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The Relative Valuation of Gold

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The Relative Valuation of Gold

Abstract

Gold is a globally traded asset and held in large quantities by investors and central banks. Since there is no established model to assess if the price of gold is overvalued or undervalued, we propose a relative valuation framework based on gold price ratios. We analyze gold prices relative to commodity prices, consumer prices, stock prices, dividend and bond yields and find that the relative value of gold varies significantly over time indicating pronounced periods of mispricing of gold relative to other assets. An analysis of the factors which drive these variations demonstrates that inflation expectations and uncertainty have a strong influence on gold ratios while macroeconomic fundamentals are less important. More specifically, a boost in confidence decreases the relative price of gold while heightened uncertainty increases the relative price of gold which confirms the role of gold as a safe haven.

JEL Classification: G10, G15

Keywords: Gold; relative valuation; gold-silver ratio; safe haven; Bayesian econometrics

February 2016

1 Dirk G. Baur, University of Western Australia; Joscha Beckmann, RUB, UDE and Kiel Institute for the World Economy; Robert Czudaj, UDE. *– We thank participants of the 13th INFINITI Conference on International Finance, Ljubljana/Slovenia and the KLU Finance Meeting on Gold, Hamburg/Germany for providing useful comments.* *- All correspondence to: Robert Czudaj, University of Duisburg-Essen, Department of Economics, Chair for Econometrics, 45117 Essen, e-mail: robert.czudaj@uni-due.de*

1 Introduction

"*Nobody really understands gold prices and I don't pretend to understand them either.*"

Ben Bernanke, Congressional Testimony, July 18, 2013

Gold was the cornerstone of the international monetary system until 1971 and even today, more than 40 years later, central banks still hold large amounts of gold. Investors and central banks appear to consider gold as an alternative currency and store of value. Despite its importance in the global monetary and financial system, gold prices are not well understood and there is no commonly accepted pricing model.

In this paper, we aim to reduce the lack of understanding regarding gold prices and investigate the usefulness of relative valuation. The theoretical foundation for such an analysis stems, among others, from the Austrian School of Economics. Menger (1871) states that "Value is nothing inherent in goods, no property of them, nor an independent thing existing by itself. It is a judgement economizing men make about the importance of the goods at their disposal for the maintenance of their lives and well-being. Hence, value does not exist out of the consciousness of men." (p. 121) The foundation for relative valuation is also rooted in the law of one price. This fundamental principle in economics states that two identical items at the same venues should sell for the same price. The law of one price implies relative valuations, e.g. that the price of an asset is too high relative to other assets. In contrast, the law of one price does not imply absolute valuations, e.g. that a price of USD $1,000$ is the right price.

Accepting that value is relative[1], we propose the use of gold price ratios to assess the relative value of gold. Whilst the use of ratios is a rather common approach in finance to value stocks, e.g. the price-earnings ratio (see Campbell and Shiller, 1998 and 2001) or more generally the rate of return and the Capital Asset Pricing Model[2], there is no commonly accepted framework to value commodities with ratios.[3] To the best of our knowledge this is the first academic paper that analyzes gold ratios with

[1] All values are relative. A fruit, say an orange, is generally expressed in terms of a currency, e.g. 1 US dollar. The same is true for a car (e.g. 30,000 US dollar) or an ounce of gold (e.g. 1,200 US dollar). If the value of the currency changes, the value of the good or service will change as well.

[2] The rate of return is a ratio of prices at t over prices at $t-1$ and the Capital Asset Pricing Model relates stock returns of companies to excess stock returns of the market.

[3] Note that the price of gold is a ratio per se. It is the value of gold relative to the price in a specific currency, usually the US dollar, e.g. 1,200 US dollar/ 1 ounce of gold. The price of gold in US dollar is a statement about

the objective to assess the relative value of gold and thus to better understand gold price dynamics.[4] We also contribute to the literature by paying specific attention to uncertainty, expectations and risk as potential drivers of gold ratios and provide a new - relative - perspective on the hedge and safe haven aspects of gold.

The existing literature generally focusses on specific variables which are potentially linked to the price of gold and uses mainly regression frameworks to analyze these relationships. Taking into account the large literature on gold prices, we only elaborate on a few selected studies in the following.[5] One strand of the literature analyzes the role of inflation and thus the store of value and inflation hedge property of gold.[6] Recent research of this kind is for example provided by Batten et al. (2014), Beckmann and Czudaj (2013) as well as Jastram (2009). Blose (2010) analyzes whether changes in expected inflation affect gold prices and finds no robust evidence for such a link. A second kind of studies focuses on the role of gold against other assets. For example, Escribano and Granger (1998) study the long-run relationship between gold and silver prices and Capie et al. (2005) examine the hedge property of gold with respect to changes of the US dollar. Baur and Lucey (2010) study the relationship of gold with equity and bond markets and focus on the safe haven property of gold. Finally, some authors have examined gold price determinants from a broader perspective. Baur (2011) studies a large range of variables including different inflation rates, interest rates and exchange rates and Bialkowski et al. (2015) estimate the influence of different variables with the aim to determine a fundamental price of gold and to identify bubbles. Faugere and Van Erlach (2005) assess the value of gold using a global required yield theory. None of these papers explicitly consider gold price ratios but relate gold price changes to changes of other variables. In other words, all studies identify certain drivers of gold, hedge or safe haven properties based on econometric measures of association.

Based on the existing literature of gold we study ten gold price ratios: The gold-silver ratio, the gold-CPI ratio, the gold-commodity price ratio, the gold-oil ratio, the gold-corn ratio, the gold-copper

how many US dollars does one need to purchase one ounce of gold. If the value of the US dollar increases, the ratio falls and one needs fewer US dollars to purchase one ounce of gold.

[4]The financial adviser Incrementum AG has analyzed gold ratios in their annual report "In Gold We Trust" (2014).

[5]See O'Connor et al. (2015) for a detailed overview of the literature on gold.

[6]The inflation hedge property of gold means that gold increases with inflation and thus acts as a store of value against a portfolio of goods and services. The inflation hedge property implies a positive correlation of gold price changes with inflation and is therefore different to a typical financial hedge which implies a zero or negative correlation.

ratio, the gold-Dow (Jones) ratio, the gold-dividend yield ratio, the gold-US Treasury bond yield ratio and the gold-federal funds rate ratio. The ratios using yields are based on a constructed index of compounded yields. The first six ratios value gold relative to different prices (silver prices, consumer prices, commodity prices) and are thus related to the question if gold is a relative store of value and an inflation hedge, i.e. a price hedge that insures against rising consumer prices. The gold-Dow ratio tests if gold is also an asset price hedge and the last three ratios study the price of gold relative to compounded yields. The dividend yield, the 10-year US Treasury bond yield and the federal funds rate can be viewed as a measure of the opportunity cost of holding physical gold. Regardless of the question whether gold is analyzed against asset prices or indices, an increase always reflects a higher relative valuation of gold. Whilst it is obvious that the ratios are not exhaustive and that one could think of a large number of additional ratios, we believe that the chosen ratios can be considered a representative sample of the large set of theoretically possible ratios.[7]

Since value is nothing inherent in goods, it can change which justifies the analysis of ratios through time with a special focus on the variation of the ratios in certain periods, e.g. high or low inflation periods. In other words, we study gold price ratios in two dimensions, across different assets and through time.

The ratios can also be used to analyze certain characteristics of gold, namely the store of value and safe haven. More specifically, a stable long-run ratio is consistent with gold's store of value and inflation hedge property, and a stable ratio in periods of uncertainty is consistent with gold's safe haven property. However, all interpretations are only valid in relative terms. For example, gold's store of value property in a relative valuation context could also imply that the price of gold falls together with other assets but not by more than the alternative assets that are considered. Moreover, there is only strong evidence for the store of value property if it holds for a large number of alternative assets. Finally, the safe haven property could entail that the price of gold falls in a crisis period but not by more than the alternative assets. In that case, gold would lose in absolute value terms but not in relative value terms. Hence, the ratio analysis provides a new perspective on these properties

[7]One of the ratios that are not explicitly examined in this paper is the gold-monetary base ratio. The US monetary base increased from 50,000 million US dollars to 4,000,000 million US dollars from 1960 to 2015. This is a total change of 7,900% compared to a change in the price of gold of about 3,264%. Hence, this ratio can be characterized by a continuously decreasing line and could not be used to predict future gold price changes (see below).

compared to other frameworks that are commonly used (e.g. see O'Connor et al., 2015). Regarding correlations, a stable ratio means that there is a perfect correlation between gold and the other asset under consideration. Such a perfect correlation may imply an inflation hedge or an asset price hedge, e.g. the price of gold moves with the other asset and thus does not lose its relative value. This clarifies that gold's "inflation hedge" and "currency hedge" properties imply protection of gold against an internal and external deterioration in value, respectively.

A stable ratio does not imply a financial hedge in the sense that gold protects investors against a falling price of an asset or an index. If the correlation is zero or negative on average, e.g. if gold returns are uncorrelated with stock returns and gold is therefore a hedge against stock returns, the gold price/ stock price ratio would not be stable but vary over time. Accordingly, since gold is defined to be a safe haven against other assets (e.g. the stock market) if the correlation is zero or negative in crisis periods only (see Baur and Lucey, 2010), the ratio would not decrease in crisis periods. Hence, we expect a stable ratio if gold is a perfect inflation and currency hedge but a time-varying ratio if gold is a hedge or a safe haven against other assets.

The variation of the ratios is also useful to make statements about the future (relative) price of gold. If the ratios did not vary it would not be possible to make statements about a relative over- or undervaluation of gold. Similarly, if the variations of the ratios were not within certain ranges, relative valuation would be impossible as well. This is why Campbell and Shiller (2001) assume stability of the valuation ratio within their historical ranges ("and neither move permanently outside nor get stuck at one extreme of their historical ranges", p. 2). This stability has important implications about mean reversion of the ratios and predictability. Campbell and Shiller (2001) argue "When a valuation ratio is at an extreme level either the numerator or the denominator of the ratio must move in the direction that restores the ratio to a more normal level." (pp. 2-3). We will analyze the dynamics of the gold price ratios both descriptively and econometrically explicitly testing for mean-reversion and predictability. We find that gold price ratios are mean-reverting which demonstrates that they are useful for policymakers and market participants who can expect that long-run deviations representing misalignments are corrected at some future point in time.

We also study the reasons for the variation, that is, which factors drive the fluctuations of ratios and what we can learn from this variation. In doing so, we apply Bayesian model averaging (BMA) in order to allow for both uncertainty about the variables that should be included in the model and the uncertainty about the model structure (Raftery, 1995). This is particularly important for the gold market that is influenced by both economic and financial variables, global and local factors. This uncertainty about the appropriate econometric model is tackled by BMA using a weighted average of posterior means based on a large number of different models as point estimates.

Relying on this framework, we consider two kinds of regressors. One group consists of macroeconomic variables from the United States, namely industrial production, money supply, consumer prices and the 3-month Treasury rates. The second set includes measures of expectations and uncertainty. We include macroeconomic uncertainty, economic policy uncertainty, sentiment, inflation expectations and smoothed US recession probabilities.[8] This overall setting includes standard macroeconomic fundamentals and also accounts for the fact that asset prices are forward looking and therefore incorporate discounted expectations. Regarding the latter, analyzing ratios allows an assessment of the impact of expectations and uncertainty on the relative price of gold. This offers a new perspective on the role of gold in general and on the role as a hedge against other assets and as a safe haven in particular.

