Journal of Economics and Business xxx (2009) xxx–xxx

Contents lists available at ScienceDirect

Journal of Economics and Business

Gold prices, cost of carry, and expected inflation

Laurence E. Blose*

Grand Valley State University, 474C DeVos Center, Grand Rapids, MI 49504-6431, United States

ARTICLE INFO

Article history:
Received 22 October 2008
Received in revised form 19 May 2009
Accepted 2 July 2009

Keywords:
Inflation
Bond yield
Gold
Cost of carry

ABSTRACT

How do changes in expected inflation affect gold prices? Using unexpected changes in the Consumer Price Index (CPI) this paper shows that surprises in the CPI do not affect gold spot prices. The results indicate that investors anticipating changes in inflation expectations should design speculation strategies in the bond markets rather than the gold markets. Additionally, investors cannot determine market inflation expectations by examining the price of gold.

1. Introduction

Many economists and market analysts believe that gold spot prices are influenced by expected inflation. Analysts in the financial press routinely attribute substantial changes in the price of gold to changes in expected inflation. When unexpected changes in the Consumer Price Index (CPI) occur on the same day as large changes in the price of gold, analysts attribute the change in gold price to the changes in the inflation indicators. Recent articles in the financial press reflect this opinion, attributing the current strength in gold price to higher inflation expectations.[1] Textbooks, popular investing books, and financial magazines propose strategies in which investors take positions in gold that are based upon predictions regarding changes in expected inflation.

In the academic literature the relationship between gold and inflation is an underlying assumption in empirical tests that use changes in gold prices as a proxy for changes in inflation expectations. Even the Federal Reserve has indicated that gold prices and returns can be used as a measure of future inflation. Alan Greenspan, the recent past chairman of the Federal Reserve, has commented

* Tel.: +1 616 331 7436; fax: +1 616 331 7445.
E-mail address: blosel@gvsu.edu.

[1] For examples of recent articles that tie gold prices to inflation expectations see Cui (2009), Wherry (2009), and Lehman (2009).

0148-6195/$ – see front matter © 2009 Elsevier Inc. All rights reserved.
doi:10.1016/j.jeconbus.2009.07.001

that the price of gold is "a very good indicator" of inflation and is useful in the battle against inflation.[2]

This paper examines and empirically tests the theory underlying the hypothesized relationship between gold and inflation expectations. It argues that the theoretical basis for the relationship is murky, and that the results of previous empirical studies are mixed. The paper then presents empirical evidence that show that gold prices do not change as a result of changes in inflation expectations.

2. Gold prices and expected inflation

2.1. The expected inflation effect hypothesis

Many gold analysts argue that upward revisions in expected inflation will cause some investors to purchase gold, either to hedge against the expected decline in money or to speculate in the associated increase in the price of gold. The buying pressure will cause an immediate increase in the price of gold at the time of the revision in expected inflation. This paper will call this the expected inflation effect hypothesis. The expected inflation effect hypothesis has the following implications:

1. The spot current price of gold will depend upon expectations regarding future inflation.
2. Economists can use gold prices to determine what level of inflation is anticipated by the market.
3. Changes in inflation expectation will be accompanied by changes in gold prices. Accordingly, investors who have superior knowledge regarding future inflation will be able to make a speculative profit by buying (or selling) gold in anticipation of market adjustments to the changes in expected inflation.

2.2. The carrying cost hypothesis

One problem with the expected inflation effect hypothesis is that it does not address the impact of inflation on interest rates and the cost of holding gold. Investors must fund their gold investments either by borrowing or by diverting owned capital from other investments. No matter how the funds are obtained, the cost of investing in gold will be affected by interest rates. An increase in expected inflation will cause the expected future price of gold to be higher than otherwise, but it will also cause interest rates to be higher as well. The higher interest rates will increase the cost of holding gold.

Any speculative profit in holding gold during inflationary periods will be offset by the higher interest costs. Any incentive for buying gold and gold related assets will be reduced and gold price reaction to the revised inflation expectations will be reduced or eliminated. This will be referred to as the carrying cost hypothesis.

Prior empirical research has shown that gold has a market beta of zero or even slightly negative.[3] Assume that the beta is zero (the assumption will be relaxed later in the discussion). If so then the capital asset pricing model would predict that gold should provide a return equal to the risk free rate. Since gold does not pay a dividend, the return on gold is realized by price appreciation each period. Thus gold should increase at the risk free rate each period. In order to buy the gold, the investor must tie up funds that could be invested in other risk free investments. The return on the alternative risk free asset is the opportunity cost of investing in gold. Thus, both the opportunity cost of investing in gold and the benefit of investing in gold are the same—the risk free rate.

[2] *Wall Street Journal* (eastern edition), February 23, 1994, page A1. Also see Angell (1992) for a discussion of Commodity Prices and Monetary Policy by Wayne Angell, a member of the Board of Governors of the Federal Reserve System.

[3] Aggarwal and Soenen (1988), and Jaffe (1989) find that the correlation between gold and the stock market is positive but small. On the other hand, Tschoegl (1980), Carter et al. (1982), Blose and Shieh (1995), Larsen and McQueen (1995), Lawrence (2003), and McCown and Zimmerman (2006) all find that gold is either uncorrelated with the stock market or that gold has a beta not significantly different from zero. Blose (1996) finds that the gold is negatively correlated with the stock market. Baur and Lucey (2006) show that although the Gold Beta is typically negative, it varies over time and can be either positive, negative, or zero depending upon the period examined.

Please cite this article in press as: Blose, L. E. Gold prices, cost of carry, and expected inflation. *Journal of Economics and Bussiness* (2009), doi:10.1016/j.jeconbus.2009.07.001

Suppose that inflation expectations change and inflation is expected to be higher. The risk free rate will increase (Fisher, 1896), so the expected appreciation in the price of gold will increase, but so will the opportunity cost of holding gold. The investor is no better off than before the change in inflation expectations and there is no incentive to buy the gold when inflation expectations change. Accordingly gold price will not be affected by changes in expected inflation.

