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THE IMPACT OF UK MONETARY POLICY ON GOLD PRICE DYNAMICS

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The impact of UK monetary policy on gold price dynamics

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Abstract

Ever since the collapse of the Bretton-Woods system, gold has retained its function as an important monetary commodity (Baur and Lucey, 2010), and continues to provide important inflation forecasting information to monetary policy setters (Tkacz, 2007). However, Capie *et al.* (2005) highlight the instability of gold price dynamics through time, attributing it to unpredictable political attitudes and events. In this paper, we investigate gold price dynamics under different monetary policy regimes using UK index-linked gilt data. We show that gold lost its role as an inflation hedge after May 1997, supporting the argument that Bank of England independence has been effective in anchoring inflation expectations at a low level. Further, we show that gold also lost its role as a stock market hedge and its position as a safe haven investment following March 2009, suggesting that the introduction of Quantitative Easing markedly changed the relationship between gold and the stock market.

Keywords: Gold price; Hedging; Bank of England independence; Quantitative Easing

JEL Classification: E58, G1, G11, G12

The impact of UK monetary policy on gold price dynamics

1. Introduction

The global financial crisis of 2007-8 presented many investors with a strong motivation to search for ‘safe haven’ assets. Since the beginning of 2016, the gold price has risen by more than 30%, placing it as one of the best performing assets for investor during that period. Conventional wisdom suggests that the gold price and the general price level move together, and as a result gold represented for millennia and across cultures an effective store of value. Even in the post-Bretton-Woods system era, gold remains an effective investment tool in many countries in the form of coins, bullion, certificates or warrants (Worthington and Pahlavani, 2007). Perusal of the academic literature on gold indicates that of the key economic drivers of the demand for gold, the rate of inflation is the most heavily researched. Fisher (1930) establishes the fundamental positive relationship between expected asset returns and expected inflation. There is an extensive empirical literature on the relationship between gold prices and inflation, commencing with Jastram (1978), and later extended by Jastram and Leyland (2009), who examines the long run relationship between the price of gold and inflation in England over the period 1560-2007 and in the US over the period 1808-2007. They find that gold maintained its purchasing power over long periods of time, for example, over 50-year intervals, but was a poor hedge against major inflation because the purchasing power of gold mirrored that of the general price level under the Gold Standard where the nominal price of gold is held constant. More recent studies confirm that gold can serve as a profitable investment opportunity under extreme market conditions (see Baur and McDermott, 2010; Narayan *et al.*, 2013; and Narayan *et al.*, 2015).

In this paper we examine the usefulness of gold as a hedge against inflation, currency depreciation and stock market fluctuation in a UK setting over the period 1985-2015. Bordo and Schwartz (1994, p.8) argue that the Bank of England exerted a powerful influence on the money supply and price level of other countries during the Gold Standard era, stating that, "because of the extensive outstanding sterling denominated assets, and because many countries used sterling as an international reserve currency (as a substitute for gold), it is argued that the Bank of England, by manipulating its bank rate, could attract whatever gold it needed and, furthermore, that other central banks would adjust their discount rates accordingly". Our paper makes two important contributions. First, we test our hypotheses using market-implied inflation expectations data. Consistent with the recent literature, the data we employ includes the break-even inflation rate (BEIR), also referred to as inflation compensation, which is the sum of inflation expectations, the inflation risk premium and the liquidity premium. Liu *et al.* (2015) argue that the BEIR is increasingly used in central bank publications, market commentaries and empirical research as it provides the timeliest indicator of inflation expectations (Joyce *et al.*, 2010; Abrahams *et al.*, 2013; and Pflueger and Viceira, 2013). BEIR may be estimated in real time every trading day without any lag, unlike conventional measures of inflation expectations extracted from economic surveys or forecasted using econometrical models, which are available only on a monthly or bi-annual basis. Second, our empirical models take account of structural shifts in UK monetary policy. There are two major events during our research sample period of 1985-2015. In the first major event, on 6th May 1997, the UK Government handed to the Bank of England responsibility for the setting of interest rates to meet its stated inflation target. This marked the beginning of the Bank's operational independence and its full commitment to inflation targeting. We argue that this change impacts upon the role of gold as an inflation hedge.[1] More specifically, the Bank's operational independence should stop the gold price reacting to inflation expectations. Once the market gives credence to the Bank's ability to anchor inflation at a low and stable level, any change in inflation expectations is more likely to be perceived merely as temporary and mean reverting. Thus, once investors take into account the transaction costs associated with buying and selling gold, they may decide that trading in gold is not worthwhile, and will stop treating gold as an inflation hedge. We build on the work of Laurent (1994) who argues that the gold price only reacts to changes in 'deep-seated' inflation expectations. If a central bank is successful in removing fear of deep-seated inflation then gold should lose its property as an inflation hedge. In the second major event, on 5th March 2009, the Bank of England announced that it would purchase £75 billion of assets over three months, marking the commencement of the unconventional monetary policy of Quantitative Easing (QE). The Bank's former Chief Economist, Spencer Dale, identifies the central objective underlying QE as the injection of a substantial amount of money into the economy via the portfolio rebalancing channel (Dale, 2010). To the extent that

[1] As an international commodity, gold is demanded by investors and consumers of all countries, therefore the price of gold in any currency not only reflects the macro factors specific to that country but those of external sources. For example, US inflation expectations could have a significant impact on gold price in pound sterling, if US demand for gold is of international significance. However, this paper does not examine the relationship between gold price and global factors, but focus on factors specific to the UK. It might be the case that gold price in pound sterling reacts to US inflation expectations, but we argue that the independence of Bank of England should change the role of UK inflation expectations in gold market, which is reflected in the relationship between gold price in pound sterling and UK inflation expectations.

