$$

$$Var(\mathbf{R}) = \begin{pmatrix} var(R_{bnd}) & cov(R_{bnd}, R_{trs}) & cov(R_{bnd}, R_{stk}) & cov(R_{bnd}, R_{gld}) \\ cov(R_{trs}, R_{bnd}) & var(R_{trs}) & cov(R_{trs}, R_{stk}) & cov(R_{trs}, R_{gld}) \\ cov(R_{stk}, R_{bnd}) & cov(R_{stk}, R_{trs}) & var(R_{stk}) & cov(R_{stk}, R_{gld}) \\ cov(R_{gld}, R_{bnd}) & cov(R_{gld}, R_{trs}) & cov(R_{gld}, R_{stk}) & var(R_{gld}) \end{pmatrix} = \boldsymbol{\Sigma}$$

The return of the portfolio can also be expressed as follows. Let R be the return of the portfolio and w be the weight attached to certain assets of the portfolio.

$$R_{portfolio,w} = \boldsymbol{w'R} = (w_{bnd}, w_{trs}, w_{stk}, w_{gld}) \cdot \begin{pmatrix} R_{bnd} \\ R_{trs} \\ R_{stk} \\ R_{gld} \end{pmatrix} = w_{bnd}R_{bnd} + w_{trs}R_{trs} + w_{stk}R_{stk} + w_{gld}R_{gld}$$

Expected return of portfolio

$$\mu_{portfolio,w} = E[w'\boldsymbol{R}] = w'E[\boldsymbol{R}] = w'\boldsymbol{\mu} = (w_{bnd}, w_{trs}, w_{stk}, w_{gld}) \cdot \begin{pmatrix} \mu_{bnd} \\ \mu_{trs} \\ \mu_{stk} \\ \mu_{gld} \end{pmatrix} = w_{bnd}\mu_{bnd} + w_{trs}\mu_{trs} + w_{stk}\mu_{stk} + w_{gld}\mu_{gld}$$

Variance of portfolio

$$\sigma^2_{portfolio,w} = var[w'\boldsymbol{R}] = w'var[\boldsymbol{R}]w = \boldsymbol{w'\Sigma w} =$$

$$\left(w_{bnd}, w_{trs}, w_{stk}, w_{gld}\right) \cdot \begin{pmatrix} \mathrm{var}(R_{bnd}) & \mathrm{cov}(R_{bnd}, R_{trs}) & \mathrm{cov}(R_{bnd}, R_{stk}) & \mathrm{cov}(R_{bnd}, R_{gld}) \\ \mathrm{cov}(R_{trs}, R_{bnd}) & \mathrm{var}(R_{trs}) & \mathrm{cov}(R_{trs}, R_{stk}) & \mathrm{cov}(R_{trs}, R_{gld}) \\ \mathrm{cov}(R_{stk}, R_{bnd}) & \mathrm{cov}(R_{stk}, R_{trs}) & \mathrm{var}(R_{stk}) & \mathrm{cov}(R_{stk}, R_{gld}) \\ \mathrm{cov}(R_{gld}, R_{bnd}) & \mathrm{cov}(R_{gld}, R_{trs}) & \mathrm{cov}(R_{gld}, R_{stk}) & \mathrm{var}(R_{gld}) \end{pmatrix} \begin{pmatrix} w_{bnd} \\ w_{trs} \\ w_{stk} \\ w_{gld} \end{pmatrix} =$$

$$(w_{bnd}^2\sigma_{bnd}^2 + w_{trs}^2\sigma_{trs}^2 + w_{stk}^2\sigma_{stk}^2 + w_{gld}^2\sigma_{gld}^2) + (2\sigma_{bnd,trs}w_{bnd}w_{trs}) + (2\sigma_{bnd,stk}w_{bnd}w_{stk}) + (2\sigma_{bnd,gld}w_{bnd}w_{gld}) + (2\sigma_{trs,stk}w_{trs}w_{stk}) + (2\sigma_{trs,gld}w_{trs}w_{gld}) + (2\sigma_{stk,gld}w_{stk}w_{gld})$$

Restriction that all weights should sum up to 1

$$\mathbf{w'1} = \left(w_{bnd}, w_{trs}, w_{stk}, w_{gld}\right) \cdot \begin{pmatrix} 1 \\ 1 \\ 1 \\ 1 \end{pmatrix} = w_{bnd} + w_{trs} + w_{stk} + w_{gld} = 1$$

Calculate the global minimum variance portfolio

$$\min_{w_{bnd}, w_{trs}, w_{stk}, w_{gld}} \sigma_{portfolio,w}^2 =$$

$$(w_{bnd}^2\sigma_{bnd}^2 + w_{trs}^2\sigma_{trs}^2 + w_{stk}^2\sigma_{stk}^2 + w_{gld}^2\sigma_{gld}^2) + (2\sigma_{bnd,trs}w_{bnd}w_{trs}) + (2\sigma_{bnd,stk}w_{bnd}w_{stk}) + (2\sigma_{bnd,gld}w_{bnd}w_{gld}) + (2\sigma_{trs,stk}w_{trs}w_{stk}) + (2\sigma_{trs,gld}w_{trs}w_{gld}) + (2\sigma_{stk,gld}w_{stk}w_{gld})$$

Subject to the constraint $w_{bnd} + w_{trs} + w_{stk} + w_{gld} = 1$

For minimizing this given this constraint, I will use the Lagrangian method.

$$L\left(w_{bnd}, w_{trs}, w_{stk}, w_{gld}, \lambda\right) = (w_{bnd}^2\sigma_{bnd}^2 + w_{trs}^2\sigma_{trs}^2 + w_{stk}^2\sigma_{stk}^2 + w_{gld}^2\sigma_{gld}^2) + \left(2\sigma_{bnd,trs}w_{bnd}w_{trs}\right) + \left(2\sigma_{bnd,stk}w_{bnd}w_{stk}\right) + \left(2\sigma_{bnd,gld}w_{bnd}w_{gld}\right) + \left(2\sigma_{trs,stk}w_{trs}w_{stk}\right) + \left(2\sigma_{trs,gld}w_{trs}w_{gld}\right) + \left(2\sigma_{stk,gld}w_{stk}w_{gld}\right) + \lambda(w_{bnd} + w_{trs} + w_{stk} + w_{gld} - 1)$$

The first order conditions that we can derive from this in order to calculate the global minimum are:

$$0 = \frac{\partial L}{\partial w_{bnd}} = 2w_{bnd}\sigma_{bnd}^2 + 2\sigma_{bnd,trs}w_{trs} + 2\sigma_{bnd,stk}w_{stk} + 2\sigma_{bnd,gld}w_{gld} + \lambda$$

$$0 = \frac{\partial L}{\partial w_{trs}} = 2w_{trs}\sigma_{trs}^2 + 2\sigma_{bnd,trs}w_{bnd} + 2\sigma_{trs,stk}w_{stk} + 2\sigma_{trs,gld}w_{gld} + \lambda$$

$$0 = \frac{\partial L}{\partial w_{stk}} = 2w_{stk}\sigma_{stk}^2 + 2\sigma_{bnd,stk}w_{bnd} + 2\sigma_{trs,stk}w_{trs} + 2\sigma_{stk,gld}w_{gld} + \lambda$$

$$0 = \frac{\partial L}{\partial w_{gld}} = 2w_{gld}\sigma_{gld}^2 + 2\sigma_{bnd,gld}w_{bnd} + 2\sigma_{trs,gld}w_{trs} + 2\sigma_{stk,gld}w_{stk} + \lambda$$

$$0 = \frac{\partial L}{\partial \lambda} = w_{bnd} + w_{trs} + w_{stk} + w_{gld} - 1$$

In order to solve this, it would be simpler to consider the first order conditions (linear equations) in matrix form.

$$\begin{pmatrix} 2\sigma_{bnd}^2 & 2\sigma_{bnd,trs} & 2\sigma_{bnd,stk} & 2\sigma_{bnd,gld} & 1 \\ 2\sigma_{bnd,trs} & 2\sigma_{trs}^2 & 2\sigma_{trs,stk} & 2\sigma_{trs,gld} & 1 \\ 2\sigma_{stk,bnd} & 2\sigma_{stk,trs} & 2\sigma_{stk}^2 & 2\sigma_{stk,gld} & 1 \\ 2\sigma_{gld,bnd} & 2\sigma_{gld,trs} & 2\sigma_{gld,stk} & 2\sigma_{gld}^2 & 1 \\ 1 & 1 & 1 & 1 & 0 \end{pmatrix} \begin{pmatrix} w_{bnd} \\ w_{trs} \\ w_{stk} \\ w_{gld} \\ \lambda \end{pmatrix} = \begin{pmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 1 \end{pmatrix},$$

We can simplify this to

$$\begin{pmatrix} 2\boldsymbol{\Sigma} & \mathbf{1} \\ \mathbf{1}' & \mathbf{0} \end{pmatrix} \begin{pmatrix} \boldsymbol{w} \\ \lambda \end{pmatrix} = \begin{pmatrix} \mathbf{0} \\ 1 \end{pmatrix}$$

Let us denote this as follows: $\boldsymbol{A_w z_w} = \boldsymbol{b}$

In order to solve for $\boldsymbol{z_w}$ one should invert the matrix $\boldsymbol{A_w}$. As the determinant of the $\boldsymbol{A_w}$matrix is not equal to zero, the inverse of this matrix exists.

Thus this boils down to $\mathbf{z_w} = \mathbf{A_w^{-1}b}$. Recall that the first four components refer to the weights attached to the assets in the portfolio in order to get the global minimum variance.

Now it boils down to compute the efficient frontier. The (μ,σ) graph contains the investment opportunity set. The shape of the investment opportunity set depends especially on the covariance terms between the assets, thus the σ_{ij} terms.

In this concept one can assume that investors want to minimize their risk given a desired expected return. In other terms, investors want to maximize their expected return given certain risk.

In terms of formula it boils down to $\max_{0 \le w_i \le 1} E[\boldsymbol{R} | \sigma^2_{\text{portfolio,w}} = \sigma^2_{\text{portfolio,0}} \cap \Sigma w_i = 1]$ in which the expected return subjects to a desired volatility level ($\sigma^2_{\text{portfolio,0}}$) and the constraint that the weights in the portfolio must total to one ($\Sigma w_i = \mathbf{1}$).

To make the calculations more comfortable, I will translate it to the task of minimizing variance given a desired return. Or in terms of formula it boils down to:

$$\min_{0 \le w_i \le 1} E[\boldsymbol{w}' \boldsymbol{\Sigma} \boldsymbol{w} | \mu_{\text{portfolio,w}} = \mu_{\text{portfolio,0}} \cap \Sigma w_i = 1]$$

If one is about to solve this equation for all possible desired expected returns $\mu_{\text{portfolio,0}}$ being higher than the expected return on the portfolio of the global minimum variance, one gets the “efficient portfolio frontier” on the ($\mu_{\text{portfolio}}$,$\sigma_{\text{portfolio}}$) graph. In case of two assets, this efficient frontier will look like a rotated parabola which is also known as the “Markowitz bullet”.

Returning to the minimization question, there are two constraints now. This means that one needs two Lagrange multipliers instead of one. For the sake of avoiding confusion with the global minimum variance portfolio, I will not use the letter w to name the weights in this portfolio, but I will use an x instead.

Constraint 1: $\mathbf{x}'\mathbf{1} = 1$

Constraint 2: $\mathbf{x}'\boldsymbol{\mu} = \mu_{\text{portfolio,0}}$

Thus, the Lagrange equation is:

$$L(x, \lambda_1, \lambda_2) = \boldsymbol{x}' \boldsymbol{\Sigma x} + \lambda_1 \left(\mathbf{x}'\boldsymbol{\mu} - \mu_{\text{portfolio,0}} \right) + \lambda_2 (\mathbf{x}'\mathbf{1} - 1)$$

The first order conditions are:

$$\frac{\partial \mathrm{L}(\mathrm{x}, \lambda_1, \lambda_2)}{\partial \mathbf{x}} = 2\boldsymbol{\Sigma}\mathbf{x} + \lambda_1 \boldsymbol{\mu} + \lambda_2 \mathbf{1} = \mathbf{0}$$

$$\frac{\partial L(x,\lambda_1,\lambda_2)}{\partial \lambda_1} = \mathbf{x}'\boldsymbol{\mu} - \mu_{\text{portfolio},0} = 0$$

$$\frac{\partial L(x,\lambda_1,\lambda_2)}{\partial \lambda_2} = \mathbf{x}'\mathbf{1} - 1 = 0$$

In terms of a matrix, these are six linear equations in six unknown parameters$(x_{bnd}, x_{trs}, x_{stk}, x_{gld}, \lambda_1, \lambda_2)$. So, one can solve this by the aid of a matrix.

$\begin{pmatrix} 2\boldsymbol{\Sigma} & \boldsymbol{\mu} & \mathbf{1} \\ \boldsymbol{\mu}' & 0 & 0 \\ 1' & 0 & 0 \end{pmatrix} \begin{pmatrix} \boldsymbol{x} \\ \lambda_1 \\ \lambda_2 \end{pmatrix} = \begin{pmatrix} \mathbf{0} \\ \mu_{portfolio,0} \\ 1 \end{pmatrix}$ or in terms of letter-notation: $\boldsymbol{A}\boldsymbol{z}_{\boldsymbol{x}} = \boldsymbol{b}_{\mathbf{0}}$ with

$$\mathrm{A} = \begin{pmatrix} 2\boldsymbol{\Sigma} & \boldsymbol{\mu} & \mathbf{1} \\ \boldsymbol{\mu}' & 0 & 0 \\ 1' & 0 & 0 \end{pmatrix}, \quad \boldsymbol{z}_x = \begin{pmatrix} \boldsymbol{x} \\ \lambda_1 \\ \lambda_2 \end{pmatrix}, \quad \boldsymbol{b}_{\mathbf{0}} = \begin{pmatrix} \mathbf{0} \\ \mu_{portfolio,0} \\ 1 \end{pmatrix}$$

In order to find the solution of the weights, one should first solve for the vector $\boldsymbol{z}_{\boldsymbol{x}}$ in terms of the inverse of matrix **A** and vector $\mathbf{b}_0$. If one writes this A matrix out, it boils down to a 6x6 matrix of which the determinant does not equal zero. Thus, this matrix is invertible and the solution to this problem exists.

$$\boldsymbol{z}_x = \mathbf{A}^{-1}\boldsymbol{b}_{\mathbf{0}}$$

The first four numbers in the vector $\boldsymbol{z}_{\boldsymbol{x}}$ show the weights attached to assets in the portfolio which were a result of this minimization process given two constraints as discussed above.

If $\mu_{\text{portfolio,0}} \geq \mu_{\text{portfolio global minimum variance}}$ then x is a portfolio being efficient.

End of proof

2 Appendix B

This part of the appendix deals with the parameter estimations for the AR(1), GARCH(1,1) and DCC(1,1) models. The order is as follows: United States, United Kingdom, Eurozone, Brazil, Russia, India and China. The results of each country are plotted on one page, where the results consist of the three different time periods: 2004-2018; 2008-2018 and 2012-2018.

The coefficient values are rounded to 4 decimal places. In case the name of the parameter is marked by two asterisks, then it basically means that its referring coefficient is significantly different from a zero-value on a 5% significance level. Some visual aspects are that blue is for positive coefficients and red for negative coefficients.

The parameter space can only take values within interval [-1,1].

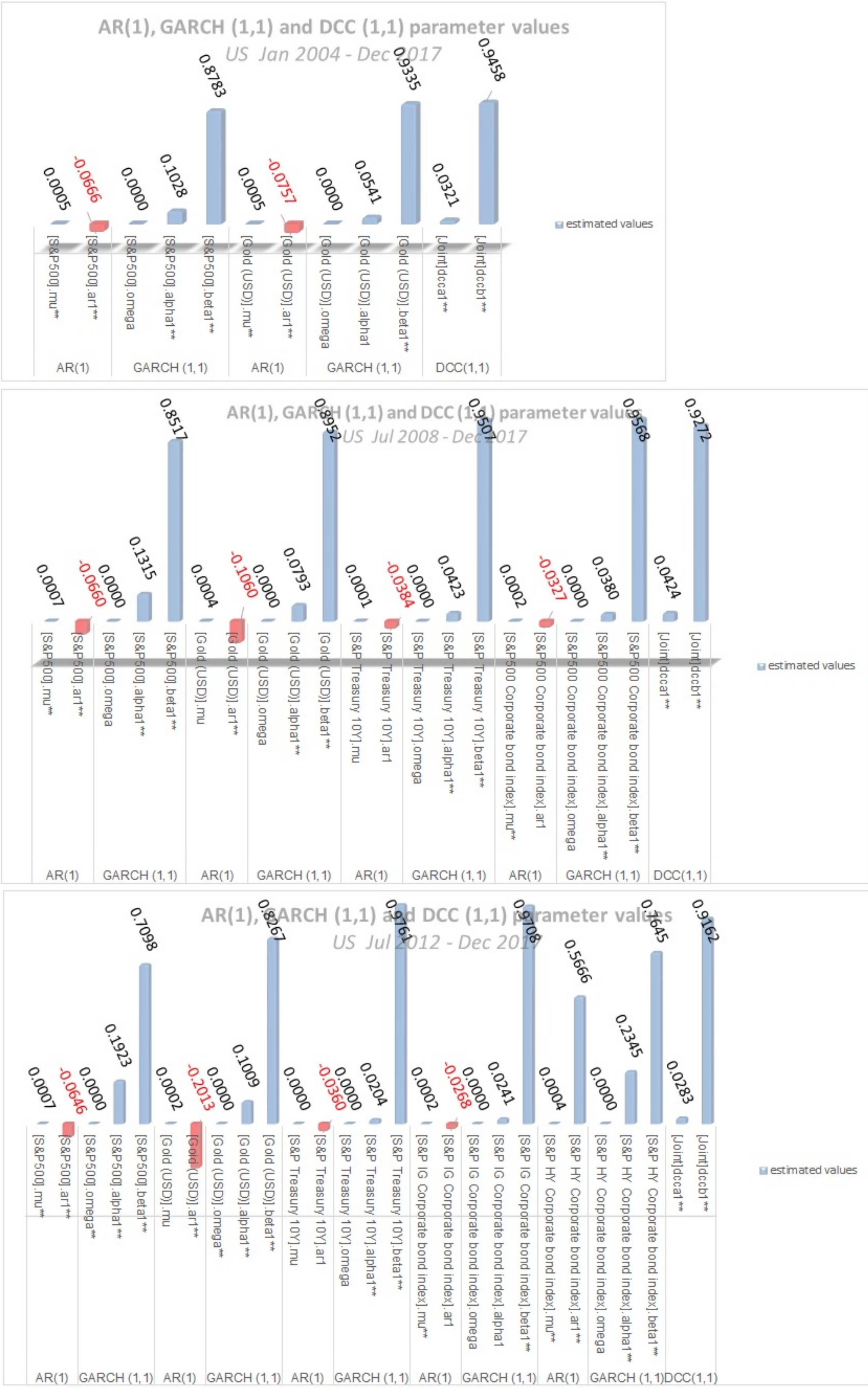
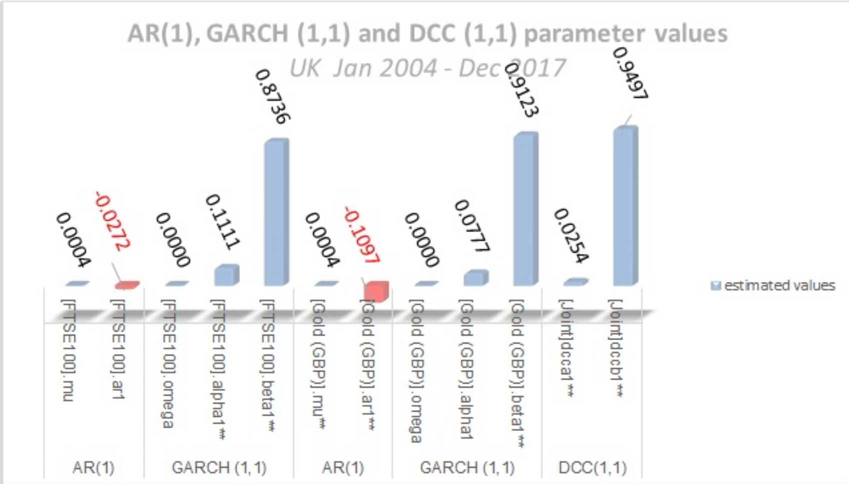
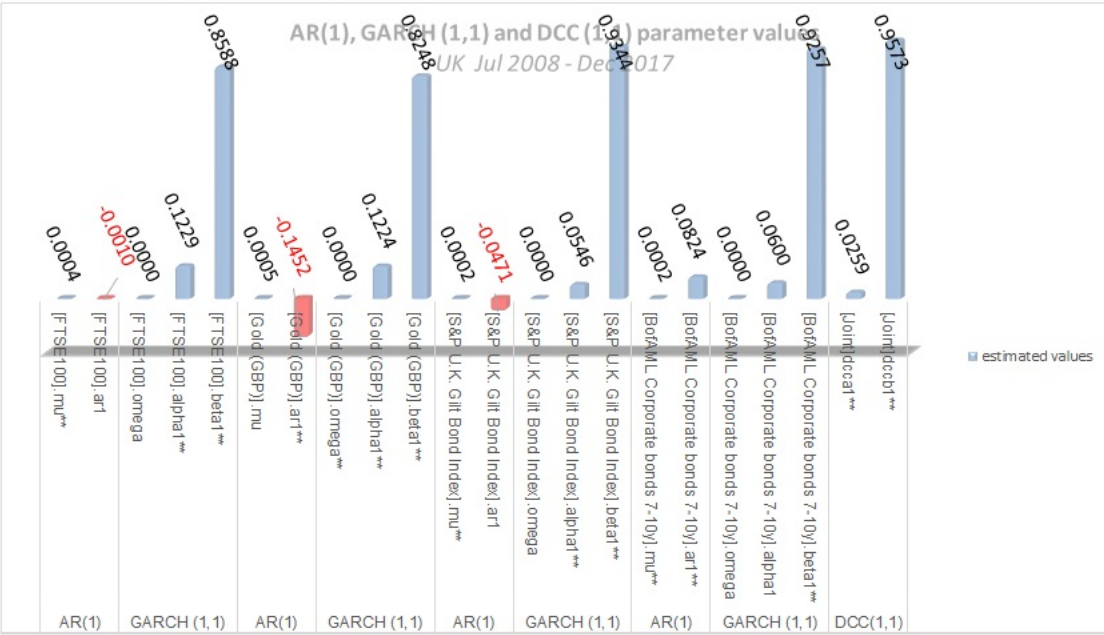


Fig. 24: Plots of the estimated values for the parameters of the AR(1), GARCH(1,1) and DCC(1,1) models for the United States. An asterisk behind a parameter name shows that referring estimated value is significant at a 5% significance level.





