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LONG MEMORY IN DIAMOND MARKET RETURNS AND VOLATILITY

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Abstract: This paper provides a first attempt to test for long memory in the international diamond market returns and volatility. The results from Lo's modified R/S statistic suggest that diamond returns do not have long memory, while strong evidence is found for long memory in diamond volatilities. The results have important implications for the efficiency of the diamond market and predictability of the diamond return and volatility.

Key words: Long memory; Modified R/S statistic; Diamond market

1. Introduction

Prior studies on the long memory of commodity market focus on Gold. This paper provides a first attempt to study the time series property of diamond prices. The diamond market shares some similarities with the gold market. Both gold and diamond have been coveted for their uniqueness and rarity, beauty, and intrinsic physical properties, as well as storage of wealth. Industrial use accounts for a very small percentage of the total production, while jewelry accounts for a large portion in the demand in both markets. In 2007, jewelry accounts for around three quarters of the gold demand (US$54 billion) and 80 percent of the market value in the diamond market for the last decade.

Despite these similarities, the market structures of the gold and diamond are very different. First, from a historical point of view, gold was widely used as currency, and it has supported international exchange since prehistoric times, while diamond has a relatively short history and is mostly used as gemstones, religious icons, and adornments. Second, considering the determinants of prices, the price of gold is determined by the open market and fluctuates rapidly in response to economic conditions.[1]

In contrast, the international diamond market is a cartel controlled by a handful of firms.[2] The DeBeers Diamond cartel is one of the longest existing cartels with duration of over 100 years between its foundation and its first breakdown (Levenstein and Suslow, 2002; Kretschmer, 2003). Shevelyova (2006) suggests that the diamond market structure

[1] Abken (1980) suggests that extreme political and economic uncertainty, flow supply, and demand for gold, inflation, and government auction policy might be the underlying factors influencing the gold price. Rohan, Mukesh, and Timothy (2000) find that the gold price responds to the news release of capacity utilization, unemployment rate, GDP, and PPI.

[2] Ariovich (1985) examines the price fluctuations in the international diamond market. He finds that the industrial diamond prices are influenced by the level of economic activity in general and the volume of the manufacturing production in particular. The prices of jewelry diamonds are highly correlated with disposable income. Both industrial diamond and jewelry diamond prices are positively correlated with the inflation rate and negatively correlated with the real interest rate.

can be described as a row of vertically organized firms, each of which can be outlined in a context of a monopoly or oligopoly competition. Spar (2006) examines the continuity and change in the international diamond market. It is found that DeBeers and the world diamond cartel have dominant power on both the supply and demand sides of the diamond market.

The phenomenon of long-range dependence, also known as long memory, has a long history and has remained a topic of active research in financial economics because of its implications on the behavior of financial asset returns over long horizon. We employed Lo's (1991) modified rescaled range statistic to test for the presence of long memory characterized by a hyperbolically decaying autocovariance function. The modified R/S statistic has high power against certain long memory structures and it is robust to the presence of short-range dependence.

The market structure of diamond has long been studied. Yet very few studies have been carried out on the diamond price and its fluctuation. This paper provides a first attempt to examine the long memory in diamond returns and volatility. The results will shed some light on the efficiency of the diamond market as well as the predictability of the diamond market returns and volatility.

The remainder of the paper is organized as follows. Section 2 provides a background of the international diamond market. Section 3 describes the data used and presents the modified R/S statistic. Section 4 studies the long memory property of the international diamond market returns and volatility. A conclusion is drawn in Section 5.

2. International Diamond Market

Diamonds are specifically known as materials with superlative physical qualities. The world annual production of diamonds is roughly 130 million carats, with a total value of US$9 billion (Yarnell, 2004). Approximately 49 percent of diamonds are mined in Central and Southern Africa. However, production countries have shifted ranks over the past years. As illustrated in Table 1, South Africa and the Union of Soviet Socialist Republics were the top two producers of diamond back in 1985 and the two countries account for over 50% of the world production (Ariovich, 1985). The world rough diamond production in 2003 is shown in Table 2[3] and Australia, Canada, Democratic Republic of the Congo, and Russia are the new sources for the mineral. Especially Australia mines a large amount of low quality diamonds as shown by its 22% of world production accounting for a mere 4% of total world market values.