investors do not view money as a perfect substitute for gilts, they will reduce the additional holding of money by switching into other sterling assets or foreign assets, thereby pushing up their prices. There is a large body of literature examining the effect of QE on asset prices (D'Amico and King, 2010; Gagnon *et al.*, 2011; Krishnamurthy and Vissing-Jorgenson, 2011; Neely, 2011; Joyce *et al.*, 2011; Ugai 2007; and Wright, 2012). Despite the different methods and sample periods used, the majority of studies agree that QE had a significant impact on Treasury yields, though the evidence of its effect on other assets such as corporate bonds and equities is mixed. By means of an event study approach, Gagnon *et al.* (2011) find the QE1 round of the US Federal Reserve had a significant and negative impact on the yield of higher-grade corporate bonds and mortgage backed securities (MBS). Using VAR analysis, Wright (2011) shows that the monetary policy shock was estimated to lower higher-grade corporate bond yields and raise stock prices, with the effects wearing off after a few months. However, Krishnamurthy and Vissing-Jorgensen (2011) demonstrate that the impact of QE1 and QE2 had a smaller effect on lower-grade corporate bonds, and the impact of QE on MBS was only large in QE1 where QE involves MBS purchases. Using both event studies and VAR analysis, Joyce *et al.* (2011) find the Bank of England's QE operation reduced corporate bond yields markedly, and its impact on equities was potentially large but highly uncertain as the announcement of QE may give investors information about the outlook of the economy and corporate earnings. If the outlook is worse than expected the it should lower their expectations for dividend payments, resulting in lower equity prices. To date, no paper has focused attention on the impact of QE on the gold price. As a store of value gold is an alternative to financial assets such as money and gilts. Even if a small proportion of gilts previously held by investors is replaced with gold as a result of QE, the increase in demand should push the gold price higher simply as a result of the portfolio rebalancing channel. Therefore, we argue that QE should end the ability of gold to act as both a stock market hedge and a safe haven asset, and should lead to greater correlation between gold and stock market prices.

Our key results may be summarised as follows. First, gold provided an effective hedge against inflation, currency depreciation and extreme stock market movements over the whole study period of 1985-2015. Second, during the study period there were two important shifts in UK monetary policy: (i) Bank of England independence in 1997 following which gold lost its role as an inflation hedge; (ii) the QE programme which commenced in 2009 following which gold lost its safe haven role when compared to the pre-QE period. Finally, our results show that gold has been an effective currency hedge for investors over both the whole study period and sub-sample periods. The rest of our paper is organised as follows. In section 2, we review the academic literature on gold as a hedging tool. In section 3 we discuss the data employed in our study, followed by the econometric model which we discuss in section 4. In section 5, we present and discuss the empirical evidence arising from our models. Section 6 provides a summary and conclusion.

2. Gold prices and their determinants

Generally speaking, there are two main reasons for people to hold gold: (i) for the purposes of consumption e.g. for jewellery; (ii) for the purposes of investment or preserving wealth, whereby gold is used to hedge against inflation, exchange rate and stock market fluctuations. Laurent (1994) argues that the stable purchasing power of gold is instrumental to the automatic price stabilisation mechanism of the Gold Standard (see also Mill, 1987 and Barro, 1979). Under the Gold Standard, a rise of the price level of goods relative to that of gold meant a fall in the purchasing power of gold. This reduced the incentive to produce gold and diverted some of the existing gold stock from monetary to consumption uses such as jewellery, thereby causing the money supply to fall. The fall in the money supply caused the price level of goods to fall until the relative price of gold rose to its long-term level. Conversely, a fall in the general price level relative to gold encouraged gold producers to find and extract new gold at a greater cost, causing the money supply and the price level of goods to rise.

However, under a system of fiat money, there is no longer a built-in stabilisation mechanism, and thus gold becomes a commodity like any other. Garner (1995) argues that whether the price of gold relative to the general price level remains stable depends on different forces. A rise in inflation expectations may cause investors to shift their funds from financial assets, such as money and bonds, to gold. As the supply of gold is more or less fixed in the short run, even a small rise in demand should cause the gold price to rise markedly. Conversely, the general price level rises gradually because the price of many goods and services adjusts only slowly. As a result, the rise in the gold price might precede a rise in general prices provided that inflation expectations are correct. Thus, the relative price of gold should still be stable in the long run, while it should also act as a leading indicator for inflation.

The empirical evidence in general shows that the nominal price of gold and the general price level move together in the long run. Herbst (1983) and Laurent (1994) study the gold price and the wholesale price index in the US and find that the two series moved closely over the last two centuries and the real price of gold on average remained constant, even though the price of gold was pegged for substantial periods and wholesale price increased dramatically during that time. In a study of the aftermath of the collapse of the Bretton Woods system, Beckmann and Czudaj (2013) find that the price of gold and the general price level are cointegrated in the US, the UK, Japan and the Euro area, indicating that a long-term stable linear relationship existed in the period from 1970 to 2011. Worthington and Pahlavani (2007) find evidence of cointegration for the US after allowing for endogenous structural breaks in the post-war period. Using a threshold cointegration technique, Wang *et al.* (2011) show that the price of gold and the general price level are characterised by a linear cointegrated relationship for the US, while for Japan there is a threshold cointegrated relationship.

