Penny Trading on the NYSE and the Compass Rose

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Abstract

Although price discreteness was originally though to be a sufficient condition for the existence of the compass rose, recent research based on simulated data suggests that the tick/volatility ratio must also exceed some critical threshold value. The introduction of decimal price quotes by the NYSE provides an ideal opportunity to test the impact of a change in the tick/volatility ratio on the presence of the compass rose using actual market data. The empirical evidence presented in this paper suggests that tick/volatility ratios for stocks are much higher than those previously observed for the foreign exchange market. Further, the 85% reduction in the tick/volatility ratio resulting from the move to decimal prices was not sufficient to eliminate the compass rose pattern.

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Abstract

Although price discreteness was originally though to be a sufficient condition for the existence of the compass rose, recent research based on simulated data suggests that the tick/volatility ratio must also exceed some critical threshold value. The introduction of decimal price quotes by the NYSE provides an ideal opportunity to test the impact of a change in the tick/volatility ratio on the presence of the compass rose using actual market data. The empirical evidence presented in this paper suggests that tick/volatility ratios for stocks are much higher than those previously observed for the foreign exchange market. Further, the 85% reduction in the tick/volatility ratio resulting from the move to decimal prices was not sufficient to eliminate the compass rose pattern.

1 INTRODUCTION

The compass rose refers to an apparent pattern which exists when current and past returns are plotted insomuch as the data will appear on rays emanating from the origin with some apparent uniformity [see Crack and Ledoit (1996)]. Until recently, it was thought that the only necessary and sufficient condition for the pattern to exist was that prices should change in discrete jumps [see Szpiro (1998) and Kramer and Runde (1997)]. If this were true, than the compass rose should be pervasive across financial markets. It is interesting to note that Lee et al. (1999), does not find evidence of the compass rose in futures markets. Further, the fact that high frequency foreign exchange transactions data have been found to display this pattern whereas daily data do not, suggests that tick size may not be the sole determining factor [see Lee et al. (1999) and Szpiro (1998)].

Gleason, Lee and Mathur (2000) argue that in addition to discreteness, volatility also plays a part in determining whether or not the compass rose exists. The authors estimate Monte Carlo simulations using model parameters based on those frequently observed in foreign exchange data and find that the pattern is visible only when the tick/volatility ratio is above some threshold level. For return series which exhibit very small standard deviations this threshold may be as low as 1/50. Where the standard deviation is greater however, the threshold may be as high as 1/4. Thus, the appearance of this pattern in intra-daily foreign exchange data and not daily data, is argued to reflect the fact that the former typically satisfy this tick/volatility constraint, whereas daily data may not.

The results of Gleason et al. (2000), suggest that a change to the minimum price variation of a stock, or tick, may impact on the frequency at which the compass rose pattern appears in that company's return series. One such change recently took place for selected stocks traded on the New York Stock Exchange (NYSE). Decimalised stock price quotes, or 'penny trading' as it has come to be known, has begun to replace the existing system of quoting stock prices in fractions of 1/16 of a dollar.[1] Under the new system, the minimum price movement will be one cent in which case

there will be 100 ticks per dollar at which a stock can trade compared to the 16 ticks per dollar which existed previously. The NYSE has estimated that his change would result in a 130% increase in quotes, and 80% increase in trades and a 9% increase in share volume. In Phase I of this scheme, seven stocks representing six companies made the transition to decimalisation on August 28, 2000.[2] The first trade under this new system occurred at 9:30:09 am when 12,000 shares of Fedex were traded at a price of $41.05. In Phase II of the scheme, an additional 52 companies representing 57 issues made the change to decimalisation on September 25, 2000. The penny trading program of the NYSE is a part of a current trend toward decimal pricing on US exchanges. In addition to the NYSE, decimalisation is also being phased in on the Pacific and Philadephia stock exchanges.

The purpose of this paper is to consider the introduction of penny trading on the NYSE which provides an ideal opportunity to study the impact of a change in tick size on the existence of the compass rose. According to the results of Gleason et al. (2000), this fall in the minimum price variation should alter the tick/volatility ratio such that that the compass rose may no longer exist at some frequencies in which it was previously visible. More specifically, the reduction in the minimum price variation introduced by the decimalisation program should reduce the tick/volatility ratio for a given standard deviation such that the compass rose pattern is less likely to be present in the data.

Knowledge of the compass rose and it properties is important for empirical researchers as it may potentially bias estimation results especially where high frequency data is involved. Kramer and Runde (1997) for example, show how the presence of such a pattern may distort the null distribution for the BDS test of nonlinearity. One implication of this finding is that the evidence supporting the

[1] A similar event took place when the NYSE made the transition from a tick size of 1/8 to 1/16 in June, 1997.

[2] These stocks were Andarko Petroleum Corp. (APC), Fedex Corp (FDX), Forest City Enterprises Inc. Class A and Class B (FCE A, FCE B) Gateway Inc. (GTW), Hughes Supply Inc. (HUG) and MSC Software Corp. (MNS). According to the NYSE, these initial issues were based on several criteria which included choosing stocks that have varying levels of trading volume, at least one stock that is traded on multiple exchanges, at least one that is part of an index, at least one that is an underlying issue for multiply listed options, and at least one that has a possible corporate actions pending (NYSE Press Release, July 5, 2000).

existence of determinism in asset price data may have been little more than a byproduct of stock price discreteness.

The contribution of this paper to the existing literature is threefold. First, the paper aims to extend the theoretical simulation results of Gleason et al. (2000) to include some market based evidence. The decimalisation program of the NYSE provides an ideal opportunity study the impact of an actual change in tick size on the existence of the compass rose. To this end, high frequency returns data will be considered to establish the impact of decimalisation on both individual stock tick/volatility ratios as well as the presence of the compass rose. Second, the focus on stock data will allow interesting comparisons to be drawn between the tick/volatility ratios in this market compared to those previously estimated for foreign exchange markets. Third, the impact of penny trading on individual stock volatility is also considered.

2 Data

The data to be used in this study consists of tick price data for 12 stocks included in Phase II of the NYSE decimalisation program. This data was sourced from Bloomberg over the sample period 1 September to 17 October, 2000 which allows 15 days before and 17 days after the September 25 transition. These 12 stocks were chosen from among the 57 issues as they were the most frequently traded during the sample period which was an important consideration to allow sufficient data for observation. This trade data was converted into 5, 10, 15, 30 and 60 minute returns.

