Does gold act as a hedge or a safe haven for stocks? A smooth transition approach *

Joscha Beckmann† Robert Czudaj‡

May 21, 2014

Abstract

This study deals with the issue if gold actually exhibits the function of a hedge or a safe haven as often referred to in the media and academia. In order to test the Baur and Lucey [2010] hypotheses, we contribute to the existing literature by the augmentation of their model to a smooth transition regression (STR) using an exponential transition function which splits the regression model into two extreme regimes. One accounts for periods where stock returns are on average and therefore allows to test if gold acts as a hedge for stocks, the other one accounts for periods characterized by extreme market conditions where the volatility of the stock returns is high. The latter state enables us to test if gold can be regarded as a safe haven for stocks. The study includes a broad set of 18 individual markets as well as five regional indices and covers a sample period running from January 1970 to March 2012 on a monthly frequency. Overall, our findings show that gold serves as a hedge and a safe haven, however this ability seem to be market-specific.

Keywords: gold, hedge, safe haven, smooth transition, stock prices

JEL classification: G11, G14, G15

*Thanks for valuable comments are due to an anonymous reviewer and the participants of the 11th INFINITI Conference on International Finance, SciencesPo Aix, Aix-en-Provence/France, the 88th WEAI Annual Conference, Seattle/Washington, and the 12th Annual EEFS Conference, Berlin/Germany.

†University of Duisburg-Essen, Department of Economics, Chair for Macroeconomics, D-45117 Essen, e-mail: joscha.beckmann@uni-due.de, phone: (0049)-201-183-3215, fax: (0049)-201-183-4181 and Kiel Institute for the World Economy, Hindenburgufer 66, D-24105 Kiel.

‡University of Duisburg-Essen, Department of Economics, Chair for Econometrics, D-45117 Essen, e-mail: robert.czudaj@uni-due.de, phone: (0049)-201-1833516, fax: (0049)-201-1834209, Center for Computational Sciences and Simulation, D-45117 Essen and FOM Hochschule für Oekonomie & Management, University of Applied Sciences, Herkulesstr. 32, D-45127 Essen.

1 Introduction

Since the breakdown of Bretton Woods gold is no longer a central cornerstone of the international monetary system, but nevertheless it still attracts considerable attention from investors, researchers, and the media. Owing to the increasing uncertainty of financial markets, diversifying a portfolio through hedging becomes more and more important. Especially, during the global financial and economic crisis that started in 2007 the gold price experienced an intense increase while other assets (in particular stock prices) exhibit losses (see Figure I). Given the surge in the price of gold following the global financial crisis and the most recent decline in the price of gold as stock markets have started to hit new highs (in April 2013), understanding the relationship between gold and stock markets is an interesting task. In the era of globalization correlations among most types of assets increased dramatically, however gold is still known to be frequently uncorrelated with other assets [Baur and Lucey, 2010] and is said to be a zero-beta asset [McCown and Zimmerman, 2006]. In this vein, gold seems to be appropriate to be considered as a hedge or safe haven for financial assets or portfolios. The reason is that, in contrast to many other commodities, gold is well-known to be durable, easily recognizable, storable, portable, divisible, and easily standardized [Baur, 2013]. Particularly, the financial media often refers to gold as a safe haven asset for portfolio investors.[1] However, Baur and Lucey [2010] are the first to formulate empirically testable definitions for a hedge and a safe haven with regard to financial assets such as bonds or stocks. Following their definitions, a hedge (safe haven) is an asset that is uncorrelated (negatively correlated) with another asset or portfolio on average (only in times of market stress or turmoil). Baur and McDermott [2010] also distinguish between a strong and a weak form of the hedge and the safe haven property.[2] With regard to this distinction, the question is whether a negative correlation of the returns on gold and on stocks occurs on average or in extreme market conditions. The former (latter) would indicate a strong hedge (safe haven) function of gold. This implies that the gold price increases after a fall of stock prices in such conditions and therefore compensates investors for losses incurred with stock investments.

Figure I about here

This study builds on the work of Baur and Lucey [2010] as well as Baur and McDermott [2010] by augmenting their empirical testing procedure. Our econometric framework is based on a regression of gold returns on stock returns as suggested by Baur and Lucey [2010]. To test the safe haven hypothesis they apply the lower 5%, 2.5%, and 1% quantiles of the stock and bond returns as regressors which take a value of zero if the particular return is larger than the quantile in a given period. Instead of adopting this ad hoc procedure, we contribute to the existing literature by the augmentation of the model to a smooth transition regression (STR) inspired by the work of Teräsvirta [1994] using an exponential transition function which splits the regression model into two extreme regimes. One accounts for periods where stock returns are on average and allows to test if gold acts as a hedge for

[1] For instance, see the article 'Gold: Haven turns riskier but retains its appeal' (Financial Times, December 20, 2011) by Jack Farchy.

[2] Aizenman and Inoue [2012] also point out that central bank's gold position signals economic might, and that gold retains the stature of a safe haven asset at times of global turbulence.

stocks, the other one accounts for periods of 'extreme times', where the magnitude of the difference between stock returns and their averages is large. The latter state enables us to test if gold can be regarded as a safe haven for stocks. Hence, the question is whether different regimes can be identified without relying on a priori thresholds. In addition, STR models allow not solely for a discrete switching from one scenario to the other, but account for a smooth transition between them. A discrete switching pattern seems inadequate in cases where investors with different expectations and risk assessments are involved, since market participants may not all act promptly and uniformly as they are confronted with heterogeneous information and opportunity costs which implies different bands of inaction. Moreover, their reaction to new information might also exhibit different delays. Therefore, our framework allows to test the Baur and Lucey [2010] hypotheses in a more fexible and thus realistic fashion. In doing so, we include a broad set of 18 individual markets as well as five regional indices that comprise the largest developed countries, the largest emerging markets as well as the major gold consumers and producers. We cover a sample period running from January 1970 to March 2012 on a monthly frequency. As will be shown, our findings indicate that the ability of gold to serve as a hedge or a safe haven depends on the economic environment. We also confirm that our approach fits the data well, since two extreme regimes with different characteristics can be distinguished.

The reminder of this paper is organized as follows. The following section provides a brief summary of previous empirical studies. Section 3 describes our dataset as well as our econometric framework and presents our findings. Section 4 concludes.