However, empirical evidence on the relationship between inflation and gold returns in the short run is somewhat inconclusive. Chua and Woodward (1982) show that actual, expected and unexpected inflation rates are significant explanatory factors for gold returns over the period 1975 to 1980 for the US, though not for Canada, Germany, Japan, Switzerland and the UK. Jaffe (1989) finds for the US that gold returns are significantly related to actual, but not expected, inflation over the period 1971 to 1987. Laurent (1994) and Garner (1995) find that lagged gold returns can explain the inflation rate, but the predictive power of such returns is inferior to the past inflation rate, the general commodity price index, and to variables that measure economic slack such as the unemployment rate and the manufacturing capacity utilization rate. Mahdavi and Zhou (1997) employ an out-of-sample forecast method and find that gold returns are the worst predictor compared to a general commodity price index and the past inflation rate.

Cecchetti *et al.* (2000) use a similar method and find that gold prices can improve the forecast accuracy of the rate of inflation. However, they find that an increase in gold prices preceding future declines in inflation appears counterintuitive, questioning the use of gold as a predictor of inflation. Examining the intraday price of gold futures, Cai *et al.* (2001) and Christie-David *et al.* (2000) find that the release of monthly inflation data increases the volatility of gold futures. However, using daily data, Blose (2010) shows that announcement day inflation surprise has no impact on gold returns in the US over the period 1988 to 2008. Erb and Harvey (2013) measure unexpected inflation simply by taking the difference between the inflation rate in any period and that of the previous period, and find little evidence that gold was an effective hedge against unexpected inflation in the US over the period 1975 to 2011. However, Tkacz (2007) finds that the return on gold predicts the rate of inflation over a 12-18 month horizon in most developed countries which have formal inflation targeting over the period 1995 to 2004. He argues that in those countries, inflation expectations are more accurate and thus gold returns are more likely to predict inflation accurately.

In relation to the role of gold as currency hedge, Sjaastad and Scacciavillani (1996) argue that an appreciation in a local currency can cause the price of gold in that currency to fall. Capie *et al.* (2005) find evidence for such a negative relationship between the US dollar gold price and the value of US dollars against the yen and sterling over the period 1971 to 2004. However, they find that the strength of this relationship varies over time and is much weaker before 1976 and after 1985. Pukthuanthong and Roll (2011) confirm the negative relationship between a given currency and the gold price denominated in that currency for the yen, euro and sterling using a bivariate GARCH (1,1) model to take account of the conditional heteroskedasticity in the residuals. Using copulas to examine the role of gold as a safe haven or hedge against the US dollar, Reboredo (2013) find significant positive average dependence and symmetric tail dependence between gold returns in six currencies and US dollar depreciation against these currencies over the period 2000 to 2012, indicating that gold can act as a hedge and a safe haven against currency movements. Using quantile regressions, Ciner *et al.* (2013) show that over the period from 1990 and 2010 gold acted as a safe haven investment against exchange rate movements in the US and UK.

It is also widely held that gold can act as a stock and bond market hedge in normal market conditions, and a safe haven in abnormal times, thereby providing diversification benefits to portfolio holders. Hillier *et al.* (2006) show in a study of the US that gold has a small negative beta in normal market conditions and a larger negative beta in volatile market conditions. Baur and McDermott (2010) conduct an extensive study for 13 countries over the period 1979 to 2009, and find that gold provides both a hedge and a safe haven for stock investors in most developed countries, while the safe haven effect in emerging countries is weaker. Using wavelet analysis, Bredin *et al.* (2015) find that gold acts as a hedge for a variety of international equity and debt markets for horizons of up to one year. Further they find that gold acted as a safe haven for equity investors around the 1987 ‘Black Monday’ crash and the global financial crisis. However, Agyei-Ampomah *et al.* (2014) study a sample of sovereign bonds for 13 countries and show that other precious metals and industrial metals tend to outperform gold as either hedging vehicles or safe haven assets against losses in sovereign bonds.

3. Data

In this paper we model gold price dynamics against data for inflation expectations, exchange rates and stock market returns. We measure gold prices using the London PM fixing price in pounds sterling. For inflation expectations, we use implied inflation expectations calculated by Bank of England using data from index-linked Gilts and conventional Gilts. Ex-ante 5-year and 10-year inflation expectations and real interest rates are estimated using a spline-based technique (Anderson and Maule, 2014). For exchange rates, we collect data for the US dollar to the UK pound sterling, and we compute returns on the FTSE 100 index for stock returns. All data other than the FTSE 100 index, which is taken from Datastream, are collected from the Bank of England's Statistical Interactive Database. Our data consists of daily observations covering the period 2nd January 1985 to 19th March 2015. Table 1 reports descriptive statistics for the model variables. Data for gold prices, exchange rates and the stock index are all transformed to natural log differences to avoid spurious regressions associated with non-stationary variables (Granger and Newbold, 1974). Specifically, our unit root test results suggest that the natural logarithms of these variables are non-stationary, but their first-order differences are stationary[2]. 5-year and 10-year inflation expectations are calculated by taking the differences between the expectations in any given day and those in the previous day.

