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# Gold prices and equity market crises: how accurate are the forecasts from a nonlinear model?

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**Abstract.** This paper examines the role of gold as a hedge during financial crises using daily data for the period 1976-2015. Although it is known that gold prices tend to increase during equity market crashes and that price volatility is symmetric or, at most, exhibits positive asymmetry; relatively little is known about the nonlinear nature of this behaviour. In fact, it seems that the magnitude of cross-correlations and the degree of shock's persistency not only varies over time but also changes from the pre-crisis and the post-crisis period. This behaviour suggests that structural changes play an important role in this process of adjustment and hedging. Therefore, we use a combined STAR-IGARCH (Smooth Transition AutoRegressive – Integrated GARCH) type model to obtain forecasts of gold prices and their underlying volatility according to the nature of each crisis event. These results are compared with those obtained from the traditional IGARCH volatility specifications and the encompassing forecast accuracy is tested. The analysis is carried out over the entire sample period and over subsamples obtained from the succession of main crisis that occurred between 1976 and 2015. Our findings show that the STAR-IGARCH forecasts outperform the traditional IGARCH volatility forecasts in most cases and that the consideration of fractional persistency improves the quality of our forecasts. The role of gold prices as a hedge, even under the presence of structural changes, is thus confirmed by our results.

## 1. Introduction

Gold has always been viewed as a refuge in periods of market turbulence and high volatility given its unique characteristics of a store of wealth, medium of exchange and unit of value (Goodman, 1956; Solt and Swanson, 1981). Its versatility is such that it has multiple applications ranging from portfolio diversification (Ciner, 2001) to jewellery, dental or even industrial components (Tully and Lucey, 2007). Although some studies have recognized the importance of gold as a "zero beta asset", the first authors who formally investigated if gold is a hedge or safe haven were Baur and Lucey (2010). Using daily data from 1979 to 2009 they found that gold is a hedge against stocks on average and a safe heaven in extreme market conditions. Following Baur and McDermott (2010), a strong (weak) hedge is defined as an asset that is negatively correlated (uncorrelated) with another asset on average, whereas a strong (weak) safe haven is described as an asset that is negatively correlated (uncorrelated) with stock markets in periods of extreme market conditions.

The severity of the recent financial crisis, which started in the US with the collapse of the Lehman Brothers bank and rapidly spread out to Europe, with major consequences in most of the eurozone countries, has prompted the discussion on how effective gold can be as a tool to protect investors against adverse market conditions.

In this paper we extend the existing literature on the properties of gold prices by using a combined STAR-IGARCH type model to obtain forecasts of gold prices and their underlying volatility according to the nature of each crisis event. To this purpose we employ daily data ranging from 1976 to 2015. We found that the STAR-IGARCH forecasts outperform the traditional IGARCH volatility forecasts in most cases and that the consideration of fractional persistency improves the quality of our forecasts.

## 2. Framework and preliminary results

The empirical analysis presented in this study is based on gold (Bullion LBM U$/Troy Ounce) and stock market (S&P 500 Composite) daily prices covering the period from August 2$^{nd}$, 1976 to June 5$^{th}$, 2015. A total of 10135 observations were collected from Datastream for each series. Gold and stock prices were then converted into daily returns by taking the first difference of the logarithm of the underlying prices. Gold returns (or price changes) is the key endogenous variable of this study. Stock market returns (or price changes) is used as the pre-determined variable in the mean equation of the GARCH-type model and as the transition or regime-switching variable in the STAR specification. Figure 1 shows the evolution of gold and stock market prices over the period.