The remainder of the paper is structured as follows. Section 2 examines the dynamics of the ratios under observation and provides an interpretation. Moreover, Section 3 describes our empirical methodology dealing with determinants of gold ratios and Section 3.2 presents the corresponding results. Section 4 summarizes the findings and provides concluding remarks.

2 Ratio Analysis

This section starts with the presentation of the data and a descriptive statistical analysis as a precursor to the ratio analysis. Figure I illustrates the evolution of the price of gold from January 1960 until

[8] The role of gold has hardly been explicitly analyzed in the context of policy uncertainty. One study is provided by Jones and Sackley (2015) who find that increases in economic uncertainty contribute to increases in the price of gold. However, the authors do not take the relative price of gold and macroeconomic uncertainty into account and do not address the role of gold as a safe haven in this context. In addition, Aye et al. (2015) consider the Kansas City Fed's financial stress index and the US economic policy uncertainty index as potential predictors of gold returns.

January 2015. The 1960s period is included to contrast two gold price regimes, one in which the price was fixed to the US dollar and one in which the fix to the US dollar was abolished. The different regimes can be clearly identified as the former is characterized by a stable price for most of the 1960s and the latter is characterized by significant fluctuations in the price of gold. All ratios display the significant undervaluation of gold in the final year of the Bretton Woods system with all of them increasing after the abolishment of the gold-dollar peg in 1973 (see Fig. II below).

*** Insert Figure I about here ***

Table I presents descriptive statistics of the prices of the assets used for the relative valuation of gold. The table includes gold prices, silver prices, US consumer prices (CPI), a commodity price index (CRB)[9], crude oil prices, corn prices, LME copper prices, the index level of the Dow Jones Industrial Average (DJIA)[10], the cumulative returns of reinvested S&P500 dividends, the cumulative returns of the 10-year US Treasury bond yields and the cumulative returns of the federal funds rate.[11]

*** Insert Table I about here ***

We calculate the ratios of gold prices relative to the other asset prices or levels for each month for the January 1960 - January 2015 sample period. The time-varying ratios are presented in Figure II and the descriptive statistics of the ratios are reported in Table II. The graphs and the table show that the ratios are rather volatile and deviate from their long-run (historical) mean for substantial periods of time.

*** Insert Figure II about here ***

[9] A reasonable alternative would be to use the IMF commodity price index as a proxy for overall commodity price behavior. However, the sample period for this series provided by the IMF starts in 1992 and would therefore strongly restrict our sample size.

[10] An alternative would be to use the MSCI world index instead of the DJIA. However, the correlation between both indices is nearly one and therefore this choice has no impact on our results.

[11] All time series used in our ratio analysis are taken from Sharelynx and Thomson Reuters Datastream.

*** Insert Table II about here ***

For example, whilst the mean of the gold-silver ratio is 50.33, its standard deviation is 19.56 which implies that the ratio varies substantially through time. Figure II shows that the ratio was around 20 in the 1970s and 1980s but increased to levels well above 80 in the 1990s. Similar variations can be observed for the other series. A common feature among nine of the ten ratios is the high ratio around the year 1980 (except for gold-silver). The fact that the ratios were equally and historically high among a large set of assets in 1980 and decreased significantly afterwards suggests that gold was overvalued relative to other assets at that time. The peak around the year 2010 for most ratios (except the gold-silver ratio) resembles the 1980 commonality and suggests that gold was overvalued relative to the other assets as it is rather unlikely that all other assets were jointly undervalued. If the drivers of the ratio are the same in the 1980s and in the 2010s will be analyzed below.

*** Insert Figure III about here ***

Figure III presents the boxplots of the ratios and illustrates that some ratios differ substantially from each other. The gold-silver ratio, for example, is rather symmetric whilst the other ratios are asymmetric and in some cases heavily skewed.

Mean reversion

A crucial question is whether the ratios are mean-reverting. If a ratio is mean-reverting, investors and policymakers can use a high relative valuation as a signal that indicates a non-persistent overvaluation whilst such a signal would be meaningless if the ratio did not exhibit a tendency to revert to its historical mean. To test for mean reversion, we apply a Perron (2006) type of test and therefore allow for the potential of structural changes in the level of each gold ratio which is reasonable bearing in mind the rather long sample period and several momentous economic events during that period.[12] The corresponding results are reported in Table III. We find that all regressions yield a negative

[12] The application of the classical ADF test points in favor of non-stationarity for the majority of gold ratios. Solely for the gold-oil, the gold-10 year bond and the gold-FFR ratio the unit root null can be rejected at a 5% level. However, it is well-known that the ADF test has very low power in the presence of structural breaks. Therefore, we do not rely on the corresponding results.

coefficient for the lagged ratio and the null of a unit root is rejected for eight out of ten gold ratios indicating mean reversion. Solely for the gold-silver and the gold-DIVY ratio the null can hardly be rejected but the corresponding test statistics are close to the 10% critical value. Bearing in mind the generally low power of unit root tests to reject the null, we do not see this finding as a clear-cut indication against mean-reversion of these two ratios. Moreover, a visual inspection of the ratios also illustrates that all ratios exhibit common features and a tendency to revert back to its long-run mean. The gold-oil ratio appears to be the most stable and also displays the largest negative coefficient estimate. Moreover, to verify the robustness of this result we have also applied this test on a sample period (i.e., 1971-2015) excluding the period prior to the breakdown of Bretton Woods to assure that our findings are not affected by the inclusion of the fixed gold price period prior to 1971. The latter confirms our finding. In addition, Table III also provides endogenously determined structural breaks for each gold ratio which roughly serve as a guideline for our (sub-sample) analysis in Section 3.2. For most of the ratios we find a structural break around the year 1978 which marks the starting point of our analysis in Section 3.2 and also around the year 2008 in which Lehman Brothers collapsed. Both dates mirror turning points of the gold price.[13]

*** Insert Table III about here ***

Valuations

For valuation purposes it is important to know whether the ratios today are similar to the historical average or clearly different. A comparison of the ratios in January 2015 with the historical averages shows that the 2015 ratios are larger in most cases with the exception of the gold-DJIA ratio and the gold-10 year bond ratio. All other ratios are clearly larger than their historical average. For the gold-silver ratio the difference is 50%, i.e. the ratio in 2015 stands at 75 compared to a historical average of 50. In contrast, a comparison of the 6-month average of the second half of 2014 with the 5-year average from 2009 to 2014 reveals that the difference is positive for all ratios except the gold-

[13]The number of break points that need to be accounted for is to some extent arbitrary. However, including more than two break points confirms the result that most of the gold ratios are mean-reverting.

DJIA ratio but relatively small and negligible compared to the comparison with the historical mean spanning the full sample period. For example, the gold-silver ratio is only 1% larger than its 5-year average. A simple regression in which the ratio is regressed on a constant and a trend reveals a positive trend for all ratios except for the DJIA, the 10-year bond and the FFR ratios. However, despite the statistical significance of the trend coefficients the results are also influenced by the relatively low ratios in the 1960s. In addition, the trend does not account for the variations throughout the sample. If the trend estimates are ordered, the gold-oil ratio exhibits the weakest positive trend followed by gold-CPI, gold-silver, gold-corn and gold-CRB. Given the trend coefficients, the gold-oil ratio could be labelled the most stable of all ratios, an interpretation that is also supported by a visual inspection of the ratio.

One can also assess the relative performance of gold over the sample period by comparing the total percentage changes of each variable. The total change of gold over the 55-year period is 3,264%, compared to 1,614% for silver, 701% for the CPI, 342% for the CRB, 1,694% for oil, 237% for corn, 827% for copper, 2,763% for the Dow Jones, 424% for the reinvested dividends of the S&P500, 3,204% for the reinvested returns on 10-year US Treasury bonds and 1,870% for the reinvested returns on the FFR. This list indicates that gold outperformed all other assets or indices.

Variations

To investigate whether the variations are statistically significant we have tested the null hypothesis that the ratio in month t is not different from the historical mean up to that month t and thus have calculated the corresponding t-statistic for each month. The results are shown graphically for a selection of ratios. The ratios are plotted and a grey-shaded area is added representing t-statistics that are larger than their respective 5% critical values. Figures IV to VIII show these areas for the gold ratios. The plots illustrate that the ratios are statistically significantly different from their historical mean especially around the years 1980, 1990 and 2010. The periods in between these years are generally not statistically different from the historical mean.

*** Insert Figures IV to VIII about here ***

Commonalities in lower bound (10%) and upper bound (90%) exceedances of the ratios are plotted in Figure IX. It shows the number of ratios that exceed their respective lower and upper bounds for each month. The time-series plot illustrates that there are two exceedance clusters of the lower bounds and two exceedance clusters of the upper bounds. The lower bound clusters are located in the late 1960s and the early 2000s whilst the upper bound clusters are located around the year 1980 and the 2010-2015 period. The exceedance commonalities show the joint under- or overvaluation of gold for each period and thus indicate that gold was rather undervalued in the lower bound exceedance clusters and overvalued in the upper bound exceedance clusters. The reasons for the overvaluation of gold in the 1980s and 2010-2015 period are likely different as the 1980 overvaluation can be attributed to a regime of high inflation and the 2010-2015 period can be attributed to a regime of low inflation and possibly high uncertainty.

*** Insert Figure IX about here ***

3 The Drivers of Gold Price Ratios

3.1 Empirical framework and potential regressors

As already mentioned in the Introduction, we make use of Bayesian model averaging (BMA) in order to account for the uncertainty about the model or more precisely about its structure and its variables. We do this since the evolution of the gold price and thus also of the gold ratios considered in this study is characterized by a high degree of uncertainty about the variables to select and about the structural form.[14]

We include m potential regressors and consider each combination of these as a potential model. This results in $K = 2^m$ different models. Following Raftery (1995), the model-averaged Bayesian point

[14]The importance to account for model uncertainty when analyzing gold has already been stressed by Baur et al. (2014) and Aye et al. (2015) in studies focusing on an appropriate gold return forecast. It appeared to be beneficial to use a dynamic version of the model averaging approach to reduce the forecast error. However, we rather focus on the identification of the main determinants of the gold ratio than on a forecast. Time-variation in the coefficients is considered by the sub-sample analysis in Section 3.2.

estimator is given by

$$E\left[\beta_j|X\right] = \sum_{k=1}^{K} \tilde{\beta}_j^{(k)} p(M_k|X)$$

where $\tilde{\beta}_j^{(k)}$ denotes the posterior mean of β_j under model M_k and $p(M_k|X)$ stands for the posterior probability that M_k is the correct model and X denotes the data. This is calculated by applying the Bayes rule

$$p(M_k|X) = \frac{p(X|M_k)p(M_k)}{\sum_{\ell=}^{K} p(X|M_\ell)p(M_\ell)}$$

where $p(X|M_k)$ is a high dimensional integral that can be approximated accurately by the simple Bayesian Information Criterion (BIC). For a linear regression, the BIC can simply be calculated by $BIC_k = n\log(1-R_k^2) + m_k \log n$, where n denotes the number of observations and m_k the number of regressors included in model M_k. We take the prior model probabilities $p(M_k)$ to be equal for each model.