We have assumed that the beta of gold is zero and that the market correctly prices risk according to the capital asset pricing model. If one or both of these assumptions is wrong, then gold may appreciate at a rate different from the risk free rate. If so, then the expected gain from the change in expected inflation might be only partially offset by the change in the cost of carry. Whether or not the gain is exactly offset by the cost is an empirical question that is addressed in the empirical section of this paper.

The carrying cost hypothesis has the following implications:

1. The spot price of gold is not affected by expectations regarding future inflation.
2. Gold prices cannot be used to determine inflation expectations.
3. Changes in inflation expectations will not affect gold prices. Investors who have superior knowledge regarding future inflation will not be able to make speculative profits by buying (or selling) gold in anticipation of market changes in expected inflation.

2.3. Previous studies

Previous studies can be separated into two groups—those that examine the long term relationship between gold prices and inflation and those that examine the impact of expected inflation on gold prices. Numerous articles published in both academic journals and the financial press show a relationship between the price of gold and actual inflation over time. For example, in the academic literature, Sherman (1982), Young and Khoury (in Khoury, 1984, pp. 355–358), Haubrich (1998), Jaffe (1989), and McCown and Zimmerman (2006) all find a significant relationship between measures of inflation and gold prices. Ghosh, Levin, Macmillan, and Wright (2004) and Worthington and Pahlavani (2007) present evidence of long run cointegration between gold and inflation. In contrast, Tully and Lucey (2007) using a power GARCH approach, do not find a significant relationship between inflation and gold.

While there is substantial theory and empirical evidence regarding the relationship between gold prices and inflation (ex post), the relationship between gold prices and expected inflation is less clear. Studies examining the impact of changes in expected inflation on gold prices provide mixed results. Table 1 presents a list of studies that have examined the extent to which expected inflation is reflected in gold prices. Some of the studies show a relationship between gold and inflation expectations. Sherman (1983) presents empirical evidence indicating a significant relationship between inflation and gold futures prices. Christie-David, Chaudhry, and Koch (2000) find a significant relationship between unexpected inflation and gold futures prices. Adrangi, Chatrath, and Raffiee (2003) find that unexpected inflation does not affect gold prices but expected inflation does have an impact. Moore (1990) reports a relationship between gold returns and a leading indicator of inflation.

Other studies have shown that gold is not a leading indicator of inflation or is either uncorrelated or negatively correlated with expected inflation. Jaffe (1989) reports that gold prices do not predict future changes in the CPI. Lawrence (2003) finds that there is no statistically significant correlation between returns on gold and changes in the Producer Price Index (PPI). Garner (1995) examined the performance of an index consisting of five leading indicators of inflation, one of which is gold. He found only qualified (weak) support for the predictive power of the indicators. Larsen and McQueen (1995) use T-bill prices to estimate unexpected inflation and find that the relationship between gold and unexpected inflation is weak. Mahdavi and Zhou (1997) examined the extent to which gold and other commodity prices are leading indicators of inflation. They concluded that gold's contribution to inflationary predictions is not statistically significant. Tkacz (2007) examines 14 different currencies

Please cite this article in press as: Blose, L. E. Gold prices, cost of carry, and expected inflation. *Journal of Economics and Bussiness* (2009), doi:10.1016/j.jeconbus.2009.07.001

Table 1
Research that examines the impact of expected inflation on gold prices.

Authors (date)	Span of study	Holding period	Calculation of inflation expectations	Does expected inflation affect gold?	Comments
Sherman (1983)	1970 through 1980	Annual	18 mo moving avg CPI	Yes	Regressed annual gold prices against unexpected inflation. Found a significant ($t = 2.06$) positive relationship
Jaffe (1989)	September 1971 to June 1987	Month	T bills	Mixed	Gold price movements are not predictive of future changes in CPI
Moore (1990)	1970 through 1988	Month	N/A	Yes	Gold prices are predicted by a leading indicator of inflation
Garner (1995)	1973 through 1994	Month	N/A	No	Tests the extent to which gold and other leading indicators of inflation predict changes in the CPI. Found that the". Indicators by themselves, have not been successful in predicting the magnitude of CPI inflation in recent years."
Larsen and McQueen (1995)	January 1972 to August 1992	Month	T bills ARIMA Naive	Mixed	Regressed return against expected and unexpected inflation. Coefficient of unexpected inflation is significant and positive but F-statistic is not significant
Mahdavi and Zhou (1997)	1970 through 1994	Quarter	N/A	No	No evidence of a cointegrating relationship between the CPI and gold price. Concludes that gold price is not useful as a leading indicator of inflation
Cecchetti et al. (2000)	1975 through 1984	Quarter	N/A	No	Gold prices do not provide accurate signals of inflation
Christie-David et al. (2000)	1992 through 1995	Intra-day	MMS Forecasts	Yes	Gold Futures reaction to unexpected changes in CPI is significant in the 15-min time period following the announcement
Lawrence (2003)	1975 through 2001	Quarter	N/A	No	Found that gold does not react to changes in the Producer Price Index
Adrangi et al. (2003)	January 1968 to December 1999	Month	ARIMA	Mixed	Gold has a positive relationship with expected inflation but no relationship with unexpected inflation
Tkacz (2007)	September 1994 to December 2005	Month	N/A	Mixed	Examines gold as a leading indicator of inflation in 14 countries. Finds that gold signals inflation in some countries over some lead times

and finds that changes in gold prices lead inflation in some of the countries.[4] Cecchetti, Chu, and Steindel (2000) found that when gold is included in a leading indicator of inflation, it enters the model with a negative coefficient. Their findings mean that higher gold prices are associated with lower expected inflation—the exact opposite of what is expected.