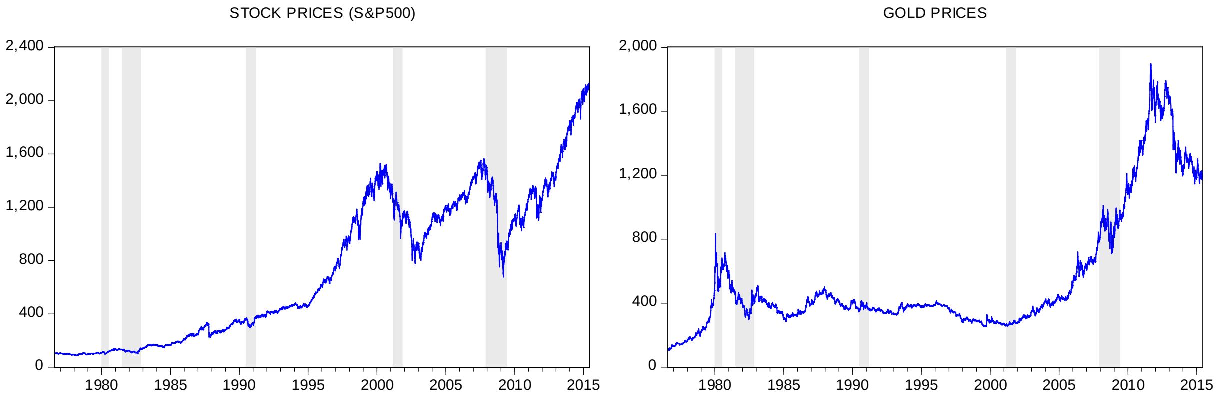


**Figure 1.** Stock market and gold prices; August, 2$^{nd}$ 1976 to June, 5$^{th}$ 2015

The shaded areas in the graphics represent the US recessions over the period. The "biggest" recessions occurred in the early 1980s and in 2008-2010. During the latter, one can clearly see the large fall of stock market prices (S&P 500). As expected, during the same period the stock market volatility increased dramatically, as shown in Figure 2.

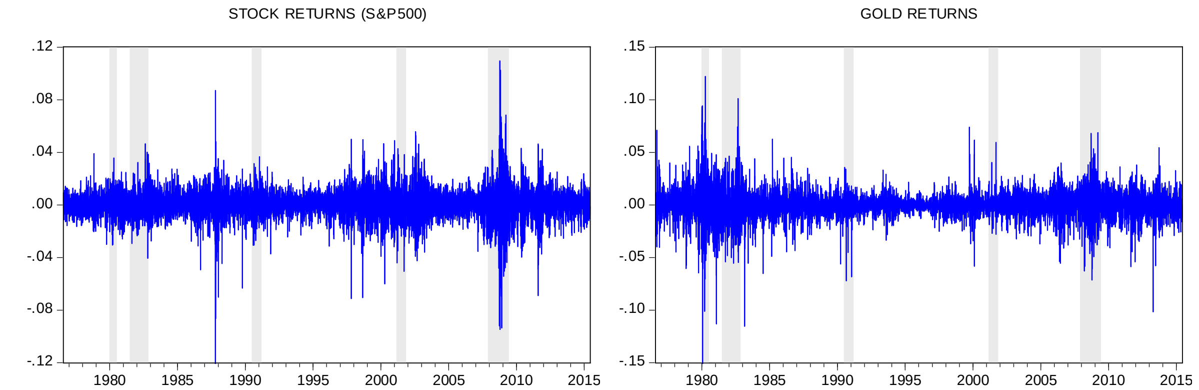


**Figure 2.** Stock market and gold returns; August, 2$^{nd}$ 1976 to June, 5$^{th}$ 2015

During the last crisis (2008-2010), gold prices initially decreased but started to rise again before the end of the crisis. This behavior is similar to the one of the early 1980s crisis, suggesting that gold prices respond with a delay to the events that occur in the stock market. Note also that gold prices reached a maximum around 2012 and started to decrease since then, while stock market prices continued to rise. However, unlike the case of stock markets, the gold price volatility increases during periods of bull market.

The above mentioned results suggest that gold price returns react to changes in stock market returns according to the level of the volatility in the latter. That is, there is a structure in the relation between stock returns and gold price returns that switches with the level of instability in the stock market. This switching regime pattern may be ruled by a sudden transition or a smooth transition process. In our case, we shall test whether a smooth transition autoregressive (STAR) process explains the relation between stock and gold price returns. The results are presented in Table 1 and Table 2.

The STAR tests presented in Table 1 assess whether gold returns are ruled by a linear transition function ($H_0$) against a nonlinear one ($H_1$). The nonlinear transition function in $H_1$ is usually defined as a logistic (LSTAR) or an exponential (ESTAR). The transition variable used here is the stock market returns (S&P 500) or the deviation from a linear path. In the latter case, the alternative hypothesis also includes the possibility of bilinearity. A LM test is conducted and the results indicate the rejection of the null hypothesis in almost all the cases. The most likely transition functions are the logistic with a cubic expansion or an exponential with two unknown residual lags.