2 Review of the literature

The gold price literature is both vast as well as manifold and the most important strands should be introduced briefly before turning to the specific studies closely related to ours. Firstly, Sherman [1982, 1983], Ariovich [1983], Fortune [1987], Dooley, Isard and Taylor [1995], Sjaastad and Scacciallani [1996], Faff and Hillier [2004], Lucey, Tully and Poti [2006], and Wang and Lee [2011] provide studies which are concerned with impacts of macroeconomic variables such as output, exchange rates, or interest rates on the price for gold. Secondly, Koutsoyiannis [1983], Diba and Grossman [1984], Baker and van Tassel [1985], and Pindyck [1993] give attention to prediction of the gold price. In general, evidence for different relationships and causalities has been provided, however a detailed description of the corresponding outcomes is beyond the scope of this paper. Thirdly, Tschoegl [1980], Solt and Swanson [1981], Ho [1985], Basu and Clouse [1993], and Smith [2002] performed tests of the market efficiency hypothesis for the gold market. More recently, motivated by the lately gold price boom Bialkowski, Bohl, Stephan and Wisniewski [2012] test whether the gold price is subject to a speculative bubble by conducting a Markov regime-switching augmented Dickey-Fuller test and conclude that the high value of the gold price seems to be fundamentally justified. In contrast, Baur and Glover [2012] identify that the price of gold followed an explosive price process between 2002 and 2012 using a test developed by Phillips, Wu and Yu [2011].

Fourthly, studies which examine the inflation hedge effectiveness of gold have been carried out by Kolluri [1981], Moore [1990], Laurent [1994], Chappell and Dowd [1997], Mahdavi and Zhou [1997], Harmston [1998], Ghosh, Levin, Macmillan and Wrigh [2004], Levin and Wright [2006], Worthington and Pahlavani [2007], and Beckmann and Czudaj [2013b]. These surveys are often based on the analysis of a long-run relationship between the price for gold and the general price level by means of cointegration techniques. The results are not clear-cut and vary depending on the sample period and the country under investigation. Early studies are based on the estimation of a conventional vector error correction model (VECM). However, Beckmann and Czudaj [2013b] recently demonstrate that conducting a Markov-switching VECM is more appropriate in this context. They indicate that gold is partially able to hedge future inflation in the long-run and this ability tends to be stronger for the USA and the UK compared to Japan and the Euro Area.

Finally, we now turn to studies related to the key question of our investigation: Does gold act as a hedge or a safe haven with regard to financial assets such as stocks or bonds?[3] The issue of correlation between gold and other major assets has previously been tackled in earlier studies by Sherman [1986], Jaffe [1989], Chua, Stick and Woodward [1990], Upper [2000], Ciner [2001], Michaud, Michaud and Pulvermacher [2006], Hillier, Draper and Faff [2006], McCown and Zimmerman [2006], and Kaul and Sapp [2006] and the overall results suggest that correlation is low or even negative.[4] Recently, Baur and Lucey [2010] provide definitions for a hedge, a diversifier or a safe haven property as follows: an asset acts as a hedge if it is uncorrelated or negatively correlated with another asset or portfolio on average. An asset is regarded as a diversifier if it is positively (but not perfectly correlated) with another asset or portfolio on average as well. A hedge and a diversifier cannot shield a portfolio of exhibiting losses in times of extreme adverse market conditions, since both proverties only work on average. Finally, an asset is seen as a safe haven if it is uncorrelated or negatively correlated with another asset or portfolio in times of market stress or turmoil. Baur and McDermott [2010] state more precisely that a strong (weak) hedge and safe haven is an asset that is negatively correlated (uncorrelated) with another asset or portfolio on average and only in times of market stress or turmoil, respectively. Baur and Lucey [2010] test whether gold acts as a hedge, a diversifier or a safe haven for US, UK, and German stocks or bonds using a sample period that ranges from November 30, 1995 to November 30, 2005 and therefore they regress gold returns on stock and bond returns as well as dummy variables for their lower 5%, 2.5%, and 1% quantiles which take a value of zero if the particular return is larger than the quantile in a given period. Their findings indicate that gold acts as a hedge for stocks in the US and in the UK but not in Germany, however, gold does not act as a hedge for bonds in the US and in the UK but in Germany. Furthermore, gold seems to be a safe

[3]It should be pointed out that our analysis solely focuses on stocks. Testing the hedging and safe haven hypotheses with regard to bonds is also promising, however we abstain from that, since the available data basis for bonds is not that profound than the one for stocks.

[4]Moreover, Capie, Mills and Wood [2005], Wang and Lee [2011], and Reboredo [2013] show that gold has the potential to hedge against fluctuations of the exchange rate. Faugère and Van Erlach [2005] illustrate that gold can be viewed as a global real store of wealth and construct a valuation theory for gold.

haven for stocks in all markets with stronger evidence in the UK and in Germany, however gold does not provide a safe haven function for bonds in any of the three markets. A portfolio analysis also indicates that the safe haven property is short-lived. Baur and McDermott [2010] apply a related approach to check whether gold is a strong (weak) hedge or a safe haven against stocks of major emerging and developing countries using daily, weekly, and monthly data for a sample spanning a period from 1979 to 2009.[5] Taken as a whole, the outcomes show that gold acts as a hedge and a strong safe haven for European countries as well as the US, but gold does not act as a hedge or a safe haven for emerging economies as well as for Australia, Canada, and Japan. Using the Baur and McDermott [2010] framework Pasutasarayut and Chintrakarn [2012] show that gold displays neither a hedge nor a safe haven ability in the Thai market for the daily dataset from July 2001 to February 2011. While adopting the same approach and using a daily sample period for the US and the UK running from January 1990 to June 2010 Ciner, Gurdgiev and Lucey [2013] investigate how and under what circumstances each of the five major financial assets (stocks, bonds, oil, gold, and the US dollar) provide a hedge or a safe haven function to each other. They detect that gold acts as a safe haven for most assets, except of oil.

