Studies on Gold and its relationship with other financial variables

Published in the summer of 2016

Abstract: Define as the currency of the last resort, gold has historically been seen as the ultimate hedge against inflation. However, recent research has founded that the commodity provides a unique source of diversification to an investor's portfolio. This study investigates the long-run relationship between gold and a set of financial variables based on daily data from January 1990 to June 2016, then use this relationship as a fair value and see what sort of interpretation we can do with the results.

1 Introduction

One topic that has been making the headlines over the past couple of years is the central banks' next step: helicopter money. As the effectiveness of monetary policy has decreased drastically since 2008, a new response to stimulate the developed nations' economy and generate some inflation in order to deflate their debt would be to transfer money directly to the nation's citizens. This money, as a contrary to Quantitative Easing or the central banks' refinancing operations, will never be reimbursed. Therefore, an asset that reacted to more easing last year was Gold, which many academics and practitioners have called the 'currency of the last resort'. According to two main sources, Kitco and World Gold Council, there is slightly more than 180,000 metric tons of Gold inventories today (i.e. total 'above-ground' gold that has been mined in all human history), which corresponds to roughly 7 trillion USD based on a spot value of USD1,230 per ounce. With now total QE running at record USD200 billion per month, the 'faith' of all currency each could start to diminish with investors increasing their portfolios' allocation in the commodity. Moreover, if we look at the major central banks' balance sheet, we can see that the money supply has been growing exponentially over the past two decades (by 16 times) with combined total assets surpassing USD 16 trillion dollars.

Although we are not on the way to come back to a Gold Standard or an international monetary system like Bretton Woods, the commodity still attracts considerable interests for both investors and researchers. One year ago, the market's view on the commodity was totally bearish based on a shift in expectations in monetary policy. The Federal Reserve was starting considering a tightening cycle, which would have shifted the yield curve on the upside and strengthened the value of the US Dollar due to the extreme monetary policy divergence between the US and the Rest of the World. Therefore it gave birth to not only look at gold as the ultimate inflation hedge, but also at the dynamic relationships between the commodity and other financial variables. It was demonstrated by many papers that gold has many drivers and has been significantly influenced by interest rates, inflation changes, stock prices and central bank reserve policies (Baur, 2013). In addition, it plays the role of a safe haven assets in the face of extreme negative market shocks (Baur and McDermott), looking at its reaction during the last financial crisis or the European sovereign debt crisis in 2011, and can also serves as a hedge for stocks (Beckmann et al., 2014). This study investigates the long-run relationship between gold and a complex of financial variables based on daily data from January 1990 to June 2016, then use this relationship as a fair value and see what sort of interpretation we can do with the results.

This paper organizes as follows. Section 2 describes the explanatory variables that we use for our study. Section 3 presents the regressions and the results of our empirical study. Section 4 concludes.

2 Explanatory variables

2.1 US real interest rates

First of all, the negative relationship between gold and US rates is pretty straightforward to understand. As opposed to a US Treasury Bond that offers a coupon (quarterly or annually), Gold has a storage cost and is a non-interest bearing asset; an investor would only benefit from a capital appreciation. Therefore, if interest rates start to rise, a rational investor would prefer to reallocate his portfolio in US Treasury bonds and receive interesting coupons rather than keeping a position in a commodity that has a 'negative carry' for him (i.e. storage cost). Therefore, a rise in interest rates would decrease the demand for the commodity, impacting its price. However, this analysis holds during periods of stable inflation expectation, which is more or less an annual 2 percent based on the developed central banks' target. If inflation expectations start to rise suddenly due to a sharp increase in the money supply for instance, the demand for Gold would increase as an inflation-hedge response despite yields on treasury being elevated. This pushed academics to look into the relationship between Gold and real interest rates. In their paper *Is Gold a Zero-Beta Asset? Analysis of the Investment Potential of Precious Metals*, McCown and Zimmerman (2006) found that the commodity shows the characteristics of a zero-beta asset with approximately the same return as a Treasury Bill with no market risk. In addition, they found that gold prices are cointegrated with the US Consumer Price Index using the Johansen Tests, putting in evidence that the metal is a good hedge against inflation risk depending on the time horizon of course (Jastram, 1978). Figure 1 represents the evolution of gold prices (red line, lhs) overlaid with US 10-year Treasury yield (blue line, percentage, rhs). As you can see, the decreasing trend in US 10-year interest rates (nominal) has played in favour of more demand for gold, especially between 2001 and 2011. The trend halted in September 2011 when gold reached of 1,900 USD/ounce before market participants started to lose their appetite on the commodity. The structural change could be explained by a sudden fall in expected inflation in the US and the huge drawdown we saw in 2013 was mainly due to the taper-tantrum when the Fed's president Ben Bernanke mentioned on May 21st the idea of gradually reducing or 'tapering' QE3 (the Fed was purchasing USD85bn of US Treasuries and agency MBS at that time).