The diamond market is traditionally regarded as composed of three main market segments, namely, the industrial diamond market, the investment diamond market, and the gemstone market. The three markets operate much differently from one another. In the industrial diamond market, diamonds are mainly valued due to their hardness and heat conductivity. Roughly 80 percent of mined diamonds are not suitable as gemstones and can only be used for industrial purposes. In addition to mined diamonds, synthetic diamonds are also widely used industrially after their discovery in the 1950s, especially in the diamond grinding grit. The investment diamond market is composed of rare and high-value diamonds. These diamonds are of high investment value. For instance, in 2008, a 35.56 carat blue diamond named the Wittelsbach Diamond was sold at a price of US$24 million

[3] Source: Mining Review Africa, 2004, Issue 4

at a Christie's auction.

In the gemstone market, diamonds are mostly valued due to their gemological characteristics, such as clarity and color. Meanwhile, carat weight and cut are also the determinants of a diamond's quality and value. A lettering system from D to Z is used to identify the color of each diamond, with D representing a rare, totally colorless diamond. The clarity of a diamond is graded by The Gemological Institute of America (GIA). Diamonds are tagged as FL, IF, VS2, SI2, I2, and so on, with FL stands for flawless.

A handful of businesses control the supply chain of diamond. Most production organizations conform to an explicit set of rules and manage their production in line with demands and stockpile the excess diamonds. The dominant company in the industry is DeBeers, which was first formed by Cecil Rhodes in 1880. It soon controlled all claims in South Africa, where the modern diamond industry was first launched with the accidental discovery of diamonds. Until now, DeBeers is the world's leading diamond company with expertise in the exploration, mining, and marketing of diamonds. It produces and markets approximately 40 percent of the world's supply of rough diamonds from its mining operations across Botswana, Namibia, South Africa, and Canada. The total sale of DeBeers in 2008 is US$6.89 billion.[4]

Even though the diamond market can be characterized by producer prices instead of exchange traded prices. Testing long memory in this market reveals systematic pattern in the diamond market that facilitates the development of accurate forecasting model for the diamond prices in turn promoting adaptation of this precious mineral as an investment instrument.

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[4] Source: DeBeers Operation and Financial Review 2008.

3. Data and Methodology

3.1. Data

The data studied are the daily price of diamond, which are obtained from DataStream.[5] There are four kinds of diamond studied in this paper, namely the 0.3 Carat diamond with color grade of G and clarity grade of VS2 (0.3 C G VS2 hereafter), the 0.5 Carat diamond with color grade of G and clarity grade of VS2 (0.5 C G VS2 hereafter), the 1 Carat diamond with color grade of G and clarity grade of VS2 (1 C G VS2 hereafter), and the 3 Carat diamond with color grade of D Flawless (3 C D FL hereafter). Each sample has a total of 1705 observations from January 1, 2002 through July 14, 2008. We choose these four types of diamonds under the restriction of data availability and also for the sake of having wide market coverage.

Returns are defined as the first difference in the natural logarithm of diamond prices. In this paper, the absolute returns, squared returns, absolute deviation, and square mean deviation are used as the proxies of volatility in Lo's modified R/S statistic estimation. Figures 1 plots the returns and the square mean deviations of these four kinds of diamonds. Even though the statistical features in squared returns and square mean deviation, analogously absolute returns and absolute mean deviation, are comparable, we present results for all four metrics for the sake of their popularity as proxies for volatilities.