We can observe that the FTSE 100 index produces higher average returns which are more volatile than gold. The average daily return of the FTSE 100 index is 0.023% which is higher than the average return of gold at 0.014%, and the standard deviation of FTSE 100 index daily return is 1.112%, slightly higher than its counterpart for gold at 1.032%. The

[2] Augmented Dick Fuller test results are available from authors upon request.

pound sterling appreciates against the US dollar during our sample period by 0.003% per day on average, or 28.56% in total. All of the model daily returns are insignificantly different from zero and exhibit fat tails, with kurtosis values which are much greater than the value of 3 for a normally distributed variable. The kurtosis of the returns on gold, the exchange rate, and the FTSE 100 index are 9.025, 7.296 and 12.704, respectively. On average, the UK's 10-year inflation expectation fell by 0.06 basis points per day over the period. This observation is not surprising as the sample commenced in January 1985 when average annual inflation expectations for the following 10 years was 7.44% and ended in March 2015 when average annual inflation expectations for the following 10 years was only 2.69%. Consistent with the model returns, the daily changes in inflation expectations are insignificantly different from zero.

[Insert Table 1 here]

4. Modelling UK gold price dynamics

Our baseline model is described in Equations 1 and 2 below. Equation 1 models the relation between gold returns and inflation expectations, the exchange rate and stock market returns. Equation 2 is a GARCH model to take account of conditional heteroskedasticity in the data.

$$r_{Gold,t} = \beta_0 + \beta_1 \Delta\pi^e_{p,t} + \beta_2 r_{£,t} + \beta_3 r_{FTSE,t} + \beta_4 r_{FTSE(q),t} + u_t \quad (1)$$

$$h_t = \gamma_0 + \gamma_1 (u_t)^2 + \gamma_2 h_{t-1} \quad (2)$$

Note that $r_{Gold,t}$ is the return on sterling gold prices in period *t*, $\Delta\pi^{e}_{p,t}$ is the change in the *p*-year UK inflation expectation in period *t* (where *p* = 5 or 10), $r_{£,t}$ is the rate of change of the pound sterling against the dollar in period *t*, $r_{FTSE,t}$ is the return on the FTSE 100 index in period *t*, and u_t is the error term. Following Baur and Lucey (2010), $r_{FTSE\,(q),t}$ (*q* = 1%, 5%, or 10%) is a multiplicative dummy variable equal to the market return when the market return was in the *q* lower quantile; $r_{FTSE\,(q),t}$ is zero in all other periods. The error term, u_t, is assumed to follow a GARCH (1,1) process with a time varying variance, h_t. The GARCH model is used to control for heteroskedasticity in the data which is common in daily financial data.

We can formulate four hypotheses in order to determine whether gold can serve as an inflation hedge, exchange rate hedge, stock market hedge and safe haven asset.

Hypothesis 1: $\beta_1 > 0$ (gold is an inflation hedge)

Hypothesis 2: $\beta_2 < 0$ (gold is a currency hedge)

Hypothesis 3: $\beta_3 \leq 0$ (gold is a stock market hedge)

Hypothesis 4: $\beta_3 + \beta_4 \leq 0$ (gold is a safe haven asset)

β_1 measures the relation between the gold return and the change in inflation expectations. A positive β_1 implies that a rise in inflation expectations would see the gold price rising, thereby producing a positive return. This could be caused by investors treating gold as an inflation hedge and diverting their holdings of financial assets to gold when inflation is expected to rise in the future. Thus, we argue that gold acts as an inflation hedge if we find support for Hypothesis 1. β_2 measures the relation between the gold return and the rate of change in the $/£ exchange rate. For an internationally traded commodity such as gold, a change in any exchange rate should result in an adjustment in its price denominated in the currency of a country which does not have absolute market power in that commodity (Sjaastad and Scacciavillani 1996). Despite the dominance of London as a trading center for gold (Lucey *et al.* 2013), the UK has little market power in the global gold market (Sjaastad and Scacciavillani 1996; Sjaastad 2008). Thus, as the pound sterling depreciates against the US dollar, the gold price in pounds sterling is expected to rise. If Hypothesis 2 is supported, then gold acts as a currency hedge as gold priced in pounds sterling decreases when the pound appreciates. Baur and Lucey (2010, p. 219) defined hedge as "an asset that is uncorrelated or negatively correlated with another asset or portfolio on average", and a safe haven asset as "an asset that is uncorrelated or negatively correlated with another asset or portfolio in times of market stress or turmoil". The correlation coefficient between the gold return and FTSE 100 index return on average is measured by coefficient β_3. If Hypothesis 3 is supported, then gold acts as a hedge for stock index returns. Finally, the sum of the estimated coefficients β_3 and β_4 measures the coefficient between the gold return and the FTSE 100 index return when the stock market is in stress. In the baseline model, the market stress is measured by the 1% lowest quantile dummy. In the alternative parameterization, 5% and 10% quantile dummies are used. If no evidence is found to reject Hypothesis 4, then gold acts as a safe haven asset.