In order to compute the real interest rate since 1990, we computed the annual inflation rate from the monthly inflation rate tracked by the US Bureau of Labor Statistics, then deducted it from the 10-year Treasury yields (Series H.15 from FRED, 10-year Treasury Constant maturities).

2.2 Exchange Rate (i.e. US Dollar index)

The second explanatory variable that we are going to use for our analysis is the value of the currency. We chose the US Dollar index as a proxy of the 'fair' value of the US Dollar even though it has been criticised due to the large Euro-

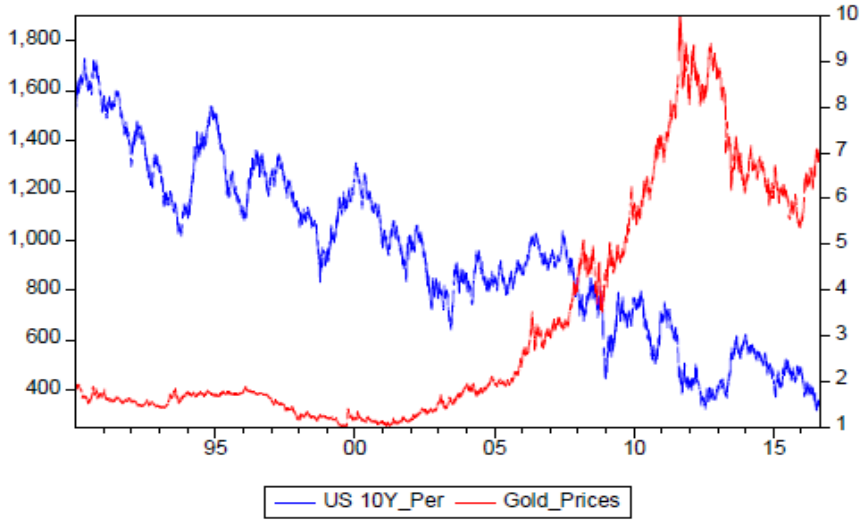

Figure 1: Gold prices and US 10-year rate

weight (the single currency represents 57.6% of the USD index). Historically, a sudden (and fast) appreciation of the US Dollar has always had a negative impact for gold (and other commodities). Since 1990, two major Dollar Rally episodes occurred in the US that impacted the price of the commodity.

The first one is the Clinton Dollar rally that started in the mid-1990s fuelled by the US tech boom and capital inflows into the US equity market in addition to the Fed raising interest rates from 3 to 5 percent. As you can see it in Figure 2, between 1995 to early 2000, the US Dollar index (blue line, rhs) rose from 80 to 100 while Gold plummeted from 400 to 280 USD per ounce.

The second move was the Obama rally that started in early July 2014 as a result of the extreme monetary policy divergence between the US and the rest of the World. That rally lasted for eight monthly; the US Dollar index surged from 80 to 100 while Gold was continuing its bearish trend decreasing from 1,300 to 1,150 USD per ounce.

2.3 US equities

The first two explanatory variables are usually considered as 'traditional' drivers. However, one interesting variable to include in the model would be the equity market, as sometimes gold serves as a hedge for US stock market. In pure theory, gold and equities should be highly correlated as both of their value should be increasing in periods of rising growth and rising inflation. Nonetheless, Figure 3, which represents the 12-month rolling correlation between the two assets over