3 Empirical analysis

3.1 The data

Our sample period ranges from January 1970 to March 2012 on a monthly basis and therefore also includes periods of major oil price shocks as well as several other crises.[6] Having also run the whole subsequent analysis for daily and weekly data, we solely rely on monthly data in the following due to the fact that both daily and weekly data appears to be too noisy to capture the regimes we are interested in, and also due to the conjecture that there may be non-synchronicity issues, which are easier to neglect at a monthly frequency. The gold price data has been provided by the World Gold Council (WGC) and is denominated in Australian dollar, British pound sterling, Canadian dollar, Chinese renmimbi, Egyptian pound, euro, Indian rupee, Indonesian rupiah, Japanese yen, Korean won, Russian ruble, South African rand, Swiss franc, Thai baht, Turkish lira, and US dollar. Stock indices for the corresponding countries denominated in their local currencies and for several regions such as Emerging Markets, the Economic and Monetary Union (EMU), the European Union (EU), North America, and the World denominated in US dollar are taken from Morgan Stanley Capital International (MSCI). Therefore our panel includes each economy and region that is part of the study carried out by Baur and McDermott [2010] and extends the latter by both a longer sample period as well as the incorporation of economies that are also regarded by the WGC as major gold consumers (Indonesia, Turkey, Thailand, Egypt, and Korea) and major gold producers (South Africa). This

[5] They include the seven largest developed countries (G7), the largest emerging markets (BRIC countries) as well as Australia and Switzerland in their study.

[6] Since the price of gold already showed significant volatility before the breakdown of Bretton Woods, we feel legitimized to start our investigation prior to 1973 when the data is available. However, in most cases the start of the estimation period is not prior to 1979 (See Table I).

helps to get a deeper insight into the functioning of gold as hedge or safe haven. We calculate gold and stock returns by taking the first difference of the natural logarithm of each series. To avoid a spurious regression, we have ascertained that all returns are stationary by the application of several unit root tests.

For some markets the sample period is shorter than mentioned above, therefore all sample periods and descriptive statistics for annualized returns are given in Table I. Overall, the latter supports the typical finding that asset returns are non-Gaussian. The descriptive statistics can be seen as prima facie evidence for gold as a hedge unconditionally, since for most of the markets we observe the following two important properties: first, stock returns exhibit negative and gold returns positive skewness. Second, stock returns have larger medians than gold returns as the former are riskier. In addition, we have also plotted the quantiles of gold and stock returns against each other (reported by Figure II) and it becomes evident that especially the lowest and highest quantiles differ. This indicates that the distributions of gold and stock returns differ for extreme market conditions.

Table I and Figure II about here

3.2 Econometric methodology

Following Baur and Lucey [2010] our econometric framework is based on a regression of gold returns on stock returns, however we account for asymmetries of positive and negative extreme shocks in a quite different manner. Thus we simultaneously estimate the following two equations by means of the BFGS numerical optimization method [Broyden, 1970; Fletcher, 1970; Goldfarb, 1970; Shanno, 1970]:

$$r_{G,t} = \xi_1 + \psi_1 r_{S,t} + (\xi_2 + \psi_2 r_{S,t})\, G(z_t, \gamma, \kappa) + \varepsilon_t, \tag{1}$$

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

where $r_{G,t}$ and $r_{S,t}$ denote gold and stock returns, respectively, and ε_t stands for a random error term. Equation (1) gives the nonlinear relation between gold and stock returns and Equation (2) represents a GARCH(1,1) model of the errors which accounts for the existing heteroscedasticity in the data. $G(z_t, \gamma, \kappa)$ is a transition function which ascertains the speed of transition between two extreme regimes, in our case a state that can be regarded as 'normal times' which allows to test the hedging hypothesis of gold and a state that can be referred to as 'extreme times' (market stress or turmoil) and therefore allows to check for the safe haven hypothesis of gold. Thus we apply a bounded continuous exponential transition function which takes values between 0 and 1 as follows:

$$G(z_t, \gamma, \kappa) = 1 - \exp(-\gamma(z_t - \kappa)^2/\sigma_{z_t}) \quad \text{with} \quad \gamma > 0, \tag{3}$$

where z_t indicates the transition variable, σ_{z_t} represents its standard deviation, γ denotes a slope parameter, and κ is a location parameter. In order to create a scale-free smoothness parameter, γ is normalized by the standard deviation of the transitional variable z_t, as suggested by Teräsvirta

[1998]. A natural choice for the transition variable is the lagged stock return $r_{S,t}$, since the asymmetry of Equation (1) depends on the state of the stock returns. If stocks exhibit extreme volatile returns, investors urge to purchase gold and this pressure boosts the gold price. In normal market conditions investors neither sell nor buy gold to a great extent. The location parameter κ can be interpreted as a threshold value and an exponential transition function is symmetrically inverse-bell-shaped ($G(z_t, \gamma, \kappa) \to 1$ for $z_t \to \pm\infty$ and $G(z_t, \gamma, \kappa) \to 0$ for $z_t \to 0$), so that an adjustment for large deviations of the stock returns above and below the threshold κ is symmetric. This allows for a distinction between low and high deviations from the threshold in Equation (1) and therefore for a discrimination between a state of 'normal times' which allows to test the hedging hypothesis of gold and a state of 'extreme times' which allows to check for the safe haven hypothesis of gold. The terms ξ_1 and ψ_1 correspond to the lower regime where the function $G(z_t, \gamma, \kappa)$ takes a value of zero, while $(\xi_1 + \xi_2)$ and $(\psi_1 + \psi_2)$ belong to the upper regime where $G(z_t, \gamma, \kappa)$ equals unity. Thus ψ_1 and $(\psi_1 + \psi_2)$ can be used to test for the hedging and safe haven hypothesis of gold, respectively. If ψ_1 turns out to be significantly negative (not to be significantly different from zero), it would imply that gold acts as a strong (weak) hedge for stocks, since the assets are negatively correlated (uncorrelated) with each other on average. Related to this, if $(\psi_1 + \psi_2)$ shows up to be significantly negative (not to be significantly different from zero), it would imply that gold acts as a strong (weak) safe haven for stocks, since the assets are negatively correlated (uncorrelated) with each other in times of extreme market conditions.