[4] Gold is widely traded in a variety of currencies. The results of this paper indicate that changes in inflation expectations for all currencies will affect bond prices and gold futures prices denominated in those currencies but not gold spot prices. The results suggest the usefulness of studies similar to that presented in this paper but performed in currencies other than the US dollar.

Please cite this article in press as: Blose, L. E. Gold prices, cost of carry, and expected inflation. *Journal of Economics and Bussiness* (2009), doi:10.1016/j.jeconbus.2009.07.001

The research presented above generally finds a clear long run relationship between inflation and gold prices. This comes about because of the corrosive impact of inflation on the value of money. However, the relationship between gold prices and expected inflation is much less clear. Despite widespread assertions in the financial press, in investment advisory media, and in textbooks, the empirical evidence is decidedly mixed and in some cases contradictory. This issue is examined in this research.

3. Inflation expectations, bond yields and the cost of carrying gold

The empirical results presented in this paper are comprised of two parts. In this section we show that bond yields are affected by surprise changes in the CPI as predicted by the Fisher hypothesis. Since bond yields change, the cost of carrying gold changes as well. The second part of the research is present in Section 4 and examines how gold prices react to surprise changes in the CPI.

3.1. Why the cost of carrying gold is affected by expected inflation

This paper examines the impact of changes in expected inflation on the cost of carrying gold by measuring the impact of unexpected changes in the CPI on the yield of US government debt that matures in one, two, and three years. Two predominant explanations link interest rates with expected inflation. The first, the Fisher hypothesis (Fisher, 1896), argues that higher future inflation makes fixed income investment less desirable. Accordingly, bonds sell for less, and their associated yields are greater. The second explanation, the policy anticipation hypothesis (Smirlock, 1986), is based upon the Federal Reserve's reaction to higher than expected inflation. Since one of the Fed's goals is low inflation, an indication that inflation will be higher than expected may prompt the Fed to tighten the money supply, which will cause an increase in interest rates. Both the Fisher hypothesis and the policy anticipation hypothesis indicate that the term structure is directly affected by expected inflation. These two hypotheses are complementary in the sense that both predict that higher expected inflation will cause higher interest rates.

Several researchers have tested the relationship between CPI announcements and changes in interest rates or bond prices. Green (2004), Balduzzi, Elton, and Green (2001), and Fleming and Remolona (1999) find significant coefficients associated with changes in the CPI. Veredas (2006) and Hess (2004) find that the impact of CPI announcements on bond futures contracts is significant. Examining earlier time periods, Urich and Wachtel (1984), and Dwyer and Hafer (1989) find CPI coefficients are not significant. Smirlock (1986) finds the CPI coefficients not significant prior to October 1979 but significant thereafter.

3.2. The Consumer Price Index and expected and unexpected inflation

This paper uses unexpected changes in the CPI as a proxy for changes in expectations regarding future inflation. When an unexpected change occurs in the CPI, the financial press often reports that analysts revise their predictions of future inflation to account for the unexpected change. Analysts typically interpret a large unexpected increase in the CPI as indicating higher expected inflation at least in the near future. When announced unexpected changes in the CPI are coincident with changes in bond prices, stock prices, or commodity prices, then analysts often attribute those price changes to a change in expected inflation arising from the CPI announcement.

The CPI figures are typically released two or three weeks into each month. The index is calculated from the results of a Bureau of Labor Statistic's price survey conducted the previous month. Thus, the CPI is a lagging indicator that reports price levels that were measured as much as fifty days earlier.

How is it that a clearly lagging indicator can be so widely viewed as a leading indicator? One explanation is that inflation is viewed not as a pure random walk, but as a chronic malady that, over time, tends to spiral either up or down. Given time, price increases in one industry will cascade over into other industries. Since it takes time for the price increases to diffuse throughout the economy, both current and near future CPI measures will be affected. Also, inflation contains a feedback mechanism in which the price increases in industry X spill into other industries, which affects the prices in industry X at a later time. Therefore, while a change in the CPI surely indicates what has

Please cite this article in press as: Blose, L. E. Gold prices, cost of carry, and expected inflation. *Journal of Economics and Bussiness* (2009), doi:10.1016/j.jeconbus.2009.07.001

Table 2
Frequency for actual changes and unexpected changes in the Consumer Price Index (monthly changes during the period March 1988 through February 2008).

% change in CPI	Frequency (# of months)	Percent	Cumulative frequency	Cumulative percent
Panel A: Frequency table for the actual reported changes in CPI				
−0.6	1	.42	1	.42
−0.5	2	.84	3	1.26
−0.3	4	1.67	7	2.93
−0.2	3	1.26	10	4.18
−0.1	7	2.93	17	7.11
0.0	16	6.69	33	13.81
0.1	38	15.90	71	29.71
0.2	55	23.01	126	52.72
0.3	47	19.67	173	72.38
0.4	27	11.30	200	83.68
0.5	18	7.53	218	91.21
0.6	11	4.60	229	95.82
0.7	5	2.09	234	97.91
0.8	3	1.26	237	99.16
1.1	1	.42	238	99.58
1.2	1	.42	239	100.00
Panel B: Frequency table for unexpected changes in CPI				
−0.5	1	.42	1	.42
−0.4	2	.84	3	1.26
−0.3	4	1.67	7	2.93
−0.2	18	7.53	25	10.46
−0.1	70	29.29	95	39.75
0.0	74	30.96	169	70.71
0.1	52	21.76	221	92.47
0.2	12	5.02	233	97.49
0.3	5	2.09	238	99.58
0.5	1	.42	239	100.00

Notes: 1. UCPI = ACPI − ECPI, where UCPI is the unexpected change in the Consumer Price Index, ACPI is the (actual) reported change in the Consumer Price Index (CPI-U), and ECPI is the expected change in the Consumer Price Index.

happened in the recent past, it is also reasonable to argue that the change has implications for the near future.