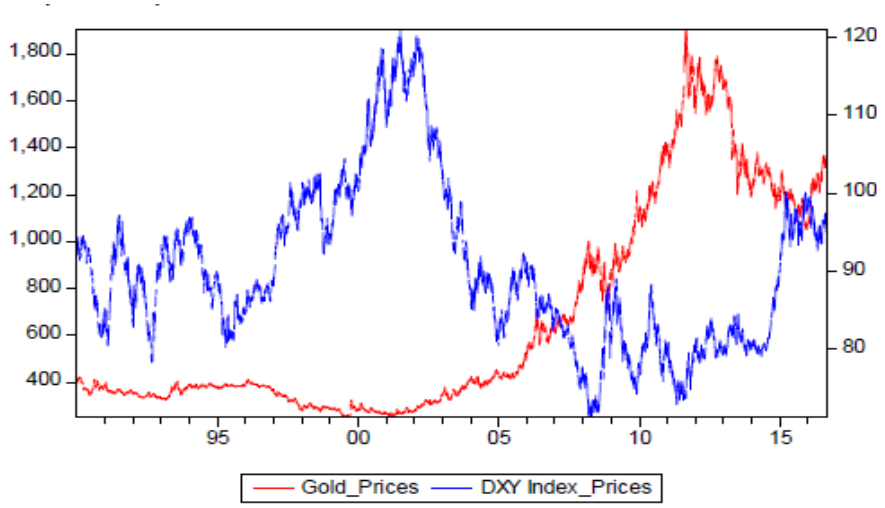

Figure 2: Gold prices and USD index

the past 26 years, shows us that there are some periods when their relationship turns really negative (correlation close to -1), with an average close to zero. Over the past 25 years, gold experienced a series of intense increase while other asset classes such as the stock market exhibited losses. For instance, after the dotcom bubble popped in the summer of the year 2000, US equities entered into a bear market for the next two years losing almost 50 percent of their valuation from peak to through; on the other hand, Gold prices rallied from 280 to 320 dollars per ounce during the same period. Another similar situation would be during the financial crises where the two assets moved in the opposite direction as well. Therefore, in periods of market stress (i.e. global asset depreciation), gold happens to be negatively correlated to stocks and therefore could be interpreted as a hedge (especially against stocks which tend to depreciate very fast in periods of market turmoil).

2.4 GOFO rate: Gold Offered Forward Rate

There are obviously many other drivers that we can include in our study, such as the trend in credit spreads, the steepness of the yield curve, the faith in banking system's solvency or the rate of change in money supply. However, we think that the first three financial variables of our model should capture most of gold's move. One main risk though that has barely been mentioned in the gold literature is the delivery risk. According to LBMA, 95 percent of the gold traded in general is unallocated and has no legal title. It can be traded in different forms of contracts – futures, forwards, options or ETFs – in OTC and standardized markets. For instance, the COMEX is the futures (and options)

