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Price limits and stock market volatility in the Athens Stock Exchange

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Abstract

In this paper, we have examined the effects of price limits on the stock volatility in the Athens Stock Exchange. We put forward two hypotheses, the information hypothesis, which implies that price limits only slow down the process of adjustment and have no effect on stock volatility; and the over-reaction hypothesis, which assumes that investors tend to overreact to new information, so that price limits give them time to reassess the information and reduce stock volatility. Our results show strong support for the information hypothesis. This evidence is obtained by performing the tests on ten stocks, which include heavily traded stocks as well as less active stocks, and covering a variety of industries, and on a market wide price index. The results are also robust to the frequency of the measurement of the returns, and to the tightness of the limits.

Keywords: *price limits and volatility, emerging capital markets, ARCH/GARCH modelling, Athens Stock Exchange.*

JEL classification: *G*14.

1. Introduction

In recent years there has been a significant increase in the volatility of returns of many financial assets which has attracted the interest of participants, regulators

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and academics. The volatility is considered excessive because it cannot be explained by the uncertainty of the future real dividend. Understanding the causes of market volatility has important policy implications for the imposition of price limits on financial assets. Price limits are considered necessary by a stock exchange because of the effects that ‘excessive’ speculation and mob psychology may have on the pricing process. It is believed that such limits would have prevented the fall in prices during the 1987 crash. Panic behaviour is thought to have caused the excessive volatility that led to the crash (Blume, Mackinlay and Tecker, 1989; Greenwald and Stein, 1991). Exchange officials argue that circuit breakers, which include both price limits and trading halts, provide, when they are activated, an opportunity for normal information transmission in times of market turbulence. Proponents of circuit breakers claim that, during major price changes there can be a breakdown in the transmission of information between the trading floor and market participants. Thus, in the words of Greenwald and Stein (1988) ‘the primary function of a circuit breaker should be to reinform participants’.

Opponents of price limits on the other hand, argue that they serve no purpose other than to slow down or delay a price change. They argue that even though price limits can stop the price of a share from free falling on the trading day when a shock hits the market, the price will continue to move towards equilibrium as new limits are established in subsequent trading periods.

In the Athens Stock Exchange (ASE) in Greece an 8% price limit was imposed in August 1992 on highly active shares.[1] The price limits allow each stock listed on ASE to fluctuate on any given trading day within the prespecified percentage level above or below the previous day’s closing price for that stock. Trading (if any) continues at the ceiling or floor price until the demand and supply conditions are reversed, or until the closing of the trading day. The purpose of this study is to examine the effects of these price limits on the volatility of stock returns.

2. A brief review of the literature

Following the 1987 crash many questions have been raised concerning its causes and whether the microstructure of the stock market had to be redesigned to protect the market from big fluctuations. Recommendations were made to establish circuit breakers, either in the form of price fluctuation limits, or trading halts, to prevent future crashes. Trading halts and price limits differ in that the former results in complete cessation of trading activity, while in the latter trading is permissible as long as it is within the trading range ‘limit’.

Many papers have been written on the effects of trading halts on volatility and trading volume. For example, Amihud and Mendelson (1987, 1991), Stoll and Whaley (1990), and Gerety and Mulherin (1992) have examined trading halts by analysing volume and price movements at the open and close of markets. Lee, Ready and Seguin (1994) have looked at the effects of unpredictable trading cessations on the levels of trading volume and price volatility relative to a control sample. They use intraday data and precise announcements to compare

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[1] The limit for the less active shares was 4%.

volume at the reopening and volume and volatility in the posthalt period to statistics associated with 'pseudohalt' periods for the same firm. A pseudohalt is a control period of continuous trading for the same firm matched on time of day and duration. Their main conclusion is that trading halts do not reduce either trading volume or volatility. In contrast, posthalt periods are characterised by higher levels of both volume and volatility.

There is little empirical evidence on the effects of price limits as very few developed markets have them. However, the limited evidence on the spot markets is also not supportive of the prime aim of circuit breakers, which is to reduce volatility of stock returns. For example, Chung (1991) looks at the Korean Stock Market and tests for any difference in volatility (i) at each price level for which the price limit is different,[2] and (ii) for periods where different price limits were applied, and finds no significant evidence that price limits reduce return volatility.[3] Chen (1993) studied the case of Taiwan by employing a projected standard deviation series corrected for heteroskedasticity as a measurement of stock volatility and arrived at similar conclusions.[4] More recently, Kim and Rhee (1997) examined the effects of price limits on the Tokyo Stock Exchange by dividing stocks in two categories, those that reach their daily price limit and those that almost reach their daily price limit, and compare the behaviour of the two categories. They find that price limits are ineffective. For example, the volatility of stocks that experience price limits does not return to normal levels as quickly as for stocks that did not reach price limits.