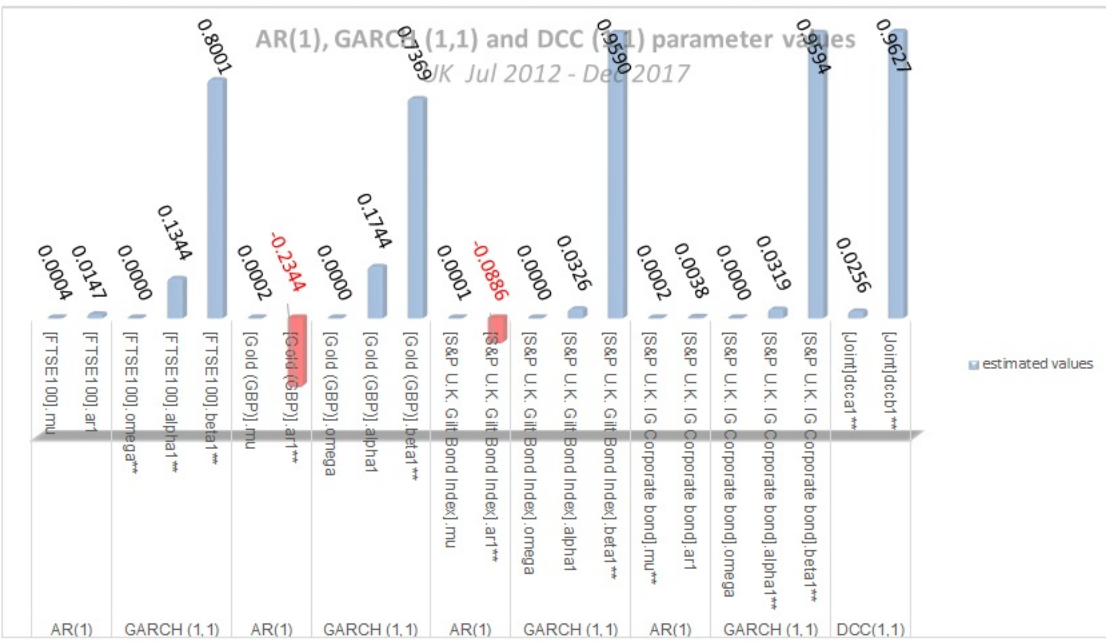
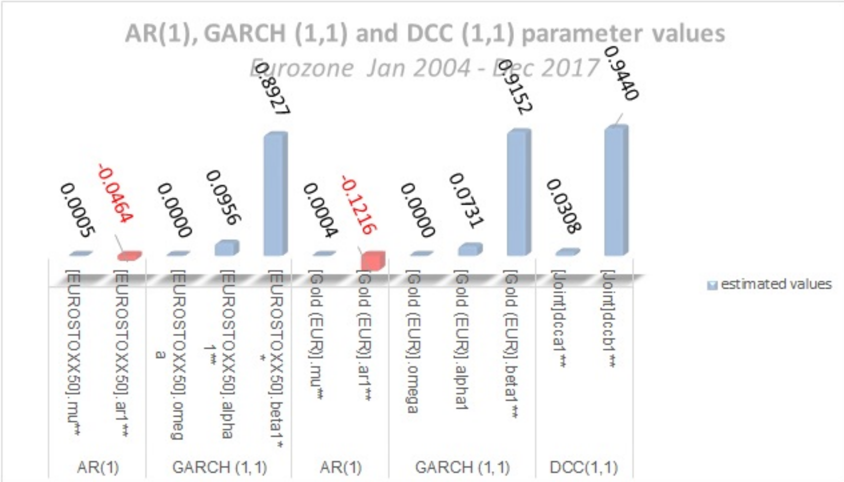
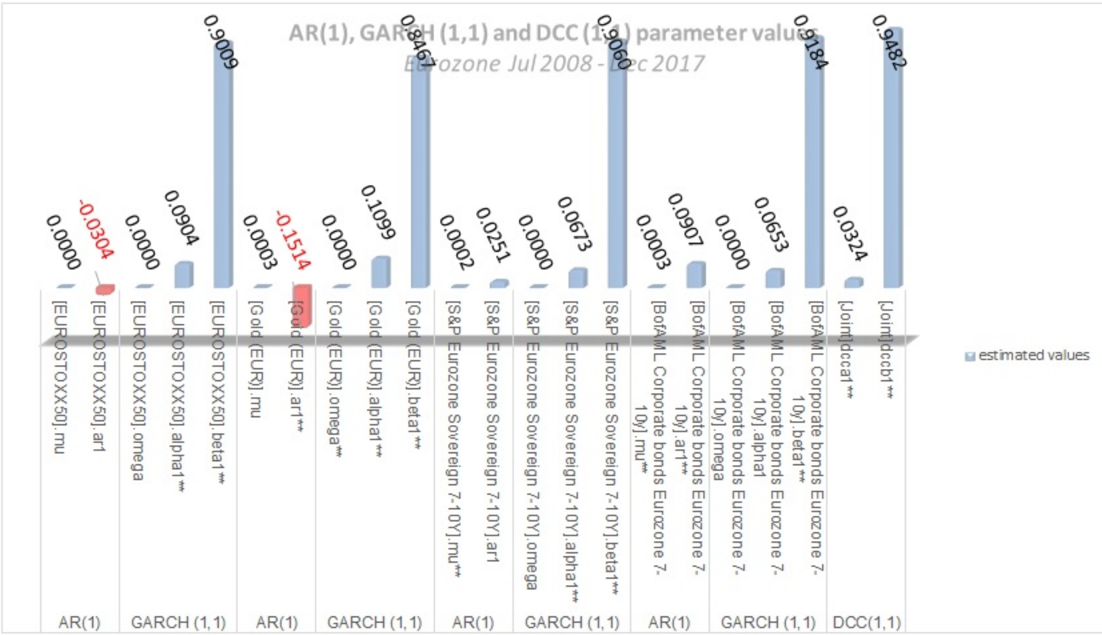


Fig. 25: Plots of the estimated values for the parameters of the AR(1), GARCH(1,1) and DCC(1,1) models for the United Kingdom. An asterisk behind a parameter name shows that referring estimated value is significant at a 5% significance level.





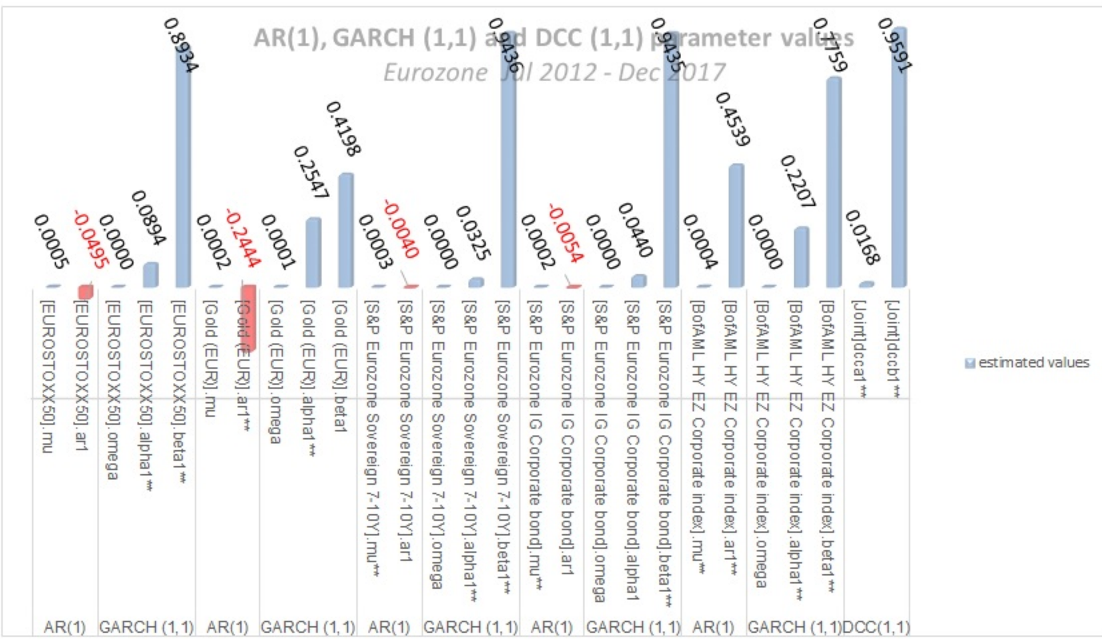
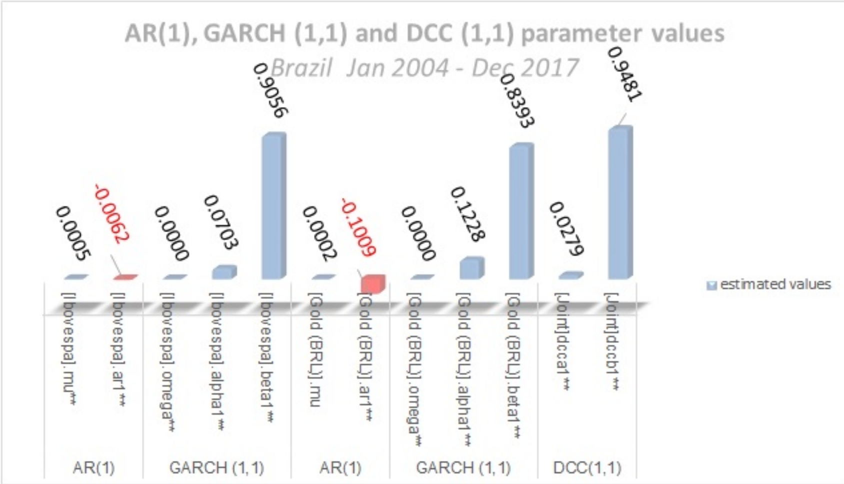
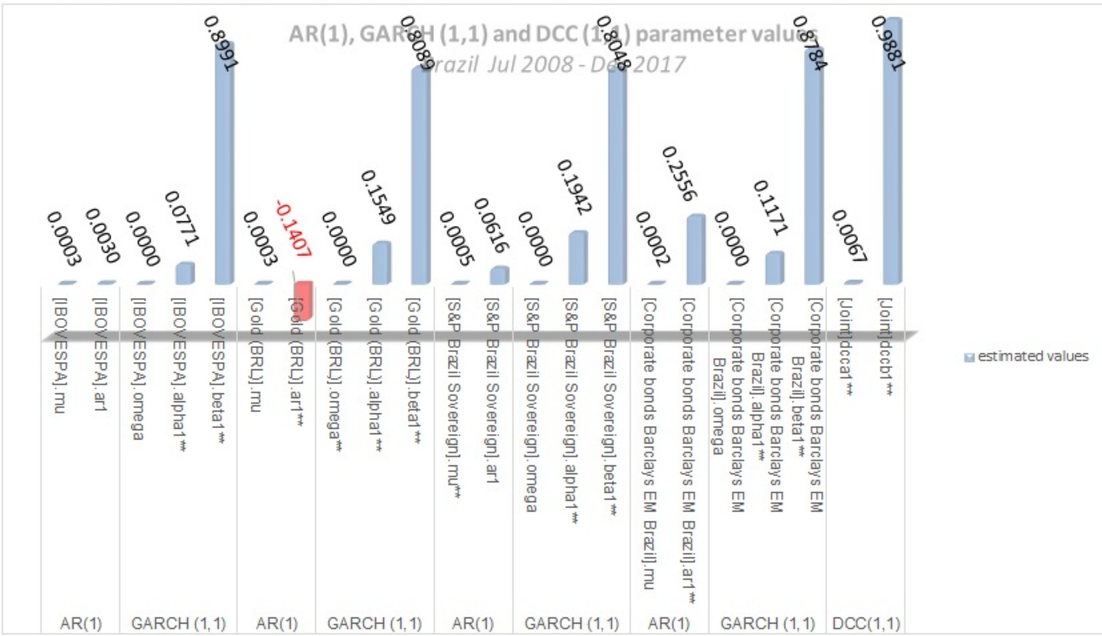


Fig. 26: Plots of the estimated values for the parameters of the AR(1), GARCH(1,1) and DCC(1,1) models for the Eurozone. An asterisk behind a parameter name shows that referring estimated value is significant at a 5% significance level.





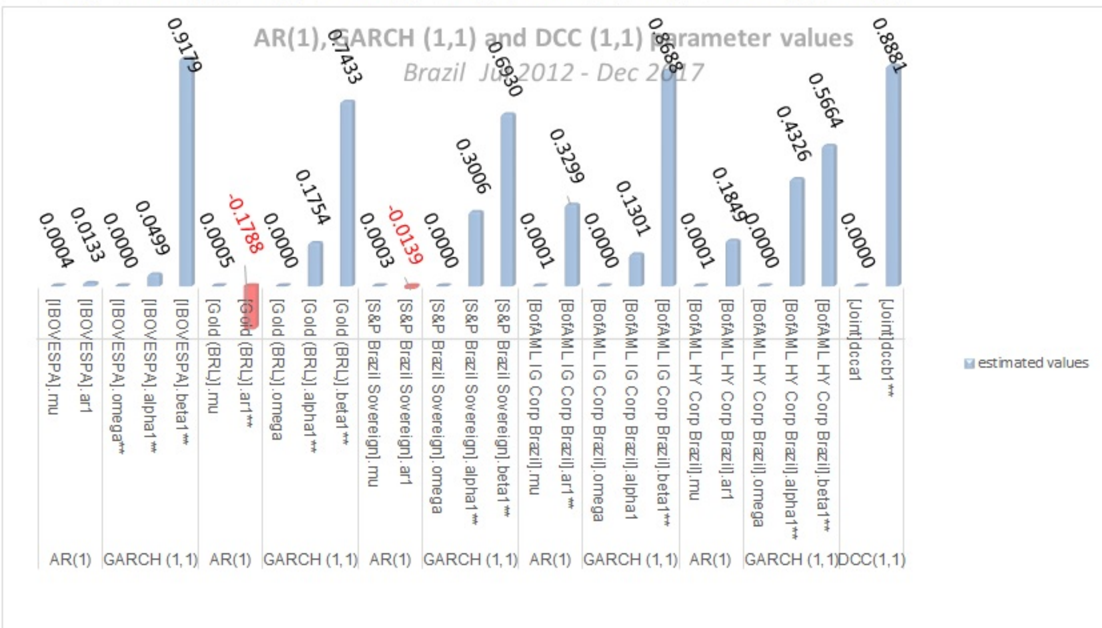
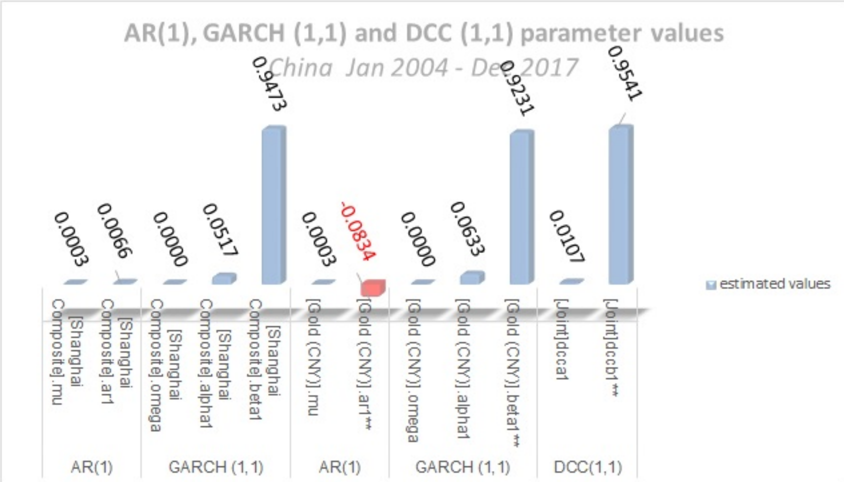
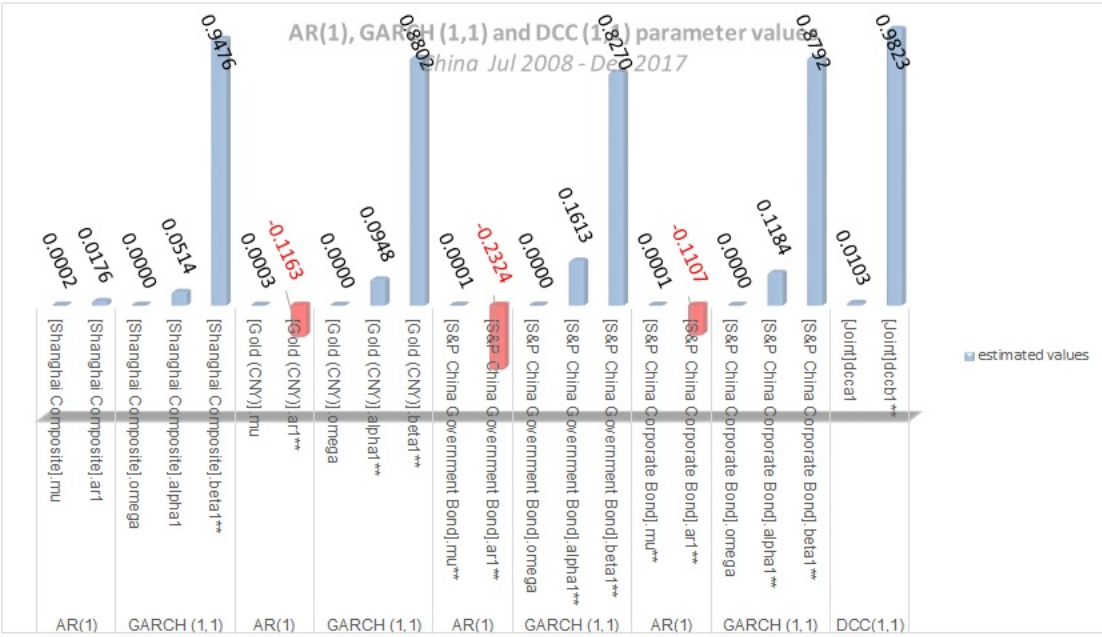


Fig. 27: Plots of the estimated values for the parameters of the AR(1), GARCH(1,1) and DCC(1,1) models for Brazil. An asterisk behind a parameter name shows that referring estimated value is significant at a 5% significance level.

Fig. 28: Plots of the estimated values for the parameters of the AR(1), GARCH(1,1) and DCC(1,1) models for Russia. An asterisk behind a parameter name shows that referring estimated value is significant at a 5% significance level.





