IS GOLD OVERPRICED?

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ABSTRACT. The price of gold has risen dramatically since 2001 and there have been intense debates regarding the current price of this asset and its long-term outlook. Here we study a long history of the price of gold and construct a quantile regression model to identify distributional relationships between the price of gold and macroeconomic indicators, financial market performance and other relative factors. We find that while the traditional mean methodology indicates that gold is overpriced, the distributional results from quantile regression imply that gold is not overpriced in the current economic and financial environment. We provide gold price forecasts based on two economic scenarios that cover both the long-run economic environment as well as the recent economic environment experienced in 2009 and 2010.

1. INTRODUCTION

The price of gold has risen dramatically since 2001 and recently closed at an all time high of USD 1,895.00 per ounce on September 6, 2011.[1] There have been intense debates about the current pricing of this asset and future price movements. To the best of our knowledge, no rigorous framework has provided a model that explains the relative pricing of this asset in a distributional context.[2] The price of gold provides a unique insight about investor's preferences due to its unique position in history and current usage profile. Gold was historically used as a store of value and today there remain few industrial applications for this material. Its current use is primarily ornamental, yet hundreds or thousands of metric tons are still held in reserve by central banks across the world. Here, we investigate the pricing of gold and provide some additional insight regarding the current price of gold by employing quantile regression to study its conditional distribution.

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[1]The price of gold was USD 1,662.50 per ounce on at the time of this draft, March 31, 2012.

[2]A few studies have investigated the *average* aspects of the gold price, for example, Eugene (1983).

It is well documented that the price of gold is influenced by many factors such as financial market performance, economic growth, expected inflation and unemployment.[3] In this paper we study such factors and their relationship with the price of gold over the period from April 1968 to June 2012. This period has numerous economic and financial cycles, and several different macro-economic regimes which permits us to provide a robust analysis of the factors that influence the price of gold. Moreover, we employ the quantile regression (QR) technique to estimate factor effects over the whole distribution of gold prices. The price of gold was very stable over extended periods of time before May 1968. Significant change occurred only during times of war or economic crisis such as the Great Depression.[4] The governmental effort to control the private market price of gold collapsed in May of 1968 and a two-tiered price system came into existence. All central-bank transactions occurred at $35 per ounce, but the free market was allowed to establish its own price.[5] The price of gold began to move freely in May of 1968 and became determined by market forces. Our study of the price of gold focuses on the time period after April 1968. We build a quantitative multi-factor model to explore the effects of various factors on the price of gold. We concentrate our study on factors that span the macroeconomy, monetary policy, financial markets, and the price of oil. We employ quantile regression to illuminate the effects of these variables on the entire distribution of gold prices. The quantile regression based approach indicates that gold is not overvalued in the current environment, while a similar OLS-based approach indicates that gold is overpriced from January 2009 to March 2012. We also present forecasts of the price of gold by constructing two scenarios that cover both the long-run and the recent U.S. economic environments.

The rest of paper is organized as follows. Section 2 reviews the gold price movement from April 1968 to March 2012 and describes relevant factors which impact the price of gold. Section 3 presents an empirical study which identifies the quantitative relationships between the price of gold and relevant factors. Section 4 discusses the overpricing issue by employing the findings in Sections 2 and 3, the results are summarized in Section 5.

[3]See Triffin (1960), Francis (1968), Salant and Henderson (1978), O'Callaghan (1993), Tufano (1998) and Officer and Williamson (2010).

[4]From 1791 to 1887, the price of gold price in the New York market remained approximately $20 per ounce till the American civil war. While the price sharply increased to $40, it ultimately returned to $20 per ounce after the war ended and remained at this level for the remainder of the period.

[5]The free market price remained in the $40 range until 15 August 1971 when President Nixon announced that the United States would no longer convert Dollars to Gold at a fixed value, thus opening the door for major price increases.

2. Gold Price Change and Relevant Factors

The private market pricing system for gold essentially began in May 1968. Although the price of central bank transactions remained fixed by the US government, the retail price of gold began to float and its movement was then determined by market forces. Figure 2.1 displays the price of gold and its volatility from April 1968 to March 2012. Gold prices quickly moved away from the fixed price of $35 per ounce to approximately $40 per ounce by the end of May 1968 and reached over $100 in 1973. The price of gold increased rapidly over 1978 and 1979, cumulating with a 48% monthly rise from December 1979 to January 1980 during Iran hostage crisis. The price of gold peaked at a value of $675.30 per ounce in January 1980 and this was to be the highest price ever observed until April 2006. Following the surge in the late 1970's and early 1980's, the price of gold declined and fluctuated in a range from $200 to $500 per ounce until 2001. The price of gold has been on an upward trend since April 2001, and has set new record highs in each recent year. This has brought renewed interest from investors, as well as attention from the popular media.

The volatility of the price of gold changes dramatically over time. Figure 2.1 (bottom) displays the trailing 36-month standard deviation of the price of gold using monthly price observations. Two distinct time periods with significantly increased volatility are easily observed: the early 1980s and late 2000s. The recession of the early 1980's is largely attributed to the oil crisis, while the most recent downturn appears to be the result of the shock created by the recent financial crisis. Clearly, gold price movements are closely related to the U.S. economic outlook.

2.1. **Factors Impacting Gold Price Movement.**

As for all goods in modern markets, the price of gold is driven by supply and demand as well as speculation. Jewelery has consistently been the primary demand for gold. The World Gold Council reports that jewelery, investment and industrial uses account for 57%, 31% and 12% respectively, of total gold demand over the last five years.[6] India is the largest consumer of gold for ornamental uses in volume terms. Indian gold demand is mainly supported by cultural and religious traditions which are not directly linked to global economic trends. In addition, numerous new investment vehicles such as gold ETFs have made this asset class available to a wider audience of investors. Investment demand for gold has increased considerably in recent years and has represented the strongest source of demand growth since 2003. Of the key drivers behind investor demand there is one common thread: gold's ability to hold value during periods of crisis. For example, with the U.S. dollar losing its value, both individuals and governments' central banks have started to increase their holdings on gold. This increases the demand for gold. With regard to industrial applications, half of all the industrial use arises from its role in electrical components. Clearly, the industry demand is related closely with economic growth and development.

[6]See the demand and supply statistics from the World Gold Council web page:*www.gold.org*.