On the other hand, there is more supportive evidence in the futures market. Ma, Rao and Sears (1989) present evidence that the price limit rule has been effective in the Treasury bond futures market in that volatility declined following limit moves. Their analysis was, however, criticised because it looked at the short-term impact of limits.[5]

The current study aims to add to the scant literature on the effects of price limits on volatility by examining the Greek capital market, which is very small compared to the markets already studied. In 1994, the market capitalisation in Greece was US$14,921 million, compared to US$191,778, US$247,325 and US$3,719,914 in Korea, Taiwan and Japan respectively. In our paper, we examine the effects of price limits on the volatility of individual stocks, as well as that of the market-wide index. By concentrating on individual stocks we are able to examine whether various characteristics of stocks affect the price discovery process when price limits are in force. For example, we include stocks which are heavily traded and stocks which are less active; we include stocks from a variety of different sectors. Characteristics, such as market size and type of industry, have been found in many studies to affect stock behaviour. The market size has implications for example for transaction costs and the degree of liquidity which

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[2] The Korean Stock Market was characterised by different price limits for each stock price level and had also experienced frequent changes in the rate of the price limits.

[3] The volatility of monthly stock returns was estimated using daily returns to the portfolio and subtracting the sample mean for the month (see French, Schwert and Stambaugh, 1987).

[4] He follows the procedure proposed by Schwert (1989) to estimate conditional volatility.

[5] As Roll (1989) says 'The measurement problem with price limits and circuit breakers is to detect their *long-run* impact on volatility if any. A reduction in short-term volality could be spurious and immaterial'.

can influence the stock price, its variance and correlation.[6] On the other hand, industry analysis of stock returns has shown that expected returns are influenced by factors, such as industry specific risk, apart from market risk.[7] In our analysis we used both daily and monthly data. The use of monthly data makes possible the inclusion of other possible determinants of volatility such as trading activity, and the variance of a variety of macroeconomic variables, avoiding in this way possible misspecification. The evidence presented in this study does not find price limits to reduce volatility suggesting that they might be ineffective.

3. Price limits and stock market volatility: some hypotheses

This section presents two testable hypotheses on the role of price limits on stock market volatility.

3.1. *Information hypothesis*

Consider a market where the true equilibrium price and volatility is driven by the arrival of information and traders have access to and process this information. If a price limit is present and the true equilibrium price falls outside the current day's price limit range, the price will move to the appropriate limit on the trading day. In subsequent trading periods, the price will continue to move in a direction towards equilibrium as new trading limits are established. Price limits only prolong the number of trading days it will take for the market to adapt to a disturbance towards equilibrium. As a result, a longer and more significant correlation of stock returns would be found and the volatility of stock returns should not change. This delaying effect of price limits on the adjustment of stock prices to changes in fundamental values has been argued for example by Fama (1989).

The testable hypotheses regarding stock price behaviour for the information hypothesis are:

H1: There should be more significant serial correlations of stock returns in post-limit periods.
H2: There should be no difference in volatility between pre- and post-limit periods.

3.2. *Overreaction hypothesis*

Consider now a different market structure, where traders do not process information efficiently. When new information arrives investors tend to 'overreact' and the share price could reach the limit. Thus, in the short-run the market price may react to new information erratically, and the activation of price limits serves to provide the market with additional time to evaluate the information and to reformulate a new investment strategy. During the 'reassessment' period, the market 'cools down'. Thus, volatility should be less when price limits are in place.

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[6] See the seminal paper by Cohen *et al.* (1980) on the implications of market frictions on stock price behaviour.

[7] See, e.g. Isimbadi (1994) and Kavussanos and Marcoulis (1997).

The testable hypothesis for the overrreaction scenario is:

H3: Volatility of returns in the post-limit period should be less than in the pre-limit period.

The overreaction in financial markets was first noted by Keynes '... day-to-day fluctuations of existing investments, which are obviously of an ephemeral and non-significant character, tend to have an altogether excessive and even an absurd influence on the market'.[8] Investors' overreactions to each other's trades has also been put forward by French and Roll (1986) as an explanation of the greater variance of stock returns during times when the stock exchanges are open.