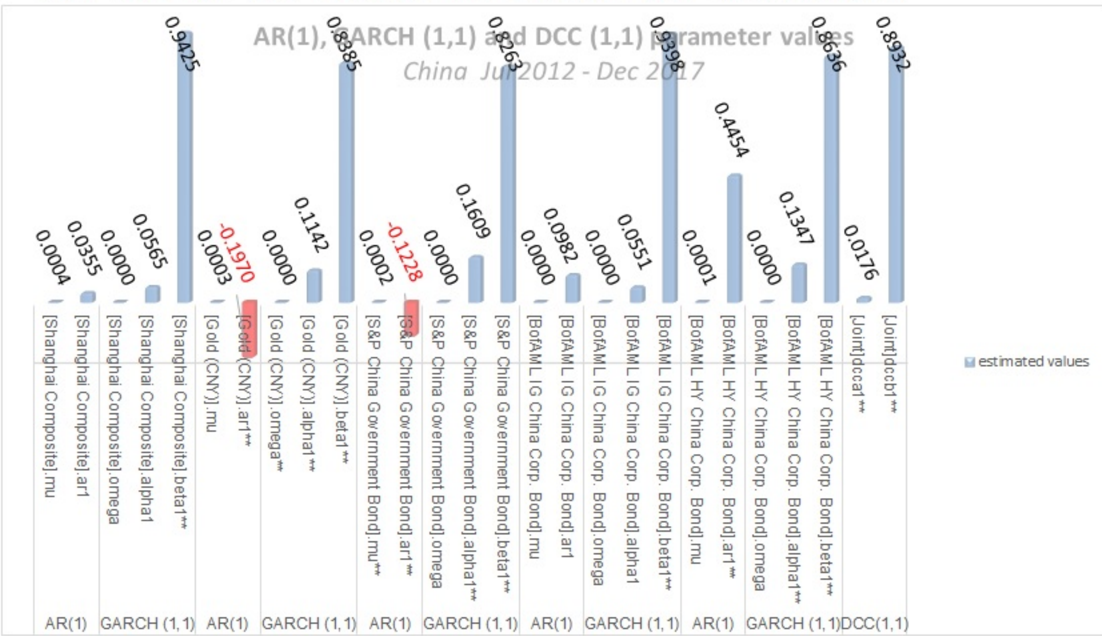


Fig. 29: Plots of the estimated values for the parameters of the AR(1), GARCH(1,1) and DCC(1,1) models for China. An asterisk behind a parameter name shows that referring estimated value is significant at a 5% significance level.

3 Appendix C

This section is an extension to section 5 of the paper. The more technical aspects will be discussed and shown here.

After examining the statistical properties of the financial time-series, we found stationary time-series in all cases. An ARCH effect, say heteroskedasticity, appeared to be present as well, because of which we are able to model the volatility according to a GARCH family member. We adopted the GARCH(1,1) model for modeling the conditional volatility as well as for modeling the dynamic conditional correlation, since it is the most commonly used lag specification for daily financial time-series as is discussed by Koima, Mwita, and Nassiuma (2015). We also modeled the first-order serial correlation of the financial time-series with an AR(1) model.

For each (sub-)sample, a plot is presented of the conditional mean estimates $\hat{\mu_t}$, the conditional volatility estimates estimates $\hat{\sigma_t}$ based on a GARCH (1,1) model and the estimates of the dynamic conditional correlation estimates $\hat{\rho_t}$ based on a DCC (1,1) model. Finally, the time-varying weight estimates of asset i in a portfolio, say $\hat{w_{it}}$, are estimated according to the mean-variance optimization concept of Markowitz as is discussed in section 4 and are depicted in each figure of a country as well. All of these plots can be found in appendix 3. An important remark regarding the notation of the time spans is that the notation *2004-2018* means that the sample runs from January 2004 until December 2017, which practically means till 2018. The notation *2008-2018* means that the time span runs from July 2008 until December 2017, and, the notation *2012-2018* means that the time span runs from July 2012 until December 2017.

General remarks are that the conditional means in the beginning of the sample seem to exhibit some fluctuating behaviour. This is because the parameter μ_t is based on 100 prior observations, however in the beginning of the sample the parameter has not that many data points to learn from causing largely biased estimates in the beginning. For the sake of interpretation, we can neglect the first few conditional parameters. Secondly, the values of parameters in estimated for the GARCH(1,1) model for the conditional volatility and parameter values for the DCC(1,1) can be found in appendix 2.

3.1 Sample period 2004-2018

3.1.1 United States

Considering the conditional mean in Figure 31, it is notable that at times the mean of gold and the mean of the S&P500 move in the same direction, whilst at other times they move in the opposite direction. The conditional mean of the returns of the stock market index S&P500 mostly touched negative values around the beginning of the Global Financial Crisis in 2008, whilst that of gold touched less extreme negative values and for a shorter period as well.

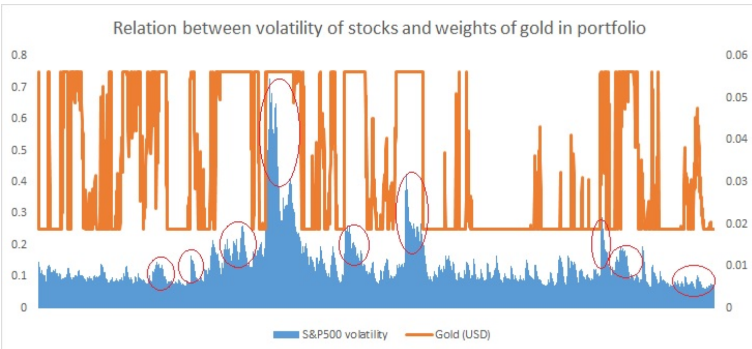


Fig. 30: Relation between the volatility on the S&P500 and the weights of gold attached in the portfolio. The left axis is a scale for the weights, whereas the right axis is a scale for the volatility. The red circles are the periods that are marked as volatile periods based on the above-average criterion.

A closer inspection of the graph of the conditional volatility shows that periods with relative higher volatility are more likely to occur when the conditional mean is negative. This is of course reasonable, as making losses will create panic on the market and therefore results in an increase of trading activity.

More interestingly is the graph of the dynamic conditional correlation in the sense to what extent the correlation between gold and the S&P500 changes as a consequence of being in relative higher volatile periods. In Table 31 the numeric results are shown for the complete sample period as well as for the sub-periods being selected as relative turbulent periods. On average, we find a positive dynamic correlation value of about 0.03 between the returns of stocks and the returns of gold for the full sample period 2004-2018. If we for instance take a closer look at the GFE-crisis period, we find that the maximum volatility on the stock market had been reached on October 16, 2008 with a rounded value of 0.055 being more than five times as high compared to the average volatility with a value of rounded 0.01, which is short after the collapse of the bank Lehman Brothers in September, 2008. If we look at the dynamic correlation between both return series around this high-volatile period, say from September 2008 until August 2009, it is remarkable that we find a negative value of about -0.006. Another relative high-volatile period is around half 2011 until the beginning of 2012. This gives again a negative correlation with an estimated value of about -0.009, which is almost twice as small as the correlation in the GFE crisis period. The volatility in this period might be a result of the *Budget Control Act of 2011* enacted in the beginning of August, 2011 in order to tackle the United States debt-ceiling crisis running at that moment. Another volatile period runs from approximately June 2015 until June 2016. This period is primarily marked as the global stock market sell-off period, which finds its cause by several factors such as a disappointing growth in the Gross Domestic Product (GDP) of China, decreasing oil prices, the default of the Greek's debt amid 2015, effect due to the nearby end of the Quantitative Easing program of the US, bond yields that were sharply increasing in the beginning of 2016 and last but not least the effects of the vote for the

Brexit by the United Kingdom in June 2016. The correlation belonging to this period also hits a negative value of -0.04. Based on this it seems that gold and the S&P500 are weakly positively correlated on average, whilst during turbulent periods they seem to exhibit relatively weak negative correlations close to nihil. This property is remarkable for a weak safe haven asset as introduced in section 2.

Table 31: Table of the estimated parameter results for the United States over the period Jan 2004 - Dec 2017, where relative volatile periods are highlighted.

	jan 2004 - dec 2017	sep 2008 - aug 2009	aug 2011 - jan 2012	jun 2015 - jun 2016
Average conditional mean S&P500	0.0002	-0.0017	-0.0008	-0.0001
Average conditional mean gold	0.0003	0.0002	0.0012	0.0002
Average volatility S&P500	0.0097	0.0250	0.0184	0.0097
Average DCC (gold,S&P500)	0.0282	-0.0059	-0.0084	-0.0391
Average weight of gold	0.4343	0.6557	0.7266	0.5044

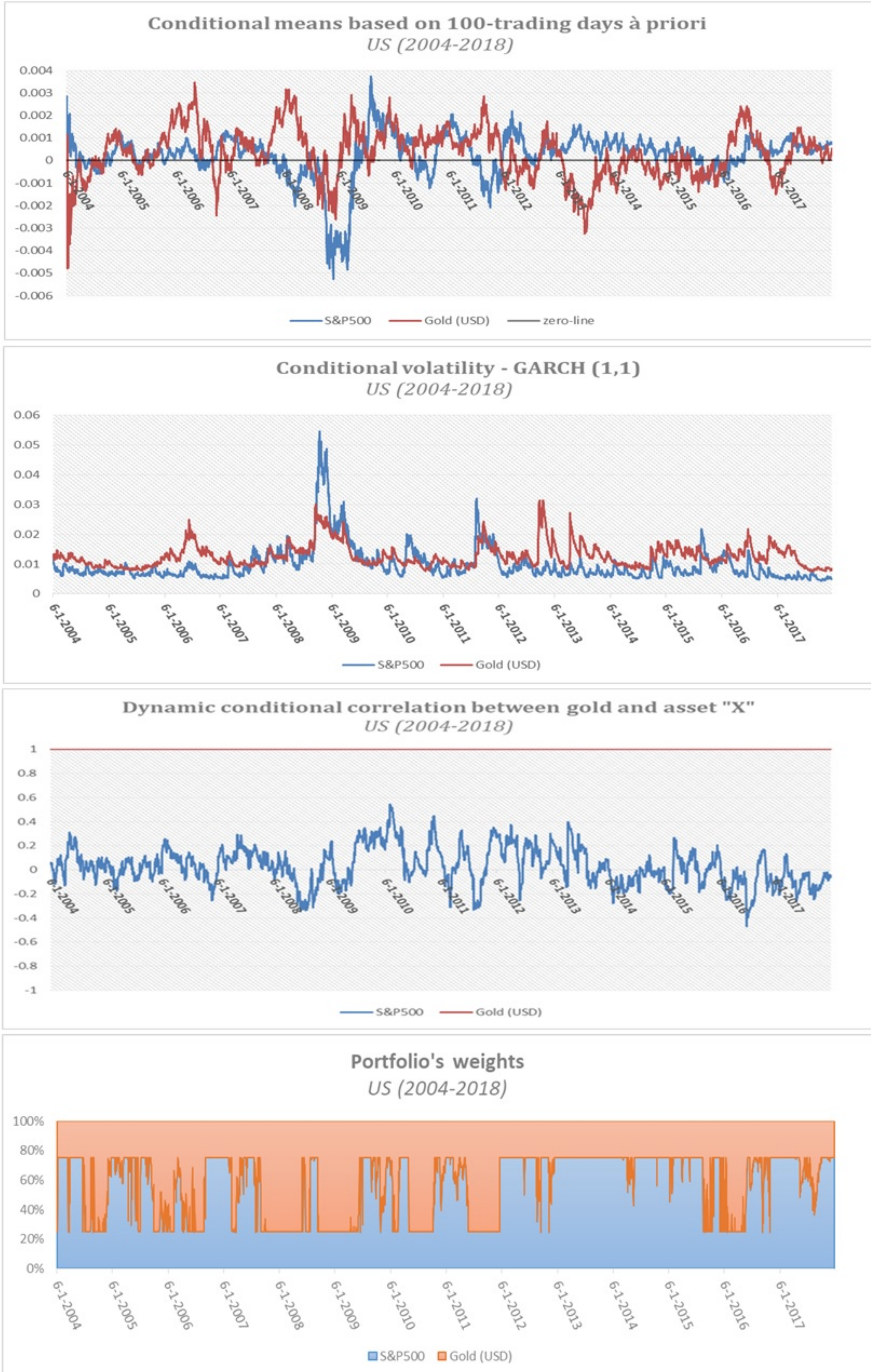


Fig. 31: Plots of the conditional mean based on prior 100 trading days, conditional volatility based on GARCH(1,1) model, dynamic conditional correlation based on the DCC(1,1) model and the portfolio weights based on the Markowitz portfolio optimization theorem where we imposed the restriction for short-selling. *Country: United States. Period: Jan 2004 - Dec 2017.*

3.1.2 United Kingdom

For the United Kingdom, we can find all numerical results in Table 32. Similar as in the case for the United States, it is notable that for the United Kingdom the conditional means of gold respectively the stock market FTSE100 at times move in tandem whilst at other times they move in the opposite direction. Obvious is that during the Global Financial Crisis period, the conditional mean of the FTSE100 touched an absolute minimum of approximately -0.005 on October 16, 2008 over this time interval where we neglect the first few observations for the conditional means. Visual inspection of Figure 33 shows that the conditional mean of gold is more likely to attain higher positive values than the stock market index FTSE100. It also seems that the negative conditional mean for the FTSE100 goes along with a relative higher volatility on the FTSE100 index. The average correlation between the weight of gold attached in a portfolio and the conditional volatility of the FTSE100 is 0.5314 suggesting that there is on average a moderate positive effect on the weight of gold when the volatility on the stock market rises. In light of this, we study several relative more volatile periods that surpass the threshold value set as the average volatility over the whole sample period of 0.0099 as is depicted in Figure 32 and Table 32.

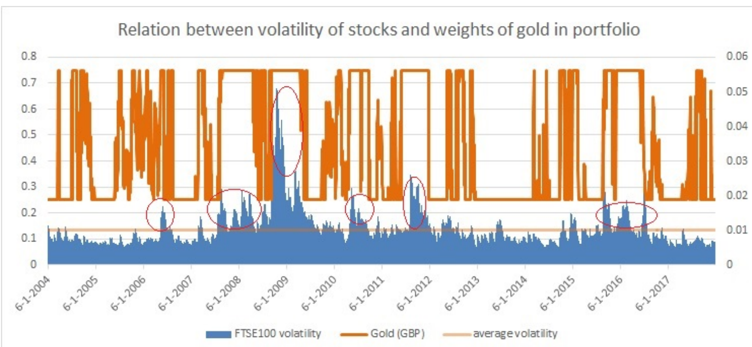


Fig. 32: Relation between the volatility on the FTSE100 and the weights of gold attached in the portfolio. The left axis is a scale for the weights, whereas the right axis is a scale for the volatility. The red circles are the periods that are marked as volatile periods based on the above-average criterion.

The first relative small volatility spike is notable on and around May 18, 2006 with a local maximum value of approximately 0.015. This volatility might be a result of the fear of rise of interest rate, which was taken as measure by central banks for rising inflation at that moment. For the estimation, the period of May 18, 2006 until June 19, 2006 is considered. The referring average conditional mean took a negative value close to zero. The average conditional mean of gold was at least double as high with a value of 0.0007 compared to its average conditional mean over the whole period with a value of 0.0003. The average volatility of the FTSE100 in this period lies roughly 46.2% higher with a value of approximately 0.0145 as compared to the average volatility over the whole period with a value of approximately 0.0099. The dynamic conditional correlation between gold and the FTSE100 was relatively high in this period with a value of approximately 0.32 compared to 0.08 as average dynamic conditional correlation over the whole sample period. This points on the intensification of the correlation between gold and stocks. From the definition of *safe haven asset* taking a perception from the correlation, we cannot conclude that gold functions as a safe haven asset in this period since the (dynamic conditional) correlation is positive. Gold functions rather as a diversification asset in this case.

The second period of relative high volatility is around August 2007 and September 2008, where we let the period range from August 1, 2007 until September 1, 2008. This volatility might be explained from the fact that it was a run up to the Global Financial Crisis. The average volatility during this sub-period is approximately 0.014, being roughly 40% higher than the average volatility over the whole sample period.It is notable that the average conditional mean of the FTSE100 was negative, whilst that of gold was roughly three times as high compared to the referring average over the whole sample period. The value of the (dynamic conditional) correlation in this period is relatively close to zero with a value of about 0.07. This comes close to the *weak safe haven* property of gold.

The third period deals with the peak period of the Global Financial crisis period.

We let the period range from September 15, 2008 until May 15, 2009. This volatility could be explained from the collapse of the Lehman Brothers in the United States entailing a global impact. The average volatility of the FTSE100 took on average value of approximately 0.025 being roughly 2.5 times bigger than the average volatility with a value of 0.01 over the whole sample period 2004-2018. It is notable that the average mean of the FTSE100 was negative in this period as well with a value of -0.002, whilst that of gold was positive with a value of 0.0011 and in addition appeared to be roughly 5 times larger than the average value 0.00034 over the whole sample period from January 2004 until December 2017. Along this period, it is notable that the DCC took on average a negative value of about -0.04, which is seemingly not far from no correlation although still negative. We can therefore classify gold as at least a weak safe haven asset, and, probably as a strong safe haven asset from the perception of correlations.

The fourth period during the period of May - August 2010 also strikes a volatile period with an average conditional volatility of 0.015 compared to 0.011 over the whole period. It is notable that a negative average conditional mean of the FTSE100 with a relative high average volatility for the FTSE100 touches a value of about 0.015. The average DCC value is -0.03, which suggests gold to function as at least a safe haven asset for the FTSE100.

The fifth period is defined from August 2011 till December 2011 shows that the conditional volatility of the FTSE100 in this period is on average 0.012, which is approximately 20% higher than the average conditional volatility of 0.01 over the whole sample period. It is notable that there is again a negative average conditional mean for the FTSE100 returns and a relative higher average conditional mean of returns of gold compared to the average over the whole sample period. A bit counter-intuitive is the value of the DCC in this period. It takes a positive value of 0.30, which indicates that it rather functions as a diversification asset instead as a safe haven asset.

The sixth period that we remarked as volatile period, ranges from August 2015 until September 2016. This period includes the period that the referendum for the Brexit was

Table 32: Table of the estimated parameter results for the United Kingdom over the period Jan 2004 - Dec 2017, where relative volatile periods are highlighted.

	Jan 2004 - Dec 2017	18 May 2006 - 19 Jun 2006	1 Aug 2007 - 1 Sep 2008	15 Sep 2008 - 15 May 2009	1 May - 1 Aug 2010	1 Aug - 1 Dec 2011	1 Aug 2015 - 1 Sep 2016
Average conditional mean FTSE100	0.00011	-0.00008	-0.00030	-0.00194	-0.00035	-0.00079	-0.00031
Average conditional mean gold	0.00034	0.00069	0.00106	0.00171	0.00141	0.00167	0.00093
Average volatility FTSE100	0.00994	0.01453	0.01350	0.02521	0.01477	0.01190	0.01168
Average DCC (gold,FTSE100)	0.07779	0.31533	0.06672	-0.04430	-0.03308	0.30038	-0.04935
Average weight of gold	0.45028	0.63759	0.66900	0.74067	0.73609	0.75000	0.61437

held. Furthermore, the average volatility of the FTSE100 with a value of 0.012 surpasses the average volatility of 0.01 by approximately 20%. Similar as in the previous volatile periods, a negative conditional mean of the FTSE100 returns has been found as well as an above average conditional mean for gold returns during this sub-period. With regard to the average DCC, we found a negative value of approximately -0.05. This signifies that gold functions as at least a weak safe haven asset for the FTSE100.