3.3. Data and methodology

The Consumer Price Index (Series CPI-U, seasonally adjusted) is one of the most widely reported and frequently used inflation measures. Each month prior to the CPI announcement, the Wall Street Journal published a consensus estimate obtained from a survey of 12–16 economists whose work includes forecasting the Consumer Price Index. The survey was conducted on the Friday prior to the CPI announcement and published in the "economic trends" column the following Monday. The *Wall Street Journal* began publishing the column in March 1988. For this reason March 1988 was the start date for this study.[5] The unexpected changes in the CPI is calculated by subtracting the expected change from the actual change. The monthly CPI announcements cover the twenty-year period from March 1988 through February 2008.

Table 2, panel A shows the frequency of actual reported changes in the CPI over the examination period.[6] The reported changes in the CPI range from a decline of −.6 to an increase of 1.2. Panel B

[5] In March, 2006 the *Wall Street Journal* stopped publishing the column. After this date a similar estimate published in Barron's was used.

[6] This study covers the period from March 1988 through February 2008, a period of 240 months. However, the number of months in the study is only 239. A US government shutdown because of budget problems combined with a paralyzing winter storm in the Washington, DC area during the second week in January 1996 caused a delay in the reporting of the CPI for December 1995. Accordingly, the *Wall Street Journal* did not estimate the expected CPI for that month.

Please cite this article in press as: Blose, L. E. Gold prices, cost of carry, and expected inflation. *Journal of Economics and Bussiness* (2009), doi:10.1016/j.jeconbus.2009.07.001

shows the frequency of unexpected changes in the CPI. The unexpected changes in the CPI range from an unexpected decline of −.5 through an unexpected increase of .5.

The root mean square error of the consensus estimate is .1304. The distribution of the unexpected change in the CPI has a mean of −.0146 which has a *t*-statistic of −1.746 which is not significant at the 5% level (two sided test). The skewness of the unexpected change in the CPI is .0183. The standard deviation of the skewness is .15844. Hence the skewness is less than one standard deviation above zero.[7] Accordingly neither the mean nor the skewness of the unexpected change is significantly different from zero.

4. The impact of unexpected changes in the CPI on bond yields

Models 1, 2, and 3 examine the impact of actual reported and unexpected changes in the CPI on bond yields[8]:

$$\Delta BY = \alpha + \beta_1 ACPI + \beta_2 ACPI^2 + e \quad (1)$$

$$\Delta BY = \alpha + \beta_1 UCPI + \beta_2 UCPI^2 + e \quad (2)$$

$$\Delta BY = \alpha + \beta_1 UCPI + \gamma_1 ECPI + \beta_2 UCPI^2 + \gamma_2 ECPI^2 + e \quad (3)$$

where ΔBY is the change in the bond yield on the day of the CPI announcement (the change from the day before), ACPI is the actual announced change in the Consumer Price Index, UCPI is the unexpected change in the CPI, and ECPI is the expected change in the CPI. UCPI is obtained by subtracting ECPI from ACPI. Model 3 disaggregates the actual reported CPI change into two parts—the expected and the unexpected.[9]

Small deviations from the expected CPI may be much less of a surprise than large deviations. This means that large unexpected changes in the CPI may have a proportionally greater impact on the bond yield than small changes. Accordingly, it is reasonable to anticipate that the relationship between UCPI and ΔBY is not strictly linear. The impact of the surprise becomes proportionally greater the larger the surprise. The squared terms in the regressions allow for a nonlinear relationship between the explanatory variables and the bond yield.

The change in the CPI is announced once for each month. The unexpected change in the CPI is revealed on the day of the announcement. How the bond yield reacts to the announced change in CPI depends upon what was expected prior to the announcement. If the announced change in the CPI was expected, then there will not be any surprise, and bond yields should not change when the announcement is made. If the announced CPI is greater than the expected CPI, then inflation was greater than previously thought. This indicates that near future inflation is also likely to be greater than previously thought. The Fisher hypothesis predicts that the bond yields should increase to adjust for the higher expected inflation. If the announced change in the CPI is lower than the expected change, then inflation was less than previously thought and the near future inflation is likely to be less than previously thought. In this case the Fisher equation would indicate that the bond yields should decline.

Since any market reaction to the announced CPI change depends upon what was expected prior to the announcement, the bond yield ΔBY should be related to the unexpected change

[7] The formula for the estimate of the standard deviation of the skewness is from Tabachnick and Fidell (1989), p. 72.

[8] The interest rates for one-, two-, and three-year treasury bonds and notes were drawn from the Federal Reserve H.15 statistical release. The yields are based on composite quotes reported by US Government securities dealers to the Federal Reserve Bank of New York. To obtain the constant maturity yields, personnel at Treasury construct a yield curve each business day, and yield values are then read from the curve at fixed maturities.

[9] This procedure matches the monthly change in the CPI as the independent variable to the daily change in the bond yield as the dependent variable. This is not a mismatch of time periods. Although the CPI is announced only once a month, the unexpected change in the CPI does not reveal itself over the entire month but it is revealed entirely and completely on the day of the CPI announcement. Accordingly the impact of the announcement on both gold and bonds will be apparent on the day of the announcement only. This is a daily event study examining the impact of the CPI announcement on bond yields and gold returns on the day of the announcement.

Please cite this article in press as: Blose, L. E. Gold prices, cost of carry, and expected inflation. *Journal of Economics and Bussiness* (2009), doi:10.1016/j.jeconbus.2009.07.001

Table 3
How reported changes in the Consumer Price Index affect bond yields.