4. Methodological issues

In order to examine the above hypotheses we have performed two tests. We have first looked at the serial correlation of daily returns, and secondly, we have estimated the time varying variance of both daily and monthly returns and examined whether the imposition of price limits had an effect.

4.1. *Serial correlations*

In order to examine H1, we estimate first the serial correlations of daily returns in the period prior to the imposition of price limits and in the period following price limits. Confirmation of H1 implies finding positive and higher serial correlation in the second sub-period.

Secondly, in the cases where H1 is confirmed we test whether serial correlations are significantly different in the pre- and post-price limit subperiods, which is equivalent to testing for structural changes on the serial correlations. That involves estimating the regression of stock returns over their lagged values as it is given below:

$$r_t = \sum_{i=1}^{N} \beta_i r_{t-i} + \varepsilon_t, \qquad \varepsilon_t \sim IN(0, h) \tag{1}$$

and testing for structural changes between the two subperiods by using the Chow test statistic.

4.2. *ARCH/GARCH models*

Hypotheses H2 and H3 are examined by modelling the time varying volatility of stock returns. Stock returns, as well as other financial series, exhibit volatility 'clustering', i.e. periods of large absolute changes are followed by periods of relatively small absolute changes. This time varying volatility has been modelled successfully in the literature by the use of autoregressive conditionally heteroskedastic (ARCH) and generalised ARCH (GARCH) models. ARCH/GARCH

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[8] See Keynes (1936), pp. 153–154.

models by imposing an autoregressive structure on conditional variance, allow volatility shocks to persist over time.

Thus, the GARCH model estimated for the daily stock returns of each of the price indices of the ASE is

$$r_t = \mu_{t-1} + \varepsilon_t; \qquad \varepsilon_t \sim IN(0, h) \tag{2}$$

$$h_t = \alpha_0 + \sum_{i=1}^{p} \alpha_i \varepsilon_{t-1}^2 + \sum_{j=1}^{q} \beta_j h_{t-j} \tag{3}$$

where μ_{t-1} represents the conditional mean of r_t based on past information, $\alpha_0 \geq 0$, and α_i, $\beta_j \geq 0$, $i = 1 \ldots, p$, $j = 1, \ldots, q$, to ensure $h_t > 0$.[9] The sum of the coefficients α_i and β_j denote the degree of persistence in the conditional variance given a shock to the system.[10] In particular, the above sum should be less than 1 in order to have a stationary variance. In the case of ARCH models $\beta_j = 0$, $\forall\, j = 1, \ldots, q$.

Previous work, however, has indicated that an important determinant of conditional volatility for the General market index in ASE is the trading activity (see Phylaktis, Kavussanos and Manalis, 1996) represented by either the daily number (volume) of transactions, or the daily value of transactions. Trading activity proxies the information flow to the market,[11] which has been given as a possible explanation for the prominence of ARCH/GARCH effects,[12] and as such, affects the GARCH coefficients. Theoretically, the relationship between returns volatility and trading volume is based on the implication of the Mixture of Distributions Hypothesis, that the variance of daily price increments is heteroskedastic, in particular positively related to the rate of daily information arrival.

Thus, the conditional volatility represented by equation (3) is modified to include the value of transactions, V one period earlier[13]

$$h_t = \alpha_0 + \sum_{i=1}^{p} \alpha_i \varepsilon_{t-i}^2 + \sum_{j=1}^{2} \beta_j h_{t-j}, + \gamma V_{t-1} \tag{4}$$

In order to test the effects of price limits on stock market volatility, we use a dummy variable D which takes the value of one after the limits were imposed on 17 August 1992 and zero before. As a result, equation (4) is further modified to:

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[9] For a detailed explanation of ARCH models, see Bera and Higgins (1993).

[10] For a review of ARCH modelling in finance see Bollerslev, Chou and Kroner (1992).

[11] For example, Berry and Howe (1994) find a positive relationship between public information, as measured by the number of news releases by Reuter's News service, and trading volume.

[12] See, e.g. Bollerslev *et al.* (1992).

[13] We use lagged V as an instrument for contemporaneous volume to avoid the problem of simultaneity. Lagged values of endogenous variables are classified as predetermined, see, e.g. Harvey (1989).

$$h_t = \alpha_0 + \sum_{i=1}^{p} \alpha_i \varepsilon_{t-i}^2 + \sum_{j=1}^{q} \beta_j h_{t-j} + \gamma V_{t-1} + \delta D_t \tag{5}$$

H2 suggests $\delta = 0$. On the other hand, H3 suggests $\delta < 0$.

