Price volatility in the silver spot market: An empirical study using Garch applications

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ABSTRACT

This paper examines the price volatility in the silver spot (cash) market. A host of Generalized Autoregressive Conditional Heteroskedasticity (GARCH) models are used to analyze and gain a better understanding of the volatility of silver prices. We find the TGARCH (1,1) model indicates that both positive and negative shocks do not have a significant effect on volatility in the silver spot market, while both the GARCH (1,1) and EGARCH (1,1) models indicate that past silver spot price volatility is significant and that volatility is observed to not be constant over time. This study has implications for both practitioners and academic researchers interested in price volatility in the silver spot market.

Keywords: Spot Market, GARCH Models, Volatility, Silver, Risk Management

INTRODUCTION

The volatility of commodity prices has drawn considerable interest from academics, investors and economist in recent years. One such commodity that is of considerable interest to all parties is silver. Silver is a precious metal and the spot price not only reflects the current supply and demand condition but it also reflects investors' expectations of future inflation and other general business/economic conditions. What sets silver apart from other commodities is that silver has many uses and the demand for silver can change rapidly due to different reasons. Derived demand theory suggests that the changes in demand for particular products have implications for commodity prices which are used as inputs into the final product. For instance, silver can be transformed from its natural state and used in the technology and medical industries to produce items such as solar energy, water purification, and X-Ray devices. Moreover, silver is also used in the electronics, and automobile industries to produce components for computers and antifreeze materials. In addition; silver can also be used as an investment vehicle by investors who seek profits or to diversify their investment portfolio or hedge. Silver's multiple industrial and investment uses have the potential of making its price more volatile than other commodities. Silver's spot and futures contracts are traded 24 hours a day on various markets. The most important and active markets are the London (center for physical trade) and COMEX (paper contracts). Silver prices are influenced not only by industrial demand as other commodities but because it is also used for investment purpose, silver prices are affected by such major macro-economic factors such as inflation, economic growth prospects or even monetary policy. The leading producers of silver by country as of 2010 were Mexico, Peru, and China. Table 1 displays the top 20 silver producing countries.

The purpose of this paper is to analyze and gain a better understanding of the time varying dynamics of price volatility in the silver spot market. We use three models from the ARCH family: GARCH (1, 1), EGARCG (1, 1), and TGARCH (1, 1) to model volatility in the silver spot market. When referring to the (1, 1) in each model, the first (1) represents the first order autoregression GARCH term and the second (1) represents the first order moving average ARCH term. In other words, the models suggest that future conditional variance is based on the past variance.

The rest of this paper is organized as follows. First, a brief review of the literature is conducted. Second, the data collection procedure is discussed. Third, the empirical results are presented. This is followed by the conclusion.

REVIEW OF THE LITERATURE

Price volatility in commodity markets has been studied extensively in the academic literature. Most of the studies can be traced to the seminal works of Workings (1949) and the theory of storage. Since then many researchers have examined commodity price volatility from different perspectives. Some studies have examined price volatility from the view point of price efficiency. For example, Aggarwal and Sundararaghavan (1987) reported that the silver market was not efficient in the weak form. But, Solt and Swanson (1981) found that futures market for gold and silver were weak form efficient and that investors cannot earn abnormal profits. Moreover, Ciner (2001) examined the long run trend in prices of gold and silver futures contracts listed on the Tokyo Commodity Exchange. Using daily closing prices from 1992 to 1998 along with Johansen's (1991) cointegration analysis, the results indicated that the long run stable relationship between gold and silver future prices had disappeared. Furthermore, investors are urged to treat each market independently for price discovery. Adrangi et al. (2006) investigated price discovery on nearby future prices of various commodities. Using the daily nearby contract of prices from 1969 to 1999 obtained from the Chicago Board of Trade (CBT), the researchers find the existence of a strong bidirectional causality in future prices. Other studies have examined how the addition of commodities can lead to a well-diversified portfolio. Kat and Oomen (2007) examined the return properties of 142 daily commodity futures from January 1965 to February 2005 using a multivariate analysis framework. They found that commodity futures are roughly uncorrelated with stocks and bonds. However, commodity returns were positively correlated with unexpected inflation. Still, differing commodities within the sample offered hedges and the researchers concluded that a well-balanced commodity portfolio offered diversification. Erb and Harvey (2006) observed similar findings and concluded that a well-diversified portfolio of commodity futures, bonds and equities offered investors risk reduction. The premise behind these studies seeks to determine what role volatility plays in determining commodity prices and the role volatility plays in determining effective portfolio diversification strategies. This study will add to existing literature by understanding the price volatility associated with silver spot market.

