Stock market liberalization and return volatility: Evidence from the emerging market of Sri Lanka

Fazeel M. Jaleela, Lalith P. Samarakoonb,∗

a Department of Economics, Macquarie University, Sydney, NSW 2109, Australia
b Department of Finance, Opus College of Business, University of St. Thomas, 2115 Summit Ave, St. Paul, MN 55105, United States

Abstract

This study examines the impact of liberalization of the Sri Lankan stock market on return volatility. We specify GARCH and TGARCH models of volatility, and estimate them using 16 years of weekly returns for the period from 1985 to 2000. The results show that liberalization of the market to foreign investors significantly increased the return volatility in the Colombo Stock Exchange. Both conditional and unconditional volatility measures are the highest in the liberalization period. Negative return shocks lead to lower volatility suggesting that there is no leverage effect, and this appears to reflect the very low levels of leverage used by Sri Lankan companies.

© 2009 Elsevier B.V. All rights reserved.

1. Introduction

A growing body of literature examines the impact of stock market liberalization on return volatility in emerging stock markets.1 Over the last two decades, a large number of developing countries have taken steps to open their stock markets to foreign investors by removing various restrictions such as taxes, ownership limits, and exchange and capital controls. The primary objective of this paper is to examine the effect of stock market liberalization on return volatility in the Colombo Stock Exchange (CSE) of Sri Lanka.

1 For example, Kassimatis (2002), Huang and Yang (2000), Kim and Singal (2000), and Bekaaert and Harvey (1997).
The Sri Lankan stock market was opened to foreign investors in June 1990 by removing the prohibitive 100% transfer of property tax imposed on share purchases of foreign investors. Did the liberalization of the market change the return volatility? Sri Lanka provides an excellent case for examining this issue because of the absence of other market characteristics that may potentially lead to higher volatility. There are no exchange-traded derivative instruments or short-selling of stocks that might otherwise lead to more volatility. Sri Lankan stocks are not cross-listed in any other exchanges, and as a result the market is immune from any volatility transfers through cross-listed shares. Although foreign investors are allowed to trade Sri Lankan equities, domestic investors are not allowed to invest outside of Sri Lanka, thus limiting the potential volatility of portfolio flows. Thus, these characteristics make Sri Lanka an interesting market to examine the impact of market liberalization on return volatility.

We study the impact of market liberalization on return volatility employing GARCH and T-GARCH models. Specifically, we investigate whether the volatility has changed in the liberalization and the post-liberalization periods relative to the pre-liberalization period. We also examine whether positive and negative return shocks have an asymmetric effect on return volatility and thereby provide evidence of any leverage effect in Sri Lanka. This study uses weekly returns data from the CSE for the 16-year period from 1985 to 2000.

The results of this study indicate that liberalization has significantly increased volatility of returns in the CSE. The volatility is significantly higher in the five-year liberalization window period compared with the pre-liberalization period. Further, the market is more volatile to positive shocks than negative shocks indicating that no leverage effect exists in the market. The capital structure data show that this lack of leverage effect possibly reflects the very low levels of leverage in Sri Lankan companies. This study contributes to the existing literature by providing strong evidence of volatility increases following stock market liberalization in a market that does not have other potential volatility increasing factors such as derivatives trading, short-selling, cross-listings, and domestic portfolio flows abroad. Further, there have been no prior published work on liberalization and volatility in the Sri Lankan stock market, although there have been research on return predictability and market efficiency.

The remainder of this paper is organized as follows. Section 2 presents a summary of previous studies. Section 3 provides an overview of the liberalization process in Sri Lanka and Section 4 describes the data used in the study. The methodology of the study is described in Section 5. The empirical results are presented in Section 6. Section 7 presents the conclusions.

2. Previous studies

The prior evidence on the impact of liberalization on volatility has been mixed. Some studies reported an increase in volatility in the post-liberalization period while others found a decrease in volatility. For example, using GARCH models, Huang and Yang (2000) examined the impact of financial liberalization on post-liberalization stock market volatility in ten emerging markets. They found evidence of volatility increases in South Korea, Mexico and Turkey, and significant volatility decreases in Argentina, Chile, Malaysia, and the Philippines. However, they found no clear change in volatility changes in Thailand, Taiwan, and Brazil.

Levine and Zervos (1998) studied the effects of capital control liberalization on volatility in 16 emerging economies and found higher volatility in the post-liberalization period. Uppal (1998) examined changes in volatility of stock returns in the Karachi Stock Exchange in Pakistan and reported significant increases in volatility following the market opening. The results also indicated that volatility stabilized after the market opening at a new and higher level. Grabel (1995) reported significant increase in volatility during financial liberalization in Chile, Colombia, Venezuela and South Korea, and less significant volatility increases in Argentina and the Philippines. Using GARCH models for the Jamaican stock market, Koot and Padmanbhan (1993) found significantly higher volatility in the period after liberalization.

While the above studies primarily show evidence of higher volatility after liberalization, there is also substantial evidence that liberalization is followed by lower volatility. Using an Exponential GARCH model, Kassimatis (2002) showed that volatility fell after important liberalization policies were implemented in Argentina, India, Pakistan, the Philippines, South Korea, and Taiwan. Kim and Singal (2000) employed ARCH and GARCH models to examine the impact of market opening on changes in the level and the volatility of stock returns in 14 emerging stock markets. Their results showed that volatility levels during the first two years after the market opening were not significantly different from those before the opening. They also showed a significant decrease in stock return volatility in the fourth and fifth year after liberalization.

Bekaert and Harvey (1997) investigated the effects of liberalization policies on stock market volatility in 17 emerging markets. They found very significant drops in volatility in Brazil, Mexico, Taiwan, Portugal, and Argentina and non-significant decreases in volatility in others. Using GARCH models, Kwan and Reyes (1997) found that liberalization led to significantly lower volatility in Taiwan.

Some studies have reported no significant changes in volatility following market liberalization. For example, De Santis and Imrohoroglu (1997) found no obvious relationship between liberalization and volatility in some countries in Europe/Middle-East, Asia and Latin America. \(^3\) Spyrou and Kassimatis (1999) also showed that there was no significant change in volatility after liberalization