3.3 Testing for linearity against nonlinearity

As a first step, it is necessary to formally test for nonlinearity, though it is also important to choose an adequate transition variable, which in the present study means the choice of a lag order for the stock return. Both issues can be tackled by applying a lagrange multiplier (LM) test introduced by Luukkonen, Saikkonen and Teräsvirta [1988] which is based on the following third order Taylor approximation of the transition function:[7]

$$r_{G,t} = \varphi_0 + \varphi_1 r_{S,t} + \varphi_2 r_{S,t} z_t + \varphi_3 r_{S,t} z_t^2 + \varphi_4 r_{S,t} z_t^3 + \varepsilon_t. \qquad (4)$$

The linear model is nested in Equation (1) for $G(z_t, \gamma, \kappa) = 0$ and the null hypothesis which refers to the linear model being adequate is tested as H_0: $\varphi_i = 0$ with $i = 2, 3, 4$ against the alternative H_1 that at least one $\varphi_i \neq 0$, implying that the higher order terms are significant [Teräsvirta, 1998]. The test statistic has a χ^2 distribution with three degrees of freedom.[8] In the case of the hypothesis of linearity being rejected, a method for choosing the transition variable lies in computing the test statistic for several transition functions, i.e. different values of the lag order j, and selecting the configuration for which its value is maximized [Taylor, Peel and Sarno, 2001; Van Dijk *et al.*, 2002; Beckmann and Czudaj, 2013a].

[7]In the case of small samples in combination with a large number of explanatory variables, F versions of the LM test statistics are preferable, as they have better size properties [Granger and Teräsvirta, 1993; Teräsvirta, 1998; Van Dijk, Teräsvirta and Franses, 2002].

[8]The number of degrees of freedom $3p$ refers to the number of regressors p which in our case is one.

In the present study, delays from one to twelve are considered. The p-values of the LM tests presented in Table II indicate that the hypothesis of linearity is rejected for almost each market at least for one lag.[9]

Table II about here

Hence, the overall conclusion is that a nonlinear framework seems to be adequate. An inspection of the tests statistics shows that the optimal transition variable differs with different lag orders for the stock return considered to be the most adequate choice. We therefore estimate each model with the lagged stock return as transition variable associated with the highest test statistic denoted by an asterisk in Table II.

3.4 Estimation results

The coefficient estimates of Equations (1) and (2) are presented in Table III.[10]

Table III about here

Table III indicates that in the EMU, Indonesia, Russia, and Turkey gold provides a strong hedging function while there appears to be no hedge in the case of China, Germany, and the whole world index, since the estimates of the ψ_1-coefficient show up to be significantly negative and positive, respectively. For all other economies gold seems to perform a weak hedging function in monthly frequency. In India, as one of the major gold consumers, the UK, and the whole world gold exhibits a strong safe haven function in the long-run, since in that case the ψ_2-coefficient estimates turn out to be significantly negative. The opposite holds for the EMU, Indonesia, and Russia; therefore gold does not show a safe haven function in these economies for the long-run. In each other economy gold appears to be a weak safe haven asset in turbulent times.

Overall, our findings show that gold can provide both a hedging as well as a safe haven function. At least a weak form of both properties has been observed in the overwhelming number of all cases (independent from the chosen data frequency). More specifically, the results depend on the market under observation. Compared to Baur and McDermott [2010] we do not get a clear pattern that gold just acts as a hedge and a safe haven for European countries as well as the United States. However, our outcomes confirm that the use of a regime-dependent approach is appropriate, since we get quite different behavior in both extreme regimes for most of the cases. The fact that the speed of transition between the two extreme cases (of normal times and times of turmoil) indicated by γ turns out to be very fast in some cases, suggests that the switching between the two states is almost instantaneous and points in favor of a nearly discrete transition between the regimes, which is also nested in our framework. However, our approach is not restricted to that case and therefore enables the data to speak freely. Moreover, the significance of the coefficient estimates for π, α, and β confirms that the

[9] A further finding is that the evidence for nonlinearity in the relationship between gold and stock returns is so much the better, the higher the frequency is chosen. For monthly data evidence appears to be weak, while daily data clearly shows the nonlinear pattern.

[10] In order to save space residual diagnostic tests are not shown in the tables, but these are available upon request. Overall, the findings do not indicate any serious violation of the classical assumptions related to the error terms.

heteroscedasticity structure of the data is appropriately accounted for by the use of a GARCH(1,1) term.

In the following we point out some drawbacks of our study. When focusing on stock prices, we use the major market indices with prices quoted in local currency. This gives a true, unitless return on the local market and the price of gold used in the analysis is the price in the local market as well. Therefore, the price of gold in the analysis could also depend on the exchange rate – the US dollar price converted into local currency. Consequently, there is a potential confounding role being played by the exchange rate in the results. This means that part of the relationship between the price of gold and the stock market could also be related to the exchange rate, however it is important to keep in mind that the gold price is much more influenced by exchange rate changes. The price of gold is mostly denominated in US dollar, but gold is also traded in the different currencies. Through arbitrage conditions, changes in the dollar price of gold also change the gold price in other currencies. On the opposite, domestic stocks are mostly traded in the domestic currency and are not directly affected by changes of the US dollar (or other foreign currencies). Correlations mostly occur if common shocks, for example through interest rates, affect both the domestic exchange rate and stock markets. The question of the linkage between gold prices and exchange rates and a potential exchange rate pass-through into the gold market is an issue that is currently under investigation by the authors in a separate study.

Another point related to the use of stock indices is that the different compositions of the indices across countries could have a potential impact on the results. For instance, Canada and Australia have many more natural resource firms in their indices than many other countries. Consequently, we would expect to see a different relationship between gold and the indices in these countries and gold and the indices from countries with less exposure to resources. Although the impact on the results is not clear, it is worth mentioning. One way to address this issue in further research could be to use industry specific indices from each country to more clearly identify the role of gold. However, this is beyond the scope of this study.

4 Conclusion

In this study we extend the existing literature by the adoption of a novel regime-dependent framework to answer the question if gold can be considered as a hedge and/or safe haven with regard to stocks. To examine the latter, we perform a broad study that includes data from 18 individual economies and five regional indices on a monthly frequency. Finally, we have shown that gold generally serves as a hedge and a safe haven, however this ability depends on the specific economic environment under observation. Interestingly, our results also do not exhibit a unique pattern for gold exporters or importers. We also confirm that our approach fits the data well, since two extreme regimes with different characteristics can be distinguished. Altogether, our findings show that previous studies have been based on a too simplistic discrete framework when analyzing nonlinearities in the relationship between stock markets and gold prices, although the transition between the two extreme regimes appears to be very fast in some cases. From an economic point of view, our results do not provide a direct explanation for the recent increase in the price of gold. However, a reasonable conclusion is that hedging or safe haven functions have played an important role for the recent pattern.