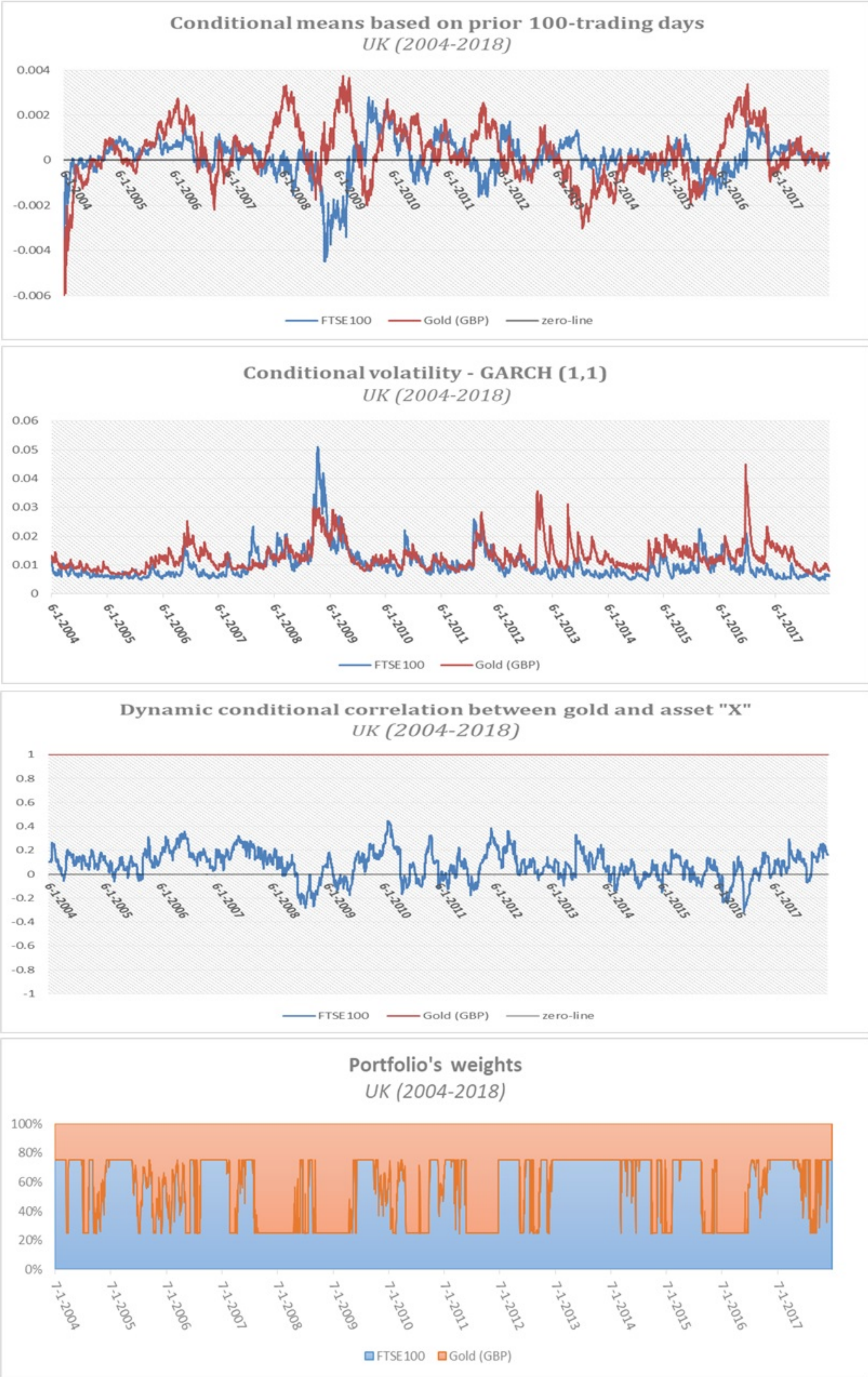


Fig. 33: Plots of the conditional mean based on prior 100 trading days, conditional volatility based on GARCH(1,1) model, dynamic conditional correlation based on the DCC(1,1) model and the portfolio weights based on the Markowitz portfolio optimization theorem where we imposed the restriction for short-selling. *Country: United Kingdom. Period: Jan 2004 - Dec 2017.*

3.1.3 Eurozone

It is notable that the average conditional volatility over the whole period is approximately 0.0124, with a maximum value of approximately 0.029 in the peak-period of the GFE-crisis, which is marked as the sub-period *5 Sep 2008 - 5 Aug 2009.* The correlation between the volatility on the stock market index Eurostoxx50 and the weight of gold in the portfolio, is 0.47.

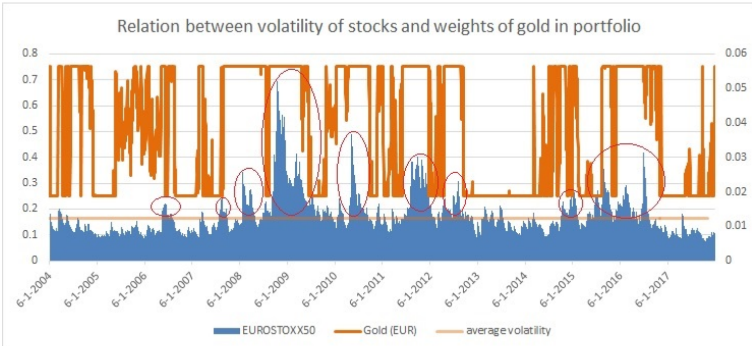


Fig. 34: Relation between the volatility on the EUROSTOXX50 and the weights of gold attached in the portfolio. The left axis is a scale for the weights, whereas the right axis is a scale for the volatility. The red circles are the periods that are marked as volatile periods based on the above-average criterion.

Table 33: Table of the estimated parameter results for the Eurozone over the period Jan 2004 - Dec 2017, where relative volatile periods are highlighted.

	Jan 2004 - Dec 2017	18 May 2006 - 23 Jun 2006	13 Aug 2007 - 13 Sep 2007	24 Jan 2008 - 24 Apr 2008	5 Sep 2008 - 5 Aug 2009	28 Apr 2010 - 8 Aug 2010	12 Jul 2011 - 18 Jan 2012	5 Apr 2012 - 11 Jun 2012	16 Oct 2014 - 26 Jan 2015	23 Jun 2015 - 29 Jul 2016
Average conditional mean EUROSTOXX50	0.00005	-0.00016	-0.00004	-0.00097	-0.00307	-0.00065	-0.00148	-0.00058	-0.00017	-0.00077
Average conditional mean gold	0.00029	0.00057	-0.00002	0.00138	0.00073	0.00168	0.00145	-0.00015	0.00033	0.00024
Average volatility EUROSTOXX50	0.01244	0.01507	0.01492	0.01741	0.02902	0.01925	0.02140	0.01491	0.01500	0.01586
Average DCC (gold,EUROSTOXX50)	-0.00813	0.20483	0.20469	0.06396	-0.14482	-0.13729	-0.13426	0.08432	0.01116	-0.05666
Average weight of gold	0.50049	0.59330	0.56438	0.75000	0.75000	0.75000	0.71548	0.62654	0.63185	0.63780

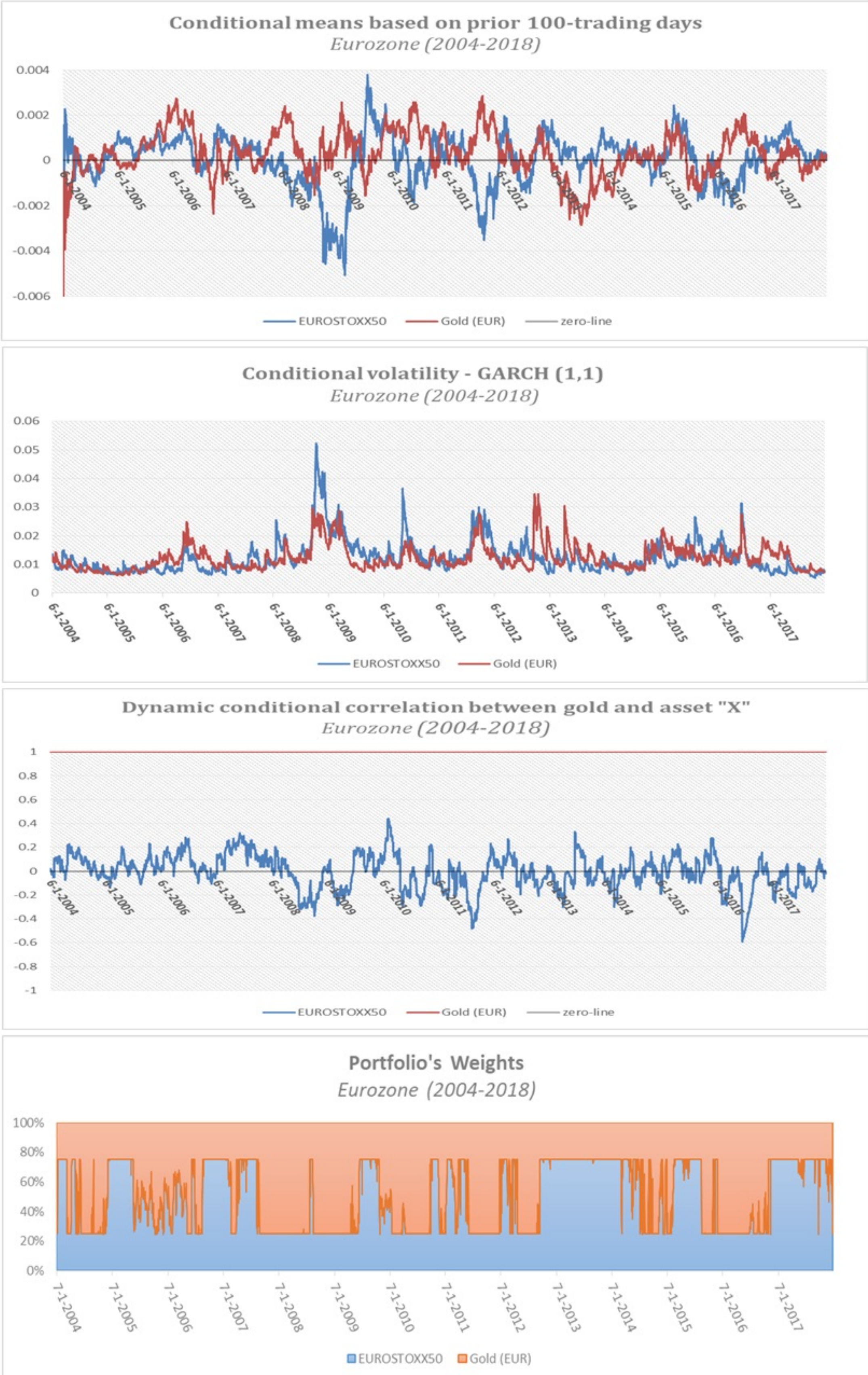


Fig. 35: Plots of the conditional mean based on prior 100 trading days, conditional volatility based on GARCH(1,1) model, dynamic conditional correlation based on the DCC(1,1) model and the portfolio weights based on the Markowitz portfolio optimization theorem where we imposed the restriction for short-selling. *Country: Eurozone. Period: Jan 2004 - Dec 2017.*

To begin with, it is notable in Table 33 that the conditional mean of the EUROSTOXX50 is negative for all sub-periods that are marked as high-volatile periods. The average conditional mean of gold in the sub-periods, however, is sometimes higher and other times lower than the average conditional mean of gold over the whole sample period. In some cases, it even takes negative values which is a bit counter-intuitive in turbulent periods on the stock market.

The average DCC value is -0.008, which means that gold is on average hardly or negatively correlated with the stock market index S&P500, which signifies as a hedge asset. A closer inspection of Table 33 shows that in some cases gold functions as a safe haven asset due to the positive correlation with the S&P500, and, in other cases as a safe haven asset due to the negative correlation. Notably is that the average DCC is relatively strongly negative around the GFE-period from 2008-2011. In the period Jun 2015 - Jul 2016, around the Brexit period, the average DCC was negative as well, however, relatively close to nihil.

3.1.4 Brazil

To begin with Table 34, it is notable that the average conditional mean of the Ibovespa is in six out of the twelve sub-periods negative. In the remaining six sub-periods, the average conditional mean of the Ibovespa is positive but also relatively higher than the average over the whole sample period. Based on the information of the volatility, it is not really clear how to determine when the conditional means would be positive respectively negative. The average conditional mean of gold's returns is positive in almost all cases, where the relatively highest values can be found in the peak-period of the GFE-crisis in period *05 Sep 2008 - 02 Jul 2009* (0.0016), the period *05 Aug 2011 - 16 Nov 2011* (0.0026) and finally in the period *19 May 2017 - 09 Jun 2017* (0.0016).

The average conditional volatility of the Ibovespa over the whole sample period is approximately 0.0163, where the relatively highest average conditional volatility is in the sub-period *05 Sep 2008 - 02 Jul 2009* (0.031), say, in the peak-period of the GFE-crisis.

Considering the average DCC of Brazil, it is notable that the average dynamic correlation between the stock market index Ibovespa's returns and the returns of gold are negative. From the perspective of correlation, it implies that gold is a hedge as well as a safe haven asset for the Ibovespa, because the correlation is negative on average over the whole sample period and on average during turbulent periods. The average DCC value over the whole sample period is approximately -0.22, where the relatively lowest value of the average DCC can be found in sub-period *19 May 2017 - 09 Jun 2017* (-0.61). In combination with the relative high average conditional volatility of the Ibovespa in this period, and, the relative high conditional mean return of gold, it might be a result of the elections that were coming up in Brazil in October 2017 accompanying the uncertainty on the Brazilian financial market.

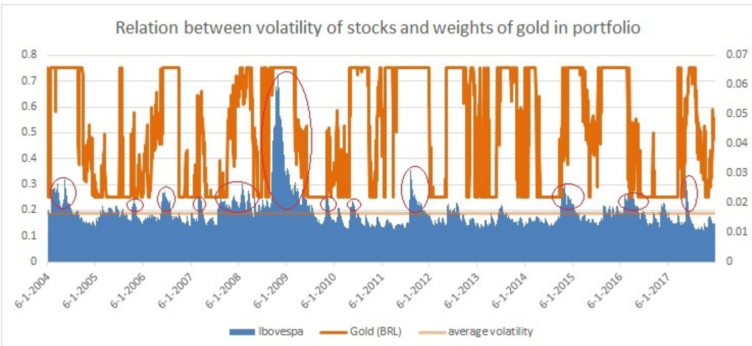


Fig. 36: Relation between the volatility on the Ibovespa and the weights of gold attached in the portfolio. The left axis is a scale for the weights, whereas the right axis is a scale for the volatility. The red circles are the periods that are marked as volatile periods based on the above-average criterion.

Table 34: Table of the estimated parameter results for Brazil over the period Jan 2004 - Dec 2017, where relative volatile periods are highlighted.

	Jan 2004 - Dec 2017	30 Jan 2004 - 30 Jun 2004	07 Oct 2005 - 09 Nov 2005	26 May 2006 - 01 Aug 2006	28 Feb 2007 - 03 Apr 2007	27 Jul 2007 - 10 Apr 2008	05 Sep 2008 - 02 Jul 2009	29 Oct 2009 - 30 Nov 2009	11 May 2010 - 15 Jun 2010	05 Aug 2011 - 16 Nov 2011	30 Sep 2014 - 26 Jan 2015	01 Feb 2016 - 20 May 2016	19 May 2017 - 09 Jun 2017
Average conditional mean Ibovespa	0.00025	-0.00211	0.00182	-0.00083	0.00118	0.00137	-0.00151	0.00235	-0.00119	-0.00155	-0.00054	0.00039	0.00049
Average conditional mean gold	0.00039	-0.00013	0.00008	0.00079	0.00050	0.00087	0.00162	0.00020	0.00085	0.00255	0.00046	0.00040	0.00156
Average volatility Ibovespa	0.01633	0.02128	0.01896	0.02033	0.02064	0.01941	0.03055	0.02106	0.01863	0.02098	0.02072	0.02025	0.02198
Average DCC (gold,Ibovespa)	-0.21496	-0.11087	-0.30095	-0.18304	-0.22998	-0.26506	-0.36811	-0.28582	-0.39593	-0.34143	-0.22880	-0.32895	-0.61084
Average weight of gold	0.50535	0.74690	0.40524	0.72550	0.50618	0.51829	0.62189	0.39495	0.74899	0.75000	0.63121	0.50088	0.60501
Correlation (gld_weight, vol stock)	0.29029												

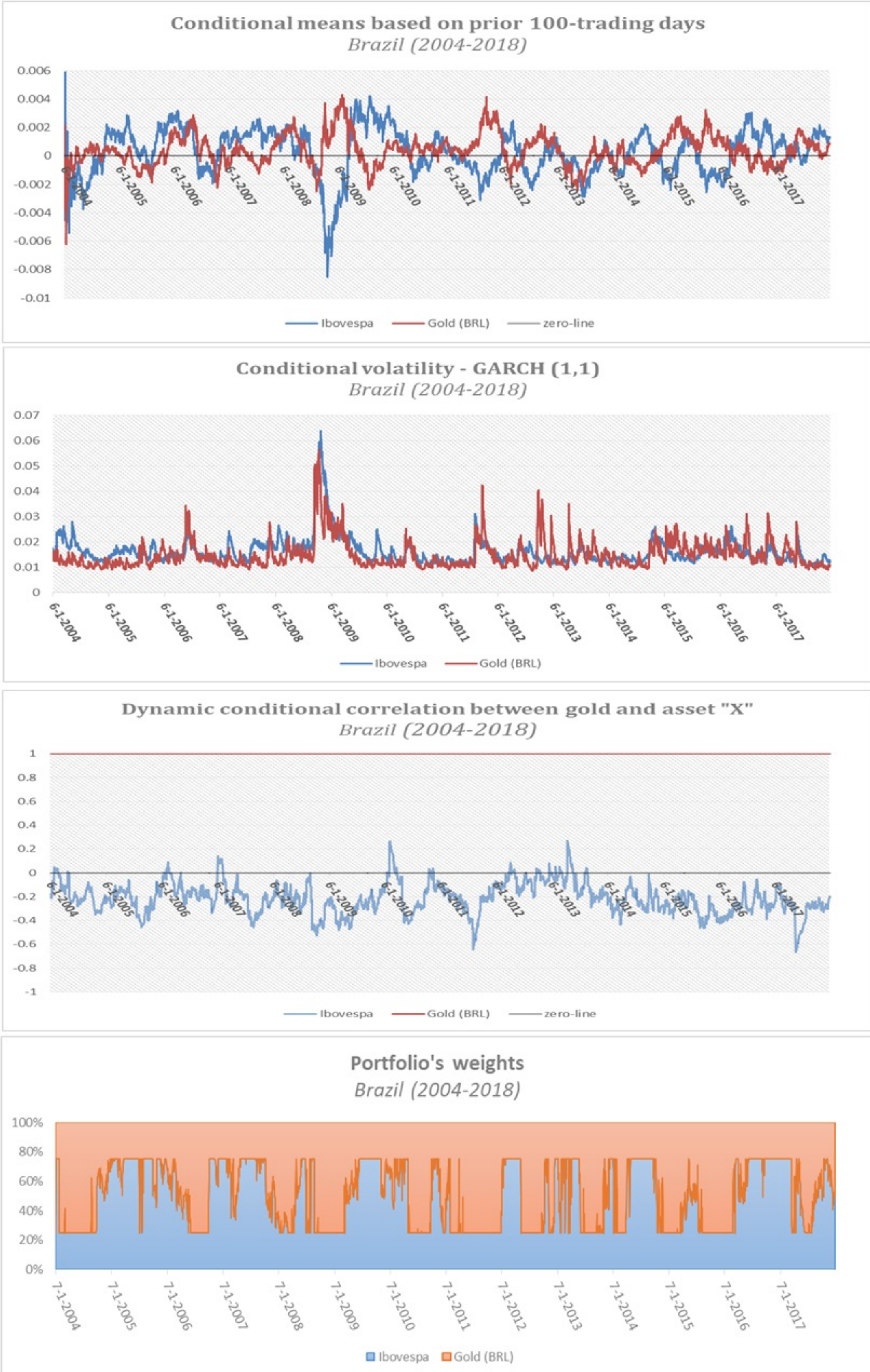


Fig. 37: Plots of the conditional mean based on prior 100 trading days, conditional volatility based on GARCH(1,1) model, dynamic conditional correlation based on the DCC(1,1) model and the portfolio weights based on the Markowitz portfolio optimization theorem where we imposed the restriction for short-selling. *Country: Brazil. Period: Jan 2004 - Dec 2017.*

3.1.5 Russia

For Russia, part of the average conditional mean returns of the MOEX in the volatile sub-periods is negative, and, the other part positive. Given the referring information about its volatility, there is no real link to be found why some are positive and other negative. From the economic theory, it would be logical to have a negative sign in the returns on average when the volatility is relatively higher. The average conditional mean of gold returns are for all except one sub-period: *22 Apr 2004 - 25 Aug 2004* positive and relatively higher than the average over the whole sample period (0.00046).

With regards to the volatility, it is notable that the average volatility of the MOEX over the whole sample period is approximately 0.017. The average volatility was relatively the highest in sub-period *18 Jul 2008 - 09 Dec 2009* (0.038), which was the peak-period of the GFE-crisis.

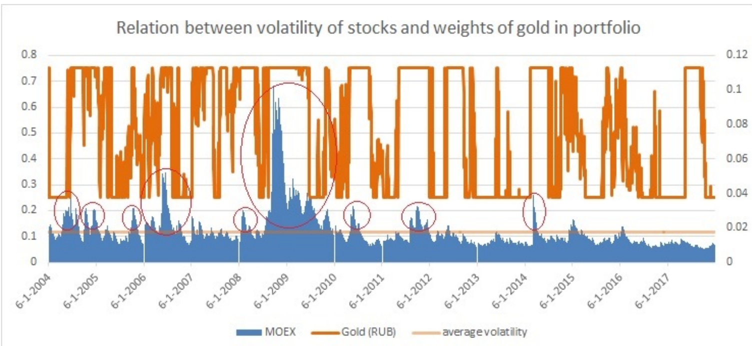


Fig. 38: Relation between the volatility on the MOEX and the weights of gold attached in the portfolio. The left axis is a scale for the weights, whereas the right axis is a scale for the volatility. The red circles are the periods that are marked as volatile periods based on the above-average criterion.