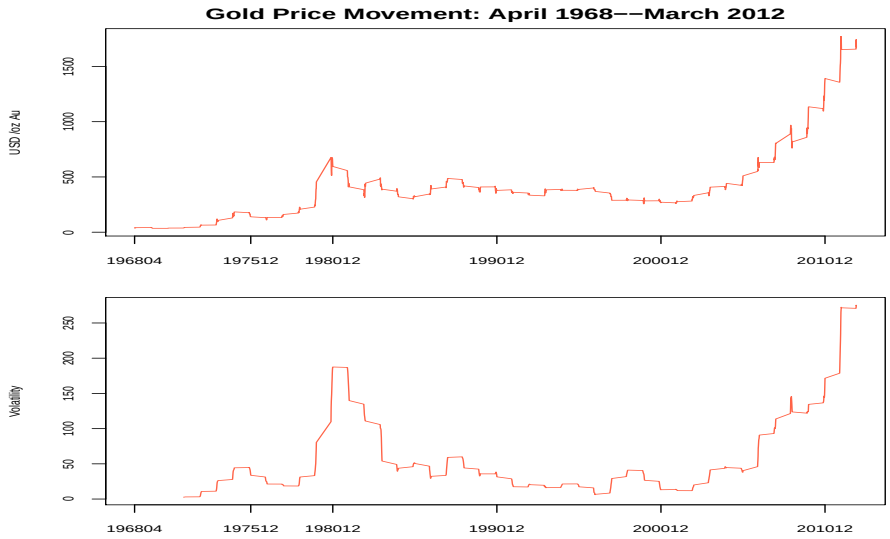

FIGURE 2.1. The monthly gold price movement from April 1968 to March 2012. The top plot describes the New York market price of gold commodity with the unit of USD per OZ Au, while the bottom plot describes the volatility, measured by 36-month standard deviation, of gold price during the same period.

Unlike most other commodities, hoarding (saving) and disposal plays a larger role in the supply of gold compared with other materials. Most of the gold ever mined still exists today in the form of jewelry and bullion. It remains in an accessible form and thus is potentially able to re-enter the gold market at the right price. During the last five years, hoarding and disposal accounts for 35% of world gold supply while mine production and government sales account for 59% and 6%, respectively, of the total gold supply.[7] While recycled gold reacts quickly to changes in the price outlook, gold mine production is relatively inelastic to the price of gold over the short period. This is due to the relatively long cycle of mine exploration, feasibility analysis, environmental study, and final mine development. The extraction of gold from the earth is an extremely capital intensive process.

Given the scarcity of gold and unique supply feature from hoarding and disposal, the price of gold is clearly driven by the demand side. The demand for gold is influenced by a wide range of factors. We will explore the underlying factors for gold demand and construct a multi-factor model using both ordinary least squares and quantile regression to disentangle the effects of several potential factors that could influence the price of gold. In order to make our analysis as parsimonious as possible, we categorize the variables under consideration along the following dimension:

[7]See the demand and supply statistics from the World Gold Council web page: *www.gold.org*.

- Macroeconomy It is generally believed that gold, particularly in physical form, will retain its value in the event of a major political, economic, currency or social crisis that might otherwise destroy the real economy. Crises such as these could materially reduce economic production, individual disposable income and purchasing power. We utilize the nominal GDP growth rate and the unemployment rate of U.S. as potential factors that proxy for the overall strength of the US economy.[8]
- Monetary System Gold has always been considered a good hedge against inflation, largely because the world supply of gold is relatively constant over time. Most of the gold produced throughout human history is still in existence because of its limited industrial applications and natural scarcity. Currencies, on the other hand, can be expanded or contracted over time by sovereign nations and are thus exposed to the phenomenon of inflation. The exchange rate of U.S. dollar against other currencies reflects currency strength and investment opportunities. A weaker U.S. dollar exchange rate is usually encouraging the increase in world gold prices. This is because investors choose to sell their dollar and then buy the gold with the hope that gold can protect the value of their assets. To study effects of monetary policy on the price of gold, we employ the U.S. inflation rate and U.S. dollar index in this paper.
- Financial Market Gold is an unusual asset because of its scarcity, and its unusual supply-demand characteristics. Gold is also an asset like stocks, bonds and real estate and we must consider its pricing relative to other asset classes. Historically, investors have favored gold when other investments are least attractive. We use the monthly return of Dow Jones Industrial Average and the yield on the U.S. treasury bill as our proxies for financial market performance.[9]
- Oil Price The price of gold is also strongly correlated with the price of oil throughout modern history. The price of these two commodities are so intertwined that they seem almost incapable of heading in separate directions over long periods of time. This relationship arises from both economic and structural linkages. Higher oil prices tend to slow the world economy as a whole and reduce disposable income for most people, which will eventually affect financial markets and also the economies of both the U.S. and other countries. In addition, the price of oil is a significant cost factor for gold production. Higher oil prices increase the cost of extracting gold and negatively impact the long run gold supply.

[8]We primarily utilize U.S. data because the U.S. economy represents a significant portion of the world economy over the time period studied in the paper.

[9]There are other proxies for the US equity market performance. We examined several alternatives (for example S&P500) and found similar results in terms of impacts on gold price.

It should be noted that the relationship between the economy, monetary indicators, financial markets and the price of oil are intertwined. Furthermore, there are structural changes in history and gold is tied to the historical events, economic health and monetary policy more than any other commodity. The regime changes in economic policy, monetary instruments and financial regulations often induce new relationships between the price of gold and the factors discussed. The identification of such structural changes and the effects of such changes on gold prices are critical. We specifically investigate the relationship between the inflation rate and the price of gold over different sub-periods due to changes in monetary policy.

3. A GOLD PRICE MODEL AND EMPIRICAL RESULTS

Based on the discussion in the previous section, we build a model of the price of gold and employ quantile regression to carry out an empirical study. The QR approach enables us to investigate the distributional effects of variables on the price of gold.

3.1. **Data Description and Summary.** We use the London P.M. gold fix as our gold price. The London P.M. fix is the price at which the world's largest gold transactions occur on a given day, and is set during the U.S. morning, about 9:00 A.M. Eastern Standard Time.[10] We utilize this measure of the price of gold because it is widely reported and is easily available over an extended time period.