DATA

This study used daily cash (spot) prices collected from the XAG index retrieved from Bloomberg for the periods January 2, 2008 to December 30, 2011. The daily spot prices for silver including 1043 observations and were measured in dollar and cents per troy ounce. All three GARCH models used in this study require that the data be stationary. In order to test for stationary, the augmented Dickey-Fuller test (1981) test is performed. The AIC criterion is used along with intercept as opposed to trend and intercept because trends are often not found in return series data. If the results indicate that the data are non-stationary, then the data will be transformed by taking the first difference of the daily spot price. The daily return series is calculated as R_t = ln(P_t/P_{t-1}) in all three GARCH models.

METHODOLOGY

The methodology used in this paper includes the Generalized Autoregressive Conditional Heteroskedasticity GARCH (1, 1) model developed by Bollerslev (1986), the EGARCH (1, 1) model developed by Nelson (1991) and the TGARCH (1, 1) model developed by Glosten, Jaganathan, and Runkle (1993). These models have been widely used in the previous studies regarding precious metal commodity prices. The GARCH models are popular for three reasons. First, the number of parameters can be easily estimated. Second, they support the statistical findings that explain the stylized fact of daily returns. Third, the volatility forecast specifications are accurate when compared with other models (Taylor, 2005). The GARCH models employed in this study contain no regressors in the mean and the variance equation is specified using the maximum likelihood approach.

Finally, in order to determine if the models are specified correctly, two tests are conducted. First, to test if the mean equation is specified correctly, a correlogram of standardized residuals is performed. Second, to test if the variance equation is specified correctly, a correlogram of the standard residuals squared is performed. These tests depict whether there are any unexplained ARCH effects in the standardized residuals.

EMPIRICAL RESULTS

To examine the time varying volatility in the silver spot markets, the GARCH (1, 1), EGARCH (1, 1) and TARCH (1, 1) models are analyzed. This section begins with a preliminary analysis of the data followed by an empirical analysis of each model. Robustness checks are then conducted to ensure that all GARCH models are correctly specified.

Descriptive Statistics

Figure 1 displays a summary of statistics for silver spot price returns from January 2008 to December 2011. The mean silver return is .000236. The standard deviation is .011291. The histogram displays that the sample return as negatively skewed at -1.083680. Also, the Jarque-Bera indicates that the silver price returns are not normally distributed. In terms of kurtosis, silver price returns have a high peak and thicker tails than a normal distribution.
The Augmented-Dickey test is a statistical procedure that examines for the presence of unit roots in time series data. Our findings indicate that the silver price series at levels as referenced in table 2 and 3 possesses a unit root. Figure 2 displays the 4 year time series of conditional variance estimates from 2008 to 2011. Noticeably during 2008 between quarters 3 and 4, the volatility is extreme and peaks near .0012 and then reverts to .0002 after quarter 4 in 2008. There are two other peaks as well. For instance, in 2011 period 2 and period 3, the conditional variance peaks at .0006 and .0007 respectively. Figure 3 indicates that the time series is indeed time varying and tends to exhibit mean reversion.