The average DCC between gold and the MOEX over the whole sample period is negative with a value of approximately -0.012. This signifies that gold was a hedge asset. By considering the high-volatile sub-samples, it is notable that 5 out of the 9 sub-samples had a positive correlation implying that gold was a diversifier asset for the

MOEX. The remaining sub-samples from *18 Jul 2008* onwards took a negative sign, with relatively the smallest value in the sub-sample period *04 Mar 2014 - 09 Apr 2014*. The latter might be explained from the annexation of the Crimea by the Russian country at that time, which went along with international sanctions on Russia.

Table 35: Table of the estimated parameter results for Russia over the period Jan 2004 - Dec 2017, where relative volatile periods are highlighted.

	Jan 2004 - Dec 2017	22 Apr 2004 - 25 Aug 2004	04 Oct 2004 - 21 Jan 2005	28 Sep 2005 - 18 Nov 2005	11 Jan 2006 - 17 Oct 2006	24 Jan 2008 - 31 Mar 2008	18 Jul 2008 - 09 Dec 2009	05 May 2010 - 16 Jul 2010	09 Aug 2011 - 23 Dec 2011	04 Mar 2014 - 09 Apr 2014
Average conditional mean MOEX	0.00034	-0.00045	0.00099	0.00355	0.00168	0.00032	-0.00116	-0.00069	-0.00159	-0.00134
Average conditional mean gold	0.00046	-0.00053	0.00080	0.00109	0.00067	0.00184	0.00135	0.00141	0.00220	0.00064
Average volatility MOEX	0.01739	0.02523	0.02294	0.02414	0.02428	0.02246	0.03774	0.02249	0.02225	0.02695
Average DCC (gold,MOEX)	-0.01217	0.11520	0.10996	0.03412	0.18603	0.09538	-0.03545	-0.07269	-0.14863	-0.38442
Average weight of gold	0.50489	0.56418	0.73118	0.59755	0.55190	0.75000	0.61558	0.75000	0.75000	0.75000
Correlation (gld_weight, vol stock)	0.38473									

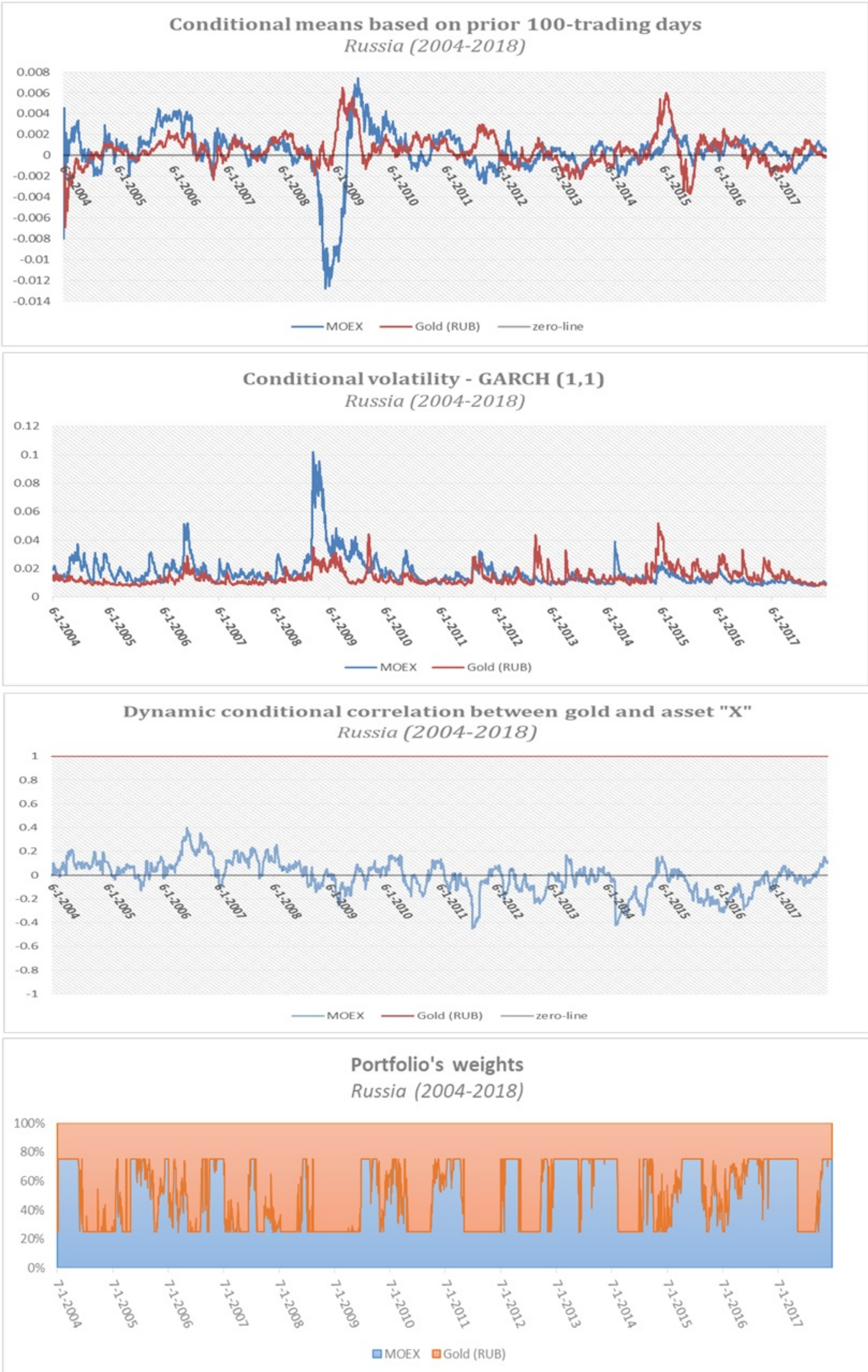


Fig. 39: Plots of the conditional mean based on prior 100 trading days, conditional volatility based on GARCH(1,1) model, dynamic conditional correlation based on the DCC(1,1) model and the portfolio weights based on the Markowitz portfolio optimization theorem where we imposed the restriction for short-selling. *Country: Russia. Period: Jan 2004 - Dec 2017.*

3.1.6 India

Also for India it is remarkable in Table 36 that the conditional mean of the stock index returns, i.e. BSE SENSEX30, is inconclusive for the volatile sub-periods. Again, some are positive and some are negative without a clear relation with the volatility. The average conditional mean of gold returns has the relatively highest positive value (0.0021) in the latter stage of the GFE-crisis, which is in this case sample period *30 Aug 2011 - 03 Nov 2011*.

The average conditional volatility on the BSE SENSEX30 over the whole sample period is approximately 0.013. The sub-sample with relatively the highest value (0.026) is *12 May 2004 - 15 Jul 2004*. This in combination with its referring negative conditional mean as in Table 36 might be explained from the general Indian election occurring at that time, where the Indian National Congres (INC) won against expectations of the observers.

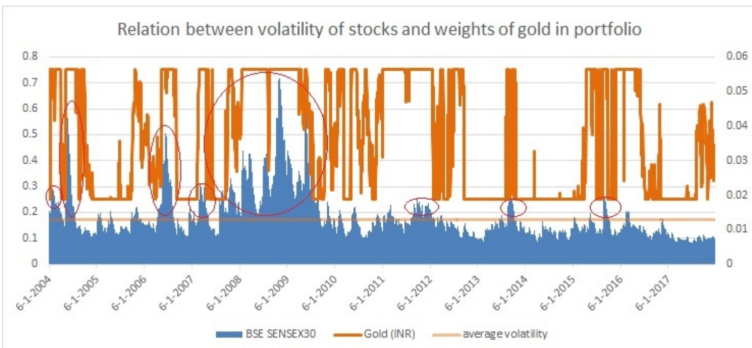


Fig. 40: Relation between the volatility on the BSE SENSEX30 and the weights of gold attached in the portfolio. The left axis is a scale for the weights, whereas the right axis is a scale for the volatility. The red circles are the periods that are marked as volatile periods based on the above-average criterion.

The average DCC is a negative value close to zero implying that gold functions as a (weak) hedge asset. Along the volatile sub-sample periods, it sometimes functions as a diversifier asset when the correlation is positive, and, other times as safe haven asset when the correlation is negative. There is no conclusive remark to make about the characteristic of gold as safe haven asset from the perspective of correlations.

Table 36: Table of the estimated parameter results for India over the period Jan 2004 - Dec 2017, where relative volatile periods are highlighted.

	Jan 2004 - Dec 2017	28 Jan 2004 - 24 Mar 2004	12 May 2004 - 15 Jul 2004	27 Apr 2006 - 10 Aug 2006	1 Mar 2007 - 25 Apr 2007	2 Aug 2007 - 17 Nov 2009	30 Aug 2011 - 03 Nov 2011	19 Aug 2013 - 04 Oct 2013	25 Aug 2015 - 15 Sep 2015
Average conditional mean BSE SENSEX30	0.00041	-0.00306	-0.00159	0.00106	0.00003	0.00019	-0.00108	-0.00023	-0.00084
Average conditional mean gold	0.00051	-0.00182	-0.00051	0.00163	0.00054	0.00149	0.00212	0.00034	-0.00006
Average volatility BSE SENSEX30	0.01303	0.01754	0.02580	0.02405	0.01906	0.02271	0.01624	0.01738	0.01846
Average DCC (gold,BSE SENSEX30)	-0.05573	0.04975	-0.10569	0.18656	0.05778	-0.08531	-0.02556	-0.15693	-0.16431
Average weight of gold	0.48095	0.74145	0.74082	0.66936	0.73296	0.62099	0.75000	0.64708	0.75000
Correlation (gld_weight, vol stock)	0.51853								

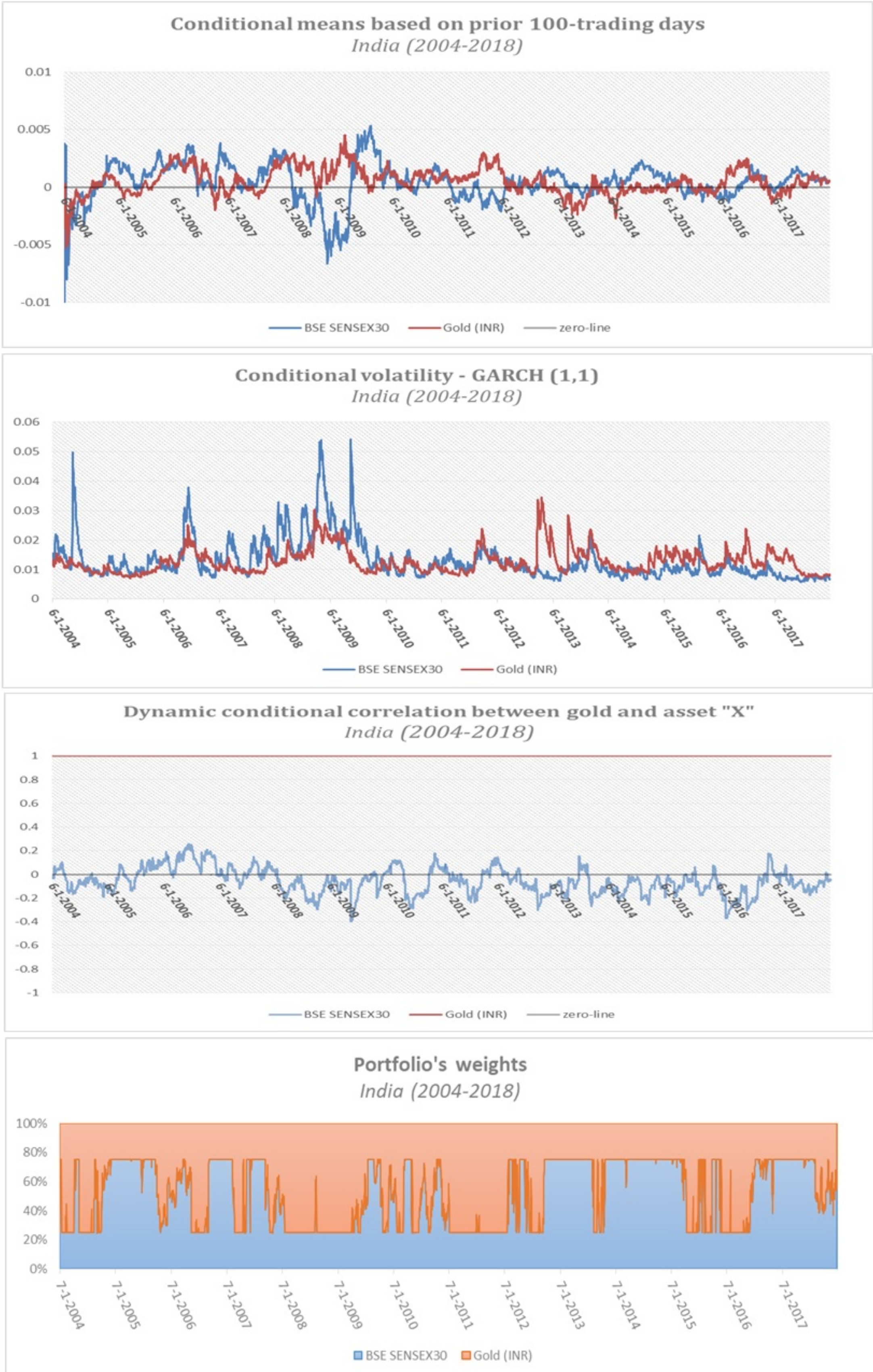


Fig. 41: Plots of the conditional mean based on prior 100 trading days, conditional volatility based on GARCH(1,1) model, dynamic conditional correlation based on the DCC(1,1) model and the portfolio weights based on the Markowitz portfolio optimization theorem where we imposed the restriction for short-selling. *Country: India. Period: Jan 2004 - Dec 2017.*

3.1.7 China

The average conditional mean of the Shanghai Composite index' returns is in one-third of the volatile sub-samples negative, and, in two-third of the sub-samples positive. The average conditional mean of gold returns is in seven cases positive, and, in two cases negative.

The average volatility of the Shanghai Composite index over the whole sample period, as visible in Table 37 and in Figure 42, is approximately 0.0152. Periods with relatively the highest volatility are the peak-period of the GFE-crisis *04 Jan 2007 - 22 May 2009*, and, in the sub-period *17 Apr 2015 - 22 Apr 2016* which contained the *Chinese stock market turbulence* period.

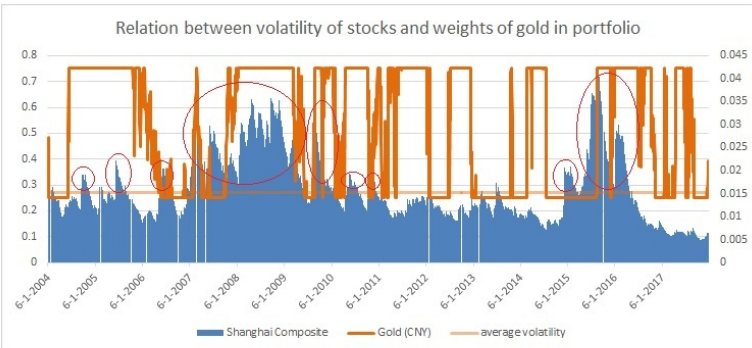


Fig. 42: Relation between the volatility on the Shanghai Composite and the weights of gold attached in the portfolio. The left axis is a scale for the weights, whereas the right axis is a scale for the volatility. The red circles are the periods that are marked as volatile periods based on the above-average criterion.

The average DCC is a positive value of approximately 0.039, which implies that gold is a diversifier asset for the Shanghai Composite Index. It only takes a negative value in the post-period of the GFE-crisis *18 May 2010 - 23 Jul 2010*, implying that it functioned as a (weak) safe haven in that period.

Table 37: Table of the estimated parameter results for China over the period Jan 2004 - Dec 2017, where relative volatile periods are highlighted.

	Jan 2004 - Dec 2017	16 Sep 2004 - 16 Nov 2004	09 Jun 2005 - 01 Aug 2005	15 May 2006 - 26 Jul 2006	04 Jan 2007 - 22 May 2009	30 Jul 2009 - 31 Dec 2009	18 May 2010 - 23 Jul 2010	15 Nov 2010 - 03 Dec 2010	09 Dec 2014 - 06 Mar 2015	17 Apr 2015 - 22 Apr 2016
Average conditional mean Shang. Comp.	0.00025	-0.00156	-0.00170	0.00289	0.00035	0.00138	-0.00192	0.00108	0.00364	0.00014
Average conditional mean gold	0.00020	0.00090	0.00001	0.00088	0.00043	0.00088	0.00053	0.00036	-0.00019	-0.00010
Average volatility Shang. Comp.	0.01517	0.01701	0.01845	0.01745	0.02447	0.02028	0.01681	0.01774	0.01847	0.02486
Average DCC (gold,Shang. Comp.)	0.03903	0.02796	0.04769	0.03370	0.04200	0.09497	-0.01219	0.15639	0.02921	0.00467
Average weight of gold	0.52213	0.75000	0.75000	0.26932	0.57942	0.62250	0.75000	0.37914	0.25000	0.56217
Correlation (gld_weight, vol stock)	0.19948									

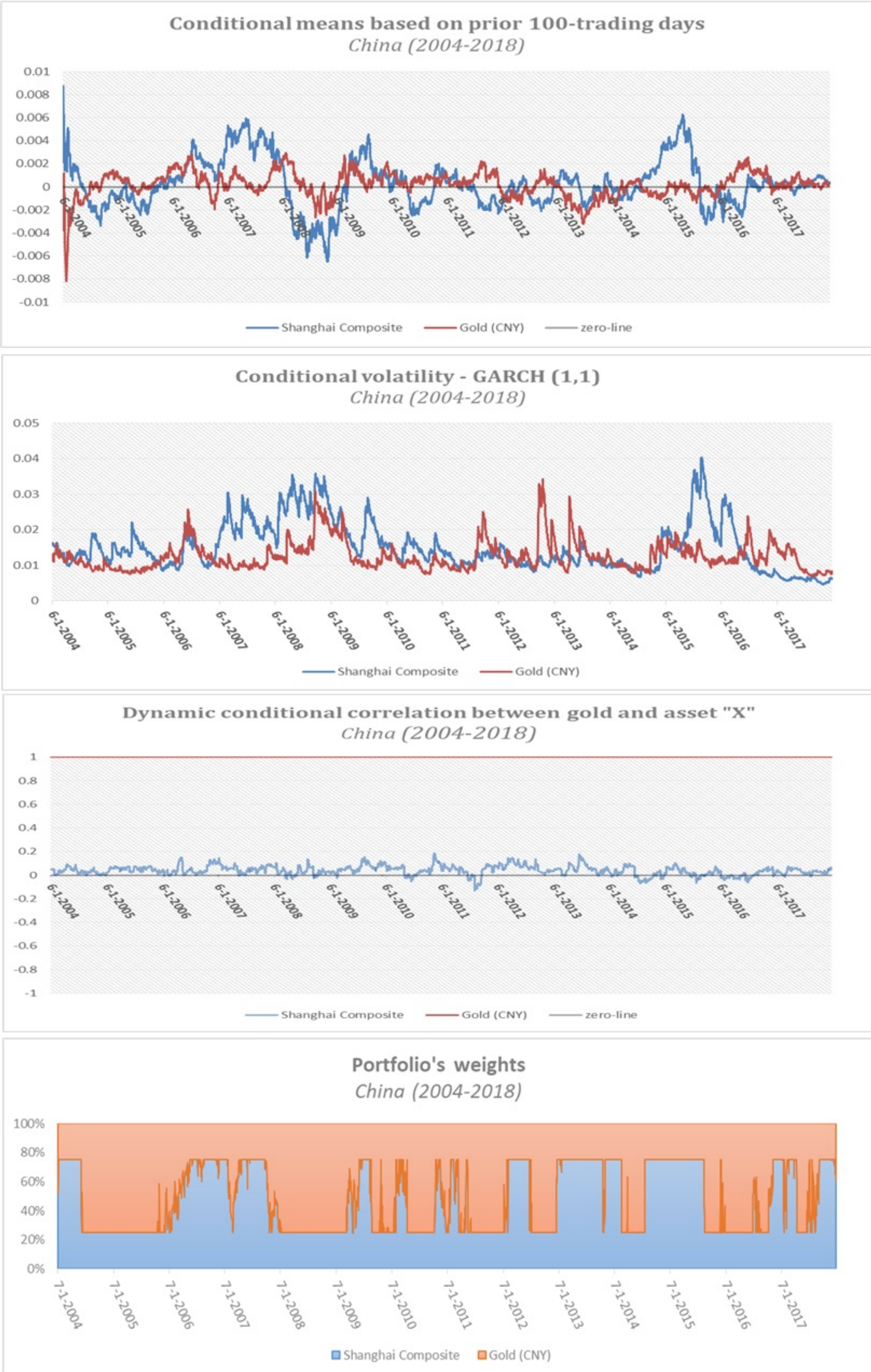


Fig. 43: Plots of the conditional mean based on prior 100 trading days, conditional volatility based on GARCH(1,1) model, dynamic conditional correlation based on the DCC(1,1) model and the portfolio weights based on the Markowitz portfolio optimization theorem where we imposed the restriction for short-selling. *Country: China. Period: Jan 2004 - Dec 2017.*