5. Data description and empirical analysis

5.1. *Data description*

The data set comprises closing price daily observations of ten stocks, the general price index and trading activity (value of transactions) from January 1990 to June 1996 giving us in total 1713 observations.[14] The data are collected from the ASE records. The 10 stocks have been selected from those which have reached price limits, and range from stocks which are heavily traded, such as the Commercial Bank of Greece, which had the highest turnover per day in the first 6 months of 1995 and the third largest capitalisation (5.8% of total equities capitalisation), to smaller companies like Lampsa Hotel, the capitalisation of which was only 0.002% of total equity capitalisation. The stocks cover also a variety of sectors, including banking, construction, metallurgical and chemical products. Information on individual stocks is given in Table 1.

The daily stock returns r_t are calculated as the logarithmic first difference in the share price of each stock, and in the general share price index.[15] To assess

Table 1
Information on individual stocks.

Stock	Abbre-viation	Sector	Market capitalisation[a] (in thousands US$)	Price limit (%)
Petsetakis	RD1	Chemical products	40,767	8
National Bank of Greece	RD2	Banking	859,465	8
Lampsa	RD3	Hotels	24,543	4
Ideal Group	RD4	Holdings[b]	8,388	4
Vis	RD5	Containers' industries	10,742	4
Aluminium of Greece	RD6	Metallurgical	299,715	8
Commercial Bank of Greece	RD7	Banking	919,813	8
Alpha Credit Bank	RD8	Banking	1,089,724	8
Intracom	RD9	Metallurgical	543,597	8
Michaniki	RD10	Construction	253,859	8

Notes: Source, Athens Stock Exchange, Statistical Highlights, January 1985–June 1995.
[a] 30 June 1995. [b] The companies in that group are mostly involved with building materials.

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[14] The stock prices and the general price index are not adjusted for dividend payouts. Gallant, Rossi and Tauchen (1992) show that volatility estimates are not influenced appreciably by dividends.

[15] Preliminary analysis has shown that the hypothesis of a unit root is strongly rejected for the logarithmic first difference of the price index. Therefore, stock returns follow a stationary process.

the distributional properties of the daily stock returns various descriptive statistics are reported in Table 2: mean, standard deviation, skewness, kurtosis and the Ljung–Box (1978) portmanteau test statistics $Q(20)$ and $Q^2(20)$ (for the squared data) for up to 20th order serial correlation. The mean return is negative in three of the stocks which also exhibit the highest volatility. All return series apart from RD5 are positively skewed and highly leptokurtic compared to the normal distribution. The Ljung–Box test statistics $Q^2(20)$ indicate the presence of conditional heteroskedasticity.[16] These findings suggest the use of GARCH modeling which recognises the temporal dependence in the second moment of price changes.

5.2. *Serial correlation*

Table 3 presents serial correlations of daily returns for the pre-limit period and the post-limit period. For H1 not to be rejected we should observe significant and positive serial correlations in the post-limit period indicating that a shock will spread over into the next days since it cannot be absorbed in one day due to the price limit. The results show that for only two of the stocks, RD3 and RD5, we do not reject H1. For both of these stocks, the serial correlation coefficients are positive for the first five lags in the post limit period. For the lags that the coefficients were positive in the pre-limit period, they become bigger in the post limit period.

For those two stocks in order to test whether the serial correlations are significantly different between the pre- and post-limit periods we proceeded to test for structural changes on the serial correlations by estimating equation (1) with 10 and 30 lags and performing a Chow test for structural stability. The results are presented in Table 4. The Chow statistic for both stocks is significant for the two different lag structures.

Thus, this test supports the assertion that price limits have a delaying effect on the adjustment of prices for these stocks and provide favourable evidence for the information hypothesis.

5.3. *ARCH/GARCH estimation using daily data*

Table 5 reports the results of GARCH models for stock returns for each of the stocks and the general index. The appropriate GARCH model is selected using the Akaike (AIC) and Schwarz (SIC) information criteria. An iterative procedure is used based upon the method of Berndt–Hall–Hall–Hausman (BHHH) to maximise the log-likelihood function. We find that on the whole a GARCH(1,1) or a GARCH(1,2) model is appropriate depending on the price index used.