A further issue which should be addressed in the context of this study is the evaluation of hedging or safe haven functions based on specific utility functions of investors which could be conducted in a portfolio analysis. Such an analysis would be of great interest for asset managers and could be based on different kinds of risk aversion, portfolio structures, and time horizons. Considering the broad set of data or economies under investigation in this paper, such a question was beyond the scope of our study, but could be a point of contact for future research.

References

Aizenman J, Inoue K. 2012. Central banks and gold puzzles. *NBER Working Paper* **No. 17894**.

Ariovich G. 1983. The impact of political tension on the price of gold. *Journal for Studies in Economics and Econometrics* **16**: 17–37.

Baker S, van Tassel RC. 1985. Forecasting the price of gold: A fundamentalist approach. *Atlantic Economic Journal* **13**: 43–51.

Basu S, Clouse ML. 1993. A comparative analysis of gold market efficiency using derivative market information. *Resources Policy* **19**: 217–224.

Baur D. 2013. Gold - Fundamental drivers and asset allocation. *Available from SSRN: http://papers.ssrn.com/sol3/papers.cfm?abstract_id=2240831*.

Baur D, Glover K. 2012. A gold bubble? *Working Paper Series, Finance Discipline Group, UTS Business School, University of Technology, Sydney* **No. 175**.

Baur D, McDermott T. 2010. Is gold a safe haven? International evidence. *Journal of Banking & Finance* **34**: 1886–1898.

Baur DG, Lucey BM. 2010. Is gold a hedge or a safe haven? An analysis of stocks, bonds and gold. *Financial Review* **45**: 217–229.

Beckmann J, Czudaj R. 2013a. The forward pricing function of industrial metal futures – Evidence from cointegration and smooth transition regression analysis. *International Review of Applied Economics* **27**: 472–490.

Beckmann J, Czudaj R. 2013b. Gold as an inflation hedge in a time-varying coefficient framework. *North American Journal of Economics and Finance* **24**: 208–222.

Bialkowski JT, Bohl MT, Stephan PM, Wisniewski TP. 2012. The gold price in times of crisis. *Available from SSRN: http://ssrn.com/abstract=1718106*.

Broyden CG. 1970. The convergence of a class of double-rank minimization algorithms. *Journal of the Institute of Mathematics and Its Applications* **6**: 76–90.

Capie F, Mills TC, Wood G. 2005. Gold as a hedge against the dollar. *Journal of International Financial Markets, Institutions and Money* **15**: 343–352.

Chappell D, Dowd K. 1997. A simple model of the gold standard. *Journal of Money, Credit and Banking* **29**: 94–105.

Chua J, Stick G, Woodward R. 1990. Diversifying with gold stocks. *Financial Analysts Journal* **46**: 76–79.

Ciner C. 2001. On the long run relationship between gold and silver: A note. *Global Finance Journal* **12**: 299–303.

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

Diba BT, Grossman HI. 1984. Rational bubbles in the price of gold. *NBER Working Paper* **No. 1300**.

Dooley MP, Isard P, Taylor MP. 1995. Exchange rates, country-specific shocks and gold. *Applied Financial Economics* **5**: 121–129.

Faff R, Hillier D. 2004. An international investigation of the factors that determine conditional gold betas. *Financial Review* **39**: 473–488.

Faugère C, Van Erlach J. 2005. The price of gold: A global required yield theory. *Journal of Investing* **14**: 99–111.

Fletcher R. 1970. A new approach to variable metric algorithms. *Computer Journal* **13**: 317–322.

Fortune JN. 1987. The inflation rate of the price of gold, expected prices and interest rates. *Journal of Macroeconomics* **9**: 71–82.

Ghosh D, Levin EJ, Macmillan P, Wrigh RE. 2004. Gold as an inflation hedge? *Studies in Economics and Finance* **22**: 1–25.

Goldfarb D. 1970. A family of variable metric updates derived by variational means. *Mathematics of Computation* **24**: 23–26.

Granger CWJ, Teräsvirta T. 1993. *Modelling Nonlinear Economic Relationships*. Oxford: Oxford University Press.

Harmston S. 1998. Gold as a store of value. *World Gold Council, Research Study* **No. 22**.

Hillier D, Draper P, Faff R. 2006. Do precious metals shine? An investment perspective. *Financial Analysts Journal* **62**: 98–106.

Ho YK. 1985. Test of the incrementally efficient market hypothesis for the London gold market. *Economics Letters* **19**: 67–70.

Jaffe J. 1989. Gold and gold stocks as investments for institutional portfolios. *Financial Analysts Journal* **42**: 53–59.

Kaul A, Sapp S. 2006. Y2K fears and safe haven trading of the U.S. dollar. *Journal of International Money and Finance* **25**: 760–779.

Kolluri BR. 1981. Gold as a hedge against inflation: An empirical investigation. *Quarterly Review of Economics and Business* **21**: 13–24.

Koutsoyiannis A. 1983. A short-run pricing model for a speculative asset, tested with data from the gold bullion market. *Applied Economics* **15**: 563–581.

Laurent RD. 1994. Is there a role for gold in monetary policy? *Federal Reserve Bank of Chicago, Economic Perspectives* **March**: 2–14.

Levin ER, Wright RE. 2006. Short-run and long-run determinants of the price of gold. *World Gold Council, Research Study* **No.32**.

Lucey BM, Tully E, Poti V. 2006. International portfolio formation, skewness and the role of gold. *Frontiers in Finance and Economics* **3**: 1–17.

Luukkonen R, Saikkonen P, Teräsvirta T. 1988. Testing linearity against smooth transition autoregressive models. *Biometrika* **75**: 491–499.

Mahdavi S, Zhou S. 1997. Gold and commodity prices as leading indicators of inflation: Tests of long-run relationship and predictive performance. *Journal of Economics and Business* **49**: 475–489.