3.2 Sample period 2008-2018

3.2.1 United States

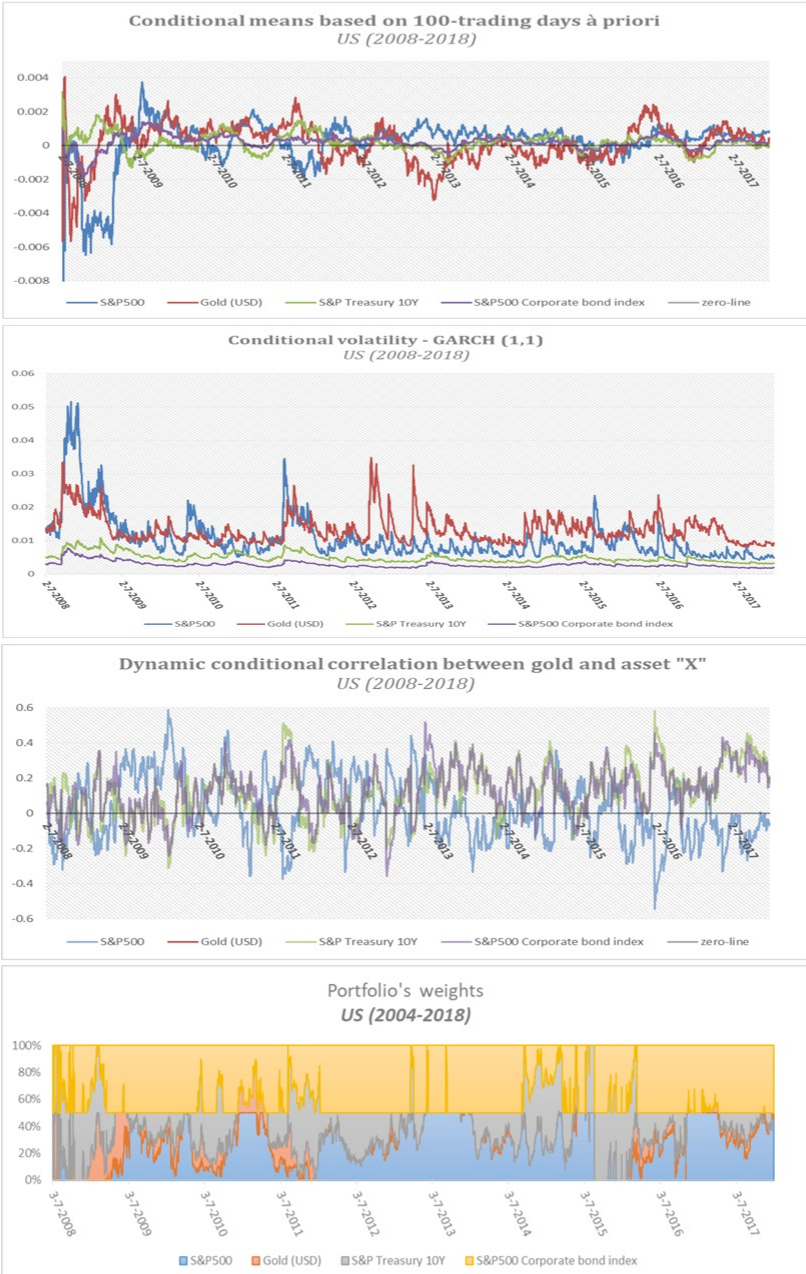


Fig. 44: Plots of the conditional mean based on prior 100 trading days, conditional volatility based on GARCH(1,1) model, dynamic conditional correlation based on the DCC(1,1) model and the portfolio weights based on the Markowitz portfolio optimization theorem where we imposed the restriction for short-selling. *Country: United States. Period: Jul 2008 - Dec 2017.*

3.2.2 United Kingdom

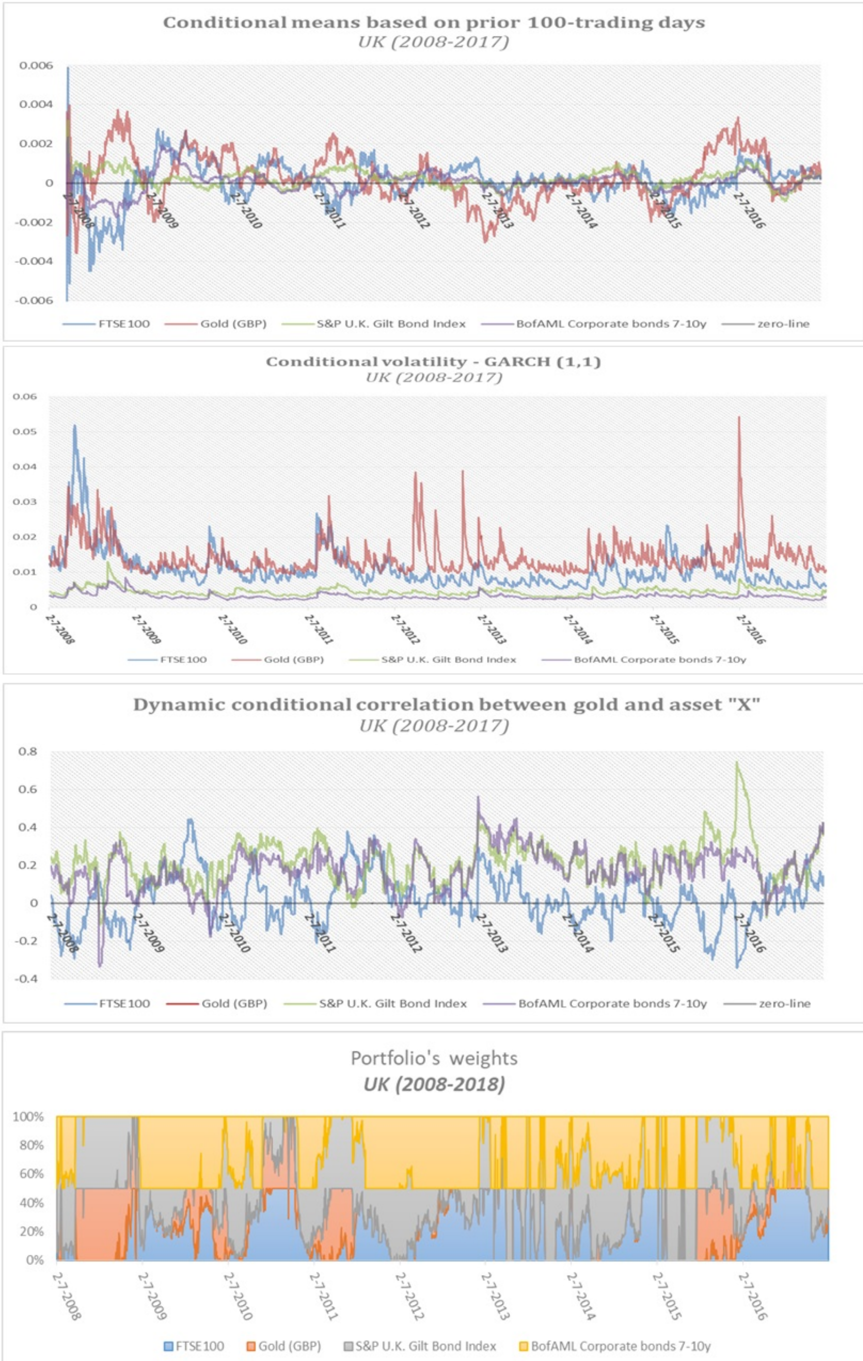


Fig. 45: Plots of the conditional mean based on prior 100 trading days, conditional volatility based on GARCH(1,1) model, dynamic conditional correlation based on the DCC(1,1) model and the portfolio weights based on the Markowitz portfolio optimization theorem where we imposed the restriction for short-selling. *Country: United Kingdom. Period: Jul 2008 - Dec 2017.*

3.2.3 Eurozone

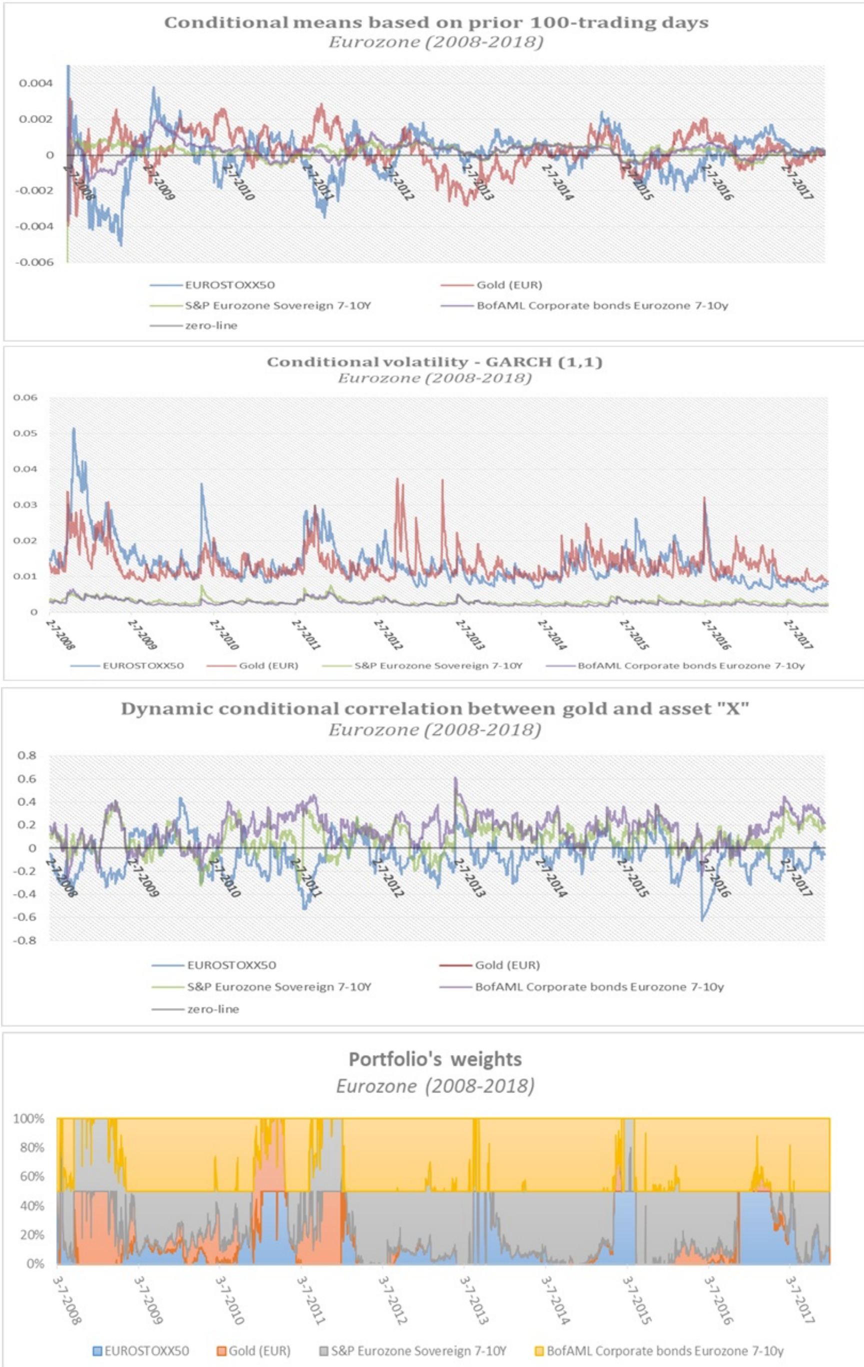


Fig. 46: Plots of the conditional mean based on prior 100 trading days, conditional volatility based on GARCH(1,1) model, dynamic conditional correlation based on the DCC(1,1) model and the portfolio weights based on the Markowitz portfolio optimization theorem where we imposed the restriction for short-selling. *Country: Eurozone. Period: Jul 2008 - Dec 2017.*

3.2.4 Brazil

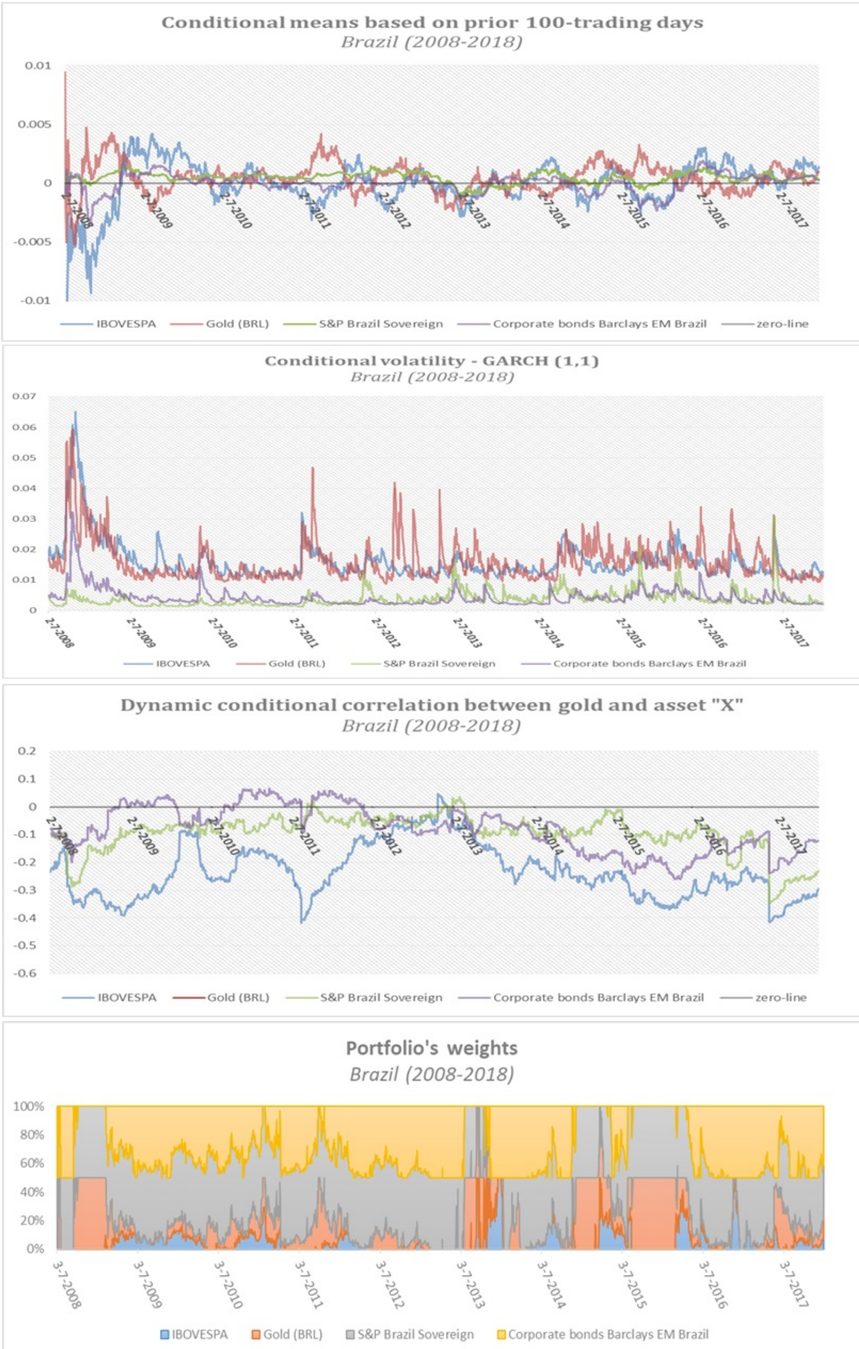


Fig. 47: Plots of the conditional mean based on prior 100 trading days, conditional volatility based on GARCH(1,1) model, dynamic conditional correlation based on the DCC(1,1) model and the portfolio weights based on the Markowitz portfolio optimization theorem where we imposed the restriction for short-selling. *Country: Brazil. Period: Jul 2008 - Dec 2017.*

3.2.5 Russia

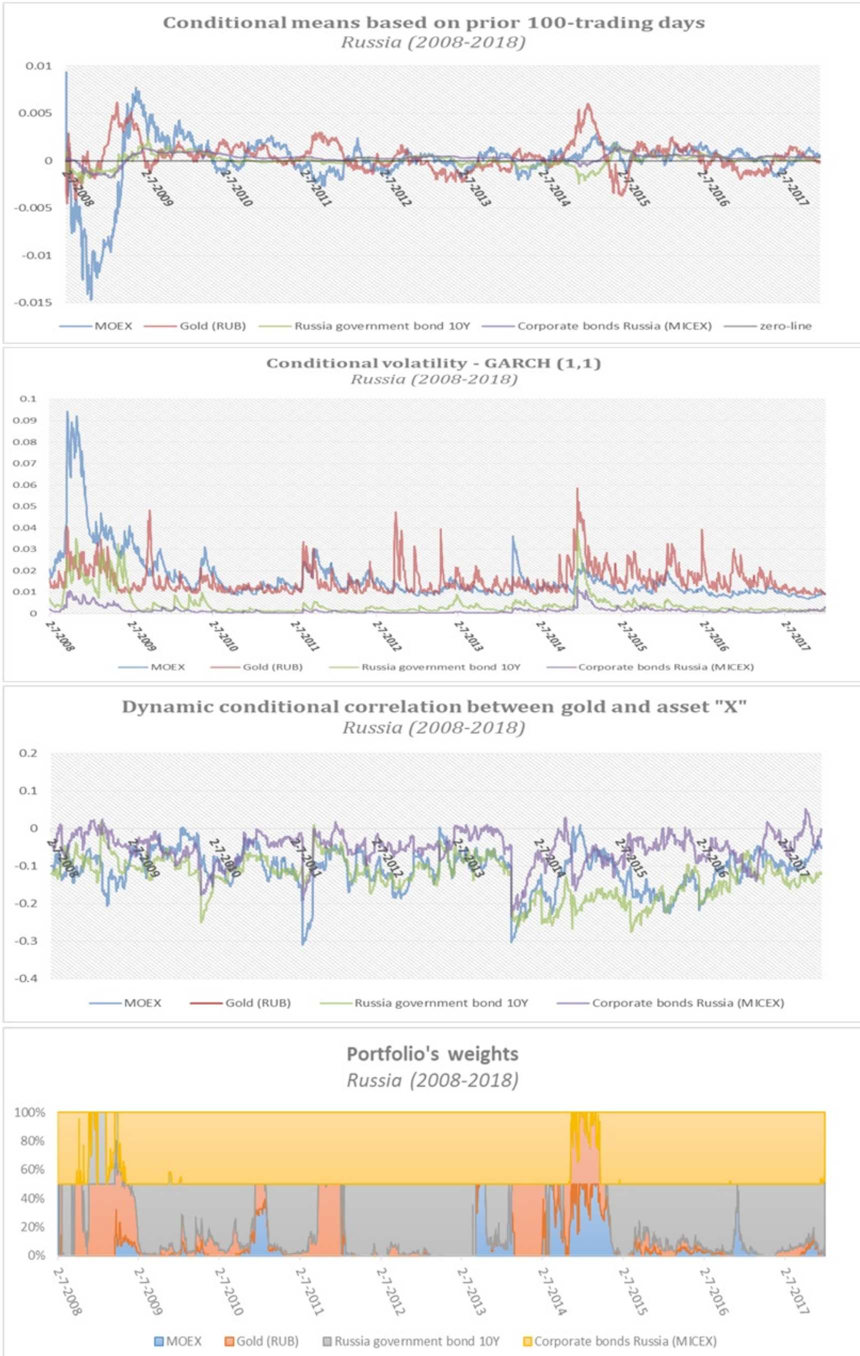


Fig. 48: Plots of the conditional mean based on prior 100 trading days, conditional volatility based on GARCH(1,1) model, dynamic conditional correlation based on the DCC(1,1) model and the portfolio weights based on the Markowitz portfolio optimization theorem where we imposed the restriction for short-selling. *Country: Russia. Period: Jul 2008 - Dec 2017.*