The summary statistics of the two typical series are reported in Table 3 for the low quality 0.3 Carat diamonds (0.3 C G VS2) and the large 3 Carat flawless diamonds (3 C D FL). The average daily returns are essentially zero for these two types of diamonds, but the flawless diamond has a large positive skewness coefficient of 6.0387 implying a relatively

[5] Source: Polished Prices

stronger upward trend for its prices. The small diamond has a relatively larger standard deviation of 0.0612 as compared to 0.0269 from the 3 Carat diamond. The price of the large diamonds is relatively more stable and it is true across all four volatility measures. The mean values of the absolute return and deviations show that the volatility of the 0.3 Carat diamonds is almost 6 times as large as the one from the 3 Carat diamonds. Similarly the average square return for the 0.3 Carat diamonds has a value of 0.0037 and increases fivefold for the large diamonds. Normality assumption is clearly rejected in all cases based on the Jarque-Bera Statistics. In summary, the large flawless diamonds have less volatile prices that tend to increase over time in a much faster pace.

3.2. Methodology

A stationary stochastic process X_t is defined as a long memory process if there exists a real number $\alpha \in (0,1)$ and a constant C>0 such that $\lim_{k \to \infty} \rho(k)/[Ck^{-\alpha}] = 1$, where $\rho(k)$ is the autocorrelation function. The Hurst exponent H, which represents the long-memory property of the time series, is defined as $H = 1 - \frac{\alpha}{2}$. Long memory occurs when $H \in \left(\frac{1}{2}, 1\right)$. Thus, a time series is said to exhibit long memory if there is a slow hyperbolic decay in autocorrelations. If H>1, the series is non-stationary. If $H \in \left(0, \frac{1}{2}\right)$, the series is anti-persistent.

In this paper, we use the modified rescaled range (R/S) statistic of Lo (1991) to test for long memory.[7] The modified R/S statistic is robust to short-term dependence and

[7] The classical R/S analysis is first introduced by Hurst (1951) and subsequently developed by Mandelbort (1972).

conditional heteroscedasticity. Consider a stationary time series X_t with a sample size N. The modified rescaled range statistic, denoted by $\hat{Q}$ as the cumulative sums of mean deviations reweighted by its consistently estimated standard deviation $\hat{s}(q)$, is

$$\hat{Q} = \frac{1}{\hat{s}(q)}\left[\max_{1\le t\le N}\sum_{k=1}^{t}\left(x_k - \bar{x}\right) - \min_{1\le t\le N}\sum_{k=1}^{t}\left(x_k - \bar{x}\right)\right], \tag{1}$$

where

$$\hat{s}^2(q) = s^2 + 2\sum_{k=1}^{q} w_k(q)\gamma_k \ ; \tag{2}$$

$$s = [\frac{1}{N}\sum_{t=1}^{N}(x_t - \bar{x})^2]^{1/2} ; \tag{3}$$

$$\bar{x} = \frac{1}{N}\sum_{t=1}^{N} x_t \ ; \tag{4}$$

$$w_k(q) = 1 - \frac{k}{q+1}, q < N \tag{5}$$

and γ_k is the sample autocovariance estimator:

$$\gamma_k = \frac{1}{N}\left[\sum_{i=k+1}^{N}\left(x_i - \bar{x}\right)\left(x_{i-k} - \bar{x}\right)\right] \tag{6}$$

which provides robustness of the statistic by allowing for short-term dependence in the time series. The null hypothesis of no long-range dependence (i.e. H = 0.5) can be tested using the asymptotic distribution as

$$P\left[\hat{Q} \le x\right] = 1 - 2\sum_{n=1}^{\infty}\left(4x^2n^2 - 1\right)e^{-2x^2n^2} \qquad (7)$$

against the composite alternative of long memory, i.e. $0.5 < H < 1$. If the truncation lag, denoted by q, is equal to zero, the modified R/S statistic is reduced to Hurst's R/S statistic. The truncation lag must be large enough to account for the short-range dependence in the data and the test results are highly sensitive to this truncation lag. Teverovsky (1999) shows that Lo's modified R/S statistic tends to under reject the null hypothesis of no long memory depending on the truncation lag. Lo (1991) suggests a data driven approach of selecting the truncation lag based on the first order autocorrelation as

$$q = \left[\left(\frac{3N}{2}\right)^{1/3}\left(\frac{2\hat{\rho}}{1-\hat{\rho}^2}\right)^{2/3}\right],$$

where $\hat{\rho}$ is the first-order autocorrelation. For robustness sake, we choose to report the modified R/S statistics for a wide range of values of the truncation lag up to a maximum of 100.