Summary statistics for the five minute returns are presented in Panel A of Table 1 for the pre and post-decimalisation sample period. The average mean return across all 12 stocks was –0.00247% and the highest 5 minute mean return was 0.01354% for Iomega Corp. (which also exhibited the highest standard deviation of 1.12914%) whereas the lowest individual stock mean return was –0.01876% for Goodyear. The average standard deviation across all 12 stocks was 0.407194% and the lowest standard deviation was 0.18414% for Cigna Corp. Most importantly, the tick/volatility ratio in this 1/16 tick trading period was 19.85 on average across all 12 stocks. The highest tick/volatility ratio observed was 33.94 for Cigna Corp. and the lowest tick/volatility ratio was 5.53 for Iomega.

In general, these tick/volatility ratios are much higher than those found in foreign exchange data. For example, the average tick/volatility ratio of 5 minute foreign exchange returns for the Euro, Swiss Franc, British Pound and Yen exchange rate (quoted against the US dollar) was 1/3.57 (0.27976) [Gleason et al. (2000, p130)]. One might be tempted to conclude that such a result was expected since the tick size in the foreign exchange market is 0.0001 which is considerably smaller than the 0.0625 tick size of stock prices. This is not necessarily the case however, as the standard deviation of foreign exchange returns are quoted in original units and as such expressed in terms relative to the tick size. Thus, while the tick size is considerably smaller compared to the stock market, the same tick/volatility ratio may be observed if the standard deviation of returns is smaller by proportion. As the average tick/volatility ratio for 5 minute stock returns is larger than that found in the equivalent foreign exchange returns, this suggests stocks exhibit less variation relative to the their tick compared to the price movements of foreign exchange markets. Thus, the tick size for stock prices is more of limiting factor for prices compared to exchange markets and zero price movement trades will be more common.

In the post-decimalisation subperiod, the average mean return was –0.00439% and the highest mean return over the 5 minute holding period was 0.01396% for Cigna Corp. while the lowest mean return was –0.01595% for America Online. The average standard deviation across all 12 stocks was 0.36087% while the highest standard deviation was 0.77574% for Compaq and the lowest standard deviation was 0.22391 for Cigna Corp.. As the focus of this paper is on these standard deviation estimates relative to the tick size, it is useful to more formally consider whether the variances are significantly different from one another. To this end the Brown-Forsythe (1974) test[3] was applied to the data and the results of this procedure are presented in the final column of Table 1. A p-value of less than 0.05 indicates that the variances of the pre and post-decimalisation period are significantly different which was found for all of the series except Lockheed Martin and Sears. Thus, the standard deviation of five

[3] A number of other variance equality tests were consulted including the Siegel-Tukey, Bartlett, Levene and F-test and the unreported results were generally consistent with those reported for the Brown-Forsythe test

minute returns is generally less in the 16 day period after the introduction of decimal ticks.[4]

Tick/volatility ratios in this post-decimalisation period are also reported in Panel A of Table 1. Ceteris paribus, a given tick size reduction would cause a fall in the tick/volatility ratio. The estimated results support this finding as the average tick/volatility ratio fell from 19.85 in the first subperiod to 2.96 in the second subperiod. The highest individual tick/volatility ratio in this post decimal period was 4.46 for CI and the lowest was 1.79 for Compaq. Thus, the fall in tick from 0.0625 to 0.01 combined with the generally lower standard deviations in the second subperiod combined to produce approximately 85% lower tick/volatility ratios for these 12 NYSE traded stocks.

2.1 The Impact of Decimalisation on the Compass Rose

The compass rose is a pattern which appears in scatter plots of the current and lagged period returns whereby rays emanating from the origin appear in the data following the various points of the compass. This phenomena is most commonly referred to in a two dimensional context, although it may be extended into higher dimensions such as the compass star which is a plot of the current return against the one and two period lagged return [for example see Crack and Ledoit (1996)]. The focus of this paper is on the impact of a change in the tick size of stocks on the presence of the compass rose.

Figure 1 presents a scatter plot of the current period to the one period lagged 5 minute return for Compaq. A grid pattern is clearly visible in the plot which would eventually become the compass rose where more observations were added (this figure is based on 2911 observations). Recall from Section 2, that the tick/volatility ratio for Compaq in the first sample period was 11.68 which was below the average ratio across all stocks of 19.56. According to the results of Gleason et al. (2000), as the tick/volatility ratio decreases, the compass rose pattern becomes less obvious. Figure 2 presents a plot of the 5 minute returns for Compaq in the post-decimalisation period

[4] The NYSE estimated that a one cent tick size would result in a 139% increase in quotes, an 80%

in which the tick/volatility ratio falls to 1.79. Compared to Figure 1, the data is far more evenly spaced and no visible evidence of the compass rose pattern can be found.

Figures 3 - 8 present similar plots for America Online, Time Warner and General Motors in the pre and post-decimalisation periods respectively. In the first subperiod, a grid pattern is again clearly evident whereas in the second period the data is again less structured with no visible pattern. These results are typical of that found for all of the stocks considered in this paper insomuch as in the first subperiod, the grid pattern is clearly evident and in the second subperiod, the data does not exhibit any discernible pattern.

The results of Gleason et al (2000) suggest that there exists some threshold which when transcended will cause the compass rose to disappear. The results presented for America Online, Compaq, General Motors and Time Warner suggest that the reduction in tick/volatility ratio caused by the introduction of penny trading may have caused this threshold to be crossed. This is not the case however, as reducing the tick size has not removed the pattern from the data. Rather, it has succeeded only in making the pattern less coarse and where the axis used to plot the data is reduced, the compass rose reappears.[5] For example, consider Figure 9 which contains a plot of the current and one period lagged returns for Compaq where both axis have a reduced scale compared to Figure 2. While less obvious than during the 1/16 trading period, the beginnings of the compass rose are evident nonetheless. This result was a feature of the data for all 10 stocks and Figures 10 – 12 present similar plots for America Online, Time Warner and General Motors in the post-decimalisation period with a reduced scale. Thus, while the tick/volatility ratio has fallen for these stocks, it was not sufficient to cross the threshold and eliminate the compass rose. In an effort to try and determine the tick/volatility threshold at which the pattern ceases to become visible, it is necessary to consider less frequently sampled data which is the subject of Section 2.2.

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increase in trades and a 9% increase in share volume.

[5] This exercise serves to highlight the point that large symbols or too wide an axis may conceal the compass rose pattern.

2.2 Tick/Volatility Ratios of Less Frequently Sampled Data

In addition to the 5 minute returns considered previously, it is possible to estimate returns for other intra-daily holding periods. Panels B – E of Table 1 presents some descriptive statistics for 10, 15, 30 and 60 minute stock returns. As expected, when the holding period lengthens, the mean return and standard deviation increases for all stocks. The average return (standard deviation) across all 12 stocks for a 5 minute holding period in the predecimalistion subperiod was -0.002% (0.407%) whereas at the 60 minute interval it was –0.028% (0.542%). A similar increase in the average return was evident in the postdecimalistion subperiod where the average mean return (standard deviation) increased from –0.004 (0.360) for the 5 minute returns to –0.050 (1.182) in the case of the hourly interval.