As the m potential regressors, we include two different sets of variables. One group consists of macroeconomic variables from the United States, namely industrial production, money supply, consumer prices and the 3-month Treasury bill rate taken from Thomson Reuters Datastream. In order to account for non-stationarity of these series, we use first differences. The second set includes measures of expectations and uncertainty. We include a measure of macroeconomic uncertainty following Jurado et al. (2015), a measure of economic policy uncertainty provided by Baker et al. (2015), consumer sentiments and inflation expectations both provided by the University of Michigan and smoothed US recession probabilities taken from FRED Economic Data. The policy uncertainty index consists of three underlying components. Newspaper coverage of policy-related economic uncertainty, the number of federal tax code provisions set to expire in future years and the disagreement among economic forecasters. The macroeconomic uncertainty measure relies on econometric estimations of common variation in the unforecastable component based on a large number of economic indicators. In both cases, an increase reflects higher uncertainty.

This overall setting includes standard macroeconomic fundamentals and also accounts for the fact that asset prices are forward looking and therefore incorporate discounted expectations. In the latter regard, analyzing ratios is interesting since we are in a position to assess the impact of expectations and uncertainty on the relative price of gold. This offers a new perspective on the role of gold as a hedge and safe haven against other assets or inflation. Due to availability of data the sample period for our estimations starts in January 1978. This excludes the period of stable gold prices in the 1960s. Table IV reports the correlations between all regressors considered and shows that these are below 0.7 for all regressors and for most of them even below 0.5 in magnitude. Therefore, multicollinearity is not a concern in our estimations.

*** Insert Table IV about here ***

3.2 Empirical Results

We start the assessment of our results by analyzing our findings over the full sample period. As a benchmark for our interpretation, we rely on posterior inclusion probabilities of each variable over all models as well as on the variables which enter the best models. We also take the magnitude of coefficients and the R^2 for the "best" model into account. Tables V to XIV provide detailed results for all ratios under consideration. We now focus on our main questions step by step.

*** Insert Tables V to XIV about here ***

Which variables are useful for explaining gold ratios?

The unambiguous pattern over the full sample period is that expectations and uncertainty turn out to be far more important for explaining movements of gold ratios than macroeconomic variables. Macroeconomic variables display inclusion probabilities below 0.5 for nearly all ratios. The only exceptions are the impact of changes in industrial production on the gold-Dow ratio, money supply changes on the gold-CPI ratio and changes of consumer prices on the gold-oil and the gold-dividend ratio. In all other cases, macroeconomic variables seem to have a negligible impact on the relative price of gold.

The results for expectations and uncertainty point into the opposite direction. These measures frequently obtain inclusion probabilities of more than 70, in many cases even more than 90 percent. For gold-silver, gold-CPI, gold-corn and gold-CRB, all five measures display probabilities of more than 95%. For the gold-dividend (gold-FFR) ratio, only inflation expectations (economic policy uncertainty) out of this group display a probability below 90%. Macroeconomic uncertainty and inflation expectations also provide probabilities above 90% for the gold-Dow and the gold-copper ratio. For the gold-oil ratio, only the recession probability and changes of the CPI provide inclusion probabilities significantly above 50%.

A comparison of the different models confirms the importance of expectations and uncertainty. Except for the gold-oil, the gold-copper and the gold-Dow ratio, at least four of the forward looking variables are part of the best model characterized by the highest posterior probability. On the contrary, fundamentals hardly enter the best models. The only exceptions are in line with the inclusion probabilities for fundamentals explained above. Overall, the lowest R^2 is obtained for the gold-oil ratio which cannot be explained by any of the considered model configurations to a convincing degree. This is not surprising since several possible market specific determinants of oil prices are not included in our setting such as important political events and global economic activity.

Our results mirror the fact that gold ratios are forward looking measures which include expectations and the current state of uncertainty. In contrast, current macroeconomic developments are hardly considered to be relevant for future gold ratios. Although the forward looking behavior of the gold price is not surprising, the importance of expectations and uncertainty is an interesting aspect which will be analyzed in greater detail in the next section.

How are gold ratios affected by uncertainty and risk?

Our results have already confirmed the frequent and significant impact of expectations and uncertainty on gold ratios. Turning to the magnitude, it is worth mentioning that many coefficients are of a comparable small magnitude despite high inclusion probabilities. In terms of the direction of the effects, both policy uncertainty and macroeconomic uncertainty mostly increase the relative price of gold according to our results.

They have a positive impact on the gold-CPI, gold-corn and the gold-dividend ratio. In addition, macroeconomic uncertainty has a positive impact on the gold-Dow and the gold-US Treasury rate ratio. In contrast, we find a negative effect for both uncertainty measures on the gold-silver ratio.

A positive impact of uncertainty on the relative price of gold can be considered evidence for the safe haven property of gold. While standard definitions of hedge and safe haven rely on correlation analyses (e.g. Baur and Lucey, 2010), our results provide a new perspective on these properties. The ratios discussed in Section 2 already illustrated that gold serves as a relative hedge against consumer price and asset price changes since the relative price of gold was not lower at the end of the sample period than at the start of the sample period. The finding that macroeconomic and policy uncertainty lead to an increase in gold ratios and thus the relative price of gold confirms the relative safe haven property of gold. The influence of sentiments further supports this conclusion. An increase in sentiment (economic confidence) decreases the relative price of gold according to most ratios. This finding is intuitively plausible considering the negative correlation between sentiments and our uncertainty measures. Overall, these findings provide a new perspective on a relative hedge/safe haven property of gold. The negative relationship of the ratios with recession probabilities further suggests that the safe haven property is a financial property and does not protect against adverse real economy phenomena.

Are the results different across samples?

An obvious question is whether our main results hold over different sub sample periods. We look at three sub periods: January 1978:01 until December 2000, January 2001 until September 2008 and October 2008 until February 2014. The inclusion probabilities are summarized in Table XV. The end of the first sample is marked by the start of a period of increasing gold prices while the third period starts after the collapse of Lehman Brothers. Although the choice of the sub samples is somehow arbitrary, this exercise is sufficient to illustrate that our main findings are robust through time, i.e. expectations as well as uncertainty and risk measures are far more important than macroeconomic fundamentals.

Nevertheless a few results are worth mentioning. Most importantly, macroeconomic uncertainty turns out to have a negative impact on most ratios over the final sample after the start of the subprime crisis except for the gold-silver ratio. However, the impact of policy uncertainty remains positive although posterior inclusion probabilities and levels of significance are subject to changes. The different impact of macroeconomic uncertainty might reflect the fact that macroeconomic uncertainty peaked in 2009 and sharply decreased afterwards while the nominal gold price initially continued to increase after 2009 leaving an asymmetric response to increasing and decreasing macroeconomic uncertainty as a possible explanation.[15] Another interesting result for the final sample is the diminishing effect of the recession probability and the increasing importance of changes in US industrial production. A convincing explanation is that financial markets pay greater attention to the current path of production in the aftermath of a recession while the probability of further recessions is less important.

*** Insert Table XV about here ***

Robustness test: exchange rate effects?

It is well-established that the gold price denominated in US dollars is inversely related to the US dollar exchange rate. The same relationship holds for other US dollar-denominated assets such as oil and corn. However, this raises the question whether fluctuations of gold against indices, mirrored by the gold ratio relative to CRB or the Dow Jones, are driven by changes of the effective dollar exchange rate. An inspection of the graphs provided in Section 2 suggests that this is not the case. While the dollar experienced a large appreciation between 1980 and 1985 and sharply depreciated afterwards, the corresponding ratios display different swings across this period. Correlation analysis and the inclusion of the nominal effective dollar exchange rate as an additional regressor in alternative specifications confirm this result. In the latter case, both the posterior inclusion probabilities and the coefficients remain nearly unchanged and for the change of the effective dollar exchange rate the probabilities of inclusion are far below 0.5 for each gold ratio.

[15] Based on the measure suggested by Jurado et al. (2015), large macroeconomic uncertainty occurs on three occasions in the post-war period: 1973-74, 1981-82 and 2007-09.

Are gold ratios useful for predicting gold prices?

Our in-sample results considered so far raise the question whether the relative price of gold can be useful for predicting future nominal gold prices. We analyze this question by considering lagged ratios as explanatory variables for future gold price changes in an out-of-sample exercise.[16] Our findings reported in Tables XVI to XVIII suggest low prediction power of ratios for future gold price changes for lags 3 and lags 12. The results for lag 6 are different as two ratios, namely the gold-CPI ratio and the gold-dividend yield ratio, display high inclusion probabilities and significant coefficient estimates. The ratios and the sign of the estimated coefficients are plausible as they suggest that an increasing gold-CPI ratio leads to a lower gold price in 6 months and that a decreasing gold-CPI ratio leads to a higher gold price in 6 months. Hence, the gold price appears to follow consumer price inflation. The results for the gold-dividend ratio are equally plausible economically. If the gold-dividend ratio increases, the price of gold increases in 6 months due to lower opportunity costs of holding gold. Similarly, if the gold-dividend ratio decreases, the price of gold decreases in 6 months due to higher opportunity costs of holding gold. These results are consistent with the overall evidence for mean reversion as reported above. However, it must be admitted that the evidence for predictability is rather weak, a finding consistent with the structural breaks in the ratios that adversely affect predictability.

*** Insert Tables XVI to XVIII about here ***

The finding of weak predictability is in line with several results in the financial economics literature. For example, exchange rates are hard to predict out-of-sample frequently leaving the random walk as the most convincing predictor. This is also due to the fact that the in-sample fit does not necessarily translate into out-of-sample predictability (Rossi, 2013).

4 Summary and Concluding Remarks

This paper is the first study on gold ratios and thus on the relative valuation of gold. We have analyzed the prices of gold relative to the prices of other assets such as silver, oil, corn, copper, a commodity

[16]Strictly out-of-sample means that no information ahead of period t is adopted for predictions for period $t+1$.

price index, consumer prices, stock prices, a portfolio based on reinvested dividends, bond yields and interest rates. The results show that the ratios share common variations and are significantly different from their historical mean for several periods especially around the year 1980, 1990 and 2010. The gold price ratios in 2015 do not indicate a clear over- or undervaluation of gold relative to the 5-year period from 2009-2014 but a clear overvaluation relative to the historical averages over the period from 1960-2015. We also find that the ratios are mean-reverting which renders them meaningful for investors and policymakers since misalignments are corrected in the long-run. Moreover, all gold ratios are higher in 2015 than in 1960 which demonstrates that gold did not lose its relative value and thus purchasing power against other variables or assets.

When analyzing the factors which drive variations, we find an important impact of expectations and uncertainty on gold ratios while macroeconomic fundamentals turn out to be less important. The finding that a boost in confidence measured by sentiments decreases the relative price of gold whilst an increase in economic policy or macroeconomic uncertainty increases the relative price of gold confirms the role of gold in general and as a safe haven in particular. Overall, the methodology to study the hedge and safe haven characteristics of gold based on ratios and thus the relative valuation of gold offers a novel perspective and opportunities for future research.

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Figure I **The Gold Price**

This figure presents the evolution of monthly gold prices (US dollar per ounce) from 1960:1 to 2015:1.