Past returns are found to be statistically significant in the conditional mean in all cases.[17] The non-zero autocorrelations could be the result of price adjustment delays such as the lag between transaction price adjustment and quotation price adjustment, and of transaction prices bouncing randomly between the bid and the ask price. This evidence on the specification of the mean return reveals weak

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[16] Under the null hypothesis of conditional homoskedasticity, the statistic $Q^2(k)$ will have an asymptotic chi-squared distribution with (k) *df*.

[17] This is consistent with the results of other studies, e.g. Conrad, Kaul and Nimalendran (1991).

Table 2

Summary statistics of daily stock returns: January 1990–June 1996.

Stocks	Mean	Std. dev.	Minimum	Maximum	Skewness	Kurtosis	$Q(20)$	$Q^2(20)$
RD1	−0.018	2.909	−17.096	19.416	0.355	4.638	36.0	251.0
RD2	0.018	2.449	−11.333	19.890	0.336	5.219	37.3	325.0
RD3	0.019	2.255	−18.232	23.317	1.213	21.385	67.2	290.0
RD4	−0.018	3.305	−15.982	14.792	0.001	2.615	43.9	40.4
RD5	0.030	2.637	−27.905	21.357	−0.488	14.971	68.5	318.0
RD6	0.012	2.068	−11.845	15.721	0.738	6.073	56.3	107.0
RD7	0.027	2.107	−12.479	11.419	0.347	4.942	56.1	452.0
RD8	0.085	2.586	−43.333	59.136	4.234	206.62	95.6	400.0
RD9	−0.010	2.966	−18.049	22.376	0.287	6.759	67.8	1140.0
RD10	0.030	1.918	−13.270	21.047	0.287	6.759	90.6	329.0
GID	0.039	1.677	−8.222	13.750	0.543	7.610	108.0	391.0

Notes: Stock return is calculated as $r_t = (\log p_t - \log p_t) \times 100$ where p_t is the share price. GID: General Price Index. $Q(20)$, and $Q^2(20)$ for the squared data, are Ljung–Box statistics of the 20th order. See also Table 1 for the abbreviations of the various stocks.

informational inefficiency as past returns contain important information for forecasting future returns.

The results show strong evidence that the daily stock returns can be characterised by the GARCH model. The sum of the GARCH coefficients, α_i and β_j (when appropriate), is close to one in all cases except in RD5, where it is about 0.4. That implies persistence of the conditional variance. The improvement in the Ljung and Box (1978) portmanteau test statistics for the standardised resid-

Table 3

Serial correlation of daily stock returns.

	Lag 1	Lag 2	Lag 3	Lag 4	Lag 5	Lag 10
RD1						
Pre-price limit	0.380	−0.126	−0.071	0.082	−0.028	0.052
Post-price limit	−0.008	−0.023	−0.044	−0.005	−0.042	−0.038
RD2						
Pre-price limit	0.119	−0.009	0.094	0.043	−0.047	0.040
Post-price limit	0.067	−0.001	−0.033	−0.037	−0.059	−0.018
RD3						
Pre-price limit	0.015	−0.129	−0.059	0.057	−0.075	0.127
Post-price limit	0.294	0.184	0.161	0.127	0.082	0.043
RD4						
Pre-price limit	0.062	−0.133	0.008	0.117	−0.034	−0.059
Post-price limit	0.123	−0.075	−0.035	−0.049	−0.014	0.008
RD5						
Pre-price limit	0.026	−0.106	0.065	0.057	−0.024	0.047
Post-price limit	0.182	0.101	0.077	0.121	0.066	−0.012
RD6						
Pre-price limit	0.169	0.038	0.084	−0.002	−0.040	0.051
Post-price limit	0.087	0.030	−0.005	0.057	−0.011	0.001
RD7						
Pre-price limit	0.52	−0.079	0.048	0.113	−0.010	0.093
Post-price limit	0.080	−0.081	−0.047	0.003	−0.002	0.025
RD8						
Pre-price limit	−0.232	−0.113	0.007	0.074	0.020	−0.001
Post-price limit	0.069	−0.053	−0.058	−0.019	0.017	−0.045
RD9						
Pre-price limit	0.054	−0.080	0.072	0.015	−0.124	−0.041
Post-price limit	−0.161	0.034	0.051	−0.001	−0.012	−0.039
RD10						
Pre-price limit	0.203	0.041	−0.056	−0.015	−0.054	−0.148
Post-price limit	0.197	0.020	0.024	0.038	−0.047	0.064
GID						
Pre-price limit	0.204	−0.002	0.073	0.085	0.004	0.136
Post-price limit	0.146	−0.017	−0.009	−0.022	−0.042	−0.001

**Note:* The sample period is January 1990–June 1996. For the abbreviations of the stocks see Table 1.

Table 4

Structural stability tests on autocorrelations.