For the macroeconomic indicators, we use quarterly nominal GDP growth (GDP), monthly unemployment rate (UEM) and monthly expected inflation rate (INFL). We proxy for the strength of the U.S. dollar with the US dollar index (USDX). The USDX measures the performance of the US Dollar against a basket of currencies: the Euro, Canadian dollar, Japanese yen, British pound, Swiss franc, Australian dollar, and Swedish krona. These seven foreign currencies trade widely in currency markets outside their respective home areas. We proxy the U.S. bond and equity market performance with the 3-month U.S. treasury bill yield (TBILL) and monthly return of Dow Jones Industrial Average (DJIA), respectively. We use monthly values of West Texas intermediate as our measure of oil prices (OIL). The WTI, also known as Texas light sweet, is a type of crude oil used as a price benchmark and is the underlying commodity of New York Mercantile Exchange's oil futures contracts.[11]

For the quantitative study in this paper, we use monthly data from April 1968 to March 2012. Unemployment and GDP growth rate data are lagged by three months because the official numbers are released approx two and half months after

[10]The term fix refers to "fixing" process when buy and sell orders of the fixing brokers are matched to bring the market into balance. This occurs at the fixing price, also known as the "fix" among practitioners.

[11]We collected data from different sources. On the gold commodity price, we collected data from *www.measuringworth.com*. On the macroeconomic factors we got the data from both *www.federalreserve.gov* and *www.bea.gov*. The data of expected inflation rate is from federal reserve at Cleveland.

each quarter end. The statistical characteristics of the data described above are summarized in Table 3.1. Pairwise scatter plots of each variable versus the price of gold is presented in the appendix.

Variable Name	**Min**	**Mean**	**Median**	**Max**	**Std**
gold price (USD)	34.94	398.37	356.38	1771.88	314.87
UEM (%)	3.40	6.24	5.90	10.80	1.64
GDP (%)	-5.37	6.91	6.35	25.51	4.17
INFL (%)	-2.10	4.47	3.64	14.76	2.94
USDX	69.07	95.78	95.01	143.91	14.29
DJIA (%)	-23.22	0.62	0.76	14.41	4.45
TBILL (%)	0.01	5.40	5.20	16.30	3.13
OIL (USD)	3.07	29.12	20.83	133.93	24.81

TABLE 3.1. Summary of Variables from April 1968 to March 2012.

Table 3.2 shows the Pearson correlation between all variables and the price of gold using monthly data from April 1968 to March 2012. The strongest correlation is between the price of gold and the price of oil. Material correlations are also observed between the price of gold and the US dollar index, the U.S. unemployment rate, the U.S. GDP growth rate, the expected inflation rate, the 3-month treasury bill yield. There is virtually no correlation between equity market performance and the price of gold. This finding is robust to alternative broad measurements of equity performance. The high correlation between oil and gold prices (87.6%) can be attributed to many structural linkages between these commodities as described above. At the other end of the spectrum, the gold price has almost no correlation with the monthly return of the DJIA, our proxy for stock market performance. In addition, the gold price is negatively correlated with treasury bill yield, implying a positive correlation with bond prices.

The results in Table 3.2 indicate that the price of gold is negatively correlated with the expected inflation rate, which is opposite to conventional wisdom. This result is very sensitive to the time-period under consideration. The plots for the inflation rate in Figure A.1-2 in the appendix reveal that a structural change between these variables occurred on or about 1981. In the low inflation zone ($\leq 5\%$), the correlation is -20% and is largely driven by the recent increase in gold prices and the mild inflation environment. During the high inflation era of 1970-1981, where the inflation rate ranged from 5-15%, we observe a significant positive correlation of 83%. After the 1981 regime change in monetary policy, the inflation rate dropped dramatically from 10% to 5% and then remained in the range of 1-4% for most periods.[12]

[12]In October 1979, under Chairman Paul Volcker, the Federal Open Market Committee (the Fed's monetary policy-making body) changed its approach to monetary policy and began to target

Among all the factors considered in this study, the inflation rate and 3-month treasury bill yield have the strongest correlation, with the magnitude of 69%, which is in line with the reality that treasury bill yield is usually adjusted on the basis of inflation.

Variable Name	UEM	GDP	INFL	USDX	DJIA	TBILL	OIL
gold Price	0.462	-0.364	-0.235	-0.587	-0.021	-0.196	0.876
UEM		-0.063	0.057	0.142	0.091	-0.019	0.301
GDP			0.419	0.321	-0.026	0.437	-0.330
INFL				0.343	-0.037	0.690	-0.196
USDX					-0.005	0.551	-0.544
DJIA						-0.036	-0.045
TBILL							-0.387

TABLE 3.2. Pooled correlation of variables using monthly data from April 1968 to March 2012.

3.2. **Methodology: a Brief Introduction of Quantile Regression.** We employ both the classical ordinary least squares method and quantile regression to explore the relationship between the price of gold and relevant factors considered in this paper. The traditional OLS method identifies the *average* effects on gold prices, that is, how independent variables impact the *average* gold price. The quantile regression method, introduced by Koenker and Basset (1978), provides a robust and distributional view of relevant factors on gold prices: for example, how would the US dollar index affect gold prices when gold prices are at different levels? This will be particularly helpful for our investigation of the gold price which has recently closed at all-time highs. Consider a simple univariate model,

$$y = x\beta + \epsilon, \tag{3.1}$$

where y represents the price of gold and x represents the unemployment rate, and ϵ is an error term. The top plot in Figure 3.1 shows the observed relationship between these variables from April 1968 to March 2012. We see that both unemployment rate and gold price variables have enough variation to support the relationship identification. By applying the OLS method, we obtain

$$\hat{\beta} = \underset{\beta}{\operatorname{argmin}} \sum_{i=1}^{n} (y_i - x_i\beta)^2,$$

which is the estimate of $\beta = \frac{\partial Ey}{\partial Ex}$, where $E(.)$ is the expected value. In simple words, how would a one percent change of the unemployment rate affect the gold price *on*

the quantity of money–specifically nonborrowed reserves. It was believed that targeting the level of nonborrowed reserves was a better approach to controll inflation.

average? This addresses our "average" concern but what if we are interested in the effects on the right tail of the gold price distribution? For example, how would one unit change of the unemployment rate affect the gold price when the gold price is already at a high level? QR provides a tool to tackle such a problem. Corresponding to equation (3.1), the quantile regression model could be written as:

$$\begin{aligned} y(\tau) &= x(\beta + \lambda F_{\epsilon_i}^{-1}) \\ &= x\beta(\tau) \end{aligned} \tag{3.2}$$

where F_{ϵ_i} is the distribution function of ϵ_i, τ is the percentile (quantile) of gold prices conditioning on the unemployment rate. Therefore, as long as $\lambda \neq 0$, $\lambda F_{\epsilon_i}^{-1}$ captures heterogeneous effects of x on y.[13] By varying τ over the range of (0, 1), we would obtain a distributional view of unemployment effects on gold prices. We use the expression $\beta(\tau)$ to indicate that β will depend upon the choice of τ, which is the percentile (quantile) of conditional distribution of gold prices. To obtain the quantile estimates we select a value for τ and then minimize the following expression,

$$\hat{\beta}(\tau) = \underset{\beta(\tau)}{\operatorname{argmin}}[\tau \sum_{y \geq \beta x} (y_i - \beta x_i) + (\tau - 1) \sum_{y < \beta x} (y_i - \beta x_i)]. \tag{3.3}$$

In words, $\beta(\tau)$ is derived as a line ($y = \beta(\tau)x$) such that τ percent of observations lie on or below the line (the first sum) while $(1 - \tau)$ percent of observations lie above the line (the second sum). Note that we can choose τ freely in the range of (0, 1).