3.2.6 India

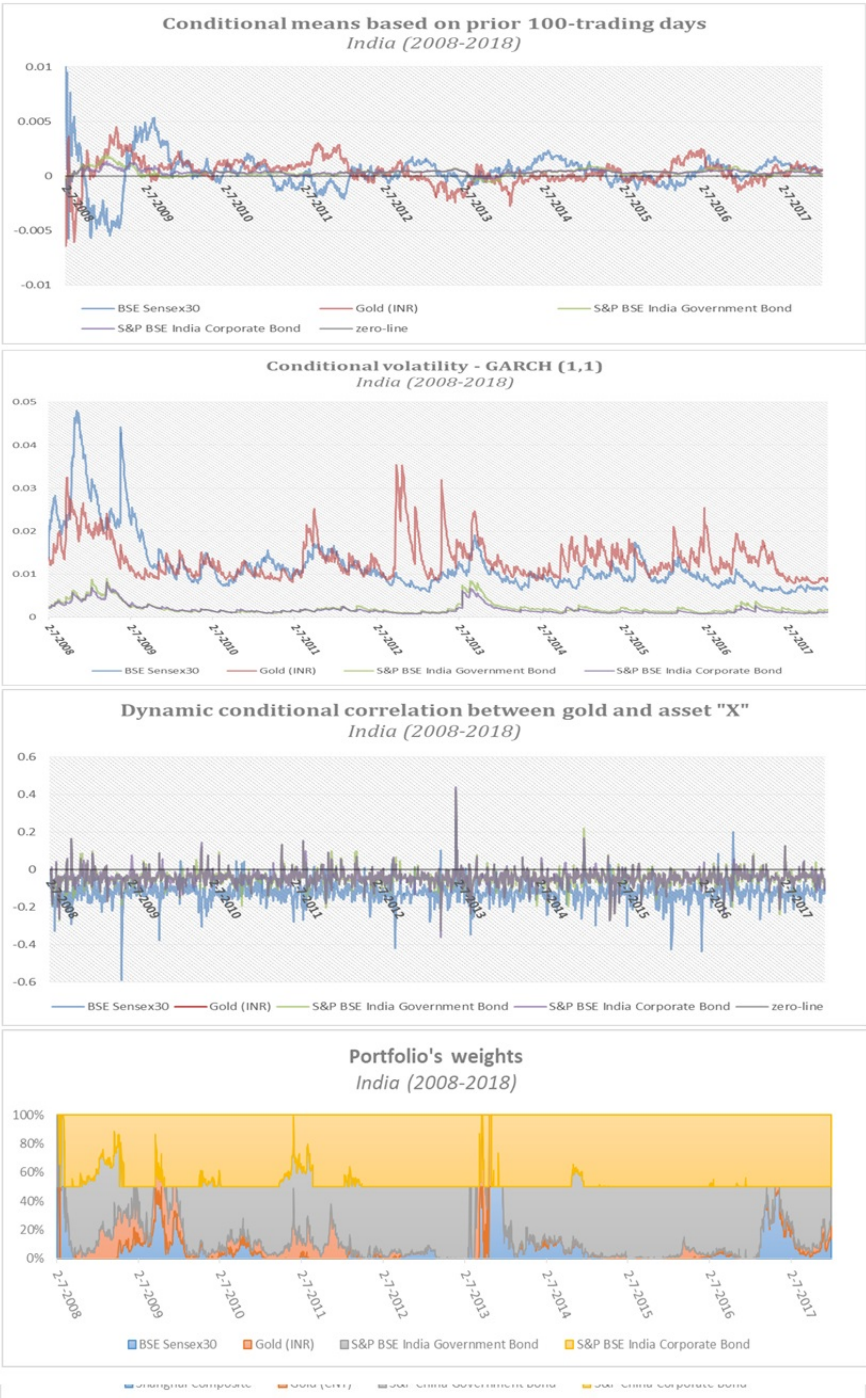


Fig. 49: Plots of the conditional mean based on prior 100 trading days, conditional volatility based on GARCH(1,1) model, dynamic conditional correlation based on the DCC(1,1) model and the portfolio weights based on the Markowitz portfolio optimization theorem where we imposed the restriction for short-selling. *Country: India. Period: Jul 2008 - Dec 2017.*

3.2.7 China

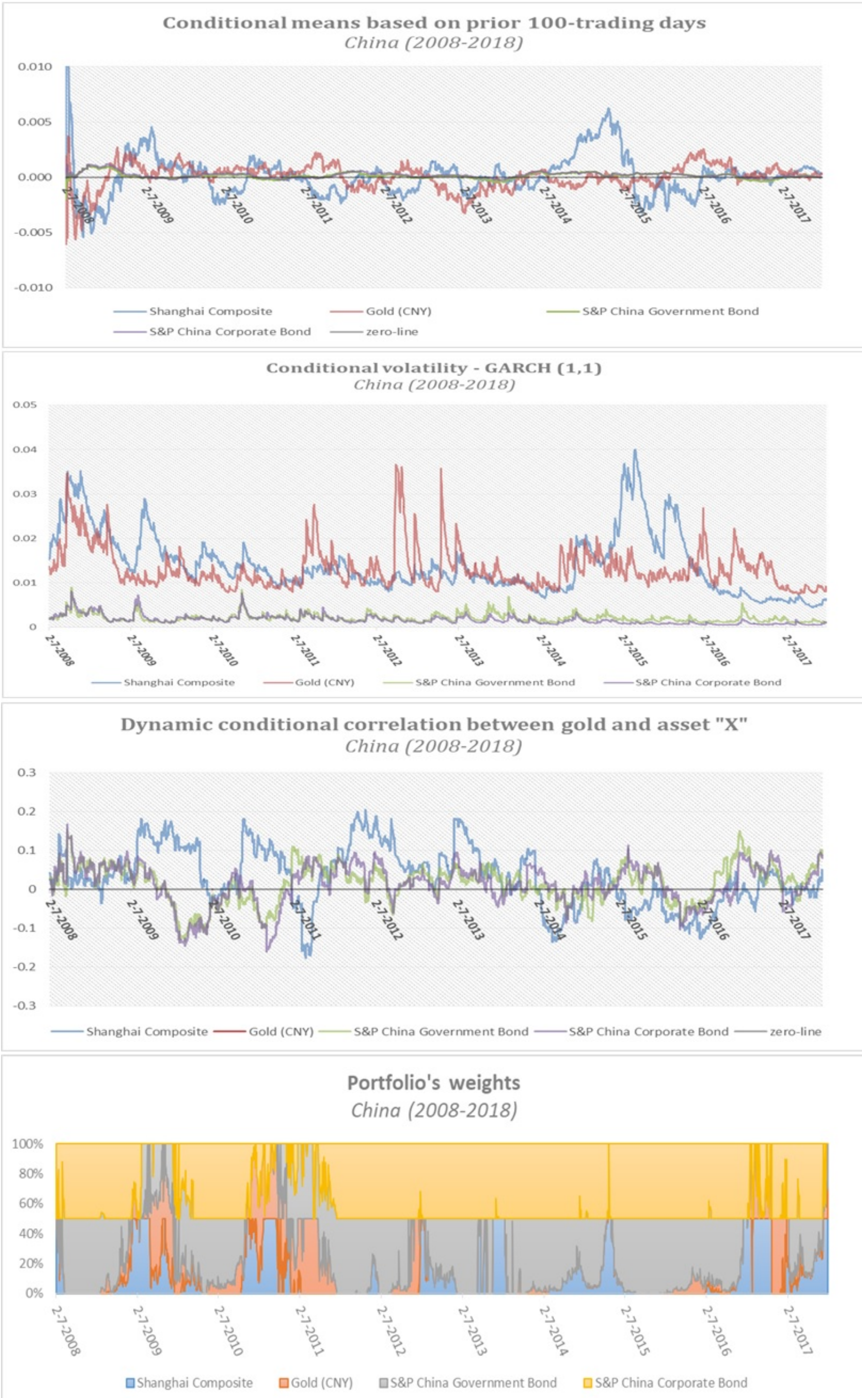


Fig. 50: Plots of the conditional mean based on prior 100 trading days, conditional volatility based on GARCH(1,1) model, dynamic conditional correlation based on the DCC(1,1) model and the portfolio weights based on the Markowitz portfolio optimization theorem where we imposed the restriction for short-selling. *Country: China. Period: Jan 2008 - Dec 2017.*

3.3 Sample period 2012-2018

3.3.1 United States

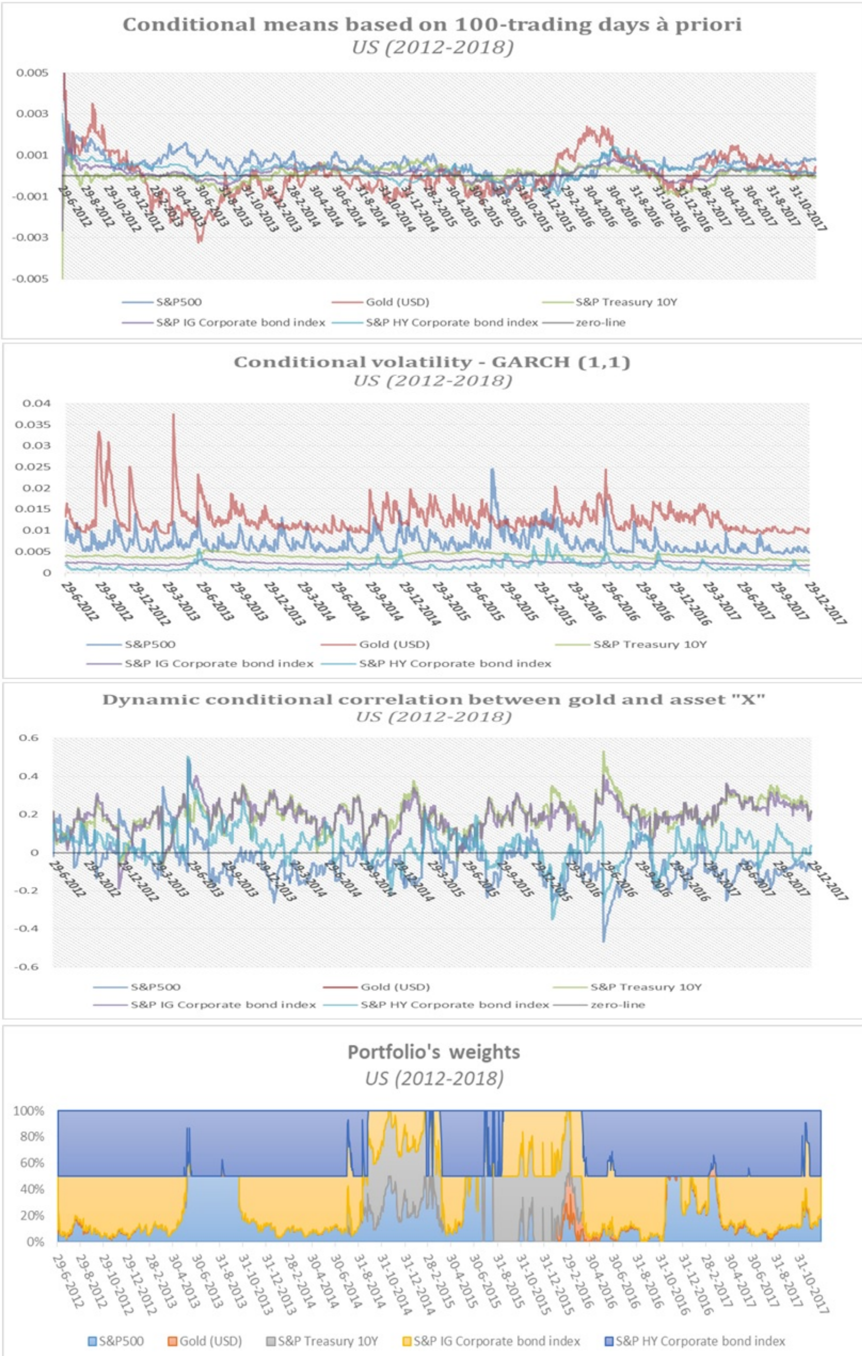


Fig. 51: Plots of the conditional mean based on prior 100 trading days, conditional volatility based on GARCH(1,1) model, dynamic conditional correlation based on the DCC(1,1) model and the portfolio weights based on the Markowitz portfolio optimization theorem where we imposed the restriction for short-selling. *Country: United States. Period: Jul 2012 - Dec 2017.*

3.3.2 United Kingdom

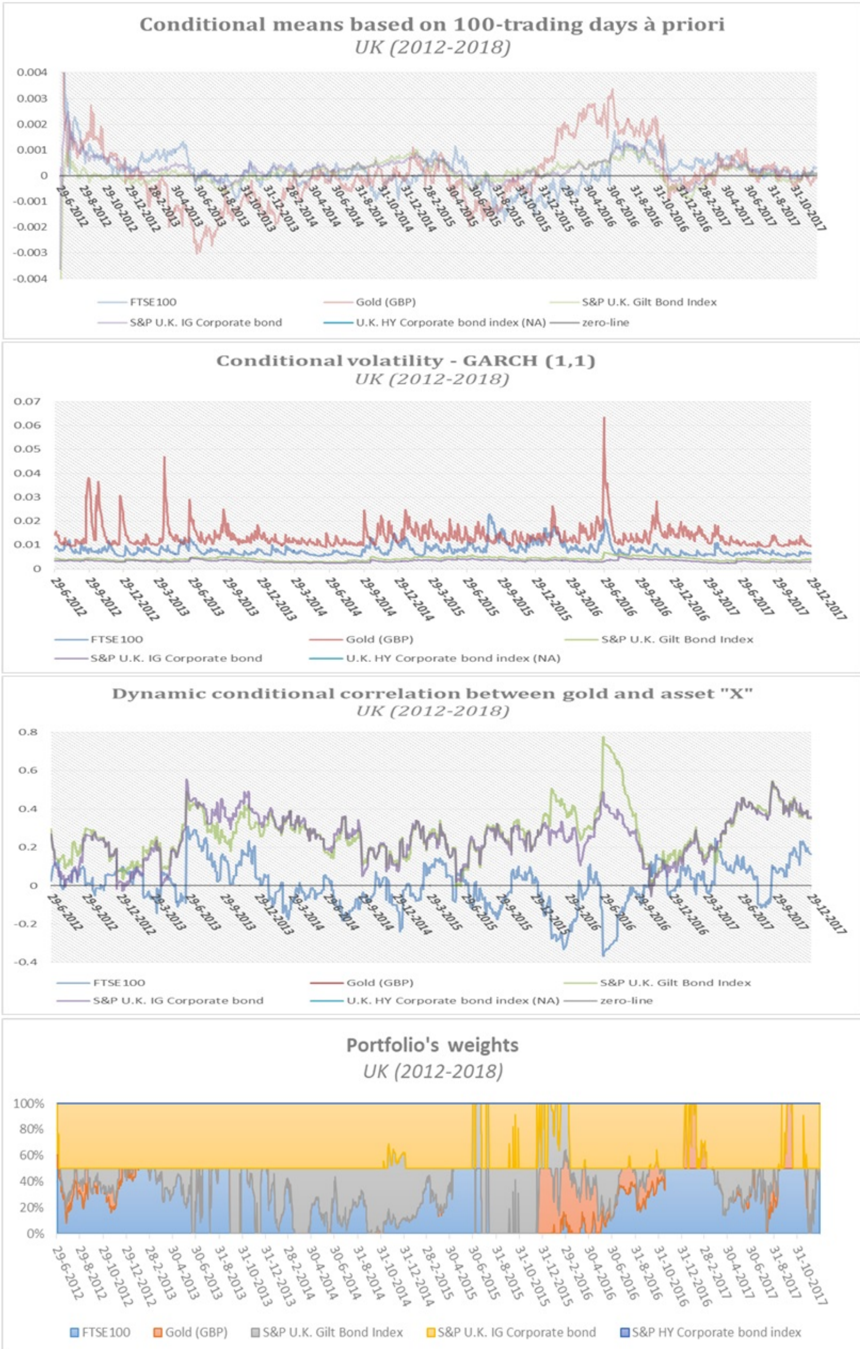


Fig. 52: Plots of the conditional mean based on prior 100 trading days, conditional volatility based on GARCH(1,1) model, dynamic conditional correlation based on the DCC(1,1) model and the portfolio weights based on the Markowitz portfolio optimization theorem where we imposed the restriction for short-selling. *Country: United Kingdom. Period: Jul 2012 - Dec 2017.*

3.3.3 Eurozone

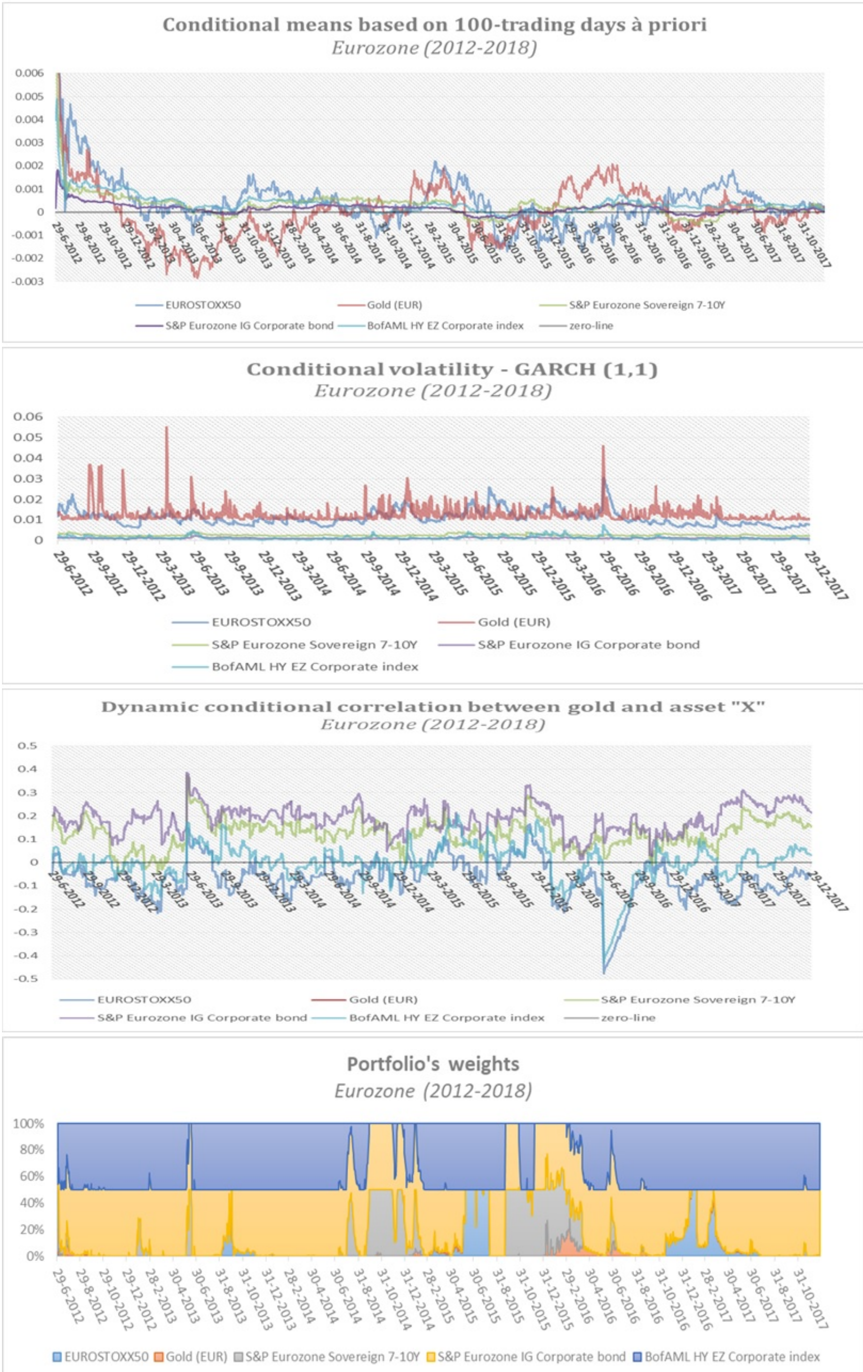


Fig. 53: Plots of the conditional mean based on prior 100 trading days, conditional volatility based on GARCH(1,1) model, dynamic conditional correlation based on the DCC(1,1) model and the portfolio weights based on the Markowitz portfolio optimization theorem where we imposed the restriction for short-selling. *Country: Eurozone. Period: Jul 2012 - Dec 2017.*