5. Empirical results

The results of our models for the whole sample are presented in Table 2. Model 1, which uses 10-year inflation expectations, shows that there is a positive relationship between gold returns and movements in inflation expectations. On average, a 1 percent movement in 10-year inflation expectations is associated with a 1.031 percent change in the gold price, and the relationship is significant at 1% level. There is a negative relationship between gold returns and movements in the exchange rate, whereby a 1 percent appreciation of the pound against the dollar is associated with a 0.599 percent fall in gold prices. In other words, the elasticity of the gold price to the dollar/sterling exchange rate is 0.599, and this coefficient is significant at the 1% level. There is no significant relationship between gold returns and stock returns, suggesting that gold acts as an effective stock market hedge. The F-test for the hypothesis $(\beta_3 + \beta_4) = 0$ is significant at the 1% level, indicating that gold acts as a safe haven asset for investors. Model 2, where 5-year inflation expectations are employed, gives results which are very similar to those in Model 1. More specifically, a 1 percent movement in 5-year inflation expectations is associated with a 0.662 percent change in gold prices, a 1 percent appreciation of the pound against the dollar is associated with a 0.603 percent fall in gold prices, and the relationship between the gold return and the stock return is insignificant in normal market conditions but is significant and negative in extreme market condition where the stock return is in its lowest 1% quantile. As a robustness check we follow Baur and McDermott (2010) and run Models 3 and 4 with the dummy variable capturing the less extreme stock market movements corresponding to the 5% lowest quantile of the return distribution, and we run Models 5 and 6 with the even less extreme stock market dummy corresponding to the 10% lowest quantile. The results of Models 3 to 6 are shown in Table 2 and they are very similar to those of Models 1 and 2 where the dummy variable picks up the most extreme stock market movements. Overall, we find evidence to support the ability of gold to act as an inflation hedge, a currency hedge, and a stock market hedge, as well as performing a role as a safe haven asset.

[Insert Table 2 here]

In order to gain insights into whether the monetary policy regime in place impacts upon the investment properties of gold, we divide our sample into three sub-periods and repeat the estimation. The periods are 2nd January 1985 to 5th May 1997, 6th May 1997 to 4th March 2009, and 5th March 2009 to 19th March 2015.

The first sub-sample period of 2nd January 1985 to 5th May 1997 is referred to as the *pre-independence period* where the monetary policy decisions were taken by the Chancellor of the Exchequer. In roughly the same period, a consensus emerged among academics and policy makers linking the level of central bank independence to price stability (Berger *et al.*, 2001). Rogoff (1985) proposes to delegate monetary policy to an independent central banker to reduce inflation bias as (s)he is more averse to inflation than government and is more likely to deliver price stability. The second sub-sample period is 6th May 1997 to 4th March 2009. On 6th May 1997, the UK government granted operational independence to the Bank of England, making it responsible for monetary policy decisions, with the aim of keeping inflation close to the target of 2.5% (reduced to 2% in 2003). The second sub-sample period is referred to as the *post-independence pre-QE period*. The results from the second are compared with those in the first sub-sample period to investigate whether the role of gold as an inflation hedge changed after the

Bank gained operational independence. In response to the deepening of the global financial crisis in the autumn of 2008, the Bank cut the base rate rather dramatically from 5% to 0.5% within 5 months (Dale, 2010). However, as the base rate already approached its zero lower bound, to implement further monetary stimulus the Bank employed the unconventional monetary policy tool of asset purchases financed by central bank money, also known as Quantitative Easing (QE). On 5th March 2009 the Bank announced that it would increase the monetary base and purchase medium to long-term gilts to the value of £75 billion, which would subsequently (through November 2011) increase to £375 billion (Joyce *et al.*, 2014). The third sub-sample period, from 5th March 2009 to 19th March 2015, is referred to as the *QE period*. The results in this period may thus be compared with those in the previous periods to highlight the role of QE in the relationship between the gold and stock markets.

Models for each of these sub-sample periods with the baseline measures of inflation expectations (10-year inflation expectations) and extreme stock market movements (1% lowest quantile of stock market index returns) are given in Table 3. Detailed test results of the models with alternative measures (5-year inflation expectations and the 5% or 10% lowest quantile stock market returns) are given in Appendix A.

[Insert Table 3 here]

Model 1 examines the period before Bank of England independence. Consistent with the full sample models, the coefficient for inflation expectations is positive at 0.856 and highly significant, indicating that gold acted as an inflation hedge during the sub-sample period. Gold prices rise by 0.856% with a 1% increase in 10-year inflation expectations. However, this significant positive relationship disappears in the second sub-sample, as shown in Model 2. In effect, gold stopped reacting to changes in inflation expectations, suggesting that it lost its ability to act as an inflation hedge, and providing some evidence for the success of the Bank's inflation targeting strategy. After gaining independence, the Bank evidently convinced the market that the long-term inflation rate was going to remain low and stable, thereby removing one of the rationales for buying or selling gold in the short term. Model 3 presents the puzzling result that gold prices are significantly negatively related to inflation expectations during the sub-sample period when quantitative easing was introduced. This may be explained by the poor quality of implied inflation expectations data around the crisis period, which was driven by the sharp increase in the liquidity premium within the yield of index-linked gilts (D'Amico *et al.*, 2014).

The coefficient for the exchange rate is negative and highly significant across the three sub-sample periods, confirming that gold has been a reliable currency hedge for UK investors over the last 30 years. However, both the level of significance and the absolute value of the coefficient have declined somewhat over the successive periods.

The stock market hedge coefficient exhibits significant change over the three sub-sample periods. Before the QE period, the coefficient is either significantly negative or positive but insignificant, indicating that gold is in general an effective stock market hedge. However, during the QE period, it becomes positive and highly significant, and thus gold tended to move in the same direction as the stock market, thereby losing its ability to act as a stock market hedge. Moreover, the test statistics for the hypothesis $(\beta_3 + \beta_4) = 0$ are highly significant in both pre-QE periods, indicating that gold was a safe haven asset for stock investors before the introduction of QE. However, the F-test is not significant for the QE period sub-sample model, indicating that the gold price failed to rise at a time when stocks suffered from big losses. While the results for the first two sub-sample (pre-QE) periods are consistent with those in Baur and Lucy (2010), the contrasting results in the period following the introduction of QE are important in the respect that it brought with it not only falling interest rates and general asset price growth, but it also distorted the long-term relationship between gold and the stock market. This result supports the argument that QE works through the portfolio rebalancing channel (Dale, 2010). As the Bank purchased gilts from the private sector, investors used the proceeds from selling gilts to buy alternative assets such as stocks and precious metals such as gold. This action led to a simultaneous increase in both stock and gold prices, rendering the gold beta coefficient positive. Thus investors seeking a tool to hedge stock market risk would have to look for another asset as gold no longer serves this role.