In our example of the relationship between the unemployment rate and price of gold, we provide QR estimates at $\tau = \{0.1, 0.5, 0.9\}$ on the top plot of Figure 3.1, which shows how the unemployment rate affect the price of gold at low, median, and high levels. We see that the slopes are different and increasing with values of τ, indicating a very different impact when the gold price is at high or low levels. For comparison purpose, we also show the OLS estimate (red line), which is very close to the special median estimate. The bottom plot in Figure 3.1 presents an alternative way to present the effects across quantiles where quantiles are shown along the x-axis and the slope coefficient corresponding to each quantile along the y-axis. The quantiles are set at $\tau = \{0.05, 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 0.95\}$. The grey area indicates the 90% confidence interval. The OLS estimate and its confidence interval are also added on the graph and are shown by solid and dashed straight lines. The bottom plot provides a more colorful view of the unemployment rate's impact on gold prices. We see that in this univariate model unemployment effects are significantly larger when gold prices are high. When gold prices are below the median level, for a one-percent increase in the unemployment rate, the price of gold will increase by about \$20-60. However, when the gold price is at high level, the impact increases to \$100-200! Clearly, the impact of unemployment rates on gold prices is very different when the price of gold is at low or high levels.

[13]Note that λ is a scalar for the distribution F.

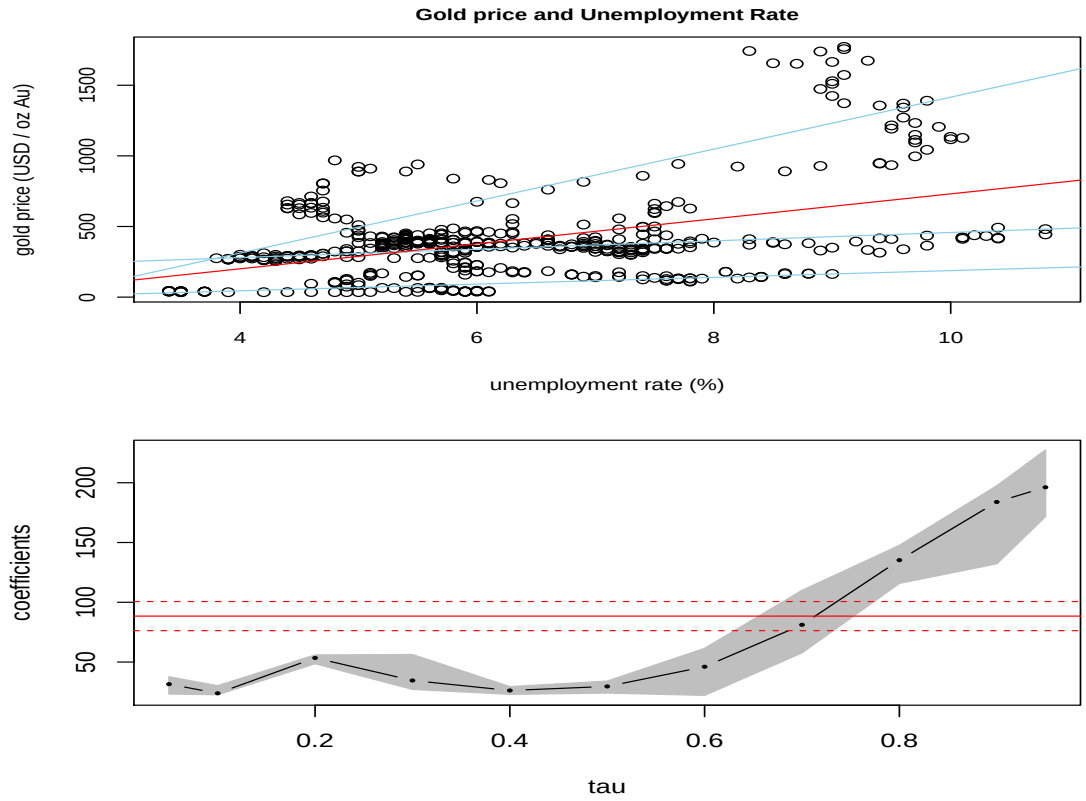

FIGURE 3.1. An example of univariate quantile regression model of gold price and unemployment rate. The top plot is the scatter plot of gold price and unemployment rate. The bottom plot describes the slope estimates from OLS and QR at different quantiles, where the shaded area is for the QR estimates with 90% confidence band and the straight solid line is for the OLS estimate with 90% confidence band.

3.3. **Empirical Results.** Before proceeding to the multi-factor model, we first investigate the distributional effects for each individual factor. The factor effects in the univariate models are presented in Figure 3.2 for the seven factors that we consider. The estimation is obtained using monthly data from April 1968 to March 2012 with quantiles set at $\{0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9\}$. Univariate OLS estimates are also provided for comparison purposes. Figure 3.2 reveals that the QR estimates are very different from the OLS estimate for most factors, indicating that distributional effects provide a more comprehensive picture than the "average" OLS effects. For every variable except the DJIA, QR estimates vary with percentiles of gold price distribution implying that the impact of each variable is different depending on the level of the price of gold itself.