The modified R/S statistic has high power against certain long-range dependence alternatives and has been extensively used to detect the presence of long memory in various markets. For instance, Cheung (1993) provides an extensive description of long memory in foreign exchange rates with the Geweke-Porter-Hudak test and ARFIMA model. Cheung and Lai (1993) show the long memory behavior in gold returns is rather unstable. Crato and Pedro (1994) find evidence of long memory in the conditional variance of US stock returns. Breidt, Crato, and Pedro (1998) test for long memory in stock market volatility. Shibley and Param (2001) find evidence for long-term dependence in weekly stock returns in the stock markets of Korea, Malaysia, Singapore, and New Zealand.

Cajueiro and Tabak (2004) show that the stock markets of Hong Kong, Singapore, and China exhibit long-range dependence.

4. Empirical Results

Table 4 reports the estimations of Lo (1991) modified R/S statistic for the 0.3 C G VS2 diamond daily returns, squared returns, absolute returns, absolute deviation, and square mean deviation. A test of the null hypothesis of no long-range dependence, i.e., H=0.5 is performed using the 95 percent critical value of 1.862 of the modified R/S statistic. The result suggests that the null hypothesis for the daily returns of the smallest and relatively low quality diamonds (0.3 C G VS2) cannot be rejected. Meanwhile, the evidence for long memory characteristics in volatilities is relatively strong. The null hypothesis is rejected in most cases except for q=100 in the absolute returns, squared returns, and absolute deviation, and for q=50 and 100 in square mean deviation. It is consistent with Teverovsky's (1999) finding that the R/S statistic has the tendency of not rejecting the null hypothesis of no long-range dependence with large truncation lag.

The estimations of Lo's modified R/S statistic for a slightly larger 0.5 Carat diamonds of the same color and clarity grading (0.5 C G VS2) are reported in Table 5. The results suggest that the null hypothesis of no long-range dependence for the daily returns cannot be rejected. Second, similar to the 0.3 Carat diamond market, significant long memory characteristics are found in the volatilities of these 0.5 Carat diamond returns.

Table 6 reports the estimates of Lo's modified R/S statistic for the 1 Carat diamonds (1 C G VS2). The null hypothesis of no long-range dependence for returns cannot be rejected for q=100. Furthermore, the evidence for long memory characteristics in volatilities is relatively strong. The null hypothesis is rejected in most tests except for q=100 in the absolute returns and absolute deviation, and for q=25, 50 and 100 in the squared returns and square mean deviation.

For the same color and clarity grades of G and VS2, increasing the size of the diamonds from 0.3 to 1 Carat does not change the overall results supporting the short memory in the return series and the presence of long memory in the volatility. However, the modified R/S statistics for the absolute return and the absolute deviation increase in sizes, as we move from 0.3 Carat to 1 Carat diamond. For example, the modified R/S statistic for the absolute return of the 0.3 C G VS2 diamond has a value of 4.1502 for q=5 and the same statistic has a value of 5.6706 for the 1 C G VS2 diamonds. This same pattern can be found in all levels of the truncation lag for both the absolute return and absolute deviations and implies that the long-range dependence structure gets stronger as the size of the diamond increases.

The values of Lo's modified R/S statistic for the large 3 Carat flawless (3 C D FL) diamonds are reported in Table 7. However, unlike the cases of the other three classes of diamonds above (0.3 C G VS2, 0.5 C G VS2, and 1 C G VS2), the volatility in the flawless (3 C D FL) diamond returns provides mixed results. The null hypothesis is rejected in the case of absolute returns and absolute deviation, while the squared returns and square mean deviation series do not provide evidence for the presence of long memory. In Figure 2, the precious 3 Carat diamond price has the steepest increasing trend over the six year sample. Even though the return of these large diamonds exhibits less daily variations over time as compared to the other three smaller diamonds, it has the highest return and most of the upward movements are contributed by infrequent abrupt changes as shown in Figure 1.

The mixed results on the long memory property of the 3 Carat diamond volatility may be attributable to the fact that it is more vulnerable to economic conditions reflected as infrequent large jumps.