	RD3		RD5	
*N*th order autocorrelation	10	30	10	30
Chow statistic	6.339	2.838	1.761	1.394
Significance level	0.000[a]	0.000[a]	0.055[b]	0.073[b]

Notes: [a] Significant at the 95% level; [b] Significant at the 90% level. For the abbreviations of the stocks see Table 1.

uals compared to the raw data presented in Table 2, indicates that GARCH specifications are appropriate.[18] The residuals, however, remain leptokurtic.

In five of the individual stocks and in the general price index, V_{t-1} is positive and statistically significant as expected. On the other hand, D_t, the dummy for the introduction of price limits, is close to zero to the extent that it does not show in our estimation, except in the case of RD7 and RD10 stocks. It is only, however, statistically significant in RD10. It is interesting to notice that its sign is positive, implying that the introduction of price limits has *increased* the volatility of that stock.

Thus, our results show that in nine of the ten stocks and in the general price index, price limits did not affect the volatility of returns, and lend support to H2.[19] In the tenth stock the imposition of price limits has had the effect of increasing volatility.

5.4. *ARCH/GARCH estimation using monthly data*

We repeat the exercise using monthly data for some of the stocks.[20] The results are shown in Table 6. The results show once again that stock returns can be characterised by GARCH specifications. Persistence of the conditional volatility is, however, less. The diagnostic tests indicate an improvement when compared to those of the raw data (not shown in the paper). In contrast to the daily data, we find V_{t-1} to be close to zero and statistically insignificant in all the cases. The coefficient of D_t is positive in three of the stocks, but statistically insignificant. The above results support H2 that there is no difference in volatility between pre- and post-limit periods.

Past evidence shows, however, that the volatility of monthly returns may be affected by other variables. For example, Schwert (1989) suggests a variety of

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[18] Estimated standardised residuals are defined as:

$$z_t = \hat{\varepsilon}_t/\hat{h}_t^{1/2},$$

where $\hat{\varepsilon}_t$ is the residual from the GARCH model and $\hat{h}_t$ is its estimated conditional variance.

[19] It should be noted that had the price limits been found important we should have had to take into account the truncated nature of the return distributions to avoid having biased estimates, see Yang and Brorsen (1995).

[20] We performed this exercise for the stocks that ARCH/GARCH effects were still prominent in the series. As it has been shown in many studies, e.g. Drost and Nijman (1993), ARCH processes converge to normality under temporal aggregation.

macroeconomic variables, such as the volatility of inflation, money growth and industrial production. A change in the level of uncertainty about future macroeconomic conditions would cause a proportional change in stock return volatility by affecting future expected cash flows.[21] In order to avoid a possible misspecifi-

Table 5

GARCH estimates of daily stock returns.

$$r_t = a_0 + a_1 r_{t-1} + a_2 r_{t-2} + a_3 r_{t-3} + a_4 r_{t-4} + a_6 r_{t-6} + \varepsilon_t; \quad \varepsilon_t \sim IN(0, h_t)$$

$$h_t = \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 + \beta_1 h_{t-1} + \beta_2 h_{t-2} + \gamma V_{t-1} + \delta D_t$$