This table presents results from the following regressions using data for the twenty-year period March 1988 through February 2008:

$$\text{Panel A: } \Delta BY = \alpha + \beta_1 ACPI + \beta_2 ACPI^2 + e$$
$$\text{Panel B: } \Delta BY = \alpha + \beta_1 UCPI + \beta_2 UCPI^2 + e$$
$$\text{Panel C: } \Delta BY = \alpha + \beta_1 UCPI + \gamma_1 ECPI + \beta_2 UCPI^2 + \gamma_2 ECPI^2 + e$$

where $\Delta BY = BY_t - BY_{t-1}$ is the change in the bond yield on the announcement date t from the previous day $t-1$. The results for treasury bonds with one-, two-, and three-year maturities are reported. ACPI is the actual change in the CPI, ECPI is the expected change in the CPI, and UCPI = ACPI − ECPI is the unexpected change in the CPI.

Panel A: $\Delta BY = \alpha + \beta_1 ACPI + \beta_2 ACPI^2 + e$

Treasury maturity	1 year	2 years	3 years
Number of observations	239	239	239
Adjusted *R*-squared	.001	.000	.000
F value	1.11	.64	0.74
Intercept	−.01475 (−2.50)*	−.00885 (−1.34)	−.00765 (−1.13)
ACPI coefficient β_1	.01067 (0.43)	−.00764 (−0.27)	−.01258 (−0.44)
$ACPI^2$ coefficient β_2	.02364 (0.67)	.03816 (0.95)	.04448 (1.10)

Panel B: $\Delta BY = \alpha + \beta_1 UCPI + \beta_2 UCPI^2 + e$

Treasury maturity	1 year	2 years	3 years
Number of observations	239	239	239
Adjusted *R*-squared	.043	.039	.045
F value	6.30**	5.83**	6.59**
Intercept	−.01280 (−2.85)**	−.01110 (−2.16)*	−.01106 (−2.15)*
UCPI coefficient β_1	.09150 (2.97)**	.09004 (2.56)*	.09177 (2.60)**
$UCPI^2$ coefficient β_2	.28355 (2.26)*	.36238 (2.53)*	.40354 (2.80)**

Panel C: $\Delta BY = \alpha + \beta_1 UCPI + \gamma_1 ECPI + \beta_2 UCPI^2 + \gamma_2 ECPI^2 + e$

Treasury maturity	1 year	2 years	3 years
Number of observations	239	239	239
Adjusted *R*-squared	.036	.038	.046
F value	3.21*	3.36*	3.85**
Intercept	−.00843 (−0.95)	.00048 (0.05)	.00187 (0.19)
UCPI coefficient β_1	.09500 (3.02)**	.09846 (2.75)**	.10109 (2.81)**
ECPI coefficient γ_1	−.02012 (−0.46)	−.06053 (−1.20)	−.06839 (−1.36)
$UCPI^2$ coefficient β_2	.27486 (2.16)*	.33719 (2.33)*	.37517 (2.58)*
$ECPI^2$ coefficient γ_2	.01138 (0.19)	.04949 (0.71)	.05734 (0.82)

Note: Parentheses contain *t*-statistics.
* Significance at the .05 level (two sided).
** Significance at the .01 level (two sided).

and not the actual change in the CPI. The results of regressions 1, 2, and 3 are presented in Table 3. In panel A the coefficients of the independent variable ACPI is not significantly different from zero for any of the maturity levels. The adjusted R^2 for all of the regressions are negligible.

Table 3 shows that announced changes in the CPI do not affect bond yields. As explained above we would anticipate that the impact of the CPI announcements will depend upon what is expected as well as what is announced. The CPI announcement could have a positive effect, a negative effect or no effect on bond yields depending upon what is expected.

Table 3, panel B presents the results of regressing the bond yield against UCPI, the unexpected portion of the announced change in the CPI. Observe that for all three maturity levels, the coefficients of UCP are significant. Panel B shows that the coefficient of $UCPI^2$ is also positive and significant. This indicates a nonlinear relationship between the variables. The impact of the unexpected change in the CPI is proportionally greater for larger changes in the CPI.

Notice that the *t*-statistics for the coefficients of UCPI are lower for the two- and three-year maturity bonds than for the one-year maturity bond. An unexpected change in the CPI is likely to have implications for the current period and the near future. It is less likely that the effect will be long lived.

Please cite this article in press as: Blose, L. E. Gold prices, cost of carry, and expected inflation. *Journal of Economics and Bussiness* (2009), doi:10.1016/j.jeconbus.2009.07.001

A one-month unexpected change in the CPI has more implication for next month then it does for a month three years from now. Accordingly, the unexpected change will affect all three maturities but will affect the longer maturities least.

Table 3, panel C presents the results of disaggregating the ACPI into its two components the ECPI and the UCPI and regressing against both. In panel A, the coefficient of UCPI is significant for all three maturities. Panel C shows that both the UCPI and $UCPI^2$ coefficients are significant.

The results presented in this section indicate that that bond yields are affected by unexpected changes in the CPI. Higher than expected changes in the CPI are associated with higher bond yields and lower than expected changes in the CPI are associated with lower bond yields.

5. The impact of unexpected changes in the CPI on gold prices

The previous section showed that bond yields (and interest rates) are affected by unexpected changes in the CPI. Accordingly, the cost of carrying an investment in gold will change with changes in expected inflation. An increase in expected inflation will indicate a higher cost of carry.

To examine the impact of unexpected changes in the CPI on gold prices and returns, models 4, 5, and 6 were estimated both with and without the squared explanatory variables:

$$R_G = \alpha + \beta_1 \mathrm{ACPI} + \beta_2 \mathrm{ACPI}^2 + e \tag{4}$$

$$R_G = \alpha + \beta_1 \mathrm{UCPI} + \beta_2 \mathrm{UCPI}^2 + e \tag{5}$$

$$R_G = \alpha + \beta_1 \mathrm{UCPI} + \gamma_1 \mathrm{ECPI} + \beta_2 \mathrm{UCPI}^2 + \gamma_2 \mathrm{ECPI}^2 \tag{6}$$

where R_G is the percentage change in gold price from the previous day, ACPI is the announced change in the CPI, UCPI is the unexpected change in the Consumer Price Index, and ECPI is the expected change in the CPI.