In summary, the results based on Lo's modified R/S statistic for the 0.3 C G VS2, 0.5 C G VS2, 1 C G VS2, and 3 C D FL diamond market prove that diamond daily returns do not have long memory. However, the results for the volatilities in the 0.3 C G VS2, 0.5 C G VS2, and 1 C G VS2 diamond markets provide strong evidence for the existence of long memory, while the results for the 3 C D FL diamond market are ambiguous. The differences between the diamond markets' behaviors can be partially explained by the pricing system for the different types of diamonds. On one hand, the 0.3 C G VS2, 0.5 C G VS2, and 1 C G VS2 diamonds might be under higher manipulation by the diamond cartel, where past volatilities in returns have a relatively high correlation with the futures volatilities. On the other hand, the 3 C D FL diamond has a much higher value than the other three types of diamonds, indicating that the price for the 3 C D FL diamond might be more vulnerable to economic and political changes such as income, economic crisis, and political instability.

Based on these results, we find that the volatility of diamond returns exhibits long range dependence implying a high level of predictability in price variations. In light of market efficiency, the evidence of predictable volatility helps support the development of a formal well-organized futures market promoting price stability and integrated price structure across the world. The existence of futures market also helps balance supply and demand in turn promotes complex and lengthy mining activities.

6. Conclusion

This paper examines the long memory property of diamond market returns and volatility. It is a pioneering study on the time series property of diamond price. The modified R/S statistic of Lo is used to test for long memory in diamond market returns and volatility. The price series of diamonds with carat weight of 0.3, color of G, clarity of VS2; carat weight of 0.5, color of G, clarity of VS2; carat weight of 1, color of G, clarity of VS2; and carat weight of 3, color of D, clarity of FL are studied. Generally, the results based on Lo's modified R/S statistic reveal that diamond daily returns do not have a long memory. However, strong evidence for the presence of long memory in diamond market volatilities is found. The existence of long memory in the diamond market suggests that the market might have experienced long periods of trending prices.

The efficient market hypothesis implies that asset returns are unpredictable; however, if the return series possesses long memories, past returns can be exploited to predict future returns. Furthermore, the presence of long memory in returns and volatilities indicates that the underlying distribution of the diamond prices might deviate from normality. Furthermore, in view of the result that the diamond market has long memory, further research on the predictability of the market is warranted. A more systematic exploration of the self-similarity property and the correlation between the international diamond cartel and diamond prices is also a good direction for future research.

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Table 1: The Production of World Rough Diamond, 1985

Rank	Country	Production (Thousand Carats)	Percentage (%)
1	South Africa	3429	34
2	USSR	2120	21
3	Namibia	1186	12
4	Angola	1050	10
5	Botswana	744	7
6	Sierra Leone	320	3
7	Zaire	260	3
	Others	988	10
	Total	10100	100

Note: The numbers are rounded to the nearest whole.

Table 2: The Production of World Rough Diamond, 2003

Rank	Country	Production (Thousand Carats)	Percentage (%)	Value (Millions of $)	Percentage (%)
1	Australia	31000	22	400	4
2	Botswana	30412	22	2300	26
3	DRC	25000	18	600	7
4	Russia	19000	13	1640	18
5	South Africa	12800	9	950	10
6	Canada	11200	8	1300	15
7	Angola	5500	4	900	10
	Others	5088	4	810	10
	Total	141000	100	8900	100

Note: The numbers are rounded to the nearest whole.