The GARCH Models

GARCH (Generalized Autoregressive Conditional Heteroskedasticity) models allow the researcher to forecast volatility when volatility changes over time. This concept is called heteroskedasticity. It is a common finding in financial time series data that financial time series data does not exhibit homoscedasticity and is therefore, changing over time. If the researcher assumes that data does not change over time and in fact it does then the results attained may violate the assumption of homoscedasticity and cause the model to be misspecified.

The GARCH (1, 1) is the most popular model used when modeling daily returns (Taylor, 2005). The parameters are estimated by maximizing the likelihood function. Table 4 displays the results of the GARCH (1, 1) model. The results indicate that both α and β, .096, and .876, are significant at the 99% level of confidence. These two parameters when combined equate to .972 and measure the persistence in spot (cash) silver prices and provide some determination as to how long silver price changes affect the future forecasts of silver price volatility. The higher the persistence parameter the longer silver price changes will affect the estimates of future volatility. The model also depicts that the around 88% of the information associated with silver price volatility is derived from the previous days forecast.

The EGARCH (1, 1) model examines the existence of asymmetry in the volatility of spot silver returns by analyzing the effect of positive and negative shocks on silver price volatility by assuming the conditional variance is exponential. Table 5 indicates the results from the model.

Since γ (.962305) is significant, this indicates that downward movement in silver spot price volatility is followed by higher volatility than an upward movement of the same magnitude. The TGARCH (1, 1) model also known as threshold ARCH determines whether downward prices are treated separately from upward prices (Seiler, 2004). Table 6 indicates that the impact of negative shocks on future silver price volatility is .036413 and is not significant. This indicates that both positive and negative shocks have the same effect on future silver price volatility.

Robustness Checks

Finally, in order to verify the models are specified correctly, we perform two tests to examine the mean equation, and the variance equation. The mean equation is specified correctly if the Q stats are not significant or above .05. Table 7 indicates that the probability value of the Q (12) statistic is not significant since the reported value is above .05. This indicates that the mean equation is specified correctly. The variance equation is specified correctly if the probability of the Q^2 (12) value is not significant and is above .05. The reported value is above .05 as indicated in table 8. Since the probability value is above .05 we can conclude that the variance equation is specified correctly.

CONCLUSIONS AND IMPLICATIONS

This paper examined and analyzed the time varying effects of price volatility using a family of GARCH (Generalized Autoregressive Conditional Heteroskedasticity) models. The results provide evidence that both good and bad news have no significant effect on silver price volatility. Both the GARCH (1,1) and EGARCH (1,1) models were significant in respect to silver price volatility. The results also have implications for the various agents that use silver. The volatility in the silver spot market could impact the futures market. Therefore, the various agents that use silver should observe the futures markets in order determine if hedging silver price volatility is an appropriate risk management tool.

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APPENDIX

Table 1: Top Silver Producers as of 2010

Country	Millions by ounces
Mexico	128.9
Peru	116.1
China	99.2
Austrailia	59.9
Chile	41.0
Boliva	41.0
United Sates	38.6
Poland	37.7
Russia	36.8
Argentia	20.6
Canada	18.0
Kazakhstan	17.6
Turkey	12.3
Morocco	9.7
India	9.7
Sweden	9.2
Indonesia	6.9
Guatemala	6.3
Iran	3.4
South Africa	2.8

Source: Silver Institute

GARCH (1,1) Table 4

Dependent Variable: SILVER

Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	0.000628	0.000327	1.918717	0.0550
AR(1)	-0.933495	0.063187	-14.77361	0.0000
MA(1)	0.998173	0.071487	13.96299	0.0000
MA(2)	0.063594	0.032581	1.951844	0.0510
	Variance Equation			
C	3.78E-06	1.15E-06	3.279799	0.0010
RESID(-1)^2	0.096037	0.013119	7.320447	0.0000
GARCH(-1)	0.876062	0.018422	47.55456	0.0000