3.3.4 Brazil

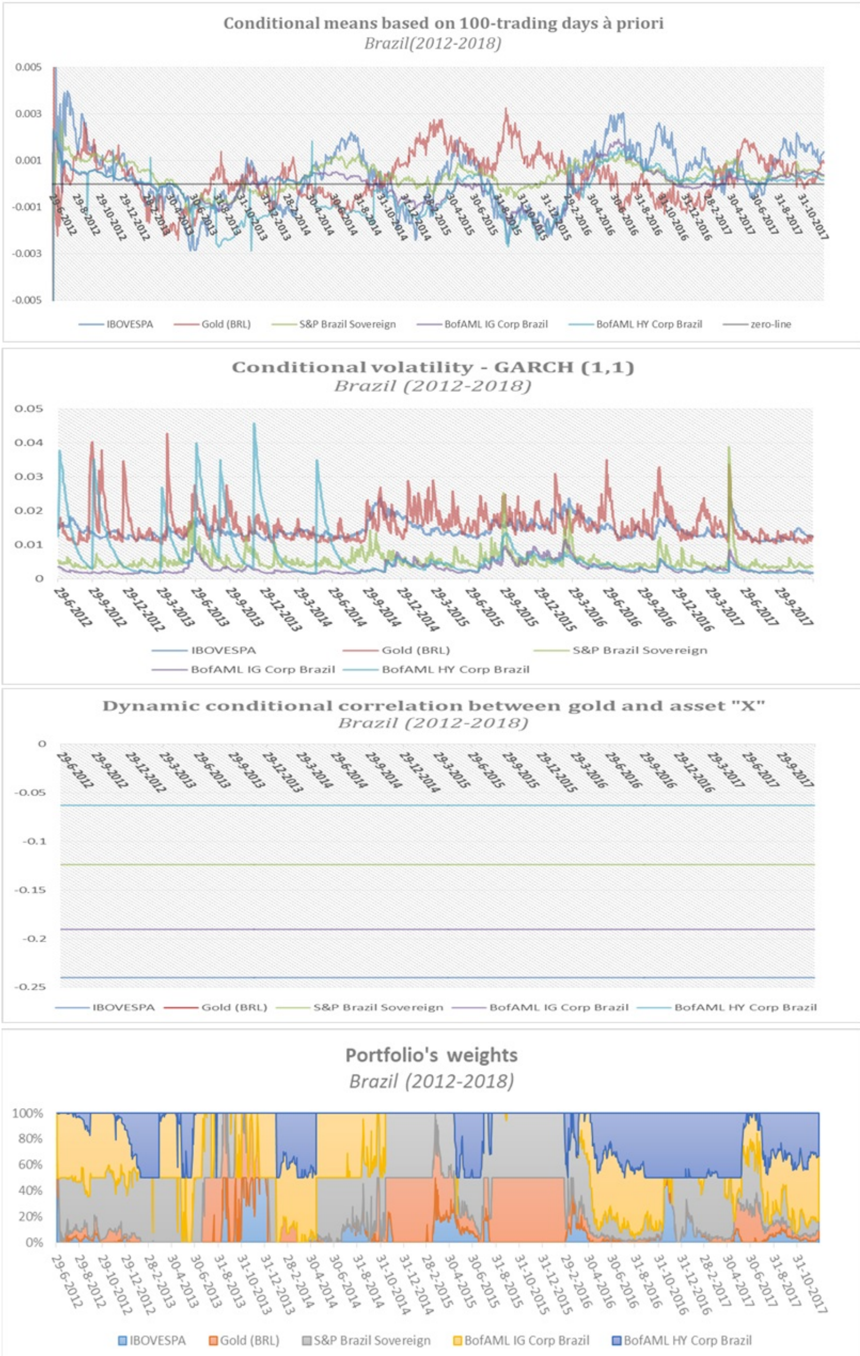


Fig. 54: Plots of the conditional mean based on prior 100 trading days, conditional volatility based on GARCH(1,1) model, dynamic conditional correlation based on the DCC(1,1) model and the portfolio weights based on the Markowitz portfolio optimization theorem where we imposed the restriction for short-selling. *Country: Brazil. Period: Jul 2012 - Dec 2017.*

3.3.5 Russia

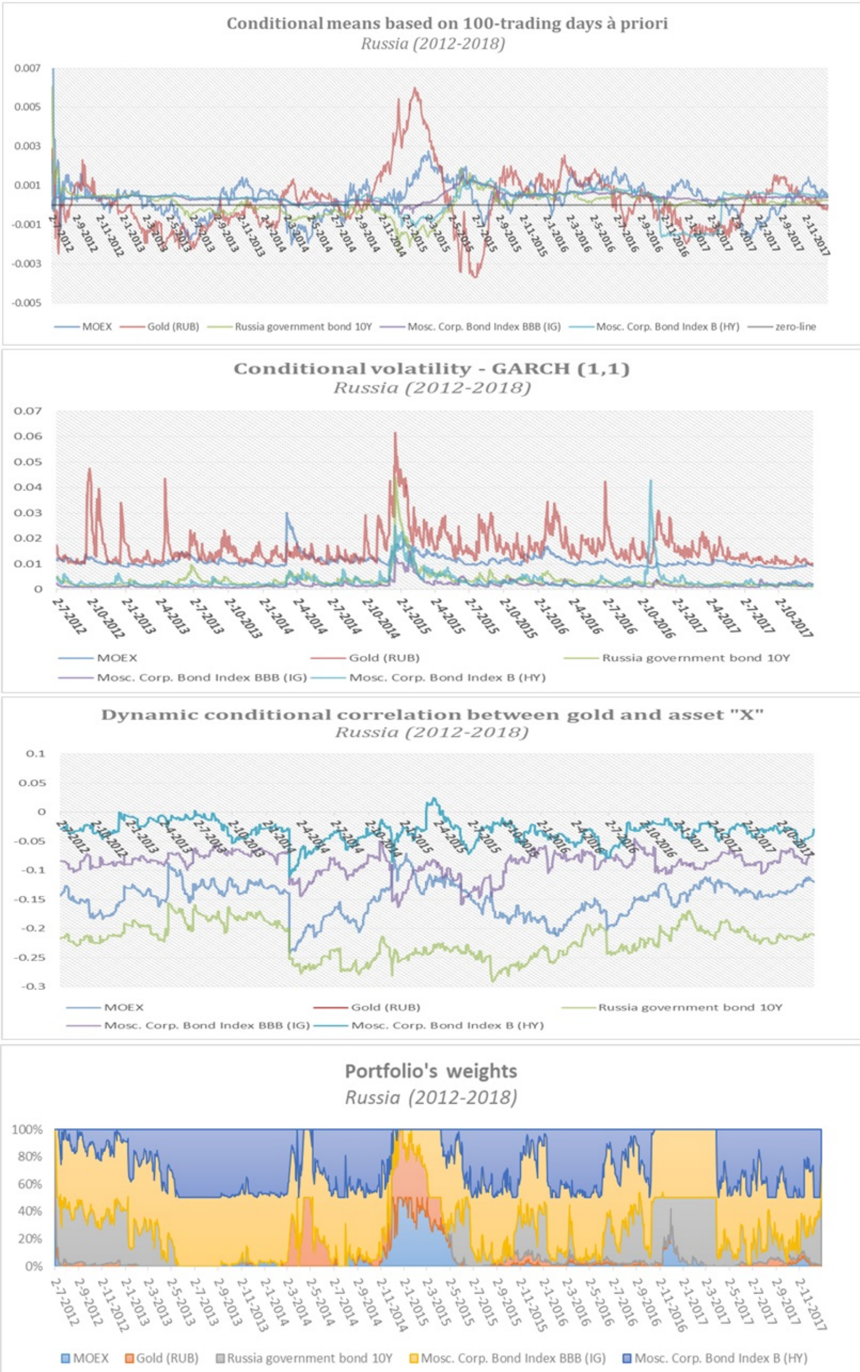


Fig. 55: Plots of the conditional mean based on prior 100 trading days, conditional volatility based on GARCH(1,1) model, dynamic conditional correlation based on the DCC(1,1) model and the portfolio weights based on the Markowitz portfolio optimization theorem where we imposed the restriction for short-selling. *Country: Russia. Period: Jul 2012 - Dec 2017.*

3.3.6 India

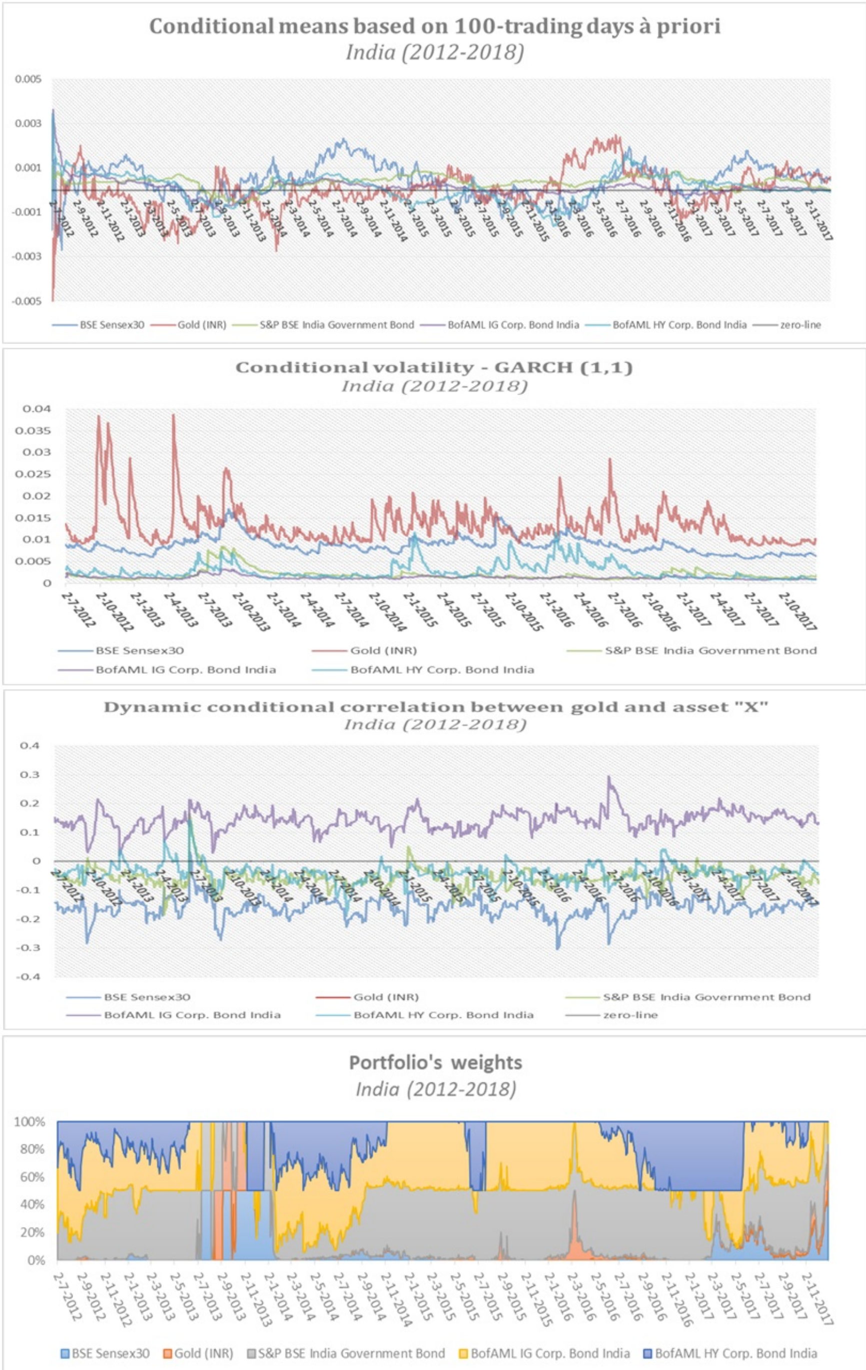


Fig. 56: Plots of the conditional mean based on prior 100 trading days, conditional volatility based on GARCH(1,1) model, dynamic conditional correlation based on the DCC(1,1) model and the portfolio weights based on the Markowitz portfolio optimization theorem where we imposed the restriction for short-selling. *Country: India. Period: Jul 2012 - Dec 2017.*

3.3.7 China

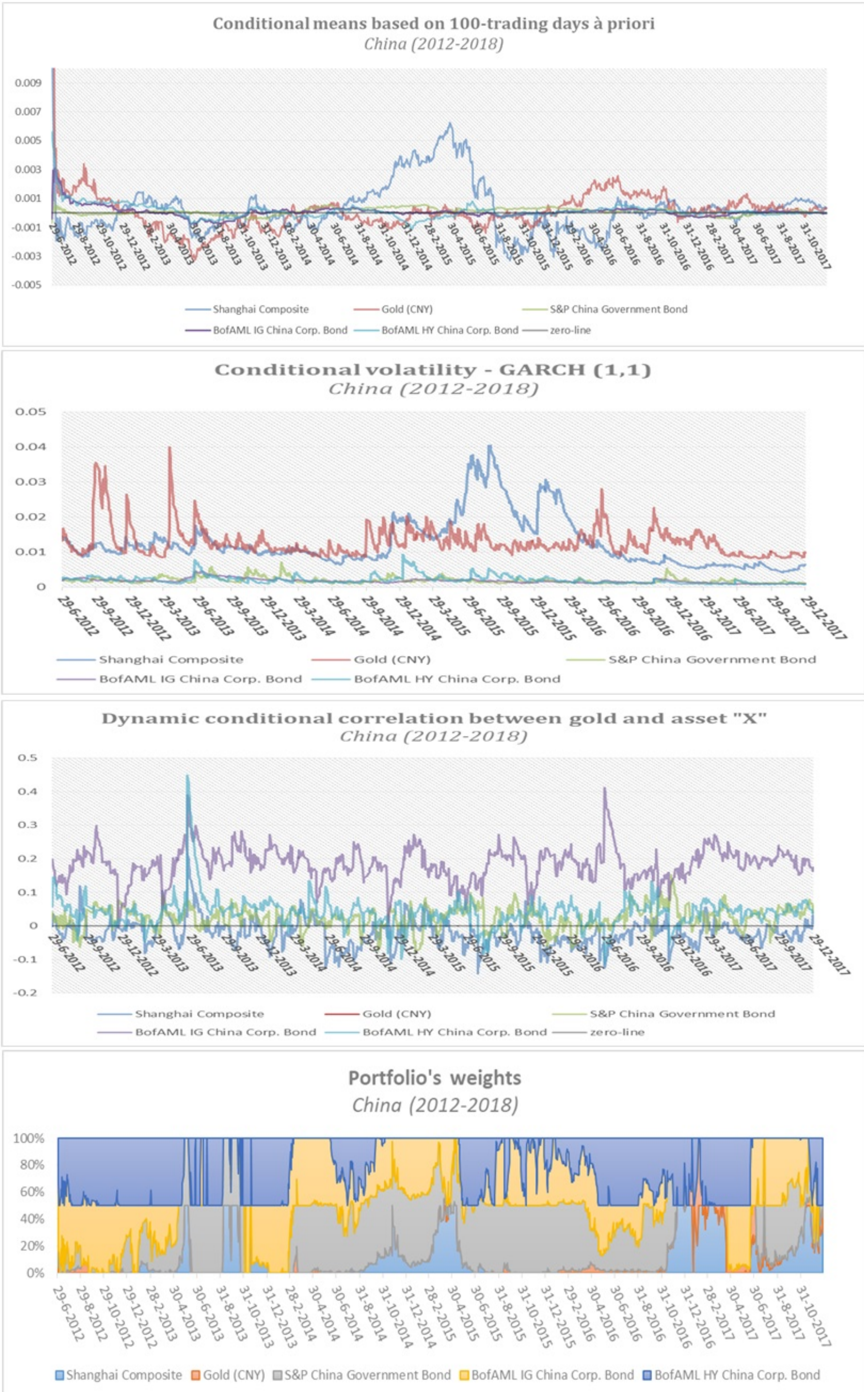


Fig. 57: Plots of the conditional mean based on prior 100 trading days, conditional volatility based on GARCH(1,1) model, dynamic conditional correlation based on the DCC(1,1) model and the portfolio weights based on the Markowitz portfolio optimization theorem where we imposed the restriction for short-selling. *Country: China. Period: Jul 2012 - Dec 2017.*

Bibliography

Arouri, M. E. H., A. Lahiani, and D. K. Nguyen (2015). "World gold prices and stock returns in China: insights for hedging and diversification strategies". *Economic Modelling* 44, pp. 273–282.

Bae, K.-H., G. A. Karolyi, and R. M. Stulz (2003). "A new approach to measuring financial contagion". *The Review of Financial Studies* 16.3, pp. 717–763.

Baur, D. (2013). "Gold-Fundamental drivers and asset allocation".

Baur, D. G. and K. J. Glover (2012). "The destruction of a safe haven asset?"

Baur, D. G. and B. M. Lucey (2010). "Is gold a hedge or a safe haven? An analysis of stocks, bonds and gold". *Financial Review* 45.2, pp. 217–229.

Baur, D. G. and T. K. McDermott (2010). "Is gold a safe haven? International evidence". *Journal of Banking & Finance* 34.8, pp. 1886–1898.

Beckmann, J., T. Berger, and R. Czudaj (2015). "Does gold act as a hedge or a safe haven for stocks? A smooth transition approach". *Economic Modelling* 48, pp. 16–24.

Białkowski, J., M. T. Bohl, P. M. Stephan, and T. P. Wisniewski (2015). "The gold price in times of crisis". *International Review of Financial Analysis* 41, pp. 329–339.

Bollerslev, T. (1990). "Modelling the coherence in short-run nominal exchange rates: a multivariate generalized ARCH model". *The Review of Economics and Statistics*, pp. 498–505.

Calvo, G. A. and E. G. Mendoza (2000). "Rational contagion and the globalization of securities markets". *Journal of International Economics* 51.1, pp. 79–113.

Capie, F., T. C. Mills, and G. Wood (2005). "Gold as a hedge against the dollar". *Journal of International Financial Markets, Institutions and Money* 15.4, pp. 343–352.

Ciner, C., C. Gurdgiev, and B. M. Lucey (2013). "Hedges and safe havens: An examination of stocks, bonds, gold, oil and exchange rates". *International Review of Financial Analysis* 29, pp. 202–211.

Cont, R. (2007). "Volatility clustering in financial markets: empirical facts and agent-based models". In: *Long Memory in Economics*. Springer, pp. 289–309.

Coudert, V. and H. Raymond (2011). "Gold and financial assets: are there any safe havens in bear markets". *Economics Bulletin* 31.2, pp. 1613–1622.

Engle, R. (2002). "Dynamic conditional correlation: A simple class of multivariate generalized autoregressive conditional heteroskedasticity models". *Journal of Business & Economic Statistics* 20.3, pp. 339–350.

Guillén, M. F. (2009). "The global economic & financial crisis: A timeline". *The Lauder Institute, University of Pennsylvania*, pp. 1–91.

Hafner, C. M. and O. Reznikova (2012). "On the estimation of dynamic conditional correlation models". *Computational Statistics & Data Analysis* 56.11, pp. 3533–3545.

Hillier, D., P. Draper, and R. Faff (2006). "Do precious metals shine? An investment perspective". *Financial Analysts Journal* 62.2, pp. 98–106.

Hood, M. and F. Malik (2013). "Is gold the best hedge and a safe haven under changing stock market volatility?" *Review of Financial Economics* 22.2, pp. 47–52.

Jaffe, J. F. (1989). "Gold and gold stocks as investments for institutional portfolios". *Financial Analysts Journal*, pp. 53–59.

Joy, M. (2011). "Gold and the US dollar: Hedge or haven?" *Finance Research Letters* 8.3, pp. 120–131.

Koima, J., P. Mwita, and D. Nassiuma (2015). "Volatility estimation of stock prices using Garch method".

Lawrence, C. (2003). "Why is gold different from other assets? An empirical investigation". *London, UK: The World Gold Council.*

Lean, H. H., W.-K. Wong, et al. (2015). "Is gold good for portfolio diversification? A stochastic dominance analysis of the Paris stock exchange". *International Review of Financial Analysis* 42, pp. 98–108.

Lucey, B. M. and S. Li (2015). "What precious metals act as safe havens, and when? Some US evidence". *Applied Economics Letters* 22.1, pp. 35–45.

Lucey, B. M. and E. Tully (2003). "International portfolio formation, skewness and the role of gold".

MacDonald and Shumsky (2015). "Gold's Role as Safe-Haven Investment Wanes". *The Wall Street Journal.*

Markowitz, H. (1952). "Portfolio selection". *The journal of finance* 7.1, pp. 77–91.

McCown, J. R. and J. R. Zimmerman (2006). "Is gold a zero-beta asset? Analysis of the investment potential of precious metals".

Pasutasarayut, P. and P. Chintrakarn (2012). "Is gold a hedge or safe haven? A case study of Thailand".

Reboredo, J. C. and A. Ugolini (2015). "Downside/upside price spillovers between precious metals: A vine copula approach". *The North American Journal of Economics and Finance* 34, pp. 84–102.

Sherman, E. J. (1982). "Gold: a conservative, prudent diversifier". *The Journal of Portfolio Management* 8.3, pp. 21–27.