Table 3: Summary Statistics

	R_t		$\lvert R_t \rvert$		R_t^2		$\lvert R_t - \bar{R} \rvert$		$(R_t - \bar{R})^2$	
	0.3 G	3 D	0.3 G	3 D	0.3 G	3 D	0.3 G	3 D	0.3 G	3 D
Mean	0.000066	0.000582	0.020099	0.003014	0.003747	0.000725	0.020153	0.003581	0.003747	0.00073
Maximum	0.391118	0.496162	0.461555	0.496162	0.213033	0.246177	0.461620	0.495580	0.213093	0.24560
Minimum	-.046155	-0.33052	0.000000	0.000000	0.000000	0.000000	0.000065	0.000582	4.23E-09	3.4E-07
S.D.	0.061223	0.026932	0.057838	0.026769	0.015344	0.009523	0.057819	0.026693	0.015345	0.00951
Skewness	-0.40714	6.038749	3.531528	11.95392	6.638964	19.96482	3.532666	11.97204	6.640173	19.9365
Kurtosis	15.7597	172.95	16.6587	172.27	60.4709	456.16	16.6690	172.70	60.4984	454.89
Jarque-Bera	15514.27	2060933	16787.68	2074931	247023.9	1.50E7	16809.94	2085264	247252.7	1.46E7
P-value	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.00000	0.000000	0.000000	0.00000

Notes: R_t, $\lvert R_t \rvert$, R_t^2, $\lvert R_t - \bar{R} \rvert$, $(R_t - \bar{R})^2$ represent diamond daily returns, absolute returns, squared returns, absolute deviation and square mean deviation respectively. 0.3 represents 0.3 C G VS2 diamond. 3 represent 3 C D FL diamond. The Jarque-Bera test for normality distributed as Chi-square with 2 degrees of freedom. The critical value for the null hypothesis of normal distribution is 5.99 at 5% significance level. Each sample has a total of 1705 observations from January 1, 2002 through July 14, 2008.

Table 4: Lo's modified R/S statistic for 0.3 C G VS2 diamond daily prices

q	Modified R/S statistic R_t	$\lvert R_t \rvert$	R_t^2	$\lvert R_t - \overline{R} \rvert$	$(R_t - \overline{R})^2$
0	0.2947	4.5252*	3.3587*	4.5247*	3.3585*
2	0.3111	4.3337*	3.1952*	4.3332*	3.1951*
5	0.3615	4.1502*	2.9125*	3.9153*	2.9125*
10	0.4631	3.3792*	2.6065*	3.3789*	2.6065*
25	0.6516	2.5606*	2.0866*	2.5605*	2.0866*
50	0.8382	2.0482*	1.7897	2.0482*	1.7897
100	1.1467	1.5941	1.4939	1.5941	1.4939

Note: R_t, $\lvert R_t \rvert$, R_t^2, $\lvert R_t - \overline{R} \rvert$, $(R_t - \overline{R})^2$ represent diamond daily returns, absolute returns, squared returns, absolute deviation and square mean deviation respectively. * indicates significance at the 5% level. The critical value is 1.862.

Table 5: Lo's modified R/S statistic for 0.5 C G VS2 diamond daily prices

q	Modified R/S statistic				
	R_t	$\lvert R_t \rvert$	R_t^2	$\lvert R_t - \overline{R} \rvert$	$(R_t - \overline{R})^2$
0	0.3360	4.9851*	3.0039*	4.9827*	3.0039*
2	0.3685	4.7199*	2.9588*	4.7178*	2.9588*
5	0.4398	4.1545*	2.5842*	4.1528*	2.5842*
10	0.5852	3.4767*	2.2695*	3.4755*	2.2696*
25	0.8610	2.6637*	1.9714*	2.6632*	1.9714*
50	1.2319	2.1014*	1.7316	2.1012*	1.7316
100	1.6297	1.6278	1.4803	1.6279	1.4803

Note: R_t, $\lvert R_t \rvert$, R_t^2, $\lvert R_t - \overline{R} \rvert$, $(R_t - \overline{R})^2$ represent diamond daily returns, absolute returns, squared returns, absolute deviation and square mean deviation respectively. * indicates significance at the 5% level. The critical value is 1.862.