The London PM fixing gold price is used in the study. The London PM fixing is quoted as of approximately 3:00 London time which is 10:00 New York time.[10] The CPI announcement is made at 7:30 New York time. Thus the gold market has 2 ½ h to adjust to the information contained in the CPI announcement.

The two competing hypotheses regarding the impact of inflationary expectations on gold prices are as follows:

Hypothesis	Explanation	Acceptance criteria
1. Carrying cost hypothesis	Carrying costs offset any benefits to speculation. Unexpected changes in CPI will not affect the price of gold on the day of the announcement.	In models 5 and 6, if the coefficient of UCPI is not significantly different from 0 then we cannot reject the carrying cost hypothesis.
2. Expected inflation effect hypothesis	Speculative (and/or hedging) purchases arising from unexpected changes in the CPI will cause gold prices to change on the day of the announcement.	In model 5 and 6, if the coefficient of UCPI is positive and significantly different from 0 then we can reject the carrying cost hypothesis in favor of the expected inflation effect hypothesis.

If the coefficients of UCPI in models 5 and 6 are positive and significant, then the carrying cost hypothesis is rejected. Otherwise, the expected inflation effect hypothesis is rejected.

Table 4 shows the results of the regressions. In every case, the coefficient of UCPI is insignificantly different from zero; also, the *F*-statistic indicates insignificance, and the adjusted *R*-squared statistic is negligible. Based upon the results presented in Table 4, we cannot reject the carrying cost hypothesis.[11]

[10] The London PM fixing is the gold price established as of 3:00 London Time. For most of the year there is a 5-h time difference between London and New York. Thus, 3:00 London time is 10:00 New York time. Because the time systems of the UK and the US switch to daylight savings time on different dates, for a few weeks in the spring the time difference is 4 h and the London Fixing price is quoted at 11:00 New York time.

[11] The study used consensus, expectations from the *Wall Street Journal* and Barron's. In addition, expectations were also generated by fitting an ARIMA(1,1,1) process to the announced CPI time series and then forecasting each month's change in the CPI.

Please cite this article in press as: Blose, L. E. Gold prices, cost of carry, and expected inflation. *Journal of Economics and Bussiness* (2009), doi:10.1016/j.jeconbus.2009.07.001

Table 4
How expected and unexpected changes in the Consumer Price Index affects gold prices.

This table presents results from the following regressions using data for the twenty-year period March 1988 through February 2008:

$$\text{Panel A: } R_G = \alpha + \beta_1 \text{ACPI} + \beta_2 \text{ACPI}^2 + e$$
$$\text{Panel B: } R_G = \alpha + \beta_1 \text{UCPI} + \beta_2 \text{UCPI}^2 + e$$
$$\text{Panel C: } R_G = \alpha + \beta_1 \text{UCPI} + \gamma_1 \text{ECPI} + \beta_2 \text{UCPI}^2 + \gamma_2 \text{ECPI}^2$$

R_G is the % change in the price of gold, ACPI is the actual change in the CPI, ECPI is the expected change in the CPI, and UCPI = ACPI − ECPI is the unexpected change in the CPI. In each panel two regressions are reported. Reg 1 omits the squared explanatory variable and Reg 2 includes the squared explanatory variable.

	Reg1	Reg 2
Panel A: $R_G = \alpha + \beta_1 \text{ACPI} + \beta_2 \text{ACPI}^2 + e$		
Number of observations	239	239
Adjusted *R*-squared	.000	.000
F value	.44	.23
Intercept α	0.00058 (0.73)	.00058 (0.72)
ACPI coefficient β_1	−0.00155 (−0.67)	−.00128 (−0.38)
ACPI^2 coefficient β_2	N/A	−.00053 (−0.11)
Panel B: $R_G = \alpha + \beta_1 \text{UCPI} + \beta_2 \text{UCPI}^2 + e$		
Number of observations	239	239
Adjusted *R*-squared[2]	.000	.000
F value	.73	.37
Intercept α	.00025 (0.45)	.00029 (0.46)
UCPI coefficient β_1	.00363 (0.86)	.00357 (0.83)
UCPI^2 coefficient β_2	N/A	−.00229 (−0.13)
Panel C: $R_G = \alpha + \beta_1 \text{UCPI} + \gamma_1 \text{ECPI} + \beta_2 \text{UCPI}^2 + \gamma_2 \text{ECPI}^2 + e$		
Number of observations	239	239
Adjusted *R*-squared[2]	.008	.003
F value	1.92	1.16
Intercept α	.00177 (1.73)	.00235 (1.93)
UCPI coefficient β_1	.00514 (1.19)	.00514 (1.18)
ECPI coefficient γ_1	−0.00568 (−1.76)	−.01021 (−1.68)
UCPI^2 coefficient β_2	N/A	−.00661 (−0.38)
ECPI^2 coefficient γ_2	N/A	.00729 (0.87)

The results presented indicate that gold prices do not change as a result of unexpected changes in the Consumer Price Index. The results are consistent with a conclusion that gold prices do not react to changes in expected inflation.

6. Additional issues

6.1. Comments on methodology

The empirical evidence presented above indicates that unexpected changes in the CPI affect bond yields, but they do not affect gold prices. The conclusion that gold prices do not change as a result of changes in expected inflation would be incorrect if the results presented in Table 4 came about as the result of a type II error (failure to reject a false hypothesis). A type II error could occur if the statistical tests were too weak to reject the null hypothesis, or if the expected change in the CPI as reported in the *Wall Street Journal* is biased or measured with too much noise.

Using the forecasted CPI as a proxy for the expected CPI, the unexpected change in the CPI was calculated and then used as the explanatory variable in Eq. (6). The *F*-statistic for the regression was 2.4 which is not significant at the 5% level. The coefficient of the unexpected change in CPI was negative (the wrong sign for the expected inflation effect hypothesis) and insignificantly different from zero at the 5% level. Accordingly, this method also indicates that gold is not affected by unexpected changes in the CPI.