Table 1 also provides the tick/volatility ratios for these less frequently sampled data and consistent with the simulation evidence of Gleason et al (2000), clear evidence of the tick/volatility ratios declining as the sampling interval widens may be found. The average tick/volatility ratio in the pre (post) subperiod for the 5 minute returns was 19.85 (2.96) and 6.03 (0.89) for the 60 minute returns. The change in the average tick/volatility ratio from the pre to the post transition period was approximately 85% across all holding periods. Further, the average tick/volatility ratio across all 12 stocks fell 70% as the time interval widened from 5 to 60 minutes in both the pre and post-decimalisation subperiods.

The compass rose is evident in the 5 minute decimal price returns data considered in this paper, albeit in a much more discrete form compared to when trading quotes of 1/16 were specified. The literature suggests that the compass rose is less likely to exist where the sampling interval widens and as such we may consider these 10, 15, 30 and 60 minute returns with a view to establishing the tick/volatility threshold at which the compass rose disappears. A problem exists however, as the estimated tick/volatility ratios do not vary significantly which lessens the chance of the data crossing the critical threshold at which the compass rose disappears. For example, the average 5 minute return tick/volatility ratio is 2.96 whereas the 60 minute return average ratio is 0.89 providing a range of only 2.07. By way of comparison, Gleason et al. (2000) used a tick/volatility range of 0.001 ~ 20 to identify the threshold value

in their simulated data. Thus, the tick/volatility ratio for these data are unlikely to cross the critical value unless by coincidence, the threshold is close to unity.

As a guide to the likely threshold value for the data considered in this study, it is possible to consult the simulation results of Gleason et al (2000). The highest standard deviation considered by Gleason et al. was 0.006 for which a critical ratio value of 0.25 was identified. By way of comparison, the average standard deviation of the 15 minute returns reported in Table 1 was 0.00605. The lowest individual stock tick/volatility ratio at the 15 minute frequency was generated by Compaq (1.14) which is well above the suggested threshold for this type of data. Further, although the 5 and 10 minute returns data yield smaller standard deviations compared to the 15 minute data, the tick/volatility ratio increases as the sampling interval is reduced. Thus, while decimalisation has reduced the tick/volatility ratio of NYSE stock returns data, it would appear that that fall was not sufficient to eliminate the compass rose pattern.[6]

3 Conclusion

The compass rose pattern is an interesting feature of stock price data whereby a plot of the current and lagged periods returns is characterised by rays emanating from the origin along the points of the compass. Recent research by Gleason et al. (2000) based on simulated data has found that in addition to price discreteness, the ratio of tick size to the volatility of returns must exceed some threshold level in order for the compass rose to be visible.

The implementation of Phase II of the NYSE decimalisation program provides a natural experiment to validate these simulated results on the impact of altering tick size on the presence of the compass rose using actual market data. In this paper, the impact of the change in tick size on 12 liquid stocks included in the decimalisation program was considered. The estimation results indicate that the tick/volatility ratio for stocks are typically considerably higher than that observed for foreign exchange data. This finding suggests that the tick size is more of a limiting factor for the stock

[6] Plots of the data reveal that, although suffering from a lack of observations particularly in the higher frequency domain, the pattern was evident.

market than it is for the foreign exchange market. The introduction of penny trading on the NYSE reduced the tick/volatility ratio for all of the stocks by 85% on average.

The compass rose pattern was found to be in evidence for all of the stocks considered in the pre-decimalisation sample period. Analysis of the advent of penny trading revealed that while the pattern was still present, its nature had changed such that it was a less obvious feature of the data. In general, these results provide an important empirical validation of the simulation results of the previous literature and confirm that the tick volatility ratio is an important determinant of the compass rose pattern. Practical limitations of using actual trade data prevented the identification of the critical threshold at which the compass rose disappears and the authors commend this for future research.

BIBLIOGRAPHY

Brown, M.B. and A.B. Forsythe (1974) "Robust Tests for the Equality of Variances," Journal of the American Statistical Association, 69, 364–367.

Crack, T.F. and Ledoit, O. (1996) "Robust Structure Without Predictability: The Compass Rose Pattern of the Stock Market" *Journal of Finance*, 51, 751 – 762.

Gleason, K.C., Lee, C.I and Mathur, I. (2000) "An Explanation for the Compass Rose Pattern" *Economics Letters*, 68, 127 – 133.

Kramer, W. and Runde, R. (1997) "Chaos and the Compass Rose" *Economics Letters*, 54, 113 – 118.

Lee, C.I, Gleason, K.C. and Mathur, I. (1999) "A Comprehensive Examination of the Compass Rose Pattern in Futures Markets" *Journal of Futures Markets*, 19, 541 – 564.

Szpiro, G.G. (1998) "Tick Size, the Compass Rose and Market Nanostructure" *Journal of Banking and Finance*, 22, 1559 – 1569.

Table 1
Descriptive Statistics and Tick/Volatility Ratio for US Stocks

The following table presents the mean and standard deviation (expressed as percentages) and tick/volatility ratio for a selection of US stocks included in phase II of the decimalisation program of the NYSE for 5, 10, 15 and 30 minute as well as 1 hour holding periods. The Final column presents the p-value associated with the Bartlett-Levine test of the equality of variances pre and post-decimalisation.