6. Conclusion

This paper tests the hypothesis that gold acts as an inflation, currency and stock market hedge, while providing a stock market safe haven for UK investors over the period 1985 to 2015. We confirm that gold is a good hedge investment instrument over the full sample period, while our results differ over the three sub-sample periods. Before Bank of England independence in 1997, the coefficient for inflation expectations is positive and highly significant, indicating that gold was a good inflation hedge. However, this relationship disappeared over the period 1997 to 2009, as gold no longer reacted to changes in inflation expectations. Thus, the Bank was evidently very effective in pursuing its inflation targeting objectives. Further, whereas gold acted as a safe haven asset in the pre-QE period, it notably failed to rise in price when stocks suffered from big losses with the onset of the implementation of Quantitative Easing as a policy response to the global financial crisis. Finally, for investors seeking to hedge against currency risk, gold remained a good hedge investment over the entire sample period.

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Table 1
Descriptive Statistics

	Mean (%)	Std. Dev. (%)	Maximum (%)	Minimum (%)	Skewness	Kurtosis	No. of Observations
Gold	0.014	1.032	6.676	-9.624	-0.218	9.025	7628
$/£	0.003	0.622	4.644	-3.960	0.030	7.296	7628
FTSE 100	0.023	1.112	9.384	-13.029	-0.495	12.704	7628
Inf Exp 10	-0.001	0.475	0.423	-0.513	-0.199	10.992	7628
Inf Exp 5	-0.001	0.564	0.466	-0.690	-0.362	15.567	7628

Notes on Table: Gold denotes the daily return of gold price denominated in £. $/£ denotes the daily rate of change of exchange rate of $ per £. FTSE 100 denotes the daily return of FTSE 100 index. Inf Exp 10 and Inf Exp 5 denote the daily change in the 10-year and 5-year inflation expectation respectively.

Table 2
Whole sample results

Estimated Equations

$$r_{Gold,t} = \beta_0 + \beta_1 \Delta\pi^e_{p,t} + \beta_2 r_{£,t} + +\beta_3 r_{FTSE,t} + \beta_4 r_{FTSE(q),t} + u_t$$

$$h_t = \gamma_0 + \gamma_1 (u_t)^2 + \gamma_2 h_{t-1}$$

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
	q = 1%		q = 5%		q = 10%	
	p = 10	p = 5	p = 10	p = 5	p = 10	p = 5
Intercept	-0.001 (0.009)	-0.002 (0.009)	-0.001 (0.009)	-0.001 (0.009)	-0.002 (0.009)	-0.002 (0.009)
Inflation Expectation	1.031 (0.144)***	0.662 (0.130)***	0.983 (0.145)***	0.610 (0.131)***	0.976 (0.144)***	0.605 (0.131)***
UK £ per US $	-0.599 (0.012)***	-0.603 (0.012)***	-0.600 (0.012)***	-0.604 (0.012)***	-0.600 (0.012)***	-0.604 (0.012)***
FTSE 100	0.006 (0.009)	0.003 (0.009)	-0.002 (0.010)	-0.006 (0.010)	-0.001 (0.011)	-0.005 (0.011)
Extreme Stock Market Dummy	-0.076 (0.010)***	-0.075 (0.010)***	-0.025 (0.012)***	-0.023 (0.012)	-0.023 (0.010)***	-0.022 (0.013)
GARCH Coef1	0.009 (0.001)***	0.009 (0.001)***	0.009 (0.001)***	0.009 (0.001)***	0.009 (0.001)***	0.009 (0.001)***
GARCH Coef 2	0.079 (0.002)***	0.079 (0.002)***	0.079 (0.002)***	0.079 (0.002)***	0.079 (0.002)***	0.079 (0.002)***
GARCH Coef3	0.916 (0.003)***	0.916 (0.003)***	0.917 (0.003)***	0.916 (0.003)***	0.916 (0.003)***	0.916 (0.003)***
DW statistic	2.063	2.063	2.065	2.067	2.066	2.067
$Q(10)$	8.859	9.173	8.629	8.949	8.645	8.96
$Q(10)^2$	9.985	9.976	10.141	10.100	10.072	10.041
F-Wald test	136.003***	140.912***	14.700***	16.491***	11.82***	14.106***
S.E. of regression	0.979	0.980	0.980	0.981	0.980	0.981

Notes on Table: standard errors in parentheses. *** indicates significance at 1%. q is the extreme stock market dummy and p = 10 and p = 5 denote 10-year and 5-year inflation expectation respectively. Q(10) and $Q(10)^2$ are test statistics for autocorrelation.