Table 6: Lo's modified R/S statistic for 1 C G VS2 diamond daily prices

q	Modified R/S statistic R_t	$\lvert R_t \rvert$	R_t^2	$\lvert R_t - \bar{R} \rvert$	$(R_t - \bar{R})^2$
0	0.4207	6.8014*	2.9555*	6.7972*	2.9555*
2	0.5322	5.6706*	2.4023*	5.6674*	2.4023*
5	0.6258	4.8542*	2.2637*	4.8521*	2.2636*
10	0.8165	3.9592*	2.1136*	3.9580*	2.1137*
25	1.1749	2.8141*	1.8512	2.8136*	1.8512
50	1.5911	2.1142*	1.6235	2.1140*	1.6235
100	2.2271	1.5829	1.3654	1.5828	1.3654

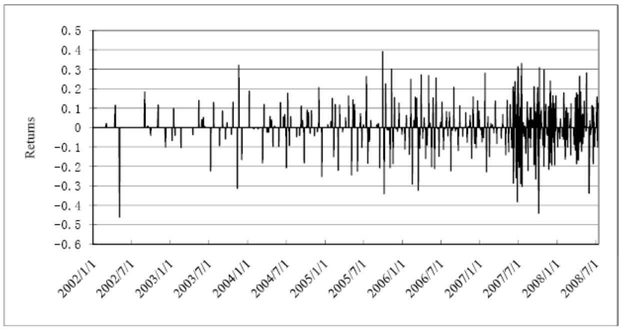
Note: R_t, $\lvert R_t \rvert$, R_t^2, $\lvert R_t - \bar{R} \rvert$, $(R_t - \bar{R})^2$ represent diamond daily returns, absolute returns, squared returns, absolute deviation and square mean deviation respectively. * indicates significance at the 5% level. The critical value is 1.862.

Table 7: Lo's modified R/S statistic for 3 C D FL diamond daily prices

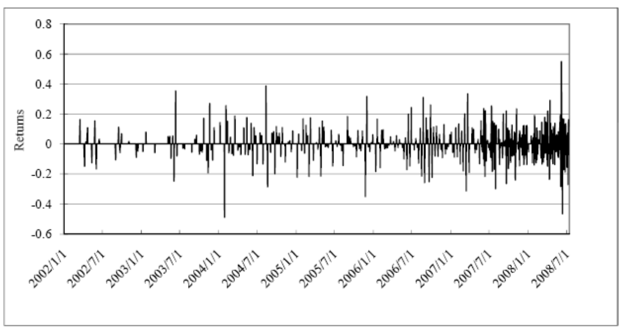
q	Modified R/S statistic R_t	$\lvert R_t \rvert$	R_t^2	$\lvert R_t - \overline{R} \rvert$	$(R_t - \overline{R})^2$
0	0.7329	2.2683*	1.6439	2.2653*	1.6451
2	0.7345	2.2936*	1.6534	2.2905*	1.6547
5	0.7432	2.2700*	1.6590	2.2672*	1.6603
10	0.7544	2.2054*	1.6621	2.2032*	1.6634
25	0.8102	1.9730*	1.5532	1.9715*	1.5541
50	0.9253	1.8250	1.5248	1.8239	1.5256
100	1.0345	1.5366	1.4397	1.5363	1.4403

Note: R_t, $\lvert R_t \rvert$, R_t^2, $\lvert R_t - \overline{R} \rvert$, $(R_t - \overline{R})^2$ represent diamond daily returns, absolute returns, squared returns, absolute deviation and square mean deviation respectively. * indicates significance at the 5% level. The critical value is 1.862.

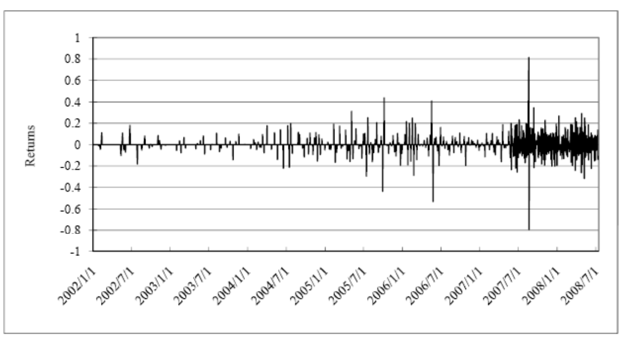
Figure 1: Diamond Returns and Square Mean Deviations.