Stock	Pre-Decimalisation			Post-Decimalisation			Brown-Forsythe Variance Equality
	Mean (%)	Standard Deviation (%)	Tick Volatility	Mean (%)	Standard Deviation (%)	Tick Volatility	(P-value)
Panel A: 5 minute returns (2911 Observations)							
America Online	-0.00468	0.27120	23.04	-0.01595	0.36415	2.74	0.000
Cigna Corp.	-0.00347	0.18414	33.94	0.01396	0.22391	4.46	0.031
Colgate Palmolive	-0.00996	0.49475	12.63	0.00787	0.24517	4.07	0.000
Compaq	-0.01063	0.53492	11.68	-0.01428	0.55754	1.79	0.002
Daimler Chrysler	-0.00796	0.20843	29.98	-0.00061	0.33568	2.97	0.000
General Motors	0.00728	0.46663	13.39	-0.01593	0.50423	1.98	0.026
Goodyear	-0.01876	0.49142	12.71	-0.00331	0.36682	2.72	0.016
Iomega Corp.	0.01354	1.12914	5.53	-0.01289	0.45636	2.19	0.000
Lockheed Martin	0.00387	0.37002	16.89	0.00535	0.35362	2.82	0.670
Sears	0.00726	0.29409	21.25	-0.00279	0.30966	3.22	0.992
State Street Corp.	-0.00030	0.19772	31.61	-0.00231	0.27959	3.57	0.000
Time Warner	-0.00581	0.24387	25.62	-0.01184	0.33372	2.99	0.000
Average	-0.00247	0.40719	19.85	-0.00439	0.36087	2.96	-
Panel B: 10 minute returns (1472 Observations)							
America Online	-0.00926	0.35284	17.71	-0.03156	0.53789	1.85	0.000
Cigna Corp.	-0.00687	0.25471	24.53	0.02763	0.32428	3.08	0.004
Colgate Palmolive	-0.01973	0.66978	9.33	0.01557	0.34020	2.93	0.001
Compaq	-0.02105	0.75225	8.30	-0.02826	0.80497	1.24	0.002
Daimler Chrysler	-0.01575	0.28002	22.31	-0.00120	0.44664	2.23	0.001
General Motors	0.01442	0.64484	9.69	-0.02728	0.67277	1.48	0.047
Goodyear	-0.03714	0.66073	9.45	-0.01120	0.51750	1.93	0.621
Iomega Corp.	0.02680	1.38484	4.51	-0.02550	0.56546	1.76	0.000
Lockheed Martin	0.00766	0.47240	13.23	0.01059	0.47184	2.11	0.932
Sears	0.01438	0.41444	15.08	-0.00553	0.44730	2.23	0.421
State Street Corp.	-0.00060	0.28235	22.13	-0.00458	0.41350	2.41	0.000
Time Warner	-0.01151	0.34593	18.06	-0.02344	0.51576	1.93	0.000
Average	-0.00489	0.54292	14.52	-0.00873	0.50484	2.09	-

Table 1 (Continued)
Descriptive Statistics and Tick/Volatility Ratio for US Stocks

Stock	Pre-Decimalisation			Post-Decimalisation			Brown-Forsythe Variance Equality
	Mean (%)	Standard Deviation (%)	Tick Volatility	Mean (%)	Standard Deviation (%)	Tick Volatility	(P-value)
Panel C: 15 minute returns (992 Observations)							
America Online	-0.01376	0.42112	14.84	-0.04683	0.68333	1.46	0.000
Cigna Corp.	-0.01020	0.32850	19.02	0.04100	0.37960	2.63	0.075
Colgate Palmolive	-0.02929	0.80370	7.77	0.02311	0.44418	2.25	0.010
Compaq	-0.03126	0.75029	8.33	-0.04194	0.87643	1.14	0.001
Daimler Chrysler	-0.02340	0.35367	17.67	-0.00178	0.54608	1.83	0.004
General Motors	0.02141	0.79612	7.85	-0.04049	0.81296	1.23	0.116
Goodyear	-0.05515	0.90894	6.87	-0.01662	0.62419	1.6	0.388
Iomega Corp.	0.03980	1.58123	3.95	-0.03784	0.68461	1.46	0.000
Lockheed Martin	0.01137	0.57852	10.80	0.01572	0.53355	1.87	0.954
Sears	0.02136	0.52030	12.01	-0.00820	0.55646	1.79	0.753
State Street Corp.	-0.00090	0.35540	17.58	-0.00679	0.48400	2.06	0.000
Time Warner	-0.01709	0.41673	14.99	-0.03478	0.64362	1.55	0.000
Average	-0.00726	0.65121	11.80	-0.01295	0.60575	1.73	-
Panel D: 30 minute returns (512 Observations)							
America Online	-0.02671	0.58168	10.74	-0.09073	0.97257	1.02	0.000
Cigna Corp.	-0.01980	0.48425	12.90	0.07944	0.54841	1.82	0.177
Colgate Palmolive	-0.05688	1.10233	5.66	0.04477	0.62388	1.60	0.087
Compaq	-0.06069	0.90247	6.92	-0.08126	1.26912	0.78	0.004
Daimler Chrysler	-0.04543	0.46714	13.37	-0.00345	0.75477	1.32	0.009
General Motors	0.04157	1.02877	6.07	-0.07845	1.22517	0.81	0.032
Goodyear	-0.10708	1.32767	4.70	-0.03221	0.83148	1.20	0.414
Iomega Corp.	0.07728	1.74990	3.57	-0.07331	0.79166	1.26	0.000
Lockheed Martin	0.02208	0.70445	8.87	0.03047	0.69628	1.43	0.917
Sears	0.04147	0.74578	8.38	-0.01590	0.76378	1.3	0.755
State Street Corp.	-0.00175	0.45807	13.64	-0.01317	0.69982	1.42	0.000
Time Warner	-0.03318	0.62343	10.02	-0.06739	0.92868	1.07	0.000
Average	-0.01409	0.84799	8.73	-0.02510	0.84213	1.25	-
Panel E: 60 minute returns (255 Observations)							
America Online	-0.05747	0.79107	7.90	-0.17791	1.46022	0.68	0.001
Cigna Corp.	-0.03979	0.69270	9.02	0.15888	0.76427	1.30	0.247
Colgate Palmolive	-0.11424	1.73007	3.61	0.08956	0.87905	1.13	0.069
Compaq	-0.11837	1.29483	4.82	-0.16562	1.77170	0.56	0.019
Daimler Chrysler	-0.09125	0.66004	9.46	-0.00691	0.98969	1.01	0.026
General Motors	0.08209	1.54879	4.03	-0.15567	1.59038	0.62	0.294
Goodyear	-0.21507	1.64828	3.79	-0.06442	1.20785	0.82	0.401
Iomega Corp.	0.15522	2.56817	2.43	-0.14664	1.01462	0.98	0.000
Lockheed Martin	0.04436	1.03275	6.05	0.06094	0.94416	1.05	0.542
Sears	0.08330	1.16804	5.35	-0.03181	1.16912	0.85	0.736
State Street Corp.	-0.00353	0.68297	9.15	-0.02635	0.99775	1.00	0.000
Time Warner	-0.06665	0.91299	6.84	-0.13479	1.39825	0.71	0.007
Average	-0.02845	1.22755	6.03	-0.05006	1.18225	0.89	-

Figure 1
Plot of Returns Data for Compaq Pre-Decimalisation

The following figure presents a plot of 5 minute current (R_t) and one period lagged (R_{t-1}) returns data for Compaq sampled over a 15 day period prior to the introduction of decimal prices on the NYSE on September 25, 2000.