McCown JR, Zimmerman JR. 2006. Is gold a zero-beta asset? Analysis of the investment potential of precious metals. *Available from SSRN: http://ssrn.com/abstract=920496* .

Michaud R, Michaud R, Pulvermacher K. 2006. *Gold as Strategic Asset*. London: World Gold Council.

Moore G. 1990. Gold prices and a leading index of inflation. *Challenge* **33**: 52–56.

Pasutasarayut P, Chintrakarn P. 2012. Is gold a hedge or safe haven? A case study of Thailand. *European Journal of Scientific Research* **74**: 90–95.

Phillips PCB, Wu Y, Yu J. 2011. Explosive behavior in the 1990s Nasdaq: When did exuberance escalate asset values? *International Economic Review* **52**: 201–226.

Pindyck RS. 1993. The present value model of rational commodity pricing. *Economic Journal* **103**: 511–530.

Reboredo JC. 2013. Is gold a safe haven or a hedge for the US dollar? Implications for risk management. *Journal of Banking & Finance* **37**: 2665–2676.

Shanno DF. 1970. Conditioning of quasi-newton methods for function minimization. *Mathematics of Computation* **24**: 647–656.

Sherman E. 1982. New gold model explains variations. *Commodity Journal* **17**: 16–20.

Sherman E. 1983. A gold pricing model. *Journal of Portfolio Management* **9**: 68–70.

Sherman E. 1986. *Gold Investment: Theory and Application*. New York: Prentice Hall.

Sjaastad LA, Scacciallani F. 1996. The price of gold and the exchange rate. *Journal of International Money and Finance* **15**: 879–897.

Smith G. 2002. Tests of the random walk hypothesis for London gold prices. *Applied Economics Letters* **9**: 671–674.

Solt ME, Swanson PJ. 1981. On the efficiency of the markets for gold and silver. *Journal of Business* **54**: 453–478.

Taylor MP, Peel DA, Sarno L. 2001. Nonlinear mean-reversion in real exchange rates: Toward a solution to the purchasing power parity puzzles. *International Economic Review* **42**: 1015–1042.

Teräsvirta T. 1994. Specification, estimation and evaluation of smooth transition autoregressive models. *Journal of the American Statistical Association* **89**: 208–218.

Teräsvirta T. 1998. Modelling economic relationships with smooth transition regressions. In Giles DEA, Ullah A (eds.) *Handbook of Applied Economic Statistics*, Marcel Dekker: New York, pages 507–552.

Tschoegl AE. 1980. Efficiency in the gold market. *Journal of Banking & Finance* **4**: 371–379.

Upper C. 2000. How safe was the 'safe haven'? Financial market liquidity during the 1998 turbulences. *Deutsche Bundesbank Working Paper* **No. 1/00**.

Van Dijk D, Teräsvirta T, Franses PH. 2002. Smooth transition autoregressive models - a survey of recent developments. *Econometric Reviews* **21**: 1–47.

Wang KM, Lee YM. 2011. The yen for gold. *Resources Policy* **36**: 39–48.

Worthington AC, Pahlavani M. 2007. Gold investment as an inflationary hedge: Cointegration evidence with allowance for endogenous structural breaks. *Applied Financial Economics Letters* **3**: 259–262.

A Tables

Table I: Descriptive statistics

Market	Series	Spl. period	Mean	Median	Max	Min	Std.dev.	Skew.	Kurt.	JB (p-val.)	Obs.
Emerg. markets	r_S	1988-2012	.10	.14	2.41	-3.83	.87	-.79	5.12	84.01 (.00)	290
EMU	r_S	1988-2012	.05	.12	1.97	-3.13	.73	-.69	4.76	60.41 (.00)	290
EU	r_S	1970-2012	.06	.12	2.49	-2.79	.63	-.61	5.12	125.98 (.00)	506
North America	r_S	1970-2012	.06	.11	1.79	-2.94	.55	-.71	5.90	219.87 (.00)	506
World	r_S	1970-2012	.06	.11	1.63	-2.50	.54	-.66	5.04	124.28 (.00)	506
Australia	r_G	1979-2012	.06	.02	2.90	-2.72	.66	.63	6.23	199.02 (.00)	397
	r_S	1970-2012	.05	.10	2.65	-5.61	.69	-1.17	12.31	1942.14 (.00)	506
Canada	r_G	1979-2012	.06	.00	2.82	-2.41	.63	.56	6.49	221.91 (.00)	397
	r_S	1970-2012	.07	.09	1.97	-2.73	.60	-.69	5.61	183.56 (.00)	506
China	r_G	1985-2012	.10	.07	4.47	-2.31	.62	1.19	11.28	1005.36 (.00)	325
	r_S	1993-2012	-.03	-.03	4.17	-3.60	1.22	-.03	3.74	5.22 (.07)	230
Egypt	r_G	1989-2012	.10	.09	2.39	-2.05	.56	.07	4.62	30.67 (.00)	278
	r_S	1995-2012	.14	.14	4.13	-3.52	1.17	.20	4.18	13.30 (.00)	206
France	r_G	1970-2012	.10	.04	3.03	-2.51	.66	.63	5.66	182.65 (.00)	505
	r_S	1970-2012	.06	.11	2.45	-3.15	.72	-.41	4.50	61.28 (.00)	506
Germany	r_G	1970-2012	.10	.04	3.03	-2.51	.66	.63	5.66	182.65 (.00)	505
	r_S	1970-2012	.04	.09	2.04	-3.45	.70	-.75	5.13	143.15 (.00)	506
India	r_G	1979-2012	.12	.07	2.89	-2.55	.65	.64	6.36	214.16 (.00)	397
	r_S	1993-2012	.10	.08	3.25	-2.98	1.01	-.13	3.15	.87 (.65)	230
Indonesia	r_G	1979-2012	.14	.07	8.36	-4.17	1.00	2.10	18.63	4334.87 (.00)	397
	r_S	1988-2012	.16	.15	8.02	-5.88	1.38	.66	10.38	678.57 (.00)	290
Italy	r_G	1970-2012	.10	.04	3.03	-2.51	.66	.63	5.66	182.65 (.00)	505
	r_S	1970-2012	.04	.06	3.16	-2.45	.81	.18	3.97	22.49 (.00)	506
Japan	r_G	1970-2012	.06	.06	3.01	-3.21	.71	.10	6.34	236.05 (.00)	505
	r_S	1970-2012	.04	.06	2.06	-3.01	.66	-.39	4.73	75.93 (.00)	506
Korea	r_G	1979-2012	.09	.03	5.09	-2.85	.77	1.30	10.83	1125.80 (.00)	397
	r_S	1988-2012	.07	.10	4.70	-3.08	1.07	.38	4.72	42.81 (.00)	290
Russia	r_G	1993-2012	.30	.21	6.58	-1.64	.90	2.57	16.09	1887.36 (.00)	229
	r_S	1995-2012	.12	.29	7.35	-10.24	2.01	-.98	8.52	294.28 (.00)	206
South Africa	r_G	1979-2012	.13	.11	2.76	-2.85	.70	.30	5.46	106.51 (.00)	397
	r_S	1993-2012	.11	.17	2.19	-3.70	.71	-.66	6.06	106.59 (.00)	230
Switzerland	r_G	1979-2012	.04	.04	3.24	-1.91	.65	.65	5.82	159.56 (.00)	397
	r_S	1970-2012	.05	.11	2.41	-3.25	.59	-.75	6.24	267.90 (.00)	506
Thailand	r_G	1979-2012	.07	.04	3.08	-2.81	.69	.53	7.27	320.36 (.00)	397
	r_S	1988-2012	.06	.05	6.38	-4.04	1.27	.15	5.95	105.98 (.00)	290
Turkey	r_G	1983-2012	.36	.38	4.35	-2.06	.70	.70	7.26	293.60 (.00)	350
	r_S	1988-2012	.37	.23	7.49	-6.60	1.79	.40	5.06	59.03 (.00)	290
UK	r_G	1970-2012	.10	.05	3.05	-2.45	.68	.63	5.62	177.05 (.00)	505
	r_S	1970-2012	.07	.14	5.15	-3.86	.68	.15	11.53	1535.21 (.00)	506
US	r_G	1970-2012	.09	.05	3.04	-3.04	.70	.37	6.72	303.05 (.00)	505
	r_S	1970-2012	.06	.12	1.91	-2.92	.55	-.70	5.74	199.75 (.00)	506