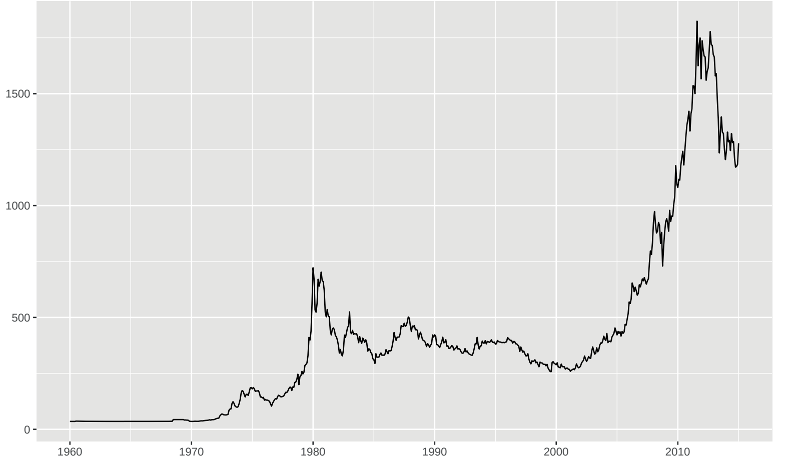
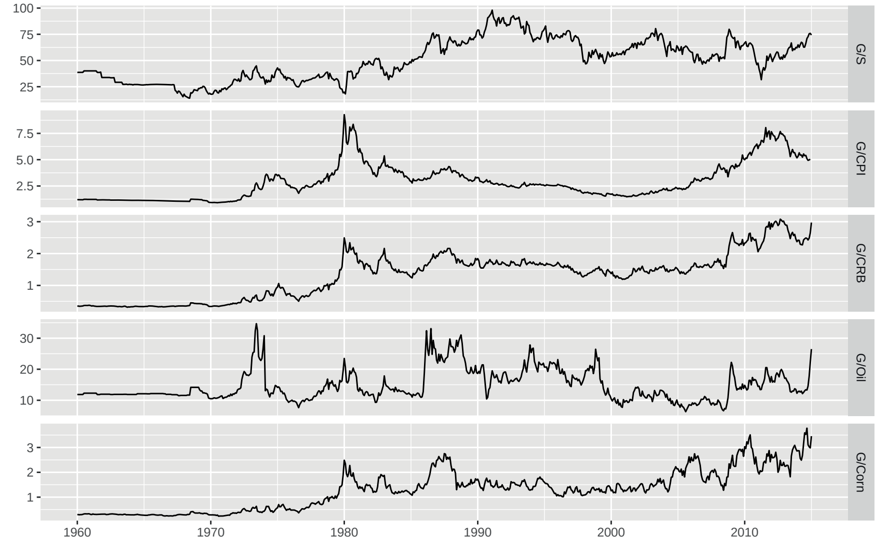


Figure II **Gold Ratios**

This figure shows the evolution of ten monthly gold ratios from 1960:1 to 2015:1. Panel A shows the gold price relative to the price of silver, the US CPI, the CRB commodity price index, the price of oil and the price of corn. Panel B shows the gold price relative to the price of copper, the Dow Jones Industrial Average (DJIA), the cumulative returns of reinvested S&P500 dividends (DIVY), the cumulative returns of the 10-year US Treasury bond yields and the cumulative returns of the federal funds rate.

Panel A



Panel B

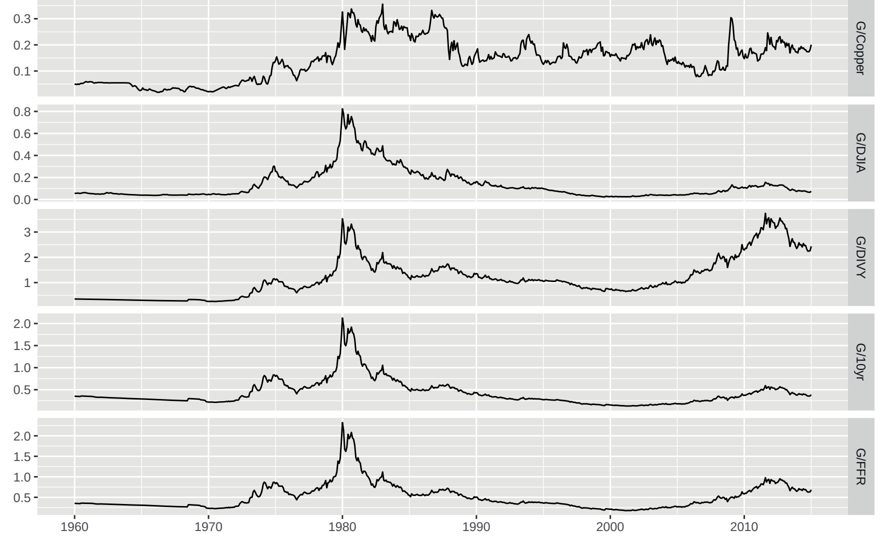


Figure III **Boxplots of the Gold Ratios**

This figure shows boxplot diagrams characterizing the variation of ten gold ratios during the period running from 1960:1 to 2015:1. The latter display the gold price relative to the price of silver, the US CPI, the CRB commodity price index, the price of oil, the price of corn, the price of copper, the Dow Jones Industrial Average (DJIA), the cumulative returns of reinvested S&P500 dividends (DIVY), the cumulative returns of the 10-year US Treasury bond yields and the cumulative returns of the federal funds rate. The gold/silver and the gold/oil ratios are divided by 10 to eliminate scale differences.

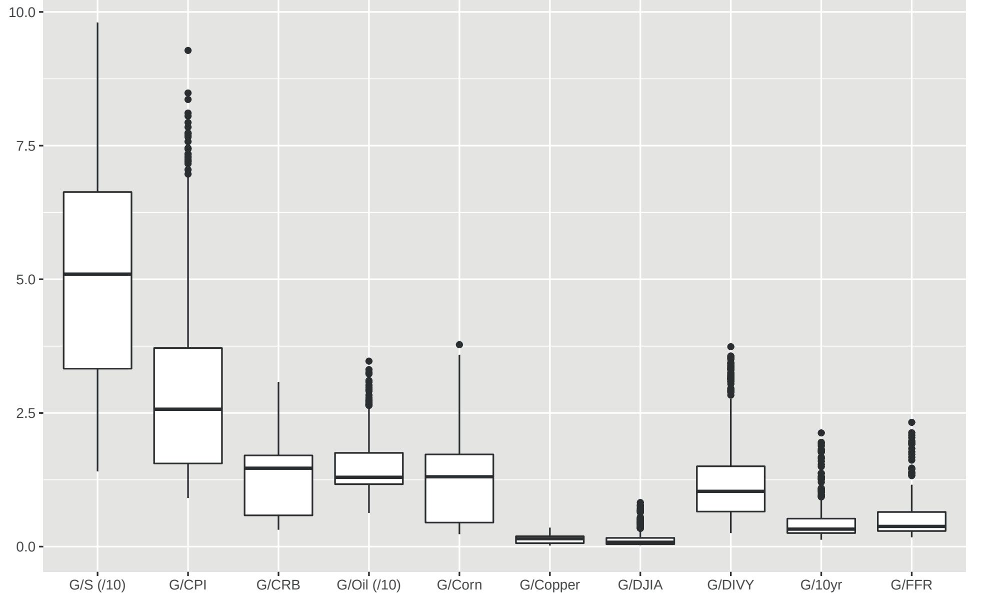


Figure IV **Gold/Silver and Gold/CPI Ratios**

This figure shows the evolution of the Gold/Silver (top panel) and Gold/CPI ratios (bottom panel) from 1960:1 to 2015:1 together with their historical mean (blue line). The grey-shaded area marks the periods in which the ratio is statistically significantly different from its historical mean on a 5% level.

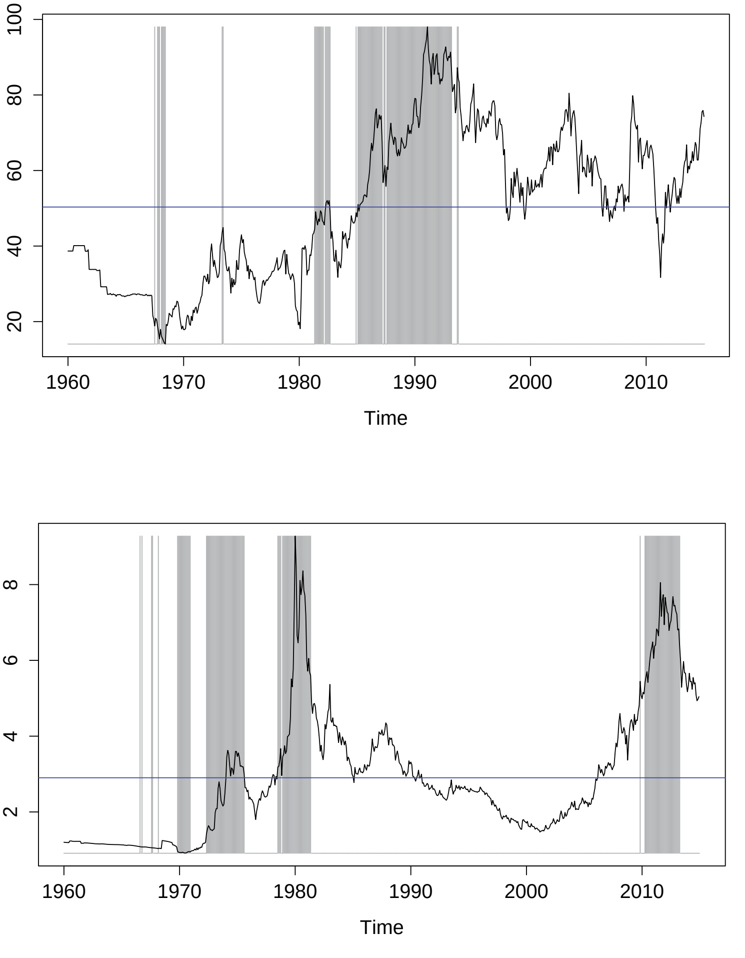
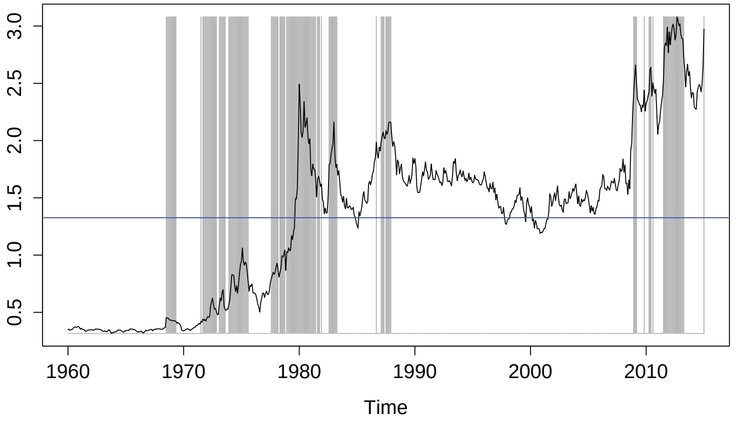


Figure V **Gold/CRB and Gold/Oil Ratios**

This figure shows the evolution of the Gold/CRB (top panel) and Gold/Oil ratios (bottom panel) from 1960:1 to 2015:1 together with their historical mean (blue line). The grey-shaded area marks the periods in which the ratio is statistically significantly different from its historical mean on a 5% level.