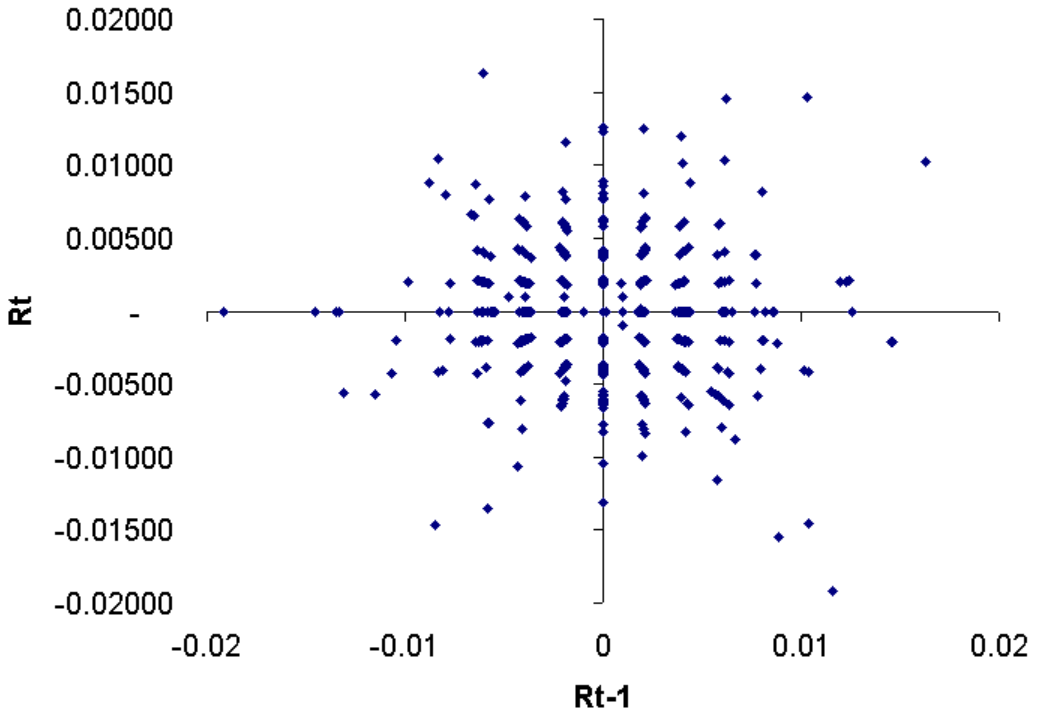

Figure 2
Plot of Returns Data for Compaq Post-Decimalisation

The following figure presents a plot of 5 minute current (R_t) and one period lagged (R_{t-1}) returns data for Compaq sampled over a 17 day period after the introduction of decimal prices on the NYSE on September 25, 2000.

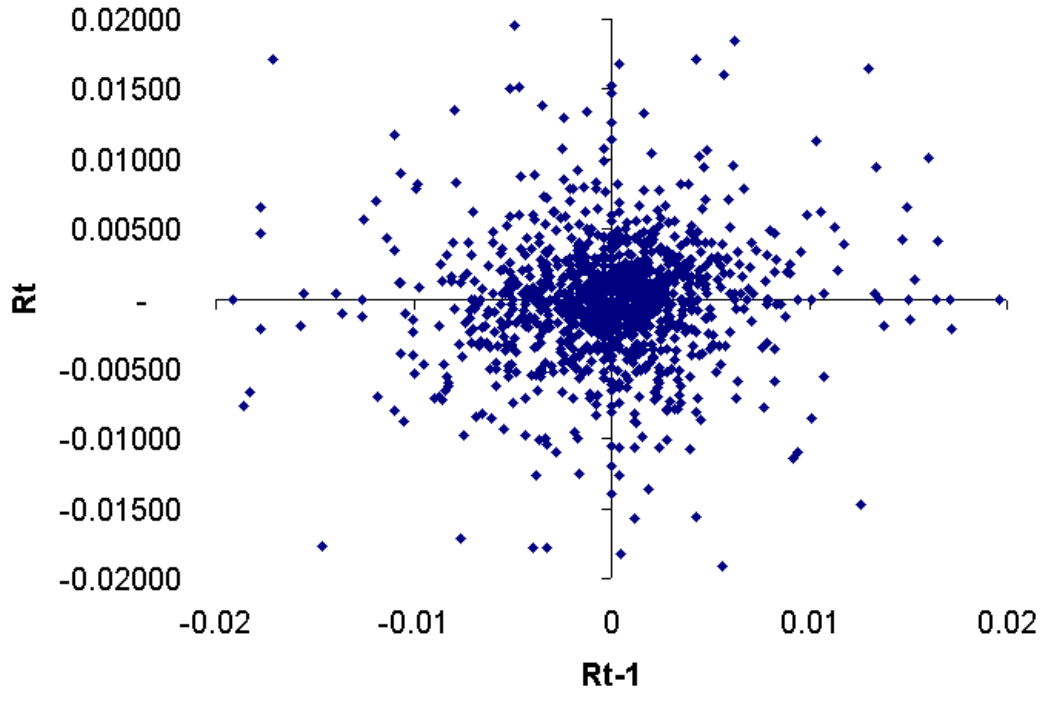

Figure 3
Plot of Returns Data for America Online Pre-Decimalisation

The following figure presents a plot of 5 minute current (R_t) and one period lagged (R_{t-1}) returns data for America Online sampled over a 15 day period prior to the introduction of decimal prices on the NYSE on September 25, 2000.

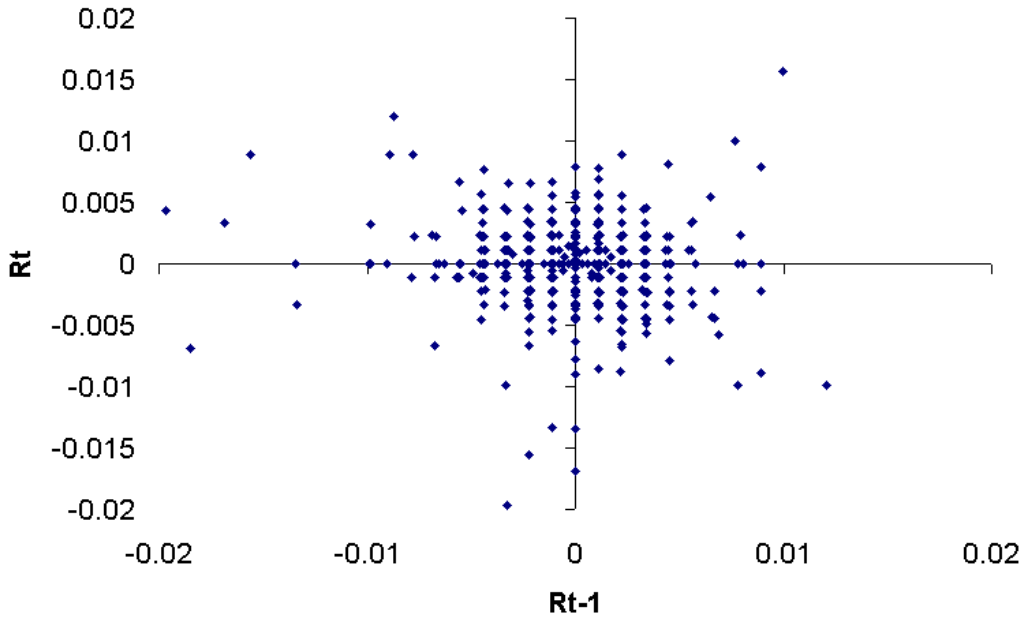

Figure 4
Plot of Returns Data for America Online Post-Decimalisation

The following figure presents a plot of 5 minute current (R_t) and one period lagged (R_{t-1}) returns data for America Online sampled over a 17 day period after the introduction of decimal prices on the NYSE on September 25, 2000.