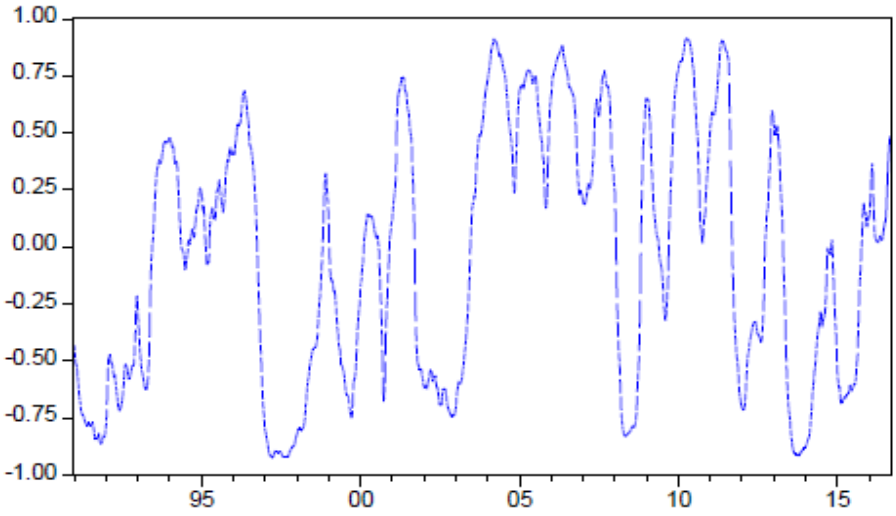

Figure 3: Correlation (12-month) between gold prices and SP500 index

exchange for gold and the world's largest one by volume (roughly 85 percent of the world's shares). It has been shown historically that only 5 percent of COMEX open interest is backed by bullion in depositories, but the COMEX Gold cover ratio (open-interest-to-registered-gold) has been increasing dramatically over the past few years. Registered gold is the eligible gold that has been placed on the COMEX (exchange) for future settlement of a futures (or options) contract. The eligible gold characterizes all the gold that was delivered into a COMEX-approved warehouse that meets the requirements to be eligible for delivery against the COMEX futures contract. In order to be accepted into the warehouse (JP Morgan Chase, Brink's...) as eligible, the precious metal needs to meet the standards of specification (including weight and purity) and requires to be eligible for settlement. Once it has been accepted into the warehouse, it becomes part of the total eligible COMEX stocks, adding to the total COMEX gold inventories. As of August 8th 2016, there was 2.4 million and 8.9 million of troy ounces of registered and eligible gold, respectively, for a combined total of 11.35 million of troy ounces. On the other hand, the aggregate open interest has constantly rallied over the past two years and the cover ratio rocketed to nearly 550 (i.e. which is 550 ounces of gold claims per ounce of deliverable gold). As not all eligible gold will become registered gold, therefore looking at the cover ratio is also interesting and could potentially explain some moments of gold rush. The problem with the cover ratio is that the data are less recurrent, and it brings difficulty for our regression.

However, a variable that was reacting quite positively to a delivery risk was the GOFO, the Gold Forward Offered Rates. The 1-month GOFO is basically

the rate at which contributors are prepared to lend gold on a swap against US Dollars for a period of 1 month. Through history, and under normal circumstances, the GOFO is usually positive, meaning that the owners of gold pay to swap it against paper money. However, there were some periods when the reality inversed and the rate turned negative for some time. The most memorable moment was after the Washington Agreement on Gold was signed on September 26th 1999, which imposed a 'cap' on gold sales to 'no more than 400 tonnes annually' to central banks. The GOFO 1-month reached a low of -4.5% that month and has since been considered as an indicator of liquidity or counterparty stress in the gold market. In addition, it reacted fairly well to the scarcity in the gold market in the last two years and could potentially reflect the risk of delivery. Unfortunately, following discussions between the LBMA and the contributors to the dataset (LBMA Market Makers), there are no more data available since January 30th 2015 as it was discontinued. However, we will run an optional regression (in Section 3) until January 2015 including GOFO 1-month rate to see if it captures some of the information.

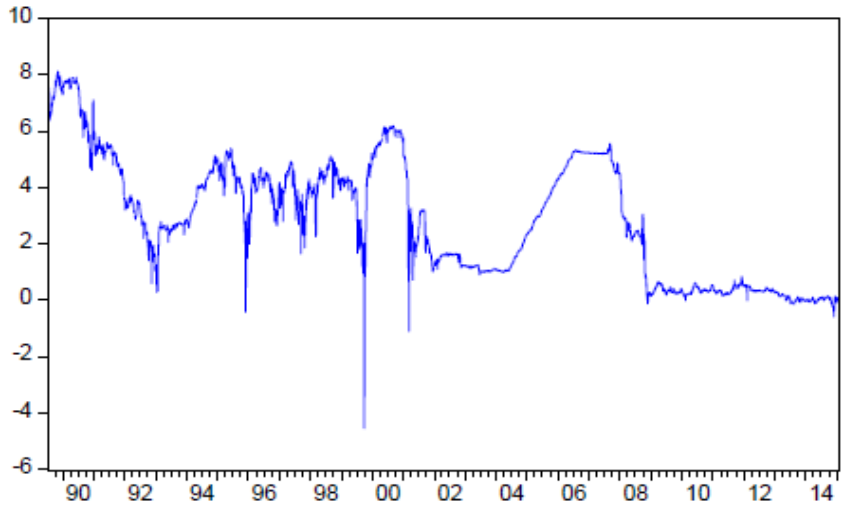

Figure 4: GOFO 1-month historical rates

3 Empirical Results

3.1 First Model: regressing gold on three financial variables using OLS with two breakpoints

We first apply the unit root test for each variable by using the Augmented Dickey-Fuller test on Eviews. Table 1 shows the results, and we can see that all variables are non-stationary as they all failed to reject the null hypothesis.

Hence, we need to differentiate all the variables once in order to proceed to the

Table 1: Unit-root test for each variable

Variable	reject UR test?
dxy	No
rr	No
sp500	No
gold	No

regression. By doing that, the variables all reject the null hypothesis of non-stariionnary with a significant ADF test statistic.