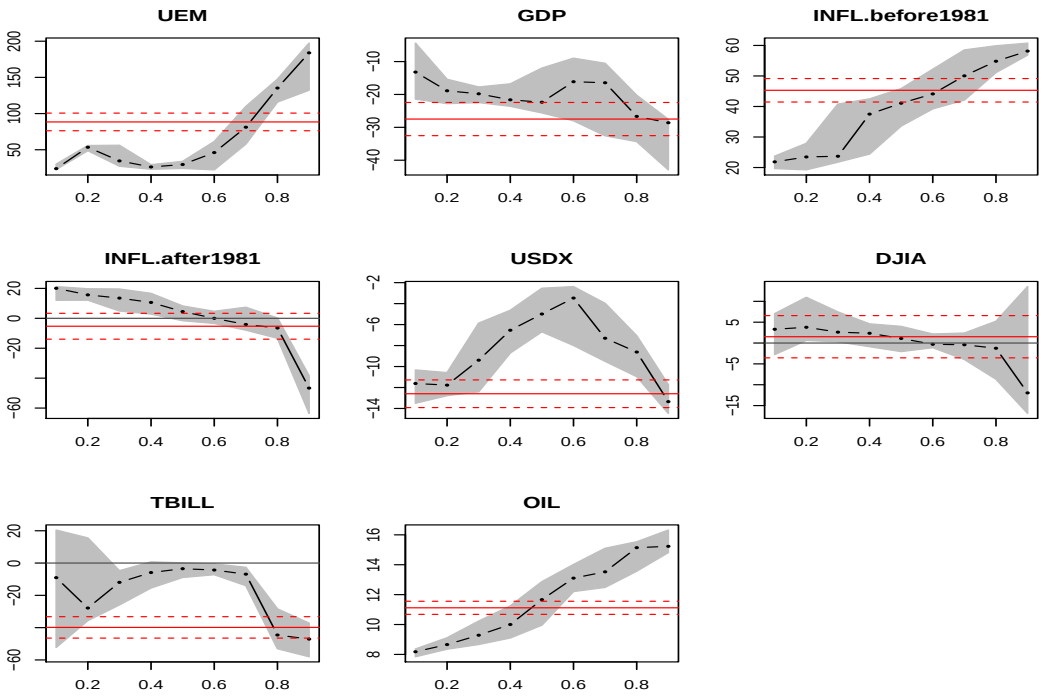

FIGURE 3.2. Univariate QR and OLS results of variables on gold price from April 1968 to March 2012. The dot-connected line is for QR estimates with 90% confidence band indicated by the greay area. The red line is for OLS estimates with 90% confidence band.

The unemployment rate has the largest impact on the gold price measured by both QR and OLS estimates. The OLS estimate indicates that a 1% increase in unemployment rate translates into a $90 increase in the gold price *on average*. The QR approach indicates that the impact of unemployment is dramatically different depending upon the gold price. At low or median gold price levels, a 1% increase in the unemployment rate produces a gold price increase of $20. However, when gold prices are already high ($\tau = 90\%$), a 1% increase in the unemployment rate will result in a $180 increase in the price of gold. The average effect delivered by OLS is indeed the "average" of quantile effects and fails to capture this detail. The GDP growth rate, another important indicator of the strength of the economy, also has a significant negative impact on gold prices. The QR estimates show that a 1% increase in the GDP growth rate will cause the gold price to decrease by $10 when the gold price is low, while at high gold price levels the effect is -$30.

We explore the impact of inflation on the price of gold before and after 1981, corresponding to the regime change in monetary policy that occurred in the U.S. The rate of inflation has a significant impact on the price of gold prior to 1981, and the effects increase with the gold price. A 1% increase in expected inflation rate corresponds to a $20 increase when the gold price is low and $55 when the gold price is high. Low inflation became the main target of U.S. monetary policy after 1981 and the observed inflation rate rarely exceeds 5% following this change in policy. For the post-1981 period, both OLS and QR show that the inflation effects are close to zero and insignificant when gold price is around the median level. Inflation appears to have an impact on the price of gold only when it is a dominant threat to economic stability and people's welfare. When inflation is low, an increase in inflation does not precipate a level of fear that can induce a change in gold prices. In contrast to conventional wisdom, our results show that gold is not a hedge against inflation during this period particularly for high gold prices.

The US Dollar Index (USDX) has the expected effect on the price of gold: gold prices increase when the US Dollar is weak and decline when the US dollar is strong. It is interesting that USDX has a nonlinear impact on the price of gold, and is most significant at either very high or very low levels of the gold price. At these levels, one unit decrease in the USDX index results in a $12 increase in gold price.

Stock market performance, proxied by the monthly return of DJIA, has a very weak and statistically insignificant effect on the price of gold.[14] The 3-month treasury bill yield exhibits a significant effect only when gold prices are high. While the OLS approach indicates a significant effect of -$40, the QR effects are insignificant for most of the gold price distribution and become significant only when the gold price is high. At $\tau = 0.90$, a 1% increase in t-bill yeild causes a decrease of $45 on the gold price.

As expected, the price of oil has a significant impact on the price of gold. The effect remains in the range of $8-$11 for $\tau < 0.5$, and then becomes more sensitive to the oil price when the price of gold is above the median level. In the present environment ($\tau = 0.9$), a $1 increase in the price of oil will "push" the price of gold by $15.

4. is gold overpriced now?

Here, we focus on the recent pricing of gold. The economic situation of last few years is very extreme in terms of both scope and depth and it is regarded as the worst economic situation since the Great Depression. To provide a quantitative forecast for the recent pricing of gold, we employ the joint effects of the seven factors discussed in the previous section.

Following the structure of the univariate model, we carry out an empirical study for a multi-factor model. We employ the following linear model to study the factor

[14]We also tried level values of the DJIA index and found same results.

effects on gold price,

$$G = \beta_0 + \beta_1 * \text{UEM} + \beta_2 * \text{GDP} + \beta_3 * \text{INFL} + \beta_4 * \text{USDX} + \beta_5 * \text{DJIA} + \beta_6 * \text{TBILL} + \beta_7 * \text{OIL} + \epsilon, \tag{4.1}$$

where G is the gold price and ϵ is the error term. Note that ϵ needs to be neither i.i.d. nor Gaussian because we are using the QR approach. The corresponding QR model is specified as,

$$G(\tau) = \beta_0(\tau) + \beta_1(\tau) * \text{UEM} + \beta_2(\tau) * \text{GDP} + \beta_3(\tau) * \text{INFL} + \beta_4(\tau) * \text{USDX} + \beta_5(\tau) * \text{DJIA} + \beta_6(\tau) * \text{TBILL} + \beta_7(\tau) * \text{OIL}. \tag{4.2}$$

Using the coefficients estimated from the QR model for the period of 1968-2008, we generate out-of-sample forecasts of gold price from January 2009 to March 2012 on a monthly basis. The results are presented in Figure 4.1 and Table B.1.