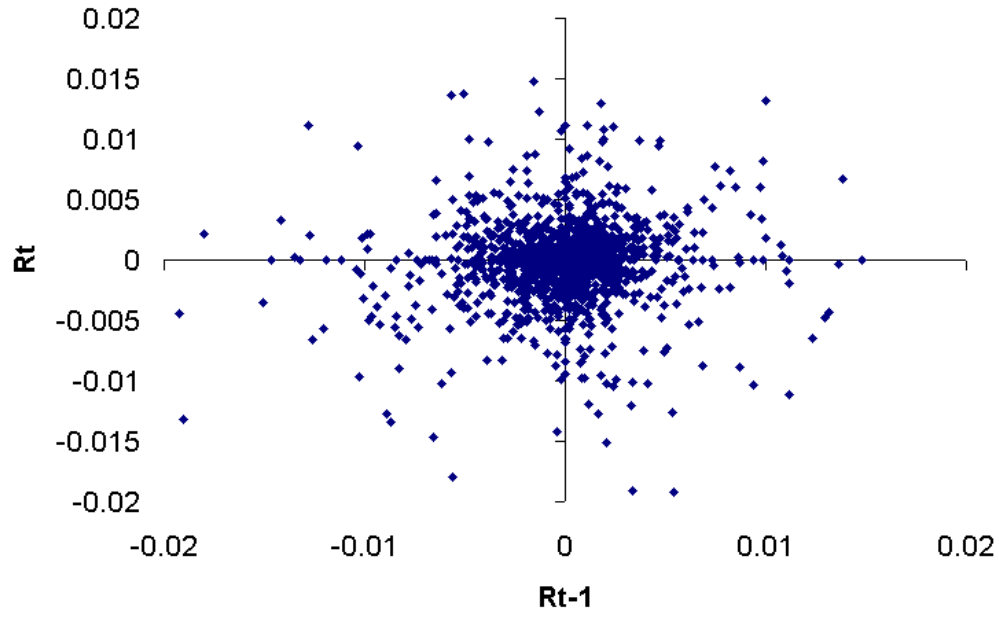

Figure 5
Plot of Returns Data for Time Warner Pre-Decimalisation

The following figure presents a plot of 5 minute current (R_t) and one period lagged (R_{t-1}) returns data for America Online sampled over a 15 day period prior to the introduction of decimal prices on the NYSE on September 25, 2000.

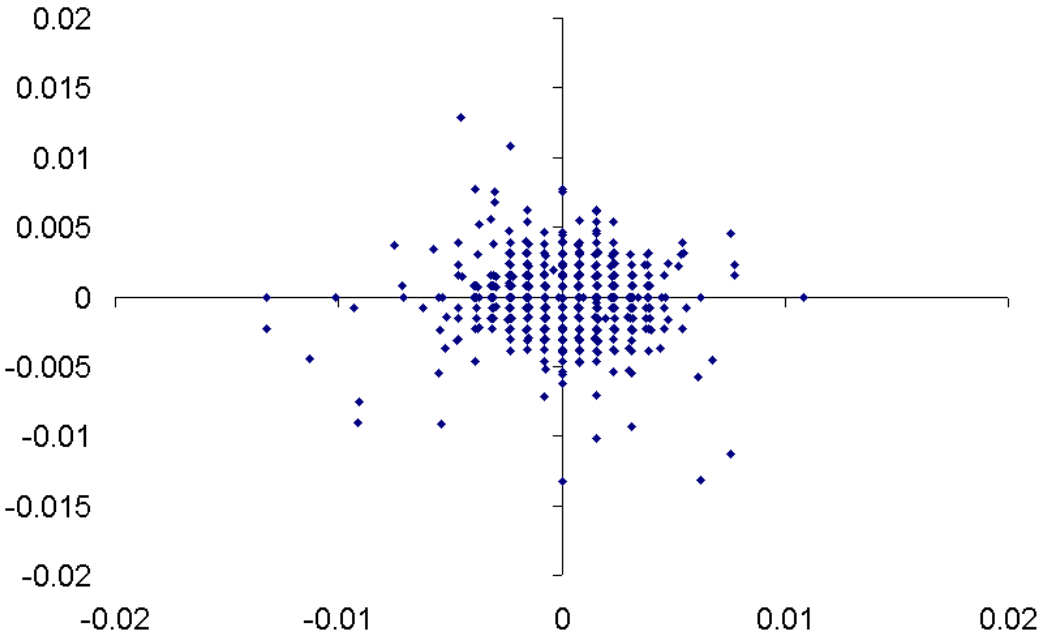

Figure 6
Plot of Returns Data for Time Warner Post-Decimalisation

The following figure presents a plot of 5 minute current (R_t) and one period lagged (R_{t-1}) returns data for America Online sampled over a 17 day period after the introduction of decimal prices on the NYSE on September 25, 2000.