Please cite this article in press as: Blose, L. E. Gold prices, cost of carry, and expected inflation. *Journal of Economics and Bussiness* (2009), doi:10.1016/j.jeconbus.2009.07.001

If weak test methodology or noisy data are the cause of the failure to reject the null hypothesis in the gold return test (Table 4), they should also affect the bond yield test (Table 3). Both sets of tests were performed using the same independent variables and identical methodology. The rejection of the null hypothesis in the bond yield tests shows that type II error was not an issue in those tests. Thus, the results in the bond yield tests present an important validation of the methodology and independent variables used in the gold price tests.

Since the change in the bond yield (ΔBY) is correlated with the unexpected changes in the CPI (UCPI). Leaving bond yields or ΔBY out of Eq. (6) may create an omitted variable problem. Accordingly, Eq. (6) was also estimated after including as additional explanatory variables both bond yields and ΔBY for each maturity bond. None of the coefficients of the explanatory variables were significant nor were any of the *F*-statistics of the regression.

6.2. Producer Price Index

In conjunction with this study, a set of similar tests were performed using unexpected changes in the Producer Price Index (PPI). Neither bond yields nor the returns on gold were significantly related to the unexpected changes in the PPI.[12]

6.3. Gold futures markets

Christie-David et al. (2000) examine the impact of unexpected changes in the CPI on gold futures contract over the four-year period 1992 through 1995. They use a consensus forecast by MMS for their estimate of expected changes in the CPI. They find that there is a significant reaction to changes in the gold futures markets associated with unexpected changes in the CPI. Why does Christie-David et al. find that the futures market is affected by ΔUCPI while this paper finds no reaction in the gold spot market?

This paper argues that unexpected changes in inflation expectations will not affect current gold prices but they will affect the risk free rate and the cost of carrying gold. Since gold (a zero beta asset) will appreciate at the risk free rate over time, the future value of gold will be greater after inflation expectations are revised upward. Accordingly, the price of futures contracts on gold will be revised upward as well. Additionally, margin requirements in the gold futures markets permit futures contracts to be purchased with substantially less cash at the time of the transaction then would be required to purchase the underlying gold. In other words, the cost of carrying gold is substantially greater than the cost of carrying gold futures contracts. Thus, unexpected changes in inflation expectations will have an impact on gold futures markets. The Christie-David, Chaudhry, and Koch finding is consistent with the carrying cost hypothesis and the findings in this paper.

6.4. Implications for investment strategy

What should you do if you have superior information regarding inflation? Suppose that the market expects inflation to be I_M but that you think inflation will be I where $I > I_M$. If you buy gold and then market expectations change, the results in this paper suggest that the price of gold will not change at the time that the market expectations change. The price of gold will change over time at the new inflation adjusted risk free rate; however the cost of borrowing will also increase to incorporate the new rate of inflation. Accordingly, the higher cost of borrowing will offset any long term speculative profit.

How can you profit from the superior information regarding inflation? If you borrow prior to the change in expectations and reinvest the funds after the change in expectations you will be borrowing at

[12] The failure to find a significant correlation between unexpected changes in the PPI and bond yields could arise from several causes: the PPI is substantially more volatile than the CPI and may be harder to predict. This would cause the unexpected producer price index to be measured with substantial noise increasing the likelihood of a type II error. Also, the PPI may be considered less of a signal regarding the future inflation. In other words, the current CPI carries a signal regarding the future CPI while the current PPI indicates less information about the future CPI.

Please cite this article in press as: Blose, L. E. Gold prices, cost of carry, and expected inflation. *Journal of Economics and Bussiness* (2009), doi:10.1016/j.jeconbus.2009.07.001

a lower rate than your investment and you profit accordingly. A mathematically equivalent procedure for capturing the value of the superior information is to short sell Treasury debt and then purchase it back after the market adjusts. Interest rates will increase and Treasury debt will decline accordingly when the new inflation rate is incorporated into the financial markets.

If you have superior information regarding inflation, you can use that information to make a speculative profit in the debt markets and in the gold futures markets but not in the gold spot market.

7. Overview and concluding remarks

This paper examines how unexpected changes in the CPI affect gold prices. Two different hypotheses purport to explain the relationship between expected inflation and gold prices. The expected inflation effect hypothesis argues that changes in expected inflation will cause immediate changes in gold prices. The carrying cost hypothesis argues that higher expected inflation will cause higher interest rates (the Fisher effect). The higher interest rates will, in turn, cause a higher cost of carry for gold investment, which will offset any speculative profit from investing in gold over the inflationary period. Accordingly, the cost of carry hypothesis predicts that the price of gold will not change when expected inflation changes. This study used unexpected changes in the CPI as a measure of changes in expected inflation. The tests show that unexpected changes in the CPI did not affect the price of gold on the day of the announcement.

This study also shows a significant relationship between changes in bond yields and unexpected changes in the CPI. These results indicate that the cost of carrying gold changes along with changes in expected inflation (i.e. unexpected changes in the CPI).

The findings presented in this paper are consistent with the following conclusions:

- Gold prices do not change as a result of changes in expectations regarding future inflation. Articles in the financial press that tie changes in gold prices to changes in expectations regarding future inflation are mistaken.
- Even if an investor has perfect foresight and knows that future inflation will be substantially different than market expectations, that investor could not set up a speculation strategy in the gold market that would profit from that information. Investors should use the bond markets not the gold spot market, to speculate in changes in inflation expectations.
- Investors cannot determine market inflation expectations by examining the spot price of gold.