Model 1 could then be written as the following:

$$\Delta gold_t = \alpha + \beta_1 \Delta dxy_t + \beta_2 \Delta rr_t + \beta_3 \Delta sp500_t + e_t \tag{1}$$

where $e_t \sim N(0, \sigma^2)$, and Δ stands for the first difference operator. All variables are expressed in log term expect the real interest rates (rr).

In addition, we also add two breaks as the behaviour of assets have changed considerably since 1990, and especially since the Great Financial Crisis. The results are shown in table 2, and the two breaks were done on July 17th 2002 and January 19th 2009. These results are very consistent with the reality, the 'Gold Decade Rally' started in the summer of 2002 and the second break is the regime switch after the financial crisis. Moreover, the constant is non-significant for each period.

First sample: Jan 2nd 1990 – Jul 17th 2002 In this sample, all three financial variables are significant at 1% level. Until the start of the Gold Decade Rally, both the SP500 and the USD index were moving in opposite direction vis-à-vis the precious metal. On the contrary, positive changes in real interest rates were positive for changes in gold prices. It is true that during that period, the trend in gold prices was bearish despite falling interest rates as we saw previously, which confirms the sign of the coefficients.

Second sample: Jul 18th 2002 – Jan 19th 2009 We have only one significant coefficient in this sample, which is the changes in the exchange rate. This period was represented by a persistent fall in the US Dollar (vs. all major currencies) as a result of a loose monetary policy ran by the Federal Reserve post September 11 2001. The dollar index fell from a high of 120 in the beginning of the century to a low of 70 before waking up at the edge of the financial crisis in Q1 2008

(Figure 2). This clearly explains the levitation in gold prices in US dollar terms.

Third sample: Jan 20th 2009 – August 5th 2016 The third sample runs until today, and all the coefficients are statistically significant. We still find that negative relationship between changes in gold prices and the exchange rate, which is totally logical as gold prices always react negatively to a sudden rise in the exchange rate. However, we can see that the sign of changes in real interest rate coefficient changed to negative, which explains the negative behaviour of gold when real interest rates are rising (i.e. taper tantrum in April 2013). The coefficient of changes in stock prices is now significant again, negative and more or less similar to the one in the first sample.

Table 2: Results of regression (1): OLS with two breaks

Regressor	$\Delta gold$
First sample: Jan 2nd 1990 – Jul 17th 2002	
Δdxy	**-0.163*****
	(0.031)
Δrr	**0.609*****
	(0.202)
$\Delta sp500$	**-0.063*****
	(0.017)
Constant	0.00
	(0.000)
Second sample: Jul 18th 2002 – Jan 19th 2009	
Δdxy	**-1.332*****
	(0.043)
Δrr	0.309
	(0.192)
$\Delta sp500$	0.005
	(0.017)
Constant	0.00
	(0.000)
Third sample: Jan 20th 2009 – August 5th 2016	
Δdxy	**-0.753*****
	(0.044)
Δrr	**-0.913*****
	(0.229)
$\Delta sp500$	**-0.076*****
	(0.0207)
Constant	0.00
	(0.000)
Standard errors in parentheses	
*** p<0.01, ** p<0.05, * p<0.1	

We now compute the gold forecasts based on our results and plot them in a graph (Figure 5). We can notice the two time series – gold forecasts from our regression (red line) and gold spot prices (blue line) have been mainly co-moving

during all the sample, except between 2010 and 2012 where we saw an important divergence between the 'fair' value and the spot value of the commodity.