**Table 1.**
STAR tests: Gold returns

| | LM-statistic | *p*-value | LM-statistic | *p*-value |
|---|---|---|---|---|
| **Transition variable: S&P returns. $H_0$: Linearity** | $H_1$: LSTAR | | $H_1$: ESTAR | |
| Unknown transition variable: expansion order 3 | 17.185 | 0.001 | | |
| Unknown transition variable | 0.305 | 0.581 | 17.185 | 0.000 |
| Unknown transition variable: cubic expansion | 17.185 | 0.000 | 17.185 | 0.000 |
| Transition variable | 0.305 | 0.581 | | |
| Transition variable: cubic expansion | 19.786 | 0.000 | | |
| **Transition variable: Deviation from a linear path. H0: Linearity** | $H_1$: LSTAR-D or bilinearity | | $H_1$: ESTAR-D or bilinearity | |
| Unknown residual lag: 2 | 13.357 | 0.001 | 7.737 | 0.021 |
| Specific residual lag: 2 | 13.238 | 0.000 | 3.013 | 0.083 |

**Table 2.**
STAR tests: S&P returns and 2 residual lags

| **Transition variable tests** | $H_0$: The transition variable is not significant (STAR or STAR-D) | | | | |
|---|---|---|---|---|---|
| Transition variable (STAR) | *F*-statistic | *p*-value | Resid lag (STAR-D) | *F*-statistic | *p*-value |
| S&P returns | 6.605 | 0.000 | 1 | 2.243 | 0.081 |
| | | | 2 | 4.728 | 0.003 |

| **Structure tests** | Choice: LSTAR or ESTAR at 5% of significance | | |
|---|---|---|---|
| Transition variable (STAR) | Structure | Residual lag (STAR-D) | Structure |
| S&P returns | ESTAR | 1 | ESTAR |
| | | 2 | ESTAR |

Table 2 presents the results on the transition function tests in order to make a choice between the logistic (LSTAR) and the exponential (ESTAR). The exponential transition function with two residual lags performs better than the logistic one in our case and is then the best choice.

Using the ESTAR(2) specification where the S&P 500 returns is used as the transition variable, we obtain the corresponding residuals to compare with the gold price returns in a conditional volatility model. The first model uses the gold price returns in a IGARCH(1,1,1) specification where the mean equation includes the S&P 500 returns as a regressor. The second model uses the ESTAR(2) residuals in a IGARCH(1,1,1) specification without any additional regressor in the mean equation (note that the S&P 500 returns were already used to obtain the ESTAR(2) residuals). The IGARCH specification is used because the null that $\alpha + \beta = 1$ is not rejected in a Wald test (in the variance equation). Therefore, shocks in the conditional volatility tend to persist infinitely.

The IGARCH results obtained by the two models are fairly similar but it is important to evaluate the forecasting accuracy of both specifications. The results are presented in Table 3. Despite their similarity, the forecasting tests presented in this table indicate that the STAR-IGARCH model provides slightly better forecasts than the traditional IGARCH counterpart. This marginal difference requires further improvement.

**Table 3.**
IGARCH and STAR-IGARCH forecasting tests

| | IGARCH | STAR-IGARCH |
|---|---|---|
| Root Mean Squared Error | 0.009835 | 0.009825 |
| Mean Absolute Error | 0.006518 | 0.006512 |
| Theil Inequality Coefficient | 0.990179 | 0.987136 |
| Akaike info criterion | -6.806388 | -6.809272 |
| Schwarz criterion | -6.803674 | -6.806558 |
| Hannan-Quinn criterion | -6.805457 | -6.808341 |
| Log likelihood | 26132.72 | 26143.80 |
| Durbin-Watson statistic | 2.019437 | 2.018433 |

The results presented in this short-paper provide evidence that the ESTAR performs better than the traditional LS mean equation in a conditional volatility model. The paper will be further enhanced with other tests in order to understand the true advantages of using a nonlinear smooth transition framework.

## References


[1] D.G. Baur, B.M. Lucey (2010). Is gold a hedge or a safe heaven? An analysis of stocks, bonds and gold. *Financial Review* 45, 217-229.

[2] D.G. Baur, T.K. McDermott (2010). Is gold a safe heaven? International evidence. *Journal of Banking and Finance* 34, 1896-1898.

[3] C. Ciner (2001). On the long-run relationship between gold and silver: a note. *Global Finance Journal* 12, 299-303.

[4] B. Goodman (1956). The price of gold and international liquidity. *Journal of Finance* 11, 15-28.

[5] M. Solt, P. Swanson (1981). On the efficiency of markets for gold and silver. *Journal of Business* 54, 453-478.

[6] E. Tully, B.M. Lucey (2007). A power GARCH examination of the gold market. *Research in International Business and Finance* 21, 316-325.