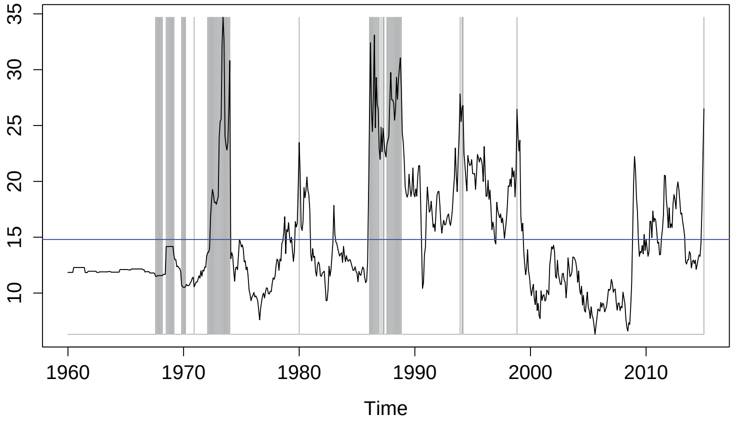
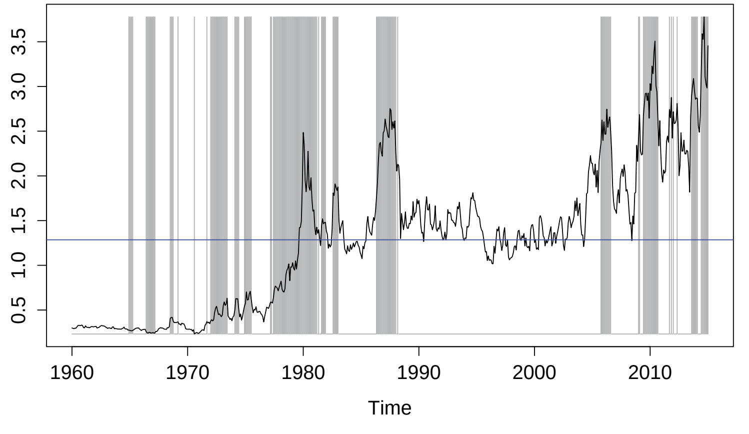


Figure VI **Gold/Corn and Gold/Copper Ratios**

This figure shows the evolution of the Gold/Corn (top panel) and Gold/Copper ratios (bottom panel) from 1960:1 to 2015:1 together with their historical mean (blue line). The grey-shaded area marks the periods in which the ratio is statistically significantly different from its historical mean on a 5% level.



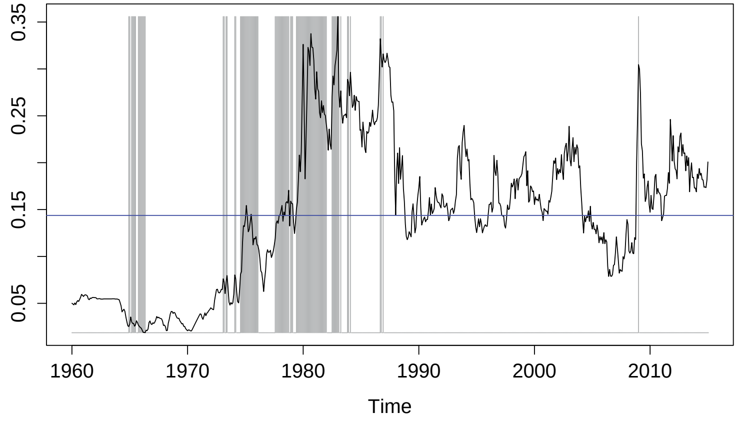
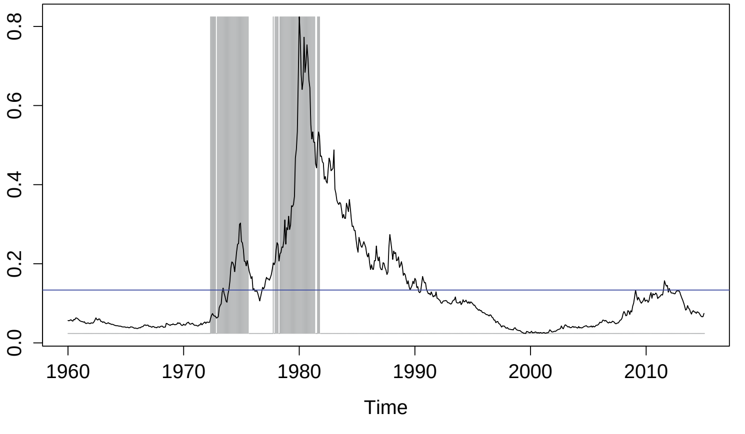


Figure VII **Gold/DJIA and Gold/DIVY Ratios**

This figure shows the evolution of the Gold/DJIA (top panel) and Gold/DIVY ratios (bottom panel) from 1960:1 to 2015:1 together with their historical mean (blue line). The grey-shaded area marks the periods in which the ratio is statistically significantly different from its historical mean on a 5% level.



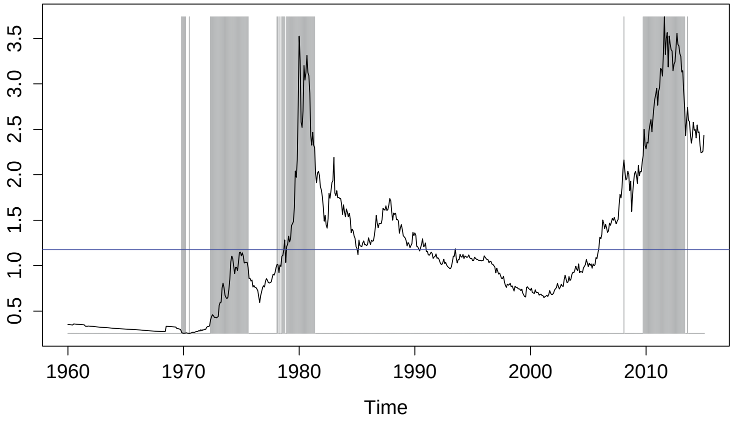
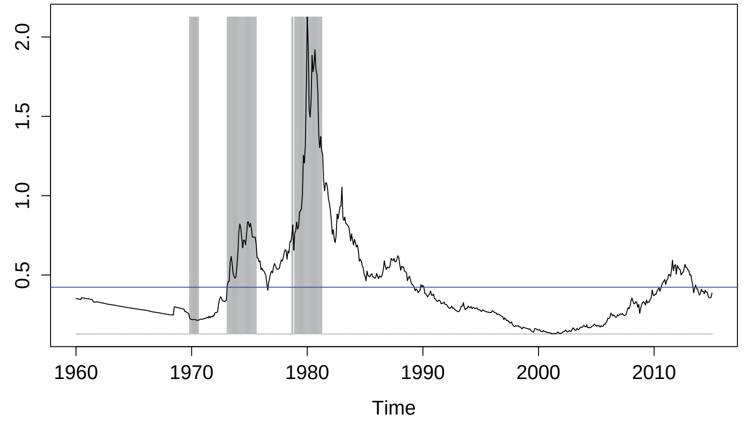


Figure VIII **Gold/10yr and Gold/FFR Ratios**

This figure shows the evolution of the Gold/10yr (top panel) and Gold/FFR ratios (bottom panel) from 1960:1 to 2015:1 together with their historical mean (blue line). The grey-shaded area marks the periods in which the ratio is statistically significantly different from its historical mean on a 5% level.



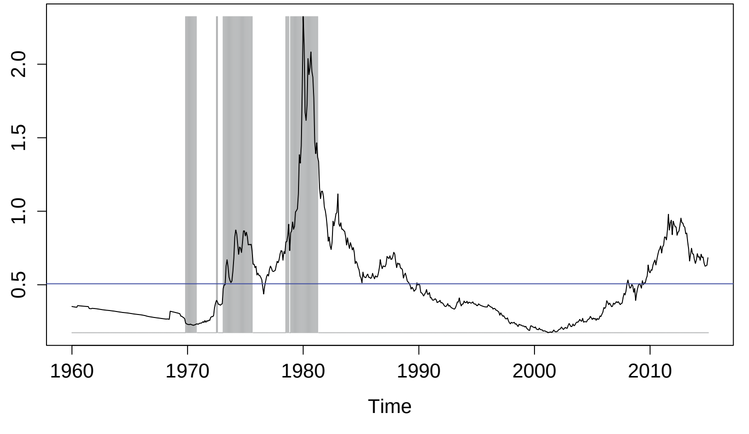


Figure IX **Commonality**

This figure shows the number of ratios that exceed their respective 10% and 90% quantiles (bounds) in each month. The time-series plot illustrates that there are two exceedance clusters of the lower bounds (undervaluations) and two exceedance clusters of the upper bounds (overvaluations). The lower bound clusters are located in the late 1960s and the early 2000s whilst the upper bound clusters are located around the year 1980 and the 2010-2015 period. The exceedance commonalities show the joint under- or overvaluation of gold for each period and thus indicate that gold was rather undervalued in the lower bound exceedance clusters and overvalued in the upper bound exceedance clusters.

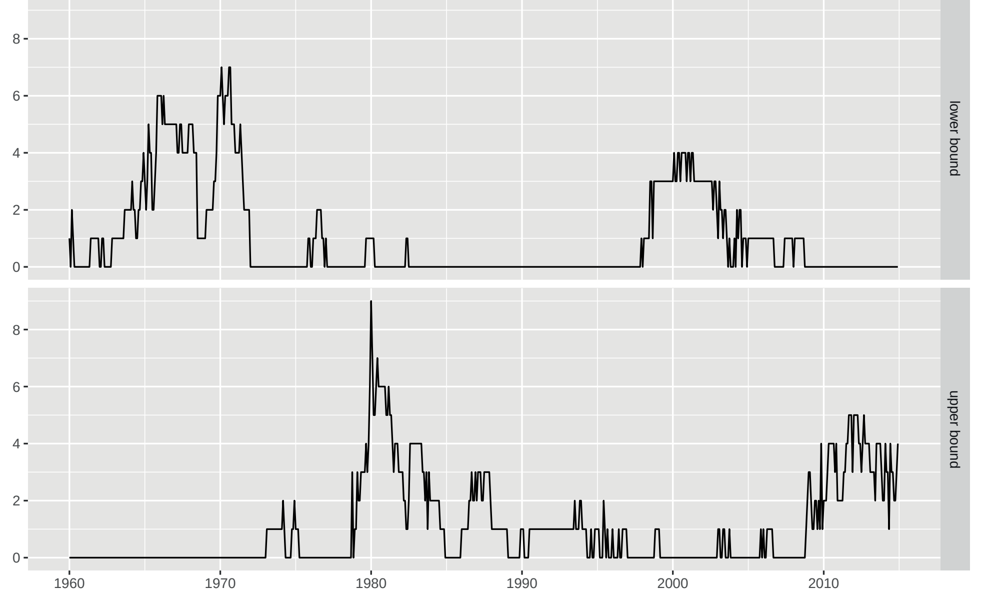


Table I **Descriptive Statistics**

	Gold	Silver	CPI	CRB	Oil	Corn	Copper	DJIA	SPDIVYcum	10yrcum	FFRcum
Median	343.40	5.18	113.65	224.75	19.61	243.00	1721.75	2031.65	285.90	783.31	680.63
Mean	401.19	7.58	117.59	244.79	28.54	262.83	2610.71	4692.76	287.03	1158.54	830.73
Min	35.15	0.91	29.30	95.80	2.92	104.00	612.90	561.28	100.00	100.00	100.00
Max	1824.20	48.48	238.34	679.00	140.00	806.50	9970.00	17828.24	524.95	3308.82	1869.91
SE.mean	15.32	0.30	2.64	5.07	1.11	5.20	85.57	185.97	5.10	40.55	25.12
CI.mean	30.07	0.58	5.19	9.95	2.18	10.21	168.02	365.17	10.01	79.62	49.33
std.dev	393.75	7.59	67.94	130.27	28.49	133.66	2199.90	4781.34	131.09	1042.49	645.85

Note: This table reports the median, the mean, the minimum, the maximum, the standard error on the mean (SE.mean), the confidence interval of the mean (CI.mean) at the 0.95 level, and the standard deviation (std.dev) of the price of gold, the price of silver, the US CPI, the CRB commodity price index, the price of oil, the price of corn, the price of copper, the Dow Jones Industrial Average (DJIA), the cumulative returns of reinvested S&P500 dividends (DIVY), the cumulative returns of the 10-year US Treasury bond yields and the cumulative returns of the federal funds rate.