Note: JB denotes the Jarque-Bera test statistic.

Table II: Linearity test

j	1	2	3	4	5	6	7	8	9	10	11	12
Emerg. markets	.08	.65	.64	.11	.46	.03	.89	.43	.21	.55	.20	.03*
EMU	.24	.78	.05	.21	.86	.26	.04*	.86	.98	.50	.46	.65
EU	.59	.24	.60	.37	.98	.54	.29	.91	.85	.83	.04*	.87
North America	.84	.87	.79	.65	.78	.52	.11*	.57	.60	.39	.38	.49
World	.62	.87	1.00	.48	.96	.73	.12	.80	.61	.67	.11*	.89
Australia	.04	.11	.17	.03	.87	.69	.85	.64	.47	.68	.00*	.46
Canada	.19	.94	.72	.17	.57	.23	.41	.62	.12	.09*	.56	.16
China	.36	.30	.89	.33	.03	.06	.18	.24	.17	.15	.02*	.23
Egypt	.67	.52	.86	.23	.67	.67	.75	.86	.95	.12*	.92	.60
France	.46	.40	.81	.85	.18	.97	.76	.71	.27	.42	.11*	.89
Germany	.33*	.55	.37	.65	.60	.84	.95	.91	.77	.58	.62	.60
India	.22	.48	.92	.06*	.28	.09	.57	.07	.23	.95	.77	.24
Indonesia	.00*	.72	.01	.01	.11	.13	.63	.00	.13	.61	.24	.65
Italy	.71	.56	.16	.80	.50	.06	.53	.99	.34	.04*	.44	.50
Japan	.71	.85	.05*	.43	1.00	.08	.67	.59	.70	.99	.66	.33
Korea	.00*	.21	.07	.70	.20	.02	.75	.01	.53	.89	.05	.67
Russia	.03	.02	.00*	.58	.08	.04	.00	.00	.00	.02	.03	.26
South Africa	.75	.62	.93	.53	.81	.51	.07	.74	.76	.00*	.99	.41
Switzerland	.59	.83	.07*	.95	1.00	.25	.49	.94	.69	.53	.64	.94
Thailand	.52	.73	.00*	.04	.00	.00	.99	.02	.70	.14	.01	.99
Turkey	.29	.00*	.89	.45	.75	.20	.10	.03	.25	.43	.29	.21
UK	.43	.77	.58	.95	.58	.91	.32	.99	.89	.37	.23*	.55
US	.91	.90	.77	.91	.62	.31	.13*	.57	.44	.34	.39	.36

Note: The table displays the p-values for the linearity test proposed by Luukkonen *et al.* [1988] for different lag orders j. The asterisk denotes the lag length which corresponds to the highest test statistic.