Log likelihood function	RD1	RD2	RD3	RD4	RD5	RD6	RD7
	3744	4089	4417	3191	3918	4266	4378
$a_0 \times 10^3$	−1.126	−0.648	−0.912	−1.451	−0.545	−0.971	−0.002
	(−1.892)	(−1.410)	(−2.687)	(−1.973)	(−1.081)	(−2.065)	(−0.007)
a_1		0.066	0.106	0.056	0.128	0.085	
		(2.292)	(3.928)	(2.192)	(4.304)	(2.859)	
a_2	−0.056			−0.082	0.060		−0.109
	(−2.316)			(−2.966)	(3.182)		(−4.161)
a_3	−0.055		0.094		0.058		
	(−0.176)		(2.926)		(3.032)		
a_4					0.078		
					(3.896)		
a_6				−0.052			
				(−1.984)			
$\alpha_0 \times 10^4$	0.234	0.292	0.143	0.304	3.936	0.811	0.156
	(5.599)	(7.218)	(22.090)	(7.138)	(55.487)	(10.737)	(3.947)
α_1	0.107	0.190	0.167	0.081	0.403	0.177	0.189
	(9.212)	(10.007)	(31.381)	(9.062)	(15.910)	(8.840)	(7.905)
β_1	0.193	0.171	0.800	0.887		0.646	0.684
	(2.867)	(3.709)	(189.573)	(97.632)		(22.412)	(28.841)
β_2	0.670	0.556					
	(10.420)	(12.784)					
$\gamma \times 10^8$	0.001	0.219	2.037	0.000	1.540	0.000	0.177
	(0.133)	(4.748)	(14.690)	(0.000)	(8.057)	(0.000)	(8.916)
$\delta \times 10^5$	0.000	0.000	0.000	0.000	0.000	0.000	0.287
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.905)
m_3	0.339	0.064	−0.429	0.129	−0.753	0.342	0.169
m_4	2.948	3.764	17.417	1.931	10.382	7.507	3.289
$Q(20)$	11.7	13.9	15.8	12.1	8.47	21.9	30.7
$Q^2(20)$	11.6	15.2	24.0	29.7	16.50	24.2	27.6

Notes: The sample period is January 1990–June 1996. *T*-statistics are in parentheses below each coefficient. m_3 and m_4 are the coefficients of skewness and kurtosis of the standardised residuals. $Q(20)$, and $Q^2(20)$ are Ljung–Box statistics of the 20th order of the standardised and squared standardised residuals respectively. For the abbreviations of the stocks see Table 1.

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[21] In the case of positively autocorrelated variables, such as the volatility of stock returns, an unexpected increase in the variable implies an increase in expected future values of the series for many steps ahead.

Table 5—*Continued*

$$r_t = a_0 + a_1 r_{t-1} + a_2 r_{t-2} + a_3 r_{t-3} + a_4 r_{t-4} + a_{10} r_{t-10} + a_{15} r_{t-15} + \varepsilon_t; \quad \varepsilon_t \sim IN(0, h_t)$$
$$h_t = \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 + \alpha_2 \varepsilon_{t-2}^2 + \beta_1 h_{t-1} + \beta_2 h_{t-2} + \gamma V_{t-1} + \delta D_t$$

Log likelihood function	RD8	RD9	RD10	GID[a]
	4492	3614	4249	2130
$a_0 \times 10^3$	0.338	−0.737	0.462	−0.643
	(1.071)	(−1.415)	(1.323)	(−1.194)
a_1	0.047	0.085	0.130	0.250
	(1.792)	(3.050)	(4.573)	(6.311)
a_2				−0.124
				(−3.767)
a_3		0.046		
		(1.676)		
a_4				0.099
				(2.979)
a_{10}			0.041	0.100
			(1.743)	(3.673)
a_{15}		−0.040		
		(−1.947)		
$\alpha_0 \times 10^4$	0.109	0.427	0.064	0.000
	(3.733)	(7.463)	(4.545)	(0.000)
α_1	0.205	0.204	0.133	0.333
	(8.153)	(7.249)	(8.500)	(6.516)
α_2	0.189			
	(5.9830			
β_1	0.506	0.467	0.809	0.470
	(16.902)	(3.140)	(41.584)	(10.443)
β_2		0.273		
		(2.177)		
$\gamma \times 10^8$	0.316	0.000	0.002	0.005
	(16.205)	(0.000)	(0.347)	(9.293)
$\delta \times 10^5$	0.000	0.000	1.891	0.000
	(0.000)	(0.000)	(6.164)	(0.000)
m_3	−0.865	0.004	0.227	0.801
m_4	18.081	2.608	2.715	7.388
$Q(20)$	20.6	24.1	21.2	17.0
$Q^2(20)$	9.8	18.1	16.5	16.7

Notes: [a] The sample period for GID is from 4 January 1990 to 30 April 1993. See also notes to Table 5.

cation of the variance, which could have biased our results, we repeated the tests and included these other determinants in the conditional variance. Equation (5) is then expanded to

$$h_t = \alpha_0 + \sum_{i=1}^{p} \alpha_i \varepsilon_{t-i}^2 + \sum_{j=1}^{q} \beta_j h_{t-j} + \gamma V_{t-1} + \delta D_t + \sum_{k=1}^{k} \zeta_k x_{k,t}, \tag{6}$$

where $x_{k,t}$ is the volatility of each macroeconomic variable (inflation, money growth and industrial production). The latter has been calculated by estimating first a 12th-order autoregressive system, AR(12), for each variable, including monthly dummy variables, and then estimating another 12th-order autoregressive system (including dummy variables) for the absolute values of the retrieved errors from the first step. The fitted values from the second AR system are the conditional variance for the variable in question.