Table II **Descriptive Statistics of the Gold Ratios**

	G/S	G/CPI	G/CRB	G/Oil	G/Corn	G/Copper	G/DJIA	G/DIVY	G/10yr	G/FFR
Median	50.97	2.57	1.47	12.97	1.31	1.48	0.08	1.03	0.33	0.38
Mean	50.33	2.90	1.33	14.80	1.29	1.44	0.13	1.17	0.42	0.51
Min	14.06	0.91	0.32	6.31	0.23	1.86	0.02	0.25	0.13	0.17
Max	98.03	9.28	3.08	34.69	3.78	3.56	0.82	3.74	2.13	2.32
SE.mean	0.76	0.07	0.03	0.20	0.03	3.06	0.01	0.03	0.01	0.01
CI.mean.0.95	1.49	0.13	0.05	0.39	0.06	6.01	0.01	0.06	0.02	0.02
std.dev	19.56	1.70	0.71	5.05	0.80	7.87	0.14	0.80	0.29	0.32

Note: This table reports the median, the mean, the minimum, the maximum, the standard error on the mean (SE.mean), the confidence interval of the mean (CI.mean) at the 0.95 level, and the standard deviation (std.dev) of the price of gold relative to the price of silver, the US CPI, the CRB commodity price index, the price of oil, the price of corn, the price of copper, the Dow Jones Industrial Average (DJIA), the cumulative returns of reinvested S&P500 dividends (DIVY), the cumulative returns of the 10-year US Treasury bond yields and the cumulative returns of the federal funds rate.

Table III **Unit Root Tests**

	1960-2015					1971-2015				
Ratio	α	**Break 1**	**Break 2**	**Lags**	t_α**-stat.**	α	**Break 1**	**Break 2**	**Lags**	t_α**-stat.**
Gold/Silver	-0.060360	1983:11	1997:03	3	-4.856862	-0.087779	1985:07	1996:07	3	-5.138989
Gold/CPI	-0.038551	1979:04	2008:01	8	-5.495496*	-0.047742	1979:04	2008:01	8	-5.732094**
Gold/CRB	-0.084105	1978:05	2008:02	5	-6.355555***	-0.101688	1978:05	2008:02	5	-6.404907***
Gold/Oil	-0.104124	1985:09	1998:12	1	-6.158746***	-0.106098	1985:09	1998:09	1	-5.677947**
Gold/Corn	-0.090598	1978:03	2007:12	7	-5.274616*	-0.094752	1978:03	2007:12	7	-4.839771
Gold/Copper	-0.100001	1978:11	1987:01	5	-6.087645***	-0.128255	1978:11	1987:01	5	-6.361668***
Gold/DJIA	-0.029113	1973:01	1979:04	8	-6.478550***	-0.028009	1979:04	2010:06	8	-5.579445**
Gold/DIVY	-0.038093	1979:04	2006:10	8	-5.227872	-0.045438	1979:04	2006:11	8	-5.284481*
Gold/10yr	-0.039389	1973:01	1979:04	8	-8.202408***	-0.038453	1979:04	2010:06	8	-7.124691***
Gold/FFR	-0.039167	1973:01	1979:04	8	-7.496402***	-0.042629	1979:04	2008:01	8	-7.176031***

Note: The test proposed by Perron (2006) checks the null of a unit root by allowing for endogenously determined structural changes in the level of each gold ratio. This table reports the mean reversion coefficient (α), the test statistic (t_α), the number of lags selected by the general to specific approach according to the p-values and two endogenously determined structural breaks. *, **, *** denote statistical significance at the 10%, 5% and 1% level, respectively. Critical values for the test statistic t_α are as follows: -5.24 (10%), -5.51 (5%) and -6.06 (1%).

Table IV **Unconditional Correlation between the Regressors**

	ΔYUS	**ΔMUS**	**ΔPUS**	**ΔIUS**	**EPU**	**MU**	**sentiments**	**inflation_exp**	**recession_prob**
ΔYUS	1.000000	-0.104938	0.014049	0.164329	-0.084420	-0.408344	0.274331	-0.109652	-0.581074
ΔMUS	-0.104938	1.000000	-0.248782	-0.061054	0.280017	0.038249	-0.204602	-0.054637	0.058480
ΔPUS	0.014049	-0.248782	1.000000	0.058023	-0.114316	-0.007940	-0.052843	0.255028	-0.017738
ΔIUS	0.164329	-0.061054	0.058023	1.000000	-0.083789	-0.063885	0.099451	0.065604	-0.252443
EPU	-0.084420	0.280017	-0.114316	-0.083789	1.000000	0.067536	-0.400460	-0.162193	0.083451
MU	-0.408344	0.038249	-0.007940	-0.063885	0.067536	1.000000	-0.615534	0.519861	0.685448
sentiments	0.274331	-0.204602	-0.052843	0.099451	-0.400460	-0.615534	1.000000	-0.492122	-0.511211
inflation_exp	-0.109652	-0.054637	0.255028	0.065604	-0.162193	0.519861	-0.492122	1.000000	0.207837
recession_prob	-0.581074	0.058480	-0.017738	-0.252443	0.083451	0.685448	-0.511211	0.207837	1.000000

Note: This table reports the unconditional correlations between the following regressors: change of US industrial production (ΔYUS), change of US money supply (ΔMUS), change of US consumer prices (ΔPUS), change of US 3-month Treasury bill rate (ΔIUS), economic policy uncertainty index (EPU), macroeconomic uncertainty (MU), consumer sentiment, inflation expectations (inflation_exp), and smoothed US recession probabilities (recession_prob).

TABLE V **BMA-Estimation Results: Gold/Silver**

	incl. prob.	$E(\beta_j\|X)$	$SD(\beta_j\|X)$	**model 1**	**model 2**	**model 3**	**model 4**	**model 5**
Intercept	100.0	1.657e+02	1.151e+01	1.645e+02	1.667e+02	1.670e+02	1.692e+02	1.688e+02
ΔYUS	30.7	-7.984e-01	1.385e+00	.	.	-2.440e+00	-2.456e+00	.
ΔMUS	14.2	-7.160e-12	2.133e-11	.	.	.	.	-5.658e-11
ΔPUS	31.8	-1.560e+00	2.619e+00	.	-4.644e+00	.	-4.674e+00	-5.634e+00
ΔIUS	2.2	-1.167e-02	1.658e-01	.	.	.	.	.
EPU	97.8	-6.363e-02	2.095e-02	-6.403e-02	-6.574e-02	-6.682e-02	-6.856e-02	-6.087e-02
MU	100.0	-6.429e+01	8.873e+00	-6.342e+01	-6.621e+01	-6.407e+01	-6.688e+01	-6.720e+01
sentiments	100.0	-4.063e-01	7.310e-02	-4.019e-01	-4.032e-01	-4.121e-01	-4.135e-01	-4.222e-01
inflation_exp	100.0	-5.049e+00	4.705e-01	-5.122e+00	-4.879e+00	-5.138e+00	-4.894e+00	-4.896e+00
recession_prob	97.7	1.306e-01	4.056e-02	1.415e-01	1.451e-01	1.100e-01	1.134e-01	1.450e-01
n. var.				5	6	6	7	7
R^2				0.444	0.449	0.449	0.455	0.454
BIC				-2.241e+02	-2.225e+02	-2.223e+02	-2.208e+02	-2.198e+02
post. prob.				0.390	0.170	0.159	0.073	0.045

Note: This table reports for each regressor the posterior probability that the variable should be included in the model (incl. prob.), the Bayesian model averaged (BMA) posterior mean ($E(\beta_j|X)$), and the BMA posterior standard deviation ($SD(\beta_j|X)$). In addition, we also report the posterior means for the five best single models according to their posterior probability (post. prob.) given below. For these five models we also present the number of variables included (n. var.), the coefficient of determination (R^2), and the Bayesian information criterion (BIC). We use the following regressors: change of US industrial production (ΔYUS), change of US money supply (ΔMUS), change of US consumer prices (ΔPUS), change of US 3-month Treasury bill rate (ΔIUS), economic policy uncertainty index (EPU), macroeconomic uncertainty (MU), consumer sentiment, inflation expectations (inflation_exp), and smoothed US recession probabilities (recession_prob).

Table VI **BMA-Estimation Results: Gold/CPI**

	incl. prob.	$E(\beta_j\|X)$	$SD(\beta_j\|X)$	model 1	model 2	model 3	model 4	model 5
Intercept	100.0	3.410e+00	1.041e+00	3.378e+00	3.588e+00	3.118e+00	3.371e+00	3.456e+00
ΔYUS	27.1	6.335e-02	1.196e-01	.	.	2.433e-01	2.162e-01	.
ΔMUS	55.8	4.071e-12	4.209e-12	7.116e-12	.	7.666e-12	.	7.209e-12
ΔIUS	6.4	7.111e-03	3.617e-02	.	.	.	.	1.135e-01
EPU	100.0	1.012e-02	1.816e-03	9.764e-03	1.042e-02	9.991e-03	1.067e-02	9.830e-03
MU	100.0	4.540e+00	8.104e-01	4.552e+00	4.502e+00	4.620e+00	4.559e+00	4.440e+00
sentiments	100.0	-5.747e-02	6.761e-03	-5.672e-02	-5.907e-02	-5.552e-02	-5.817e-02	-5.687e-02
inflation_exp	100.0	1.730e-01	4.213e-02	1.764e-01	1.678e-01	1.788e-01	1.693e-01	1.744e-01
recession_prob	100.0	-2.366e-02	3.372e-03	-2.450e-02	-2.460e-02	-2.134e-02	-2.180e-02	-2.355e-02
n. var.				6	5	7	6	7
R^2				0.562	0.556	0.567	0.559	0.564
BIC				-3.219e+02	-3.217e+02	-3.205e+02	-3.193e+02	-3.173e+02
post. prob.				0.348	0.317	0.175	0.096	0.035

Note: See Table V for details. Compared to all other gold ratios ΔPUS has not been included as a regressor for obvious reason.

Table VII **BMA-Estimation Results: Gold/CRB**

	incl. prob.	$E(\beta_j\|X)$	$SD(\beta_j\|X)$	model 1	model 2	model 3	model 4	model 5
Intercept	100.0	2.675e+00	3.062e-01	2.702e+00	2.648e+00	2.653e+00	2.589e+00	2.719e+00
ΔYUS	12.3	6.310e-03	2.061e-02	.	.	4.860e-02	5.553e-02	.
ΔMUS	34.6	6.496e-13	1.024e-12	.	1.834e-12	.	1.959e-12	.
ΔPUS	6.4	4.178e-03	2.317e-02	.	.	.	.	.
ΔIUS	3.5	8.354e-04	6.836e-03	.	.	.	.	2.360e-02
EPU	100.0	3.092e-03	5.340e-04	3.143e-03	2.974e-03	3.199e-03	3.025e-03	3.159e-03
MU	100.0	8.482e-01	2.402e-01	8.403e-01	8.532e-01	8.532e-01	8.688e-01	8.169e-01
sentiments	100.0	-1.862e-02	1.983e-03	-1.887e-02	-1.826e-02	-1.866e-02	-1.799e-02	-1.890e-02
inflation_exp	100.0	-9.317e-02	1.249e-02	-9.377e-02	-9.154e-02	-9.344e-02	-9.101e-02	-9.422e-02
recession_prob	100.0	-5.237e-03	9.277e-04	-5.332e-03	-5.305e-03	-4.703e-03	-4.584e-03	-5.135e-03
n. var.				5	6	6	7	6
R^2				0.453	0.459	0.455	0.462	0.454
BIC				-2.312e+02	-2.299e+02	-2.273e+02	-2.266e+02	-2.259e+02
post. prob.				0.514	0.264	0.071	0.051	0.035

Note: See Table V for details.