R-squared	0.001231	Mean dependent var	0.000263
Adjusted R-squared	-0.001653	S.D. dependent var	0.011297
S.E. of regression	0.011306	Akaike info criterion	-6.298858
Sum squared resid	0.132809	Schwarz criterion	-6.265637
Log likelihood	3291.854	Hannan-Quinn criter.	-6.286257
Durbin-Watson stat	2.080195		

Inverted AR Roots	-.93	
Inverted MA Roots	-.07	-.93

EGARCH: Table 5

Dependent Variable: SILVER

Variable	Coefficient	Std. Error	z-Statistic	Prob.
AR(1)	-0.929494	0.068670	-13.53568	0.0000
MA(1)	0.987368	0.075891	13.01030	0.0000
MA(2)	0.057717	0.032209	1.791972	0.0731
	Variance Equation			
C(4)	-0.502994	0.089324	-5.631147	0.0000
C(5)	0.211433	0.026415	8.004230	0.0000
C(6)	-0.044094	0.016873	-2.613254	0.0090
C(7)	0.962305	0.008884	108.3147	0.0000

R-squared	0.002330	Mean dependent var	0.000263
Adjusted R-squared	0.000411	S.D. dependent var	0.011297
S.E. of regression	0.011294	Akaike info criterion	-6.297633
Sum squared resid	0.132663	Schwarz criterion	-6.264413
Log likelihood	3291.216	Hannan-Quinn criter.	-6.285033
Durbin-Watson stat	2.067348		

Inverted AR Roots	-.93	
Inverted MA Roots	-.06	-.92

TGARCH (1, 1) Table 6

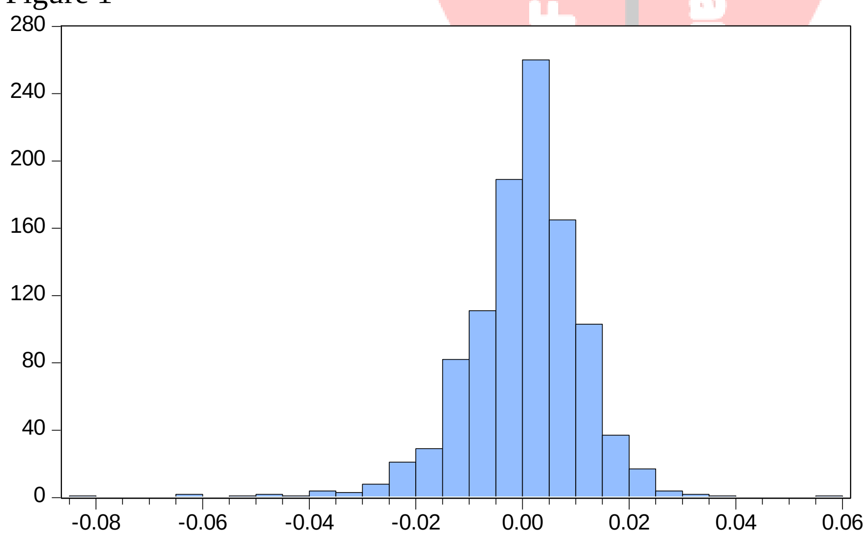
Dependent Variable: SILVER

Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	0.000545	0.000340	1.601980	0.1092
AR(1)	-0.933391	0.063841	-14.62062	0.0000
MA(1)	0.998976	0.072402	13.79762	0.0000
MA(2)	0.064557	0.033432	1.930990	0.0535
	Variance Equation			
C	4.76E-06	1.30E-06	3.653337	0.0003
RESID(-1)^2	0.078676	0.022309	3.526675	0.0004
RESID(-1)^2*(RESID(-1)<0)	0.036413	0.024254	1.501331	0.1333
GARCH(-1)	0.863936	0.021021	41.09962	0.0000