Table III: Estimation results

Market	Lag	ξ_1	ψ_1	ξ_2	ψ_2	γ	κ	π	α	β
Emerg. markets	12	-.01*	-.08	.02**	.11	523.33	.03***	.00**	.15***	.79***
		(.01)	(.08)	(.01)	(.10)	(402.47)	(.00)	(.00)	(.05)	(.06)
EMU	7	.01	-.21**	-.00	.43***	39.34**	.03***	.00	.10***	.88***
		(.00)	(.09)	(.01)	(.11)	(20.15)	(.01)	(.00)	(.04)	(.04)
EU	11	.01	-.59	-.00	.63	2.87	-.82	.00***	.14***	.84***
		(.03)	(1.80)	(.03)	(1.80)	(2.87)	(1.61)	(.00)	(.02)	(.03)
North America	7	-.02**	.09	.02***	-.09	538.50*	.02***	.00***	.13***	.85***
		(.01)	(.16)	(.01)	(.18)	(323.39)	(.00)	(.00)	(.03)	(.03)
World	11	-.11***	1.23**	.11***	-1.20**	27662.73**	.00***	.00***	.13***	.85***
		(.03)	(.58)	(.03)	(.58)	(13944.11)	(.00)	(.00)	(.03)	(.03)
Australia	11	-.00	.43	1.75	-200.38	.00*	.21	.00***	.22***	.61***
		(.01)	(.64)	(1.80)	(133.47)	(.00)	(.29)	(.00)	(.06)	(.07)
Canada	10	.01**	.03	-.01*	-.10	56.08*	.01	.00**	.16***	.79***
		(.00)	(.08)	(.01)	(.12)	(33.04)	(.01)	(.00)	(.04)	(.05)
China	11	-.00	.11***	.14	-1.20	.34	.05**	.00*	.11*	.89***
		(.00)	(.04)	(.37)	(2.91)	(.97)	(.02)	(.00)	(.06)	(.06)
Egypt	10	.00	-.03	.01	.27	3.67	-.04	.00***	.26**	-.22**
		(.01)	(.05)	(.01)	(.22)	(3.76)	(.04)	(.00)	(.10)	(.11)
France	11	.00	.07	.00	.13	7.84	-.03	.00***	.15***	.77***
		(.01)	(.05)	(.01)	(.22)	(19.79)	(.05)	(.00)	(.04)	(.05)
Germany	1	.01**	.08*	-.08	.20	.61	-.02	.00**	.13***	.83***
		(.00)	(.04)	(.34)	(.67)	(3.22)	(.04)	(.00)	(.04)	(.04)
India	4	.01**	.05	-4.04	-143.14***	.00***	.03	.00***	.23**	-.11
		(.00)	(.04)	(7.50)	(33.19)	(.00)	(.03)	(.00)	(.10)	(.17)
Indonesia	1	-.01	-1.29***	.02	1.27***	9.44**	-.34***	.00**	.35***	.65***
		(.04)	(.46)	(.04)	(.46)	(4.01)	(.02)	(.00)	(.07)	(.06)
Italy	10	.01	.09	-102.34	-1720.72	.00	-.13	.00***	.14***	.78***
		(.00)	(.08)	(2154.15)	(36062.37)	(.00)	(.26)	(.00)	(.04)	(.05)
Japan	3	.01	-.10	-.01	.21	103.27	.02	.00**	.13***	.83***
		(.01)	(.13)	(.01)	(.14)	(181.79)	(.01)	(.00)	(.04)	(.05)
Korea	1	-.01*	.08	.02***	-.14	58.04	-.02***	.00**	.34***	.63***
		(.01)	(.08)	(.01)	(.09)	(59.77)	(.01)	(.00)	(.10)	(.09)
Russia	3	.04***	-.18***	-.04***	.19**	115.11	-.00	.00***	.62***	.06
		(.01)	(.07)	(.01)	(.08)	(78.58)	(.01)	(.00)	(.16)	(.06)
South Africa	10	.00	.06	574.94	-7163.84	0.00	.00	.00	.48**	.56***
		(.00)	(.04)	(663.11)	(8029.30)	(.00)	(.02)	(.00)	(.20)	(.10)
Switzerland	3	-.01	-.05	.01	.19	25.36	.06***	.00***	.21***	.56***
		(.01)	(.16)	(.01)	(.20)	(27.49)	(.01)	(.00)	(.06)	(.09)
Thailand	3	.01***	.06*	-.05	-.43	1.56	.01	.00*	.14***	.75***
		(.00)	(.04)	(.06)	(.44)	(2.72)	(.02)	(.00)	(.06)	(.09)
Turkey	2	.03***	-.06**	-109.68	22027.97	.00	.10***	.00	.15*	.59**
		(.00)	(.03)	(704.10)	(141344.48)	(.00)	(.03)	(.00)	(.08)	(.26)
UK	11	.01	.47**	-.01	-.50**	722.79	.03***	.00***	.14***	.80***
		(.01)	(.20)	(.01)	(.21)	(694.65)	(.00)	(.00)	(.03)	(.04)
US	7	-.02***	.25	.03***	-.26	1144.19	.02***	.00***	.14***	.85***
		(.01)	(.18)	(.01)	(.20)	(734.22)	(.00)	(.00)	(.03)	(.03)

Note: * Statistical significance at the 10% level, ** at the 5% level, *** at the 1% level. The coefficients are estimated by nonlinear least squares. Newey-West standard errors are given in parentheses. The table provides estimates for the following equations: (1) $r_{G,t} = \xi_1 + \psi_1 r_{S,t} + \left(\xi_2 + \psi_2 r_{S,t}\right) G(z_t, \gamma, \kappa) + \varepsilon_t$, (2) $h_t = \pi + \alpha\varepsilon_{t-1}^2 + \beta h_{t-1}$, (3) $G(z_t, \gamma, \kappa) = 1 - \exp(-\gamma(z_t - \kappa)^2/\sigma_{z_t})$.

B Figures

FIGURE I **Gold prices (black line) and US stock prices (blue line) both in US dollar**

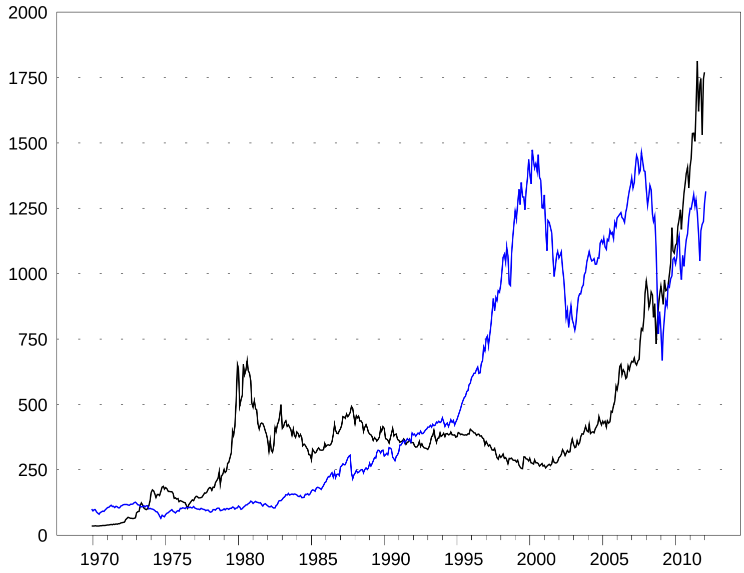

FIGURE II **QQ-plot for each market**