Table VIII **BMA-Estimation Results: Gold/DJIA**

	incl. prob.	$E(\beta_j\|X)$	$SD(\beta_j\|X)$	model 1	model 2	model 3	model 4	model 5
Intercept	100.0	-3.542e-01	3.959e-02	-3.509e-01	-3.832e-01	-3.742e-01	-3.433e-01	-3.328e-01
ΔYUS	90.3	2.689e-02	1.223e-02	3.043e-02	2.425e-02	.	3.010e-02	3.009e-02
ΔMUS	2.9	3.359e-16	3.954e-14	.	.	.	.	.
ΔPUS	6.7	-1.549e-03	7.428e-03	.	.	.	-2.328e-02	.
ΔIUS	2.9	-1.613e-05	1.321e-03	.	.	.	.	.
EPU	5.8	-8.603e-06	4.582e-05	.	.	.	.	-1.478e-04
MU	100.0	4.627e-01	6.111e-02	4.551e-01	5.148e-01	5.100e-01	4.435e-01	4.648e-01
sentiments	3.9	1.329e-05	1.106e-04	.	.	.	.	.
inflation_exp	100.0	5.331e-02	3.075e-03	5.334e-02	5.243e-02	5.264e-02	5.458e-02	5.252e-02
recession_prob	15.7	-8.434e-05	2.287e-04	.	-3.996e-04	-7.004e-04	. .	
n. var.				3	4	3	4	4
R^2				0.641	0.643	0.638	0.643	0.642
BIC				-4.267e+02	-4.228e+02	-4.225e+02	-4.223e+02	-4.220e+02
post. prob.				0.597	0.085	0.072	0.067	0.058

Note: See Table V for details.

Table IX **BMA-Estimation Results: Gold/Oil**

	incl. prob.	$E(\beta_j\|X)$	$SD(\beta_j\|X)$	model 1	model 2	model 3	model 4	model 5
Intercept	100.0	1.952e+01	3.454e+00	16.62376	16.16210	23.99670	22.98196	22.50085
ΔYUS	2.2	-6.115e-03	8.837e-02	.	.	.	.	.
ΔMUS	2.1	9.185e-14	2.079e-12	.	.	.	.	.
ΔPUS	67.7	-1.804e+00	1.493e+00	-2.50480	.	-3.20142	-2.46153	.
ΔIUS	4.8	2.116e-02	1.363e-01	.	.	.	.	.
EPU	2.0	4.291e-05	1.009e-03	.	.	.	.	.
MU	50.2	-5.118e+00	5.757e+00	.	.	-13.58118	-10.00045	-9.95348
sentiments	1.2	-3.311e-05	2.410e-03	.	.	.	.	.
inflation_exp	18.9	7.121e-02	1.695e-01	.	.	0.42203	.	.
recession_prob	61.0	-2.455e-02	2.190e-02	-0.04335	-0.04291	.	.	.
n. var.				2	1	3	2	1
R^2				0.060	0.044	0.070	0.057	0.042
BIC				-14.58319	-13.62836	-13.29521	-13.24210	-12.54428
post. prob.				0.244	0.151	0.128	0.125	0.088

Note: See Table V for details.

Table X **BMA-Estimation Results: Gold/Corn**

	incl. prob.	$E(\beta_j\|X)$	$SD(\beta_j\|X)$	model 1	model 2	model 3	model 4	model 5
Intercept	100.0	2.327e+00	4.051e-01	2.349e+00	2.265e+00	2.291e+00	2.332e+00	2.359e+00
ΔYUS	18.8	1.575e-02	3.799e-02	.	8.383e-02	.	.	.
ΔMUS	3.5	1.933e-14	2.343e-13	.	.	.	5.510e-13	.
ΔPUS	9.5	1.184e-02	4.464e-02	.	.	1.241e-01	.	.
ΔIUS	3.3	4.647e-04	7.231e-03	.	.	.	.	1.392e-02
EPU	100.0	2.548e-03	6.994e-04	2.527e-03	2.623e-03	2.573e-03	2.476e-03	2.537e-03
MU	100.0	2.027e+00	3.192e-01	2.016e+00	2.039e+00	2.091e+00	2.020e+00	2.003e+00
sentiments	100.0	-2.039e-02	2.595e-03	-2.046e-02	-2.011e-02	-2.043e-02	-2.028e-02	-2.049e-02
inflation_exp	100.0	-1.527e-01	1.661e-02	-1.522e-01	-1.517e-01	-1.587e-01	-1.515e-01	-1.525e-01
recession_prob	100.0	-8.940e-03	1.278e-03	-9.139e-03	-8.054e-03	-9.235e-03	-9.131e-03	-9.023e-03
n. var.				5	6	6	6	6
R^2				0.384	0.389	0.387	0.385	0.384
BIC				-1.801e+02	-1.776e+02	-1.762e+02	-1.742e+02	-1.741e+02
post. prob.				0.648	0.188	0.095	0.035	0.033

Note: See Table V for details.

Table XI **BMA-Estimation Results: Gold/DIVY**

	incl. prob.	$E(\beta_j\|X)$	$SD(\beta_j\|X)$	model 1	model 2	model 3	model 4	model 5
Intercept	100.0	1.790e+00	4.757e-01	1.719e+00	1.600e+00	2.046e+00	1.983e+00	1.867e+00
ΔYUS	28.9	3.201e-02	5.749e-02	.	1.138e-01	.	.	.
ΔMUS	78.9	3.196e-12	2.067e-12	4.168e-12	4.443e-12	.	3.212e-12	.
ΔPUS	67.6	1.839e-01	1.509e-01	2.767e-01	2.838e-01	.	.	2.022e-01
ΔIUS	3.3	1.616e-03	1.171e-02	.	.	.	.	.
EPU	100.0	4.704e-03	7.632e-04	4.678e-03	4.771e-03	4.791e-03	4.422e-03	5.058e-03
MU	100.0	2.219e+00	3.487e-01	2.248e+00	2.289e+00	2.120e+00	2.171e+00	2.165e+00
sentiments	100.0	-2.862e-02	2.857e-03	-2.813e-02	-2.762e-02	-3.028e-02	-2.951e-02	-2.944e-02
inflation_exp	1.9	1.695e-04	2.986e-03	.	.	.	.	.
recession_prob	100.0	-1.063e-02	1.486e-03	-1.103e-02	-9.578e-03	-1.110e-02	-1.114e-02	-1.101e-02
n. var.				6	7	4	5	5
R^2				0.542	0.547	0.527	0.533	0.532
BIC				-3.028e+02	-3.016e+02	-3.005e+02	-3.005e+02	-2.991e+02
post. prob.				0.362	0.204	0.120	0.119	0.058

Note: See Table V for details.

Table XII **BMA-Estimation Results: Gold/10yr**

	incl. prob.	$E(\beta_j\|X)$	$SD(\beta_j\|X)$	model 1	model 2	model 3	model 4	model 5
Intercept	100.0	-7.382e-01	1.697e-01	-5.812e-01	-8.462e-01	-8.631e-01	-6.068e-01	-8.651e-01
ΔYUS	48.1	2.173e-02	2.599e-02	.	.	4.549e-02	4.382e-02	4.825e-02
ΔMUS	10.1	6.623e-14	2.485e-13	.	.	.	.	7.794e-13
ΔPUS	5.9	-1.962e-03	1.154e-02	.	.	.	.	.
ΔIUS	1.1	4.834e-05	1.666e-03	.	.	.	.	.
EPU	6.5	2.502e-05	1.130e-04	.	.	.	.	.
MU	100.0	1.234e+00	1.365e-01	1.189e+00	1.269e+00	1.278e+00	1.201e+00	1.270e+00
sentiments	45.7	-9.976e-04	1.245e-03	-2.235e-03	.	.	-2.156e-03	.
inflation_exp	100.0	1.221e-01	6.584e-03	1.194e-01	1.241e-01	1.237e-01	1.192e-01	1.245e-01
recession_prob	100.0	-2.788e-03	5.994e-04	-3.213e-03	-2.933e-03	-2.369e-03	-2.660e-03	-2.355e-03
n. var.				4	3	4	5	5
R^2				0.722	0.718	0.722	0.726	0.724
BIC				-5.316e+02	-5.314e+02	-5.314e+02	-5.312e+02	-5.283e+02
post. prob.				0.212	0.191	0.187	0.174	0.041

Note: See Table V for details.

Table XIII **BMA-Estimation Results: Gold/Copper**

	incl. prob.	$E(\beta_j\|X)$	$SD(\beta_j\|X)$	model 1	model 2	model 3	model 4	model 5
Intercept	100.0	2.525e-02	3.046e-02	2.529e-02	4.886e-02	-2.180e-02	6.867e-02	2.771e-02
ΔYUS	15.1	1.570e-03	4.339e-03	.	1.232e-02	.	.	.
ΔMUS	4.1	5.488e-15	3.769e-14	.	.	.	.	.
ΔPUS	6.8	-9.551e-04	4.360e-03	.	.	.	.	-1.407e-02
ΔIUS	2.7	-6.229e-05	8.390e-04	.	.	.	.	.
EPU	2.5	4.602e-07	1.129e-05	.	.	.	.	.
MU	100.0	2.354e-01	3.887e-02	2.427e-01	1.991e-01	2.650e-01	1.725e-01	2.430e-01
sentiments	11.6	4.742e-05	1.572e-04	.	.	3.707e-04	.	.
inflation_exp	2.7	-2.464e-05	3.238e-04	.	.	.	.	.
recession_prob	80.8	-3.420e-04	2.083e-04	-4.294e-04	.	-3.979e-04	.	-4.327e-04
n. var.				2	2	3	1	3
R^2				0.129	0.122	0.133	0.109	0.133
BIC				-4.783e+01	-4.414e+01	-4.396e+01	-4.389e+01	-4.384e+01
post. prob.				0.498	0.079	0.072	0.070	0.068

Note: See Table V for details.

Table XIV **BMA-Estimation Results: Gold/FFR**

	incl. prob.	$E(\beta_j\|X)$	$SD(\beta_j\|X)$	**model 1**	**model 2**	**model 3**	**model 4**	**model 5**
Intercept	100.0	-1.965e-01	2.253e-01	-2.840e-01	-3.329e-01	1.707e-02	-9.092e-03	-3.646e-01
ΔYUS	45.8	2.219e-02	2.777e-02	.	4.880e-02	.	4.473e-02	5.219e-02
ΔMUS	22.5	2.244e-13	4.834e-13	.	.	.	.	9.594e-13
ΔPUS	3.2	-4.302e-04	7.145e-03	.	.	.	.	.
ΔIUS	3.8	4.548e-04	4.001e-03	.	.	.	.	.
EPU	61.1	5.106e-04	4.776e-04	8.219e-04	8.777e-04	.	.	7.927e-04
MU	100.0	1.197e+00	1.445e-01	1.191e+00	1.204e+00	1.190e+00	1.201e+00	1.212e+00
sentiments	100.0	-6.019e-03	1.391e-03	-5.523e-03	-5.319e-03	-7.245e-03	-7.165e-03	-4.988e-03
inflation_exp	100.0	1.116e-01	8.243e-03	1.143e-01	1.147e-01	1.060e-01	1.058e-01	1.159e-01
recession_prob	100.0	-4.027e-03	6.572e-04	-4.235e-03	-3.604e-03	-4.459e-03	-3.894e-03	-3.546e-03
n. var.				5	6	4	5	7
R^2				0.708	0.712	0.704	0.707	0.715
BIC				-5.045e+02	-5.044e+02	-5.038e+02	-5.027e+02	-5.019e+02
post. prob.				0.232	0.220	0.162	0.092	0.064

Note: See Table V for details.