References

Adrangi, B., Chatrath, A., & Raffiee. (2003). Economic activity, inflation, and hedging: The case of gold and silver investments. *The Journal of Wealth Management*, *6*, 60–77.
Aggarwal, R., & Soenen, L. A. (1988). The nature and efficiency of the gold market. *Journal of Portfolio Management*, *14*, 18–21.
Angell, W. D. (1992). Commodity prices and monetary policy: What have we learned? *CATO Journal*, *12*, 185.
Balduzzi, P., Elton, E. J., & Green, T. C. (2001). Economic news and bond prices: Evidence from the U.S. treasury market. *Journal of Financial & Quantitative Analysis*, *36*, 523–543.
Baur, D. G., & Lucey, B. M. (2006). Is gold a hedge or a safe haven? an analysis of stocks, bonds and gold, *The Institute for International Integration Studies Discussion Paper Series iiisdp198*.
Blose, L. E. (1996). Gold price risk and the returns on gold mutual funds. *Journal of Economics and Business*, *48*, 499–513.
Blose, L. E., & Shieh, J. C. P. (1995). The impact of gold price on the value of gold mining stock. *Review of Financial Economics*, *4*, 125–139.
Carter, K. J., Affleck-Graves, J. F., & Money, A. H. (1982). Are gold shares better than gold for diversification? *Journal of Portfolio Management*, *9*, 52–55.
Cecchetti, S. G., Chu, R. S., & Steindel, C. (2000). The unrealiability of inflation indicators. *Current Issues in Economics & Finance*, *6*, 1–6.
Christie-David, R., Chaudhry, M., & Koch, T. W. (2000). Do macroeconomics news releases affect gold and silver prices? *Journal of Economics and Business*, *52*, 405–421.
Cui, C. (2009). Gold retains its allure. *Wall Street Journal—Eastern Edition*, *253*(75), C9.
Dwyer, G. P., & Hafer, R. W. (1989). Interest rates and economic announcements. *Federal Reserve Bank of St. Louis Review*, *71*, 34–46.
Fisher, I. (1896). Appreciation and interest. *Publications of the American Economic Association*, *11*, 1–98.
Fleming, M. J., & Remolona, E. M. (1999a). Price formation and liquidity in the U.S. treasury market: The response to public information. *Journal of Finance*, *54*, 1901–1915.
Fleming, M. J., & Remolona, E. M. (1999b). What moves bond prices? *Journal of Portfolio Management*, *25*, 28–38.

Please cite this article in press as: Blose, L. E. Gold prices, cost of carry, and expected inflation. *Journal of Economics and Bussiness* (2009), doi:10.1016/j.jeconbus.2009.07.001

Garner, C. A. (1995). How useful are leading indicators of inflation? *Economic Review (01612387)*, *80*, 5–18.
Ghosh, D., Levin, E. J., Macmillan, P., & Wright, R. E. (2004). Gold as an inflation hedge? *Studies in Economics and Finance (Charlotte, NC)*, *22*, 1–25.
Green, T. C. (2004). Economic news and the impact of trading on bond prices. *Journal of Finance*, *59*, 1201–1233.
Haubrich, J. G. (1998). Gold prices. *Economic Commentary*, 1–4.
Hess, D. (2004). Determinants of the relative price impact of unanticipated information in U.S. macroeconomic releases. *Journal of Futures Markets*, *24*, 609–629.
Jaffe, J. F. (1989). Gold and gold stocks as investments for institutional portfolios. *Financial Analysts Journal*, *45*, 53.
Khoury, S. J. (1984). *Speculative markets*. New York: Macmillan.
Larsen, A. B., & McQueen, G. R. (1995). REITs, real estate, and inflation: Lessons from the gold market. *Journal of Real Estate Finance & Economics*, *10*, 285–297.
Lawrence, C. (2003). Why is gold different from other assets? An empirical investigation. In *Research manuscript*. London, UK: World Gold Council.
Lehman, R. (2009). Prepare for inflation. *Forbes*, *183*(7), 106.
Mahdavi, S., & Zhou, S. (1997). Gold and commodity prices as leading indicators of inflation: Tests of long-run relationship. *Journal of Economics & Business*, *49*, 475–489.
McCown, J. R., & Zimmerman, J. R. (2006). Is gold a zero-beta asset? analysis of the investment potential of precious metals, *Social Science Research Network Working Paper no. 920396*.
Moore, G. H. (1990). Gold prices and a leading index of inflation. *Challenge*, *33*, 52–56.
Sherman, E. J. (1982). Gold: A conservative, prudent diversifier. *Journal of Portfolio Management*, *8*, 21–27.
Sherman, E. J. (1983). A gold pricing model. *Journal of Portfolio Management*, *9*, 68–70.
Smirlock, M. (1986). Inflation announcements and financial market reaction: Evidence from the long-term bond market. *Review of Economics & Statistics*, *68*, 329–333.
Tabachnick, B. G., & Fidell, L. S. (1989). *Using multivariate statistics*. New York: HarperCollins.
Tkacz, G. (2007). Gold prices and inflation, *Bank of Canada Working Paper 2007-35*.
Tschoegl, A. E. (1980). Efficiency in the gold market—a note. *Journal of Banking & Finance*, *4*, 371–379.
Tully, E., & Lucey, B. M. (2007). A power GARCH examination of the gold market. *Research in International Business and Finance*, *21*, 316–325.
Urich, T., & Wachtel, P. (1984). The effects of inflation and money supply announcements on interest rates. *Journal of Finance*, *39*, 1177–1188.
Veredas, D. (2006). Macroeconomic surprises and short-term behavior in bond futures. *Empirical Economics*, *30*, 843–866.
Wherry, R. (2009). Gold has a wild ride: What's next? *Wall Street Journal—Eastern Edition*, *253*(15), B10.
Worthington, A. C., & Pahlavani, M. (2007). Gold investment as an inflationary hedge: Cointegration evidence with allowance for endogenous structural breaks. *Applied Financial Economics Letters*, *3*, 259–262.

Please cite this article in press as: Blose, L. E. Gold prices, cost of carry, and expected inflation. *Journal of Economics and Bussiness* (2009), doi:10.1016/j.jeconbus.2009.07.001