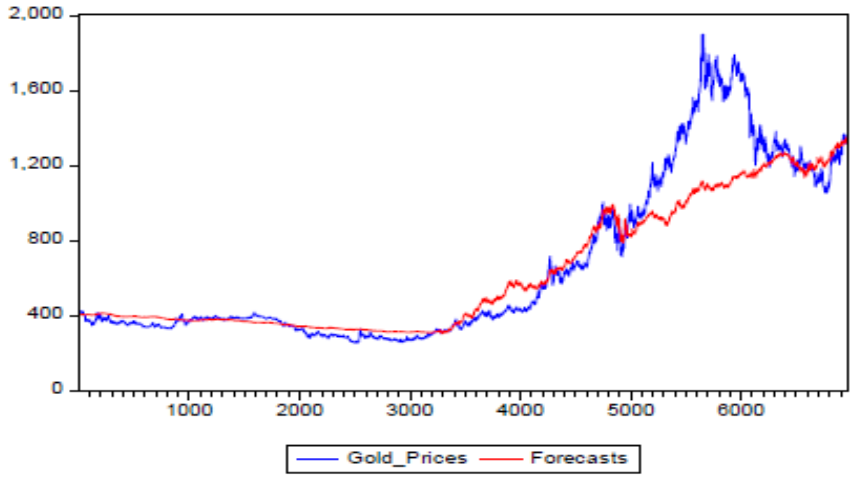

Figure 5: Gold prices vs. forecasts

3.2 Cointegration analysis

3.2.1 The Error Correction Model (ECM)

Now that we have estimated the long-term relationship between gold and the financial variables, we are interested to see if deviations from the 'fair' value convey useful and statistically significant information for future movements in the gold prices.

We will now build an Error Correction model (ECM) that is represented by the following equation:

$$gold_t = b(resid_{t-1}) + \sum_{i=1}^{k} c_i \Delta dxy_{t-i} + \sum_{i=1}^{k} d_i \Delta rr_{t-i} + \sum_{i=1}^{k} f_i \Delta sp500_{t-i} + e_t \quad (2)$$

Where *resid* represents the fitted residual from the long-run equation (i.e. deviation of the actual spot price from 'fair' value determined by the financial variables), and the rest of the right-hand side variables control for short-term effects in changes of gold prices. We chose k=4 lags. We would expect the coefficient b to be negative and statistically significant so that every important deviation from the equilibrium value will tend to mean-revert.

Table 3 shows the results of our ECM model, and coefficient b is indeed negative

Table 3: Results of regression (1): OLS with two breaks

Regressor	$\Delta gold$
resid (lag 1)	**-0.142****
	(0.067)

and statistically significant at a 5-percent level. Therefore, even though gold prices tend to diverge from the forecasted values on many occasions (and quite importantly during 2011), our results show that the two values tend to close in the medium term.

3.2.2 Gregory-Hansen Cointegration Test

As the power of the Johansen test falls drastically when a structural break exists in the data (Gregory and Hansen, 1996b), another interesting study was the cointegration between Gold and financial variables with one regime shift, using the Gregory-Hansen cointegration test (Miyazaki et al, 2014). By using the *ghansen* function in Stata and applying it to our sample, we estimate the most general model, regime shift model, as the following:

$$Y_t = a_1 + b_1\phi_{t,\tau} + b_2 X_t + b_3 X_t \phi_{t,\tau} + e_t \tag{3}$$

where $e_t \sim N(0, \sigma^2)$, Y would represent gold prices (in log terms), X the vector of our financial variables (USD index, sp500 and real rates), and ϕ represents a dummy variable such that $\phi_{t,\tau} = 0 if t > \tau and \phi_{t,\tau} = 0 if t \leq \tau$.

Note that we are not differentiating our time series like in Model 1, as the idea of the paper is to see if there exist a cointegration between gold (not stationary, I(1)) and three financial variables, which are also I(1).

τ denotes a possible structural break date, and the test statistics of the GH test are computed as:

$ADF^* = inf ADF(\tau), t \in T$
$Z_{\alpha *} = inf Z_\alpha(\tau), t \in T$
$Z_{t*} = inf Z_t(\tau), t \in T$

The results (Table 4) are very similar to the ones find in the paper of Miyazaki et al. The test rejects the null hypothesis of no cointegration with the three statistics being significant at the 5% level, therefore supporting the existence of cointegration with a structural break. The break date is detected on September 9th or 20th 2005, which is pretty close to the break dated detected in the paper

Table 4: Results Gregory Hansen Test for Cointegration with One Regime Shift

	T Stat	Breakpoint	5% t-stat level
ADT	**-7.40**	Sep 9th 2005	-6.04
Z_t	**-7.34**	Sep 20th 2005	-6.29
Z_a	**-115.48**	Sep 20th 2005	-80

December 8th or 13th the same year (considering that we have more than 3 years of additional daily data).

The previous part (Gregory Hansen cointegration test) was just a brief (and fun) exercise that I ran into while I was doing the research on Gold, however the next part is based on the results we found in part 3.1 and 3.2.1).