Table 3
Subsample results: p = 10; q = 1%

Equation	$r_{Gold,t} = \beta_0 + \beta_1 \Delta\pi^e_{p,t} + \beta_2 r_{£,t} + +\beta_3 r_{FTSE,t} + \beta_4 r_{FTSE(q),t} + u_t$ $h_t = \gamma_0 + \gamma_1 (u_t)^2 + \gamma_2 h_{t-1}$		
	Model 1 3/1/85-5/5/97	Model 2 6/5/97-4/3/09	Model 3 5/3/09-19/3/15
Intercept	-0.011 (0.012)	0.010 (0.016)	0.028 (0.026)
Inflation Expectation	0.856 (0.171)***	0.297 (0.390)	-2.145 (0.641)***
UK £ per US $	-0.779 (0.014)***	-0.336 (0.025)***	-0.267 (0.045)***
FTSE 100	-0.041 (0.014)***	0.021 (0.013)	0.115 (0.025)***
Extreme Stock Market Dummy	-0.015 (0.016)	-0.109 (0.201)***	-0.106 (0.073)
GARCH Coef1	0.003 (0.001)***	0.025 (0.003)***	0.041 (0.007)***
GARCH Coef 2	0.073 (0.004)***	0.097 (0.006)***	0.077 (0.007)***
GARCH Coef3	0.927 (0.004)***	0.883 (0.007)***	0.889 (0.009)***
DW statistic	2.157	2.014	2.025
$Q(10)$	12.537	9.871	10.457
$Q(10)^2$	5.403	11.996	4.917
F-Wald test	64.126***	29.249***	0.016
S.E. of regression	0.818	1.052	1.084

Notes on Table: standard errors in parentheses. *** indicates significance at 1%. q is the extreme stock market dummy and p = 10 denotes 10-year inflation expectation. Q(10) and $Q(10)^2$ are test statistics for autocorrelation.

Appendix A
Sub-period estimation results

Appendix A1
For *p* = 5 and *q* = 1%

Equation	$r_{Gold,t} = \beta_0 + \beta_1 \Delta\pi^e_{p,t} + \beta_2 r_{£,t} + +\beta_3 r_{FTSE,t} + \beta_4 r_{FTSE(q),t} + u_t$ $h_t = \gamma_0 + \gamma_1 (u_t)^2 + \gamma_2 h_{t-1}$

	Model 1 3/1/85-5/5/97	Model 2 6/5/97-4/3/09	Model 3 5/3/09-19/3/15
Intercept	-0.011 (0.012)	0.010 (0.016)	0.029 (0.025)
Inflation Expectation	0.461 (0.150)***	0.271 (0.325)	-1.847 (0.588)***
UK £ per US $	-0.786 (0.014)***	-0.337 (0.025)***	-0.269 (0.044)***
FTSE 100	-0.051 (0.014)***	0.021 (0.013)	0.112 (0.025)***
Extreme Stock Market Dummy	-0.007 (0.016)	-0.109 (0.021)***	-0.109 (0.073)
GARCH Coef1	0.004 (0.001)***	0.025 (0.003)***	0.040 (0.007)***
GARCH Coef 2	0.073 (0.004)***	0.097 (0.006)***	0.076 (0.007)***
GARCH Coef3	0.927 (0.004)***	0.883 (0.007)***	0.890 (0.009)***
DW statistic	2.159	2.014	2.022
$Q(10)$	12.924	9.812	10.863
$Q(10)^2$	5.246	11.906	4.504
F-Wald test	68.950***	29.603***	0.002
S.E. of regression	0.820	1.051	1.085

Notes on Table: standard errors in parentheses. *** indicates significance at 1%. q is the extreme stock market dummy and p = 10 denotes 10-year inflation expectation. Q(10) and $Q(10)^2$ are test statistics for autocorrelation.

Appendix A2
For *p* = 10 and *q* = 5%

Equation	$r_{Gold,t} = \beta_0 + \beta_1 \Delta\pi^e_{p,t} + \beta_2 r_{£,t} + +\beta_3 r_{FTSE,t} + \beta_4 r_{FTSE(q),t} + u_t$ $h_t = \gamma_0 + \gamma_1 (u_t)^2 + \gamma_2 h_{t-1}$

	Model 1 3/1/85-5/5/97	Model 2 6/5/97-4/3/09	Model 3 5/3/09-19/3/15
Intercept	-0.013 (0.012)	0.023 (0.016)	0.030 (0.027)
Inflation Expectation	0.904 (0.169)***	0.249 (0.389)	-2.142 (0.638)***
UK £ per US $	-0.777 (0.014)***	-0.342 (0.015)***	-0.269 (0.045)***
FTSE 100	-0.027 (0.015)*	-0.009 (0.015)	0.110 (0.031)***
Extreme Stock Market Dummy	-0.045 (0.017)***	0.046 (0.022)**	0.002 (0.045)
GARCH Coef1	0.004 (0.001)***	0.030 (0.003)***	0.041 (0.007)
GARCH Coef 2	0.073 (0.004)***	0.109 (0.007)***	0.077 (0.007)
GARCH Coef3	0.927 (0.004)***	0.866 (0.008)***	0.890 (0.009)
DW statistic	2.156	2.027	2.023
$Q(10)$	12.270	8.822	10.262
$Q(10)^2$	5.388	9.248	5.048
F-Wald test	128.358***	6.236**	10.399***
S.E. of regression	0.818	1.054	1.085

Notes on Table: standard errors in parentheses. *** indicates significance at 1%. q is the extreme stock market dummy and p = 10 denotes 10-year inflation expectation. Q(10) and $Q(10)^2$ are test statistics for autocorrelation.