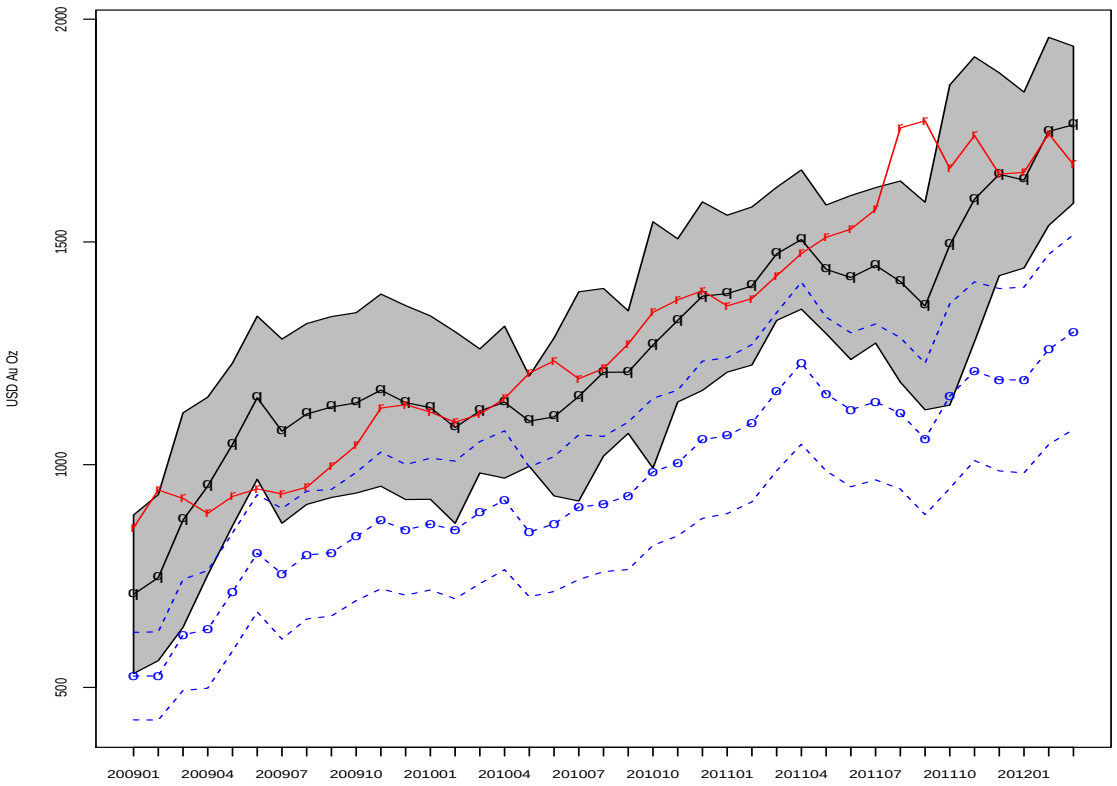

FIGURE 4.1. The forecasted and real monthly gold price from January 2009 to March 2012. The solid line with letter "q" is for the QR forecasts with 90% confidence band while the dashed line with letter "o" is for the OLS forecasts with 90% confidence band. The solid line with letter "r" is for the actual price of the gold.

We compare our forecasts with the actual gold price, which tests the efficacy of the QR model. We use QR estimates at the 90^{th} percentile to extract the QR forecast of gold prices. We also provide forecasts based on the OLS estimates for comparison purposes. The actual gold price, QR forecasts and OLS forecasts are shown in Figure 4.1 on a monthly basis from January 2009 to March 2012. The gold prices forecasted by quantile regression follow actual gold prices closely, with an average deviation of of 8% from actual gold prices. In addition, the actual gold price remains in the 90% confidence interval of QR forecasts for the entire time period except for the months of August and September of 2011. To address the issue of gold overpricing in a more formal way, we test the hypothesis:

$$H_0 : G_t = Q_t, \qquad H_a : G_t > Q_t,$$

where G is the market gold price and Q is the "true" price at time t. To test the above hypothesis, we use the forecasted value from quantile regression to approximate the intrinsic value of gold. The 95% one-side t-test yields: t = 0.4556, df = 74.6250, p-value = 0.3250, indicating that we can not accept the alternative hypothesis. In another words, the quantile regression method does not indicate that gold has been overpriced after 2008. We note that the OLS method yields: t = 5.9567, df = 68.5010, p-value = 4.953e-08, which implies that gold has indeed been overpriced during this period.

The U.S. economy has been materially impacted by the financial crisis of 2008. As the central banks of the world print money in order to maintain low interest rates, it is not surprising to see investors flock to gold. As in the past, investors have purchased gold as a safe haven in the event that paper money loses its worth. We understand that the gold price will rise during such a difficult period but the magnitude and duration remain a critical question. While the answer depends on many factors, one key factor is the strength of the U.S. economy. The current economic crisis differs from the Great Depression in that each country is only one part of the global economy and each country's economic recovery depends on not only itself but also more heavily other economies. There is thus more uncertainty from such a perspective.

Scenario	**UEM**	**GDP**	**INFL**	**USDX**	**TBILL**	**OIL**
A (long run average)	5.59	4.73	2.46	89.23	3.27	82.59
B (recent period)	8.91	3.90	3.32	71.16	0.04	98.06

TABLE 4.1. Two set of scenarios of economic recovery and assumed values for variables. We exclude the variable of DJIA as it is not significant in terms of impact on the price of gold and it is more difficult to predict the future range of this variable.

We consider two future economic scenarios regarding the U.S. economic recovery and hence their impacts on the price of gold. Scenario A and B presented in Table 4.1

Scenario	lower bound	gold price	upper bound
A	883.07	1122.68	1362.30
B	1324.99	1581.50	1838.01

TABLE 4.2. Gold price (USD per Au ounce) forecast based on two set of scenarios.

represent the long-run and "current" economy, with the values for the factors derived from the period of January 1995 to December 2008 and January 2009 to March 2012, respectively. The QR forecasts for the price of gold under Scenario A and B are presented in Table 4.2, and the results for the two scenarios are very different. The QR model predicts a gold price of USD 1,123 per ounce with a range of USD 883–USD 1,362 under Scenario A, which corresponds to a return to the long-run economic average. Scenario B represents a continuation of the high unemployment rate and weak currency environment and under this scenario the gold price is forecasted to be USD 1,582 per ounce with a range of USD 1,325–USD 1,838.