Table XV **Summary of the Inclusion Probabilities**

		Intercept	**ΔYUS**	**ΔMUS**	**ΔPUS**	**ΔIUS**	**EPU**	**MU**	**sentiments**	**infl_exp**	**recess_prob**
	G/S	100.0	30.7	14.2	31.8	2.2	97.8	100.0	100.0	100.0	97.7
	G/CPI	100.0	27.1	55.8	.	6.4	100.0	100.0	100.0	100.0	100.0
	G/CRB	100.0	12.3	34.6	6.4	3.5	100.0	100.0	100.0	100.0	100.0
	G/DJIA	100.0	90.3	2.9	6.7	2.9	5.8	100.0	3.9	100.0	15.7
full	**G/Oil**	100.0	2.2	2.1	67.7	4.8	2.0	50.2	1.2	18.9	61.0
sample	**G/Corn**	100.0	18.8	3.5	9.5	3.3	100.0	100.0	100.0	100.0	100.0
	G/DIVY	100.0	28.9	78.9	67.6	3.3	100.0	100.0	100.0	1.9	100.0
	G/10yr	100.0	48.1	10.1	5.9	1.1	6.5	100.0	45.7	100.0	100.0
	G/Copper	100.0	15.1	4.1	6.8	2.7	2.5	100.0	11.6	2.7	80.8
	G/FFR	100.0	45.8	22.5	3.2	3.8	61.1	100.0	100.0	100.0	100.0
	G/S	100.0	20.4	2.8	82.3	4.4	3.0	100.0	100.0	100.0	11.5
	G/CPI	100.0	6.5	4.6	.	19.4	4.7	100.0	100.0	49.2	100.0
	G/CRB	100.0	4.0	4.1	13.0	5.0	5.9	100.0	100.0	100.0	96.6
	G/DJIA	100.0	13.2	4.7	17.7	10.5	5.3	100.0	100.0	89.6	95.1
sub	**G/Oil**	100.0	3.4	3.3	28.9	3.2	79.8	32.9	7.1	14.0	96.5
sample I	**G/Corn**	100.0	4.0	10.9	5.0	4.4	100.0	100.0	6.1	100.0	6.5
	G/DIVY	100.0	7.7	4.4	3.6	16.2	4.3	100.0	100.0	3.7	100.0
	G/10yr	100.0	15.2	4.7	17.0	19.6	6.3	100.0	100.0	100.0	100.0
	G/Copper	100.0	7.2	22.8	55.9	2.2	2.1	100.0	7.2	100.0	100.0
	G/FFR	100.0	13.1	4.4	11.9	22.4	5.6	100.0	100.0	100.0	100.0
	G/S	100.0	13.6	7.0	9.2	23.3	100.0	8.1	4.2	100.0	4.4
	G/CPI	100.0	18.2	6.9	.	48.3	73.6	100.0	75.8	100.0	100.0
	G/CRB	100.0	8.3	4.7	17.5	49.9	6.8	100.0	18.8	7.9	100.0
	G/DJIA	100.0	11.5	6.2	16.2	9.4	31.9	100.0	100.0	100.0	100.0
sub	**G/Oil**	100.0	7.3	14.1	5.1	37.2	9.5	7.7	16.6	100.0	11.2
sample II	**G/Corn**	100.0	7.1	8.3	9.0	5.1	29.2	100.0	8.5	100.0	100.0
	G/DIVY	100.0	12.6	6.3	20.3	51.0	81.9	100.0	84.8	96.2	100.0
	G/10yr	100.0	16.2	5.3	24.8	48.8	76.5	100.0	81.8	95.0	100.0
	G/Copper	100.0	6.8	10.7	6.6	36.4	96.2	100.0	37.9	100.0	100.0
	G/FFR	100.0	18.4	5.1	23.7	41.6	77.7	100.0	73.9	98.8	100.0
	G/S	100.0	22.6	7.8	56.5	39.9	6.1	100.0	100.0	100.0	5.7
	G/CPI	100.0	59.4	3.4	.	3.8	73.6	100.0	96.0	74.9	31.6
	G/CRB	100.0	11.4	5.8	8.2	6.1	84.9	100.0	9.4	38.6	90.9
	G/DJIA	100.0	10.6	7.2	56.0	25.1	39.6	95.4	100.0	7.2	11.7
sub	**G/Oil**	100.0	99.6	12.3	22.8	35.9	100.0	16.0	28.7	56.6	8.5
sample III	**G/Corn**	100.0	85.0	6.8	7.9	5.4	6.4	24.3	6.1	100.0	52.6
	G/DIVY	100.0	58.8	3.3	3.5	3.8	71.0	100.0	96.3	85.9	30.0
	G/10yr	100.0	55.3	3.0	4.4	3.4	69.3	100.0	95.1	80.9	27.8
	G/Copper	100.0	28.0	8.9	10.3	22.3	13.9	100.0	49.4	99.0	100.0
	G/FFR	100.0	58.0	6.7	6.7	6.5	80.9	100.0	74.5	92.1	46.9

Note: This table provides a summary of the posterior inclusion probabilites for the full sample period (1978:01-2014:02) and three sub-sample periods: 1978:01-2000:12 (I), 2001:01-2008:09 (II), and 2008:10-2014:02 (III). The full sample period results are also included in Tables V to XIV.

Table XVI **Predictive Power of the Gold Ratios: 3-Month Ahead**

	incl. prob.	$E(\beta_j\|X)$	$SD(\beta_j\|X)$	**model 1**	**model 2**	**model 3**	**model 4**	**model 5**
Intercept	100.0	1.860247	1.26769	1.892	1.682	1.668	1.712	1.867
Δ**G/S**$_{t-3}$	2.4	0.002734	0.06827	.	.	.	.	.
Δ**G/CPI**$_{t-3}$	10.3	-2.161063	25.16574	.	.	.	-116.493	.
Δ**G/CRB**$_{t-3}$	2.3	0.008296	2.60311	.	.	.	.	.
Δ**G/Oil**$_{t-3}$	2.4	0.005150	0.12466	.	.	.	.	.
Δ**G/Corn**$_{t-3}$	2.8	-0.168440	1.85625	.	.	.	.	.
Δ**G/DJIA**$_{t-3}$	2.3	0.295658	11.29194	.	.	.	.	.
Δ**G/DIVY**$_{t-3}$	14.2	17.569647	61.99291	.	100.467	78.353	292.698	8.651
Δ**G/10yr**$_{t-3}$	8.4	-10.451685	44.30188	.	.	-166.009	.	.
Δ**G/Copper**$_{t-3}$	2.3	0.318915	12.64718	.	.	.	.	.
Δ**G/FFR**$_{t-3}$	9.0	-13.443665	54.13202	.	-187.518	.	.	.
n. var.				0	2	2	2	1
R^2				0.000	0.012	0.011	0.011	0.001
BIC				0.000	5.243	5.622	5.662	6.067
post. prob.				0.592	0.043	0.036	0.035	0.028

Note: This table reports the BMA-estimation results of the change of the gold price regressed on lagged changes of the ratios. See Table V for further details.

Table XVII **Predictive Power of the Gold Ratios: 6-Month Ahead**

	incl. prob.	$E(\beta_j\|X)$	$SD(\beta_j\|X)$	**model 1**	**model 2**	**model 3**	**model 4**	**model 5**
Intercept	100.0	1.559e+00	1.2568	1.550	1.607	1.602	1.545	1.589
Δ**G/S**$_{t-6}$	6.9	-4.402e-02	0.1982	.	.	-0.638	.	.
Δ**G/CPI**$_{t-6}$	95.1	-1.791e+02	61.4475	-188.897	-184.665	-178.298	-179.625	-184.025
Δ**G/CRB**$_{t-6}$	3.6	-8.594e-01	6.5941	.	.	.	.	-23.682
Δ**G/Oil**$_{t-6}$	2.4	-3.147e-03	0.1292	.	.	.	.	.
Δ**G/Corn**$_{t-6}$	8.5	-1.418e+00	5.5808	.	-16.773	.	.	.
Δ**G/DJIA**$_{t-6}$	2.5	1.213e+00	21.8334	.	.	.	.	.
Δ**G/DIVY**$_{t-6}$	97.3	4.597e+02	144.0782	481.284	481.363	451.468	473.277	483.207
Δ**G/10yr**$_{t-6}$	7.3	-3.312e+01	182.7609	.	.	.	.	.
Δ**G/Copper**$_{t-6}$	5.8	-8.102e+00	41.4068	.	.	.	-140.503	.
Δ**G/FFR**$_{t-6}$	5.3	2.733e+01	162.0581	.	.	.	.	.
n. var.				2	3	3	3	3
R^2				0.031	0.035	0.034	0.033	0.032
BIC				-7.467	-3.532	-3.126	-2.767	-1.841
post. prob.				0.604	0.085	0.069	0.058	0.036

Note: This table reports the BMA-estimation results of the change of the gold price regressed on lagged changes of the ratios. See Table V for further details.

TABLE XVIII **Predictive Power of the Gold Ratios: 12-Month Ahead**

	incl. prob.	$E(\beta_j\|X)$	$SD(\beta_j\|X)$	model 1	model 2	model 3	model 4	model 5
Intercept	100.0	1.921834	1.28341	1.917	1.938	1.918	1.929	1.960
ΔG/S$_{t-12}$	3.2	0.010130	0.09539	.	.	.	.	.
ΔG/CPI$_{t-12}$	3.8	-0.189838	1.43540	.	.	.	.	.
ΔG/CRB$_{t-12}$	2.5	0.092895	2.81965	.	.	.	.	.
ΔG/Oil$_{t-12}$	2.6	0.007033	0.13369	.	.	.	.	.
ΔG/Corn$_{t-12}$	3.2	-0.216737	2.12240	.	.	.	.	.
ΔG/DJIA$_{t-12}$	2.5	-0.333065	11.78456	.	.	.	.	.
ΔG/DIVY$_{t-12}$	4.1	-0.557450	3.84439	.	.	.	.	-13.590
ΔG/10yr$_{t-12}$	4.2	-1.255965	8.38525	.	.	-29.641	.	.
ΔG/Copper$_{t-12}$	6.8	-7.874954	36.21825	.	-116.427	.	.	.
ΔG/FFR$_{t-12}$	4.1	-1.059871	7.28829	.	.	.	-25.754	.
n. var.				0	1	1	1	1
R^2				0.000	0.003	0.002	0.002	0.002
BIC				0.000	4.462	5.397	5.456	5.462
post. prob.				0.630	0.068	0.042	0.041	0.041

Note: This table reports the BMA-estimation results of the change of the gold price regressed on lagged changes of the ratios. See Table V for further details.