R-squared	0.001563	Mean dependent var	0.000263
Adjusted R-squared	-0.001320	S.D. dependent var	0.011297
S.E. of regression	0.011304	Akaike info criterion	-6.298031
Sum squared resid	0.132765	Schwarz criterion	-6.260065
Log likelihood	3292.423	Hannan-Quinn criter.	-6.283630
Durbin-Watson stat	2.082701		

Inverted AR Roots	-.93	
Inverted MA Roots	-.07	-.93

Figure 1



Series: SILVER
Sample 1/01/2008 12/30/2011
Observations 1044

Mean	0.000263
Median	0.001309
Maximum	0.057241
Minimum	-0.080295
Std. Dev.	0.011291
Skewness	-1.083680
Kurtosis	8.842516
Jarque-Bera	1689.211
Probability	0.000000

Figure 2

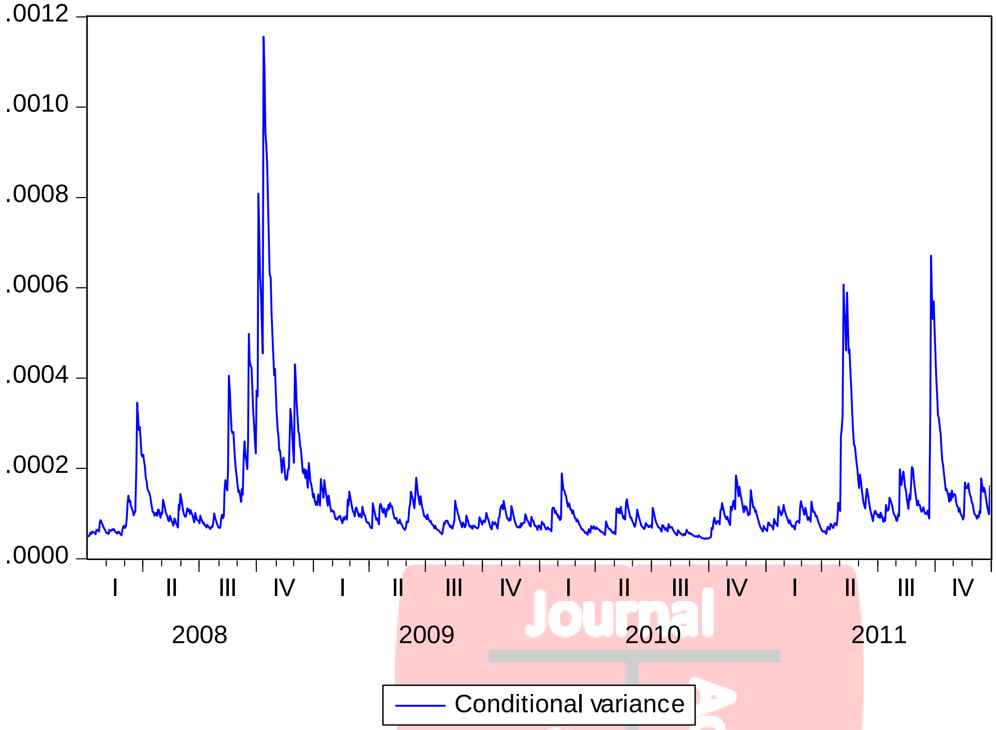


Figure 3

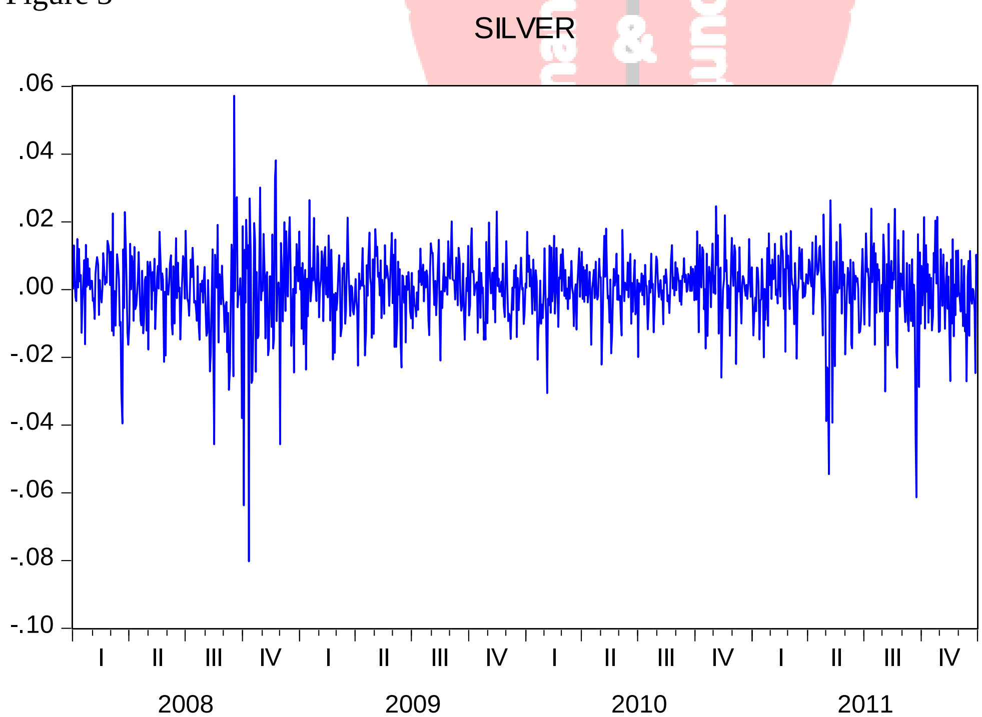


Table 7

	AC	PAC	Q-Stat	Prob
1	0.010	0.010	0.1063	
2	0.010	0.010	0.2179	
3	-0.001	-0.002	0.2199	
4	-0.016	-0.016	0.4720	0.492
5	0.005	0.005	0.4979	0.780
6	-0.018	-0.018	0.8427	0.839