Appendix A3
For *p* = 5 and *q* = 5%

Equation	$r_{Gold,t} = \beta_0 + \beta_1 \Delta\pi^e_{p,t} + \beta_2 r_{£,t} + +\beta_3 r_{FTSE,t} + \beta_4 r_{FTSE(q),t} + u_t$ $h_t = \gamma_0 + \gamma_1 (u_t)^2 + \gamma_2 h_{t-1}$		
	Model 1 3/1/85-5/5/97	Model 2 6/5/97-4/3/09	Model 3 5/3/09-19/3/15
Intercept	-0.013 (0.012)	0.022 (0.016)	0.031 (0.027)
Inflation Expectation	0.511 (0.148)***	0.201 (0.323)	-1.840 (0.588)***
UK £ per US $	-0.784 (0.014)***	-0.343 (0.025)***	-0.271 (0.045)***
FTSE 100	-0.037 (0.015)**	-0.008 (0.015)	0.108 (0.031)***
Extreme Stock Market Dummy	-0.039 (0.017)**	0.045 (0.022)**	0.001 (0.045)
GARCH Coef1	0.004 (0.001)***	0.030 (0.003)***	0.040 (0.007)***
GARCH Coef 2	0.074 (0.004)***	0.109 (0.007)***	0.076 (0.007)***
GARCH Coef3	0.926 (0.004)***	0.866 (0.008)***	0.891 (0.009)***
DW statistic	2.158	2.027	2.019
$Q(10)$	12.631	8.786	10.672
$Q(10)^2$	5.263	9.196	4.630
F-Wald test	141.164***	6.116**	9.782***
S.E. of regression	0.820	1.054	1.086

Notes on Table: standard errors in parentheses. *** indicates significance at 1%. q is the extreme stock market dummy and p = 10 denotes 10-year inflation expectation. Q(10) and $Q(10)^2$ are test statistics for autocorrelation.

Appendix A4
For *p* = 10 and *q* = 10%

Equation	$r_{Gold,t} = \beta_0 + \beta_1 \Delta\pi^e_{p,t} + \beta_2 r_{E,t} + +\beta_3 r_{FTSE,t} + \beta_4 r_{FTSE(q),t} + u_t$ $h_t = \gamma_0 + \gamma_1 (u_t)^2 + \gamma_2 h_{t-1}$

	Model 1 3/1/85-5/5/97	Model 2 6/5/97-4/3/09	Model 3 5/3/09-19/3/15
Intercept	-0.014 (0.012)	0.020 (0.017)	0.029 (0.028)
Inflation Expectation	0.870 (0.165)***	0.257 (0.389)	-2.142 (0.638)***
UK £ per US $	-0.779 (0.014)***	-0.342 (0.025)***	-0.269 (0.045)***
FTSE 100	-0.031 (0.017)*	-0.002 (0.017)	0.110 (0.035)***
Extreme Stock Market Dummy	-0.030 (0.018)*	0.020 (0.024)	-0.007 (0.049)
GARCH Coef1	0.004 (0.001)***	0.029 (0.003)***	0.041 (0.007)
GARCH Coef 2	0.073 (0.004)***	0.106 (0.007)***	0.077 (0.007)
GARCH Coef3	0.927 (0.004)***	0.870 (0.008)***	0.890 (0.009)
DW statistic	2.158	2.026	2.023
$Q(10)$	12.618	8.808	10.229
$Q(10)^2$	5.410	9.738	5.062
F-Wald test	81.895***	1.529	9.895***
S.E. of regression	0.818	1.054	1.085

Notes on Table: standard errors in parentheses. *** indicates significance at 1%. q is the extreme stock market dummy and p = 10 denotes 10-year inflation expectation. Q(10) and $Q(10)^2$ are test statistics for autocorrelation.

Appendix A5
For *p* = 5 and *q* = 10%

Equation	$r_{Gold,t} = \beta_0 + \beta_1 \Delta\pi^e_{p,t} + \beta_2 r_{£,t} + +\beta_3 r_{FTSE,t} + \beta_4 r_{FTSE(q),t} + u_t$ $h_t = \gamma_0 + \gamma_1 (u_t)^2 + \gamma_2 h_{t-1}$		
	Model 1 3/1/85-5/5/97	Model 2 6/5/97-4/3/09	Model 3 5/3/09-19/3/15
Intercept	-0.013 (0.012)	0.020 (0.017)	0.029 (0.025)
Inflation Expectation	0.482 (0.145)***	0.221 (0.323)	-1.847 (0.588)***
UK £ per US $	-0.785 (0.014)***	-0.343 (0.025)***	-0.270 (0.044)***
FTSE 100	-0.041 (0.017)**	-0.002 (0.017)	0.112 (0.025)***
Extreme Stock Market Dummy	-0.025 (0.019)	0.019 (0.024)	-0.109 (0.073)
GARCH Coef1	0.004 (0.001)***	0.029 (0.003)***	0.040 (0.007)***
GARCH Coef 2	0.074 (0.004)***	0.106 (0.007)***	0.076 (0.007)***
GARCH Coef3	0.926 (0.004)***	0.870 (0.008)***	0.890 (0.009)***
DW statistic	2.159	2.027	2.022
$Q(10)$	12.930	8.769	10.863
$Q(10)^2$	5.260	9.676	4.504
F-Wald test	98.221***	1.466	0.002
S.E. of regression	0.820	1.054	1.085

Notes on Table: standard errors in parentheses. *** indicates significance at 1%. q is the extreme stock market dummy and p = 10 denotes 10-year inflation expectation. Q(10) and $Q(10)^2$ are test statistics for autocorrelation.

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