5. SUMMARY

We investigate the relationship between the price of gold and relevant factors from April 1968 to March 2012. The gold price was determined by market forces during this period and has been on an upward trend since 2001. We identify seven underlying factors for gold price movement: unemployment rate, GDP growth rate, expected inflation rate, U.S. dollar index, Dow Jones Industrial Average return, 3-month U.S. treasury bill yield, and oil price. The employment of quantile regression enables us to investigate the impacts of these factors on the gold price when the gold price at different levels. Thus quantile regression provides a natural tool to evaluate the overpricing issue as recent gold prices are at historical highs and remain at the right tail of the distribution. Using the data from 1968 to 2008, we derive the joint effects of seven factors in a linear multi-factor model and then use the derived estimates to forecast the price of gold for each month from January 2009 to March 2012. We find that by quantile regression the price of gold is not overvalued although OLS implies gold is overpriced for the period of January 2009–March 2012. Also, we make simple forecasts by constructing two economic scenarios for the U.S. economy. The QR framework predicts that the price of gold will fall to $1,123 with a one standard deviation range of ($883, $1,362) if the U.S. economy returns to its long-run economic average. However, if the recent U.S. economic trends continue, then the QR predicts that the gold price will remain at $1,582 with a one-standard deviation range of ($1,325, $1,838).

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Appendix A. scatter plot for a factor and gold Price

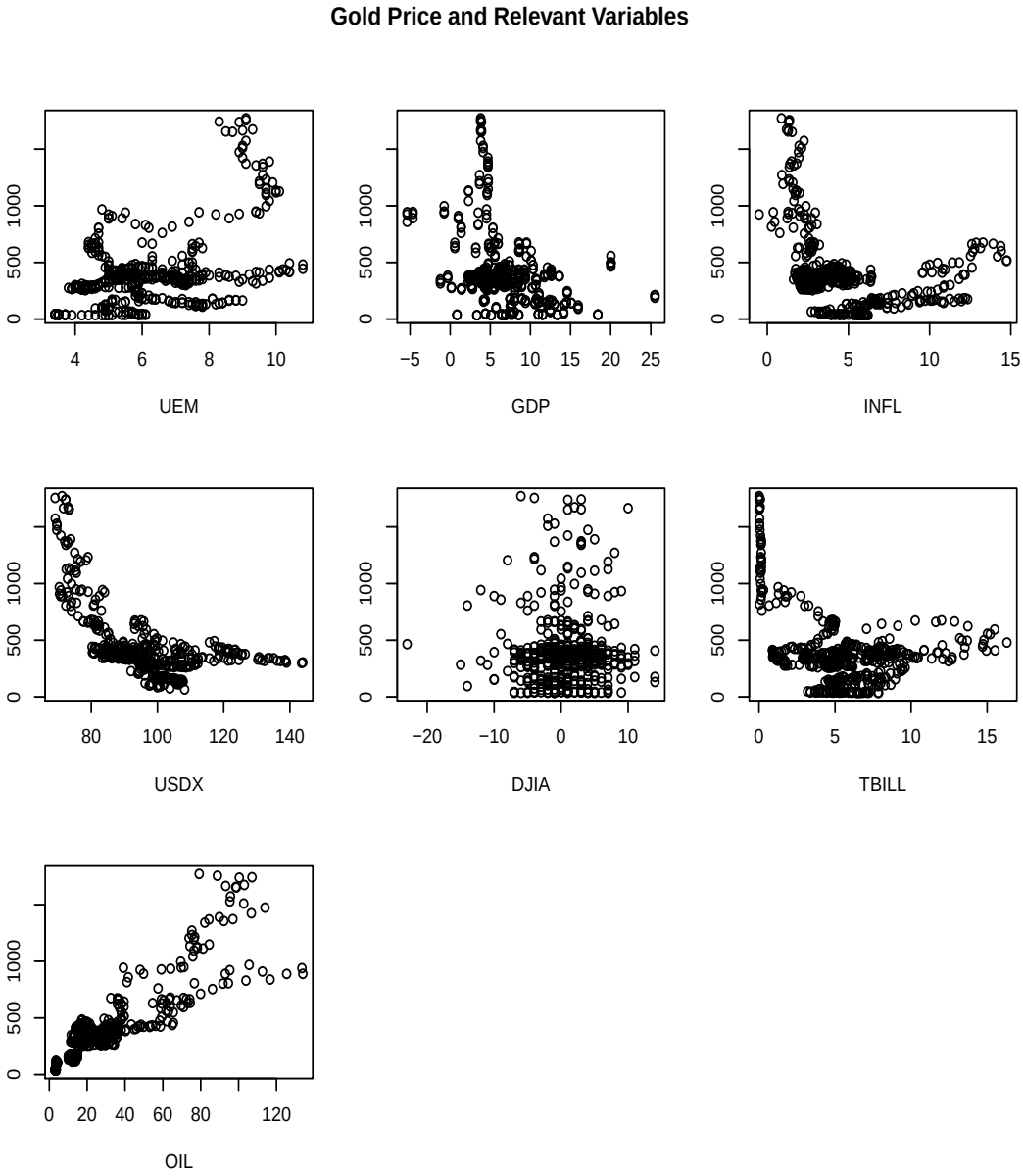

Figure A.1. Pairwise scatter plots for each independent variable versus the price of gold. All data are monthly from April 1968 to March 2012. The y-axis is for the price of gold and x-axis is for each independent variable.