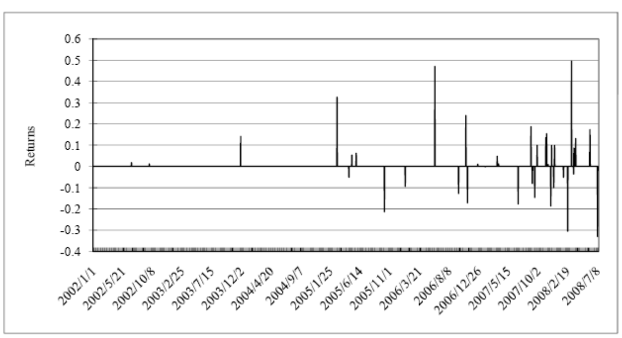
(a) 0.3 C G VS2 diamond Daily Returns



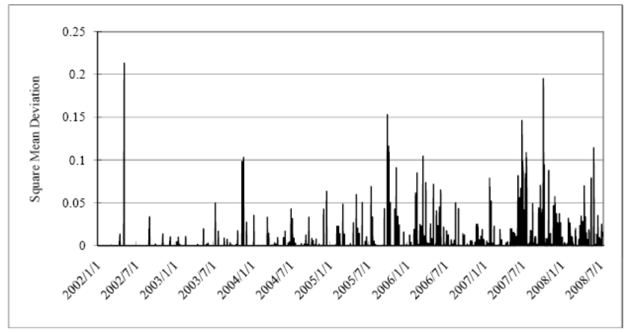
(b) 0.5 C G VS2 diamond Daily Returns



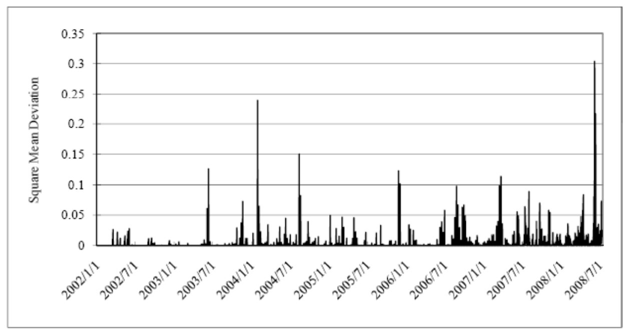
(c) 1 C G VS2 diamond Daily Returns



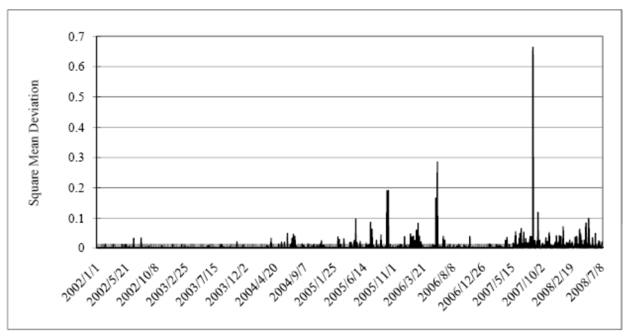
(d) 3 C D FL diamond Daily Returns



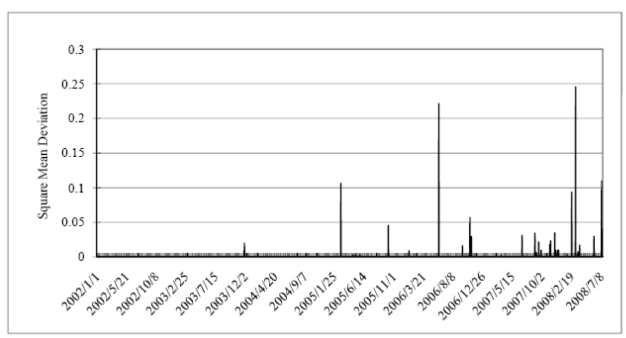
(e) 0.3 C G VS2 diamond Square Mean Deviation



(f) 0.5 C G VS2 diamond Square Mean Deviation



(g) 1 C G VS2 diamond Square Mean Deviation



(h) 3 C D FL diamond Square Mean Deviation

Figure 2: Time series plot of 0.3 C G VS2, 0.5 C G VS2, 1 C G VS2 and 3 C D FL diamond Prices.