The evidence indicates (results not shown but can be made available from the authors), that there is no change in our conclusions with regard to the effects of the price limits. In fact, it was found that in very few cases the variance of the macroeconomic variables was statistically significant.

6. Summary and conclusion

In this paper, we have examined the effects of price limits on the stock volatility of a cross section of individual shares and the general price index in the Athens Stock Exchange. We put forward two hypotheses, the information hypothesis,

Table 6

GARCH estimates of monthly stock returns.

$$r_t = a_0 + a_3 r_{t-3} + a_4 r_{t-4} + a_7 r_{t-7} + \varepsilon_t; \quad \varepsilon_t \sim IN(0, h_t)$$
$$h_t = \alpha_0 + \alpha_1 \varepsilon^2_{t-1} + \alpha_3 \varepsilon^2_{t-3} + \beta_1 h_{t-1} + \gamma V_{t-1} + \delta D_t$$

Log likelihood function	RM1	RM3	RM4	RM6	RM7
	64.47	57.95	46.89	62.69	84.73
a_0	−0.016	−0.024	−0.023	−0.007	−0.003
	(−1.233)	(−2.510)	(−1.730)	(−0.703)	(−0.349)
a_3	−0.260				
	(−1.765)				
a_4		−0.297			−0.450
		(−2.881)			(−4.572)
a_7		0.220			−0.177
		(2.443)			(−1.826)
$\alpha_0 \times 10^3$	0.000	1.952	6.441	6.512	0.210
	(0.000)	(1.035)	(1.534)	(2.930)	(0.117)
α_1		0.412	0.235	0.598	
		1.327	(2.446)	(2.275)	
α_3			0.303		
			(1.716)		
β_1	0.969				0.899
	(32.138)				(4.201)
$\gamma \times 10^6$	0.000	0.631	0.000	0.002	
	(0.000)	(2.833)	(0.000)	(0.006)	
$\delta \times 10^3$	0.183	0.000	1.467	0.000	0.187
	(0.578)	(0.000)	(0.333)	(0.000)	(0.191)
m_3	0.266	0.063	−0.433	0.316	−0.267
m_4	0.289	0.295	0.607	0.481	0.402
$Q(20)$	22.1	24.6	23.1	27.9	12.0
$Q^2(20)$	15.3	14.8	19.4	18.3	12.1

Notes: The sample period is January 1990–June 1995. See also notes to Table 5.

which assumes that the true equilibrium price and volatility is driven by the arrival of information and traders act upon it, so that price limits only slow down the process of adjustment and have no effect on stock volatility; and the overreaction hypothesis, which assumes that investors tend to overreact to new information, so that price limits give them time to reassess the information and reduce stock volatility.

Using econometric techniques such as serial correlation and GARCH models, our results show strong support for the information hypothesis. Price limits only prolong the number of trading days it will take for the market to adapt to a disturbance towards equilibrium and have no effect on volatility. This evidence was obtained by performing the tests on ten stocks, which include heavily traded stocks as well as less active stocks, and cover a variety of industries, and on a market wide price index. The results are also robust to the frequency of the returns (we use both daily data and monthly data), and to the tightness of the limits (we use both, shares which are subject to the 8% limit and shares which are subject to the 4% limit).

In only one case, we find price limits to have an effect on stock volatility and that was to increase it. In a thinly traded market, such as the one in Greece, price limits could be used by big hands to signal their manipulation to uninformed traders. Big hands can push a share price to its daily limit for a few sessions and that could attract many uninformed traders as it gives them the illusion that the price could keep on hitting its limits, and that could increase volatility.[22]

In conclusion, based on our cross-section of stocks and the general price index the imposition of price limits in the Athens Stock Exchange have not had the desired effect on stock market volatility, which was to reduce it.

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[22] The big hand theory has been proposed by Keynes (1936), who found that price limits merely provide a tool for big hands to signal their manipulation to attract followers.

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