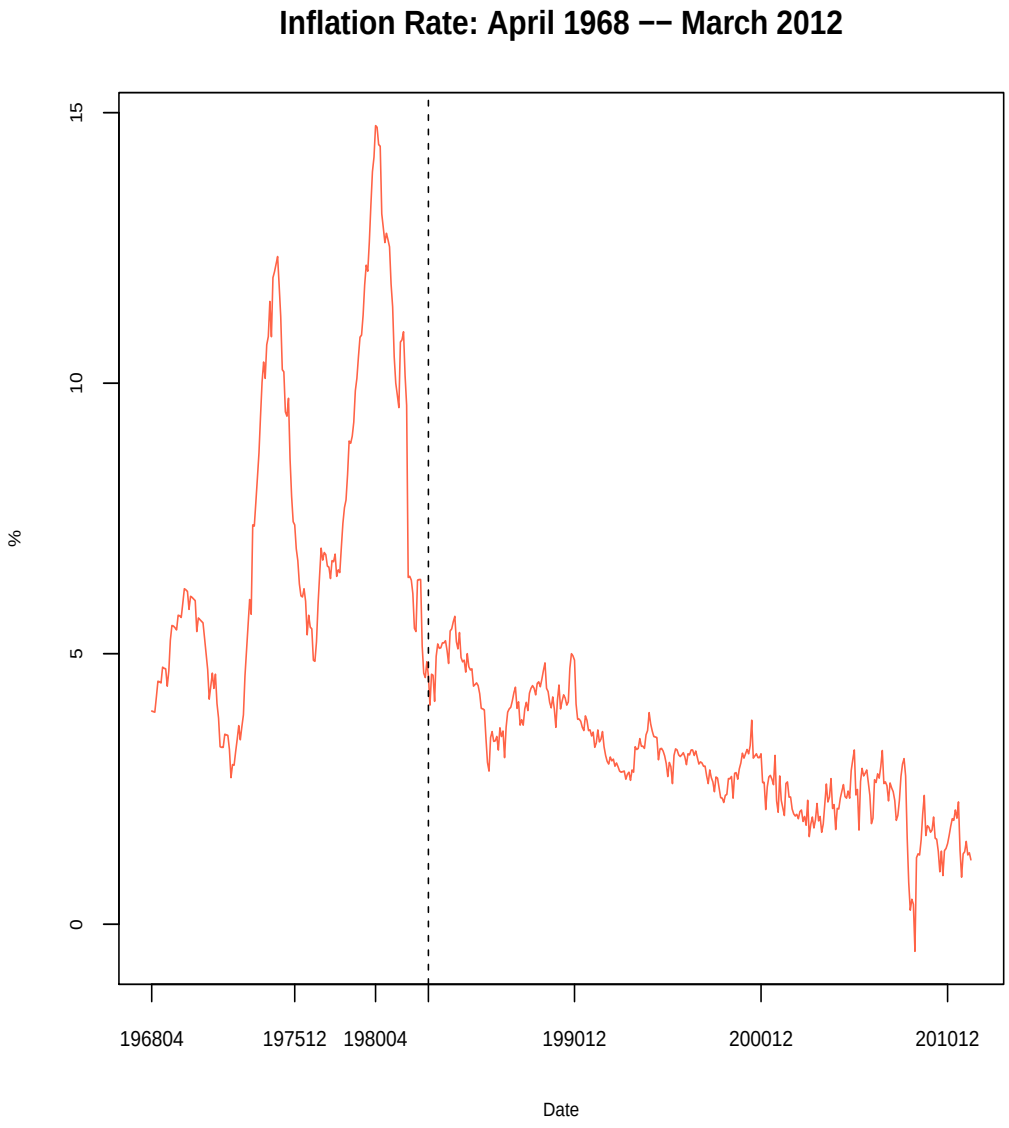

FIGURE A.2. Inflation rate from April 1968 to March 2012. Due to the monetary policy change in late 1970s and early 1980s the structure of the inflation rate changed dramatically after 1981 indicated by the dashed vertical line.

Appendix B. gold price forecast based on the expanding window from 196804 to 201203

Date	QR.lower	QR	QR.upper	OLS.lower	OLS	OLS.upper	actual
200901	531.04	709.06	887.07	427.16	525.42	623.68	858.69
200902	560.14	746.44	932.75	426.82	525.76	624.71	943.16
200903	634.89	875.65	1116.41	493.00	617.73	742.45	924.27
200904	752.54	952.08	1151.62	498.29	630.33	762.37	890.66
200905	862.70	1045.42	1228.14	581.71	714.14	846.58	928.64
200906	967.25	1150.34	1333.44	669.48	801.09	932.70	945.67
200907	868.58	1075.24	1281.90	608.53	755.07	901.61	934.23
200908	910.73	1113.71	1316.68	653.61	797.05	940.50	949.38
200909	926.35	1129.41	1332.46	660.24	802.36	944.47	996.59
200910	936.23	1138.71	1341.18	694.89	838.71	982.53	1043.16
200911	951.59	1167.28	1382.97	721.47	874.95	1028.42	1127.04
200912	921.73	1139.42	1357.11	706.99	853.68	1000.38	1134.72
201001	922.37	1128.20	1334.04	718.77	866.61	1014.45	1117.96
201002	868.40	1083.44	1298.48	699.02	853.57	1008.11	1095.41
201003	981.40	1120.59	1259.77	732.82	892.32	1051.83	1113.34
201004	969.79	1140.34	1310.90	764.25	920.05	1075.86	1148.69
201005	996.33	1097.83	1199.33	703.49	849.06	994.62	1205.43
201006	929.92	1107.19	1284.45	715.29	866.81	1018.32	1232.92
201007	918.39	1153.26	1388.12	742.12	904.53	1066.95	1192.97
201008	1019.23	1207.39	1395.55	759.85	911.65	1063.45	1215.81
201009	1070.32	1207.80	1345.27	764.67	930.13	1095.59	1271.1
201010	992.16	1268.74	1545.31	818.80	983.90	1149.00	1342.02
201011	1140.68	1323.84	1506.99	840.11	1003.67	1167.23	1369.89
201012	1166.82	1378.38	1589.94	879.61	1056.04	1232.47	1390.55
201101	1207.70	1383.82	1559.95	890.19	1065.12	1240.06	1356.4
201102	1223.75	1401.13	1578.51	916.67	1093.13	1269.59	1372.72
201103	1323.79	1473.23	1622.66	986.37	1163.81	1341.24	1424.01
201104	1349.04	1505.36	1661.67	1045.68	1227.75	1409.82	1473.81
201105	1294.34	1438.62	1582.90	986.19	1158.70	1331.20	1510.44
201106	1236.00	1420.09	1604.18	950.42	1123.30	1296.19	1528.66
201107	1272.88	1447.42	1621.97	965.91	1140.86	1315.80	1572.81
201108	1185.27	1411.05	1636.82	945.28	1115.27	1285.27	1755.81
201109	1123.12	1356.13	1589.13	887.90	1057.91	1227.91	1771.88
201110	1133.63	1493.01	1852.38	946.98	1154.15	1361.31	1665.21
201111	1276.20	1595.89	1915.57	1009.13	1209.79	1410.46	1738.98
201112	1424.37	1652.01	1879.65	986.04	1190.67	1395.31	1652.31
201201	1441.43	1638.87	1836.31	981.37	1189.95	1398.53	1656.12
201202	1537.05	1748.15	1959.24	1045.29	1258.78	1472.26	1742.62
201203	1586.84	1763.09	1939.34	1079.27	1297.67	1516.07	1673.77

Table B.1. Gold price forecasts by quantile regression for the period from January 2009 to March 2012.