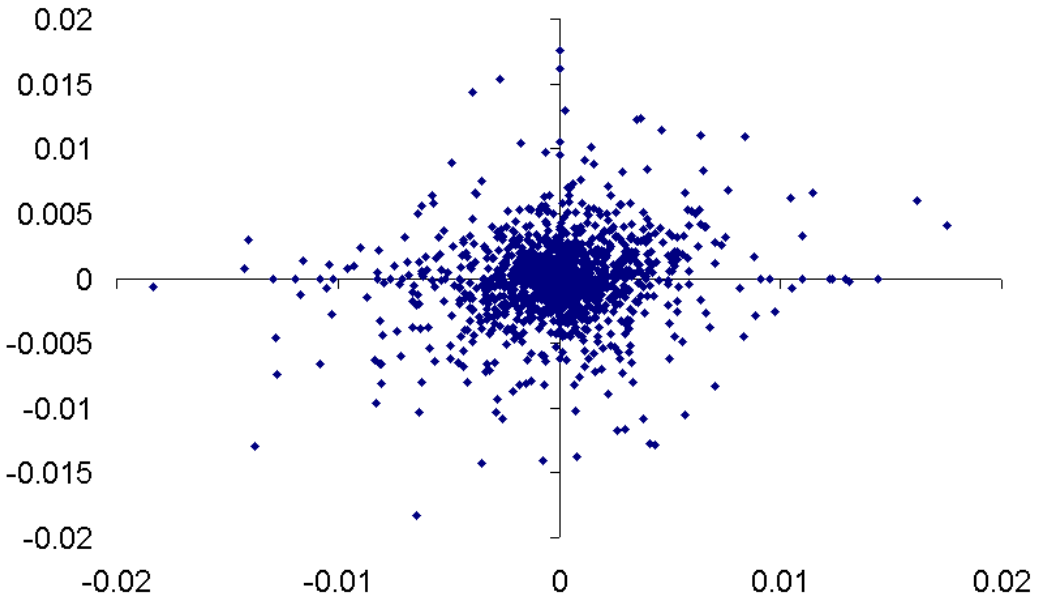

Figure 7
Plot of Returns Data for General Motors Pre-Decimalisation

The following figure presents a plot of 5 minute current (R_t) and one period lagged (R_{t-1}) returns data for America Online sampled over a 15 day period prior to the introduction of decimal prices on the NYSE on September 25, 2000.

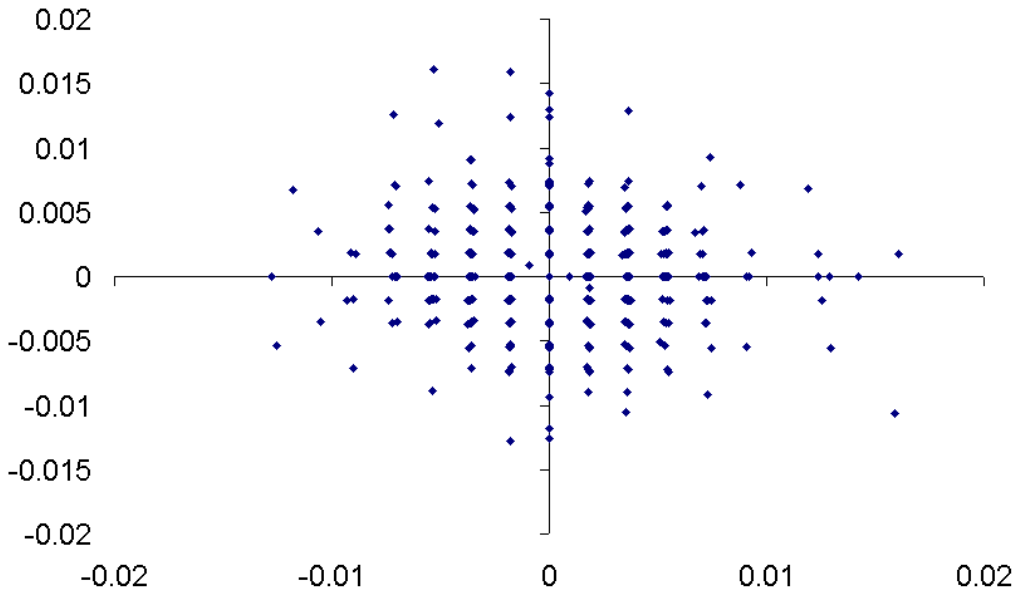

Figure 8
Plot of Returns Data for General Motors Post-Decimalisation

The following figure presents a plot of 5 minute current (R_t) and one period lagged (R_{t-1}) returns data for America Online sampled over a 17 day period after the introduction of decimal prices on the NYSE on September 25, 2000.

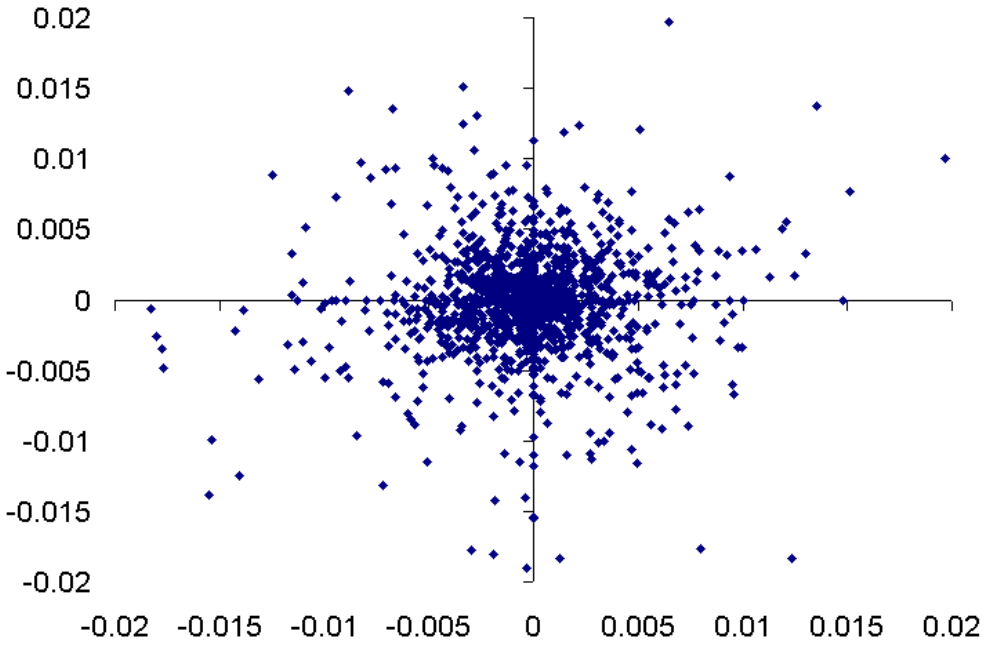

Figure 9

Plot of Returns Data for Compaq Post-Decimalisation with Reduced Axis Range

The following figure presents a plot of 5 minute current (R_t) and one period lagged (R_{t-1}) returns data for Compaq sampled over a 17 day period after the introduction of decimal prices on the NYSE on September 25, 2000 with the x and y-axis reduced in range to emphasise the data.