7	0.016	0.016	1.1165	0.892
8	0.024	0.024	1.7338	0.885
9	0.018	0.018	2.0905	0.911
10	0.025	0.024	2.7517	0.907
11	-0.013	-0.014	2.9430	0.938
12	-0.028	-0.028	3.7910	0.925
13	0.008	0.009	3.8538	0.954
14	-0.012	-0.010	3.9972	0.970
15	-0.029	-0.030	4.8919	0.961
16	-0.040	-0.040	6.5838	0.922
17	0.034	0.034	7.8399	0.897
18	0.027	0.025	8.5952	0.898
19	-0.027	-0.028	9.3601	0.898
20	0.054	0.054	12.501	0.769
21	-0.049	-0.048	15.042	0.659
22	0.009	0.010	15.130	0.714
23	0.002	0.005	15.132	0.769
24	-0.012	-0.008	15.275	0.809
25	-0.028	-0.031	16.138	0.809
26	0.006	0.008	16.173	0.848
27	0.036	0.029	17.534	0.825
28	0.007	0.004	17.585	0.860
29	0.032	0.036	18.710	0.848
30	-0.013	-0.017	18.904	0.873
31	-0.001	-0.002	18.905	0.901
32	-0.010	-0.006	19.016	0.921
33	0.026	0.030	19.753	0.923
34	0.054	0.055	22.896	0.853
35	0.029	0.027	23.826	0.851
36	-0.003	-0.007	23.837	0.879