3.3 Interpretation: Long/Short strategy, macro forecast?

There are different interpretations we can do now based on the results we found. The first one would be to find a statistical mean-reverting strategy that would go long Gold when the spot price is too low compare to the forecasted [or 'fair' value] of the commodity, and short Gold when the spot price is too high relative to the forecasted value. In order to implement those signals, we could define two statistical bands based on the (realized) volatility of gold prices: these bands tend to widen when the realized volatility increases in the gold market, and narrow when the realized volatility decreases. Now the question is when is the appropriate moment to enter long or short Gold based on the significant divergence we see in the market? We found there exists a relationship between Gold and financial variables, now convert this study into a profitable trading strategy is a different job.

A second interpretation would be to make a more qualitative analysis with a global macro approach, to see if the variables of our model will still make sense in a year from now. As we saw in our first regression (table 2), all the three financial variables' coefficients are negative, meaning that changes in gold prices react positively to a negative change in interest rates, a negative change in stock prices and a negative change in US dollars. If we stick with the scenario that the 10-year US yield has more probability to decrease and print record lows than increase based on the current situation, with inflation being constant, real interest rates will tend to decrease within the next 12 months, pushing the price of the commodity on the upside. The other variable that may stay 'quiet' this is the US Dollar. With the current dubious situation in the financial markets (Brexit, Protectionism and Political Uncertainty, European Banking System...), the Federal Reserve officials may review their tightening cycle (gradual path) in the year to come in order to prevent the US Dollar from appreciating in the near future. On the top of that, despite US equities reaching new record highs (the

SP500 is on its way to hit the 2,200 psychological resistance), we think that stocks are very obscure and vulnerable at the moment especially based on the fundamentals. If we think of an upside/downside scenario, there is much more probability to see a [important] contraction in the equity market than further appreciation for the months to come. Therefore, we think that gold will react as a safe-haven and will be negatively correlated to the stock market in case of a sharp correction.

3.4 Quick analysis of the regression of model (1) with GOFO variable

In this part of the section, we will include the GOFO 1-month interest that we introduced in section 2 as an additional explanatory variable. As we mentioned it, the data are only available until January 30th 2015, so we will run the entire regression until that date. Adding the GOFO 1-month in the regression while keeping the US real rates gives integers another explanatory variable [implicitly], which is the US yield curve [1M – 10Y slope]. However, GOFO 1-month is not statistically significant for the three samples (OLS regression with 2 breaks), which means that the first three variables incorporate the delivery and liquidity risk in the gold market.

4 Conclusion

To conclude, we find that there is a long-term relationship between gold and three financial variables, which are the US real interest rates, the US Dollar index and the SP500 index. In addition, we found that the three variables captures most of the Gold moves and can be potentially called the fundamental 'drivers' of the commodity. As we mentioned in Section 3, we switched to a new regime since the financial crisis with the massive intervention of the central banks, and explanatory variables changed their market 'behaviour'. The difficult part now is to detect a new structural change in the financial market, for instance the implementation of helicopter money in our system. It will be interesting to understand how market variables will react to such an event (if such an event occurs). However, we are pretty optimistic that Gold could continue its upward trend over the near term (next 12 months) with the current global situation. Expensive equities, Protectionism, Political Uncertainty and the weak European Banking System are important topics of the agenda. Therefore, the *safe haven* asset to rise in those periods of market uncertainty will be the currency of the last resort, Gold.

5 References

Baur, D.G. B.M. Lucey, 2010. “Is Gold a Hedge or a Safe Haven? An Analysis of Stocks, Bonds and Gold”, The Financial Review, 45, 217-229.

Baur, D.G., 2013. ”Gold – Fundamental Drivers and Asset Allocation”, working paper.

Beckmann, J. , Berger, T. R. Czudaj, 2015. ”Does gold act as a hedge or a safe haven for stocks? A smooth transition approach”, Economic Modelling, 48, 16-24.

Jastram, Roy, W. 1978. ”The Golden Constant”. The English and American Experience. McCown, J. J. Zimmerman, 2006. ”Is Gold a Zero-Beta Asset? Analysis of the Investment Potential of Precious Metals”. University of Oklahoma.

Miyazaki, T. S. Hamori, 2014. ”Cointegration with Regime Shift between Gold and Financial Variables”. International Journal of Financial Research.

The London Bullion Market Association