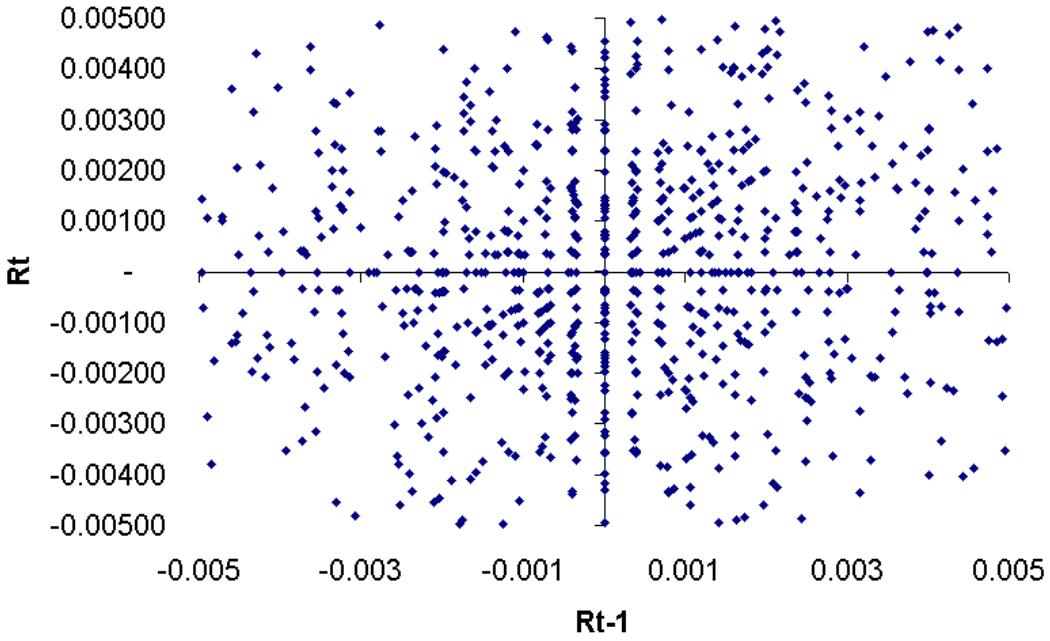

Figure 10

Plot of Returns Data for America Online Post-Decimalisation with Reduced Axis Range

The following figure presents a plot of 5 minute current (R_t) and one period lagged (R_{t-1}) returns data for Compaq sampled over a 17 day period after the introduction of decimal prices on the NYSE on September 25, 2000 with the x and y-axis reduced in range to emphasise the data.

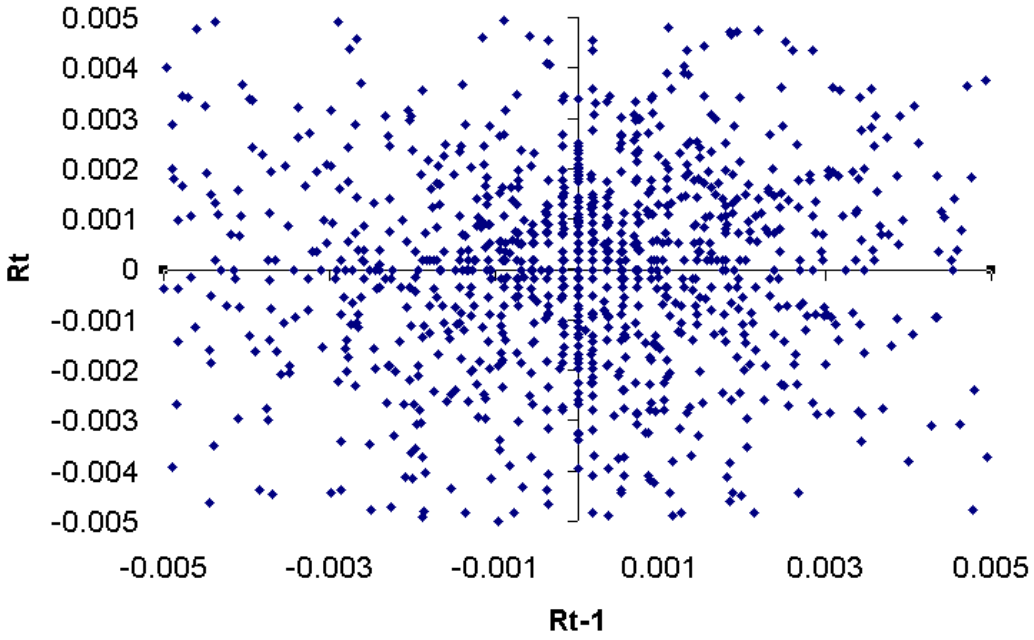

Figure 11
Plot of Returns Data for Time Warner Post-Decimalisation with Reduced Axis Range

The following figure presents a plot of 5 minute current (R_t) and one period lagged (R_{t-1}) returns data for Compaq sampled over a 17 day period after the introduction of decimal prices on the NYSE on September 25, 2000 with the x and y-axis reduced in range to emphasise the data.

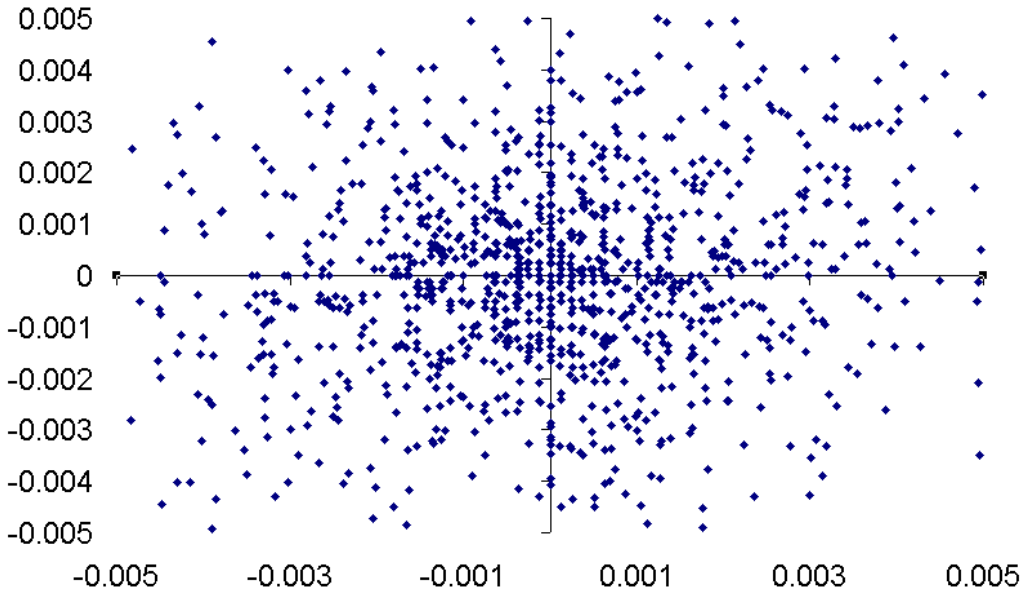

Figure 12
Plot of Returns Data for General Motors Post-Decimalisation with Reduced Axis Range

The following figure presents a plot of 5 minute current (R_t) and one period lagged (R_{t-1}) returns data for Compaq sampled over a 17 day period after the introduction of decimal prices on the NYSE on September 25, 2000 with the x and y-axis reduced in range to emphasise the data.