Table 8

	AC	PAC	Q-Stat	Prob
1	0.059	0.059	3.6713	
2	-0.034	-0.038	4.9119	
3	0.027	0.031	5.6516	
4	-0.001	-0.006	5.6520	0.017
5	0.005	0.007	5.6757	0.059
6	0.032	0.030	6.7447	0.080
7	-0.042	-0.046	8.6045	0.072
8	-0.010	-0.002	8.7016	0.122
9	-0.020	-0.024	9.1068	0.168
10	-0.005	0.000	9.1290	0.244
11	0.049	0.048	11.666	0.167
12	0.015	0.009	11.908	0.219
13	-0.034	-0.029	13.134	0.216
14	-0.038	-0.038	14.665	0.198
15	-0.024	-0.022	15.286	0.226
16	-0.020	-0.020	15.715	0.265
17	0.054	0.054	18.777	0.174
18	-0.017	-0.021	19.086	0.210
19	-0.013	-0.002	19.267	0.255
20	-0.036	-0.039	20.684	0.241
21	-0.049	-0.046	23.219	0.182
22	0.058	0.058	26.794	0.110
23	0.072	0.057	32.274	0.040
24	-0.027	-0.020	33.033	0.046
25	-0.006	0.000	33.076	0.061
26	-0.058	-0.061	36.735	0.035
27	-0.025	-0.018	37.390	0.040
28	-0.011	-0.028	37.520	0.051
29	-0.015	-0.013	37.775	0.064
30	-0.002	0.009	37.779	0.081
31	0.005	0.011	37.804	0.102
32	0.004	0.015	37.825	0.126
33	-0.049	-0.062	40.441	0.097
34	0.025	0.014	41.102	0.106
35	0.026	0.017	41.820	0.115
36	0.047	0.055	44.171	0.093

Null Hypothesis: SILVERL has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 1 (Automatic - based on AIC, maxlag=4)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		0.540644	0.9994
Test critical values:	1% level	-3.966879	
	5% level	-3.414131	
	10% level	-3.129170	

*MacKinnon (1996) one-sided p-values.
Augmented Dickey-Fuller Test Equation
Dependent Variable: D(SILVERL)
Method: Least Squares

Included observations: 1042 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
SILVERL(-1)	0.002567	0.004748	0.540644	0.5889
D(SILVERL(-1))	-0.114561	0.031193	-3.672664	0.0003
C	-0.018652	0.022486	-0.829468	0.4070
@TREND(1/01/2008)	1.51E-05	5.44E-06	2.771594	0.0057

R-squared	0.018809	Mean dependent var	0.001214
Adjusted R-squared	0.015973	S.D. dependent var	0.053007
S.E. of regression	0.052582	Akaike info criterion	-3.049040
Sum squared resid	2.869974	Schwarz criterion	-3.030042
Log likelihood	1592.550	Hannan-Quinn criter.	-3.041834
F-statistic	6.632718	Durbin-Watson stat	1.984763
Prob(F-statistic)	0.000194		

Unit Roots Differences: Table 3

Null Hypothesis: D(SILVERL) has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 3 (Automatic - based on AIC, maxlag=4)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-14.64294	0.0000
Test critical values:	1% level	-3.966905	
	5% level	-3.414144	
	10% level	-3.129177	

*MacKinnon (1996) one-sided p-values.
Augmented Dickey-Fuller Test Equation
Dependent Variable: D(SILVERL,2)
Method: Least Squares
Included observations: 1039 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(SILVERL(-1))	-0.977984	0.066789	-14.64294	0.0000
D(SILVERL(-1),2)	-0.140833	0.058171	-2.421001	0.0156
D(SILVERL(-2),2)	-0.107954	0.047095	-2.292270	0.0221
D(SILVERL(-3),2)	-0.057641	0.031364	-1.837798	0.0664
C	-0.005275	0.003278	-1.609041	0.1079
@TREND(1/01/2008)	1.27E-05	5.46E-06	2.330859	0.0200

R-squared	0.561120	Mean dependent var	7.22E-05
Adjusted R-squared	0.558996	S.D. dependent var	0.078615
S.E. of regression	0.052207	Akaike info criterion	-3.061453
Sum squared resid	2.815485	Schwarz criterion	-3.032891
Log likelihood	1596.425	Hannan-Quinn criter.	-3.050617
F-statistic	264.1437	Durbin-Watson stat	1.995482
Prob(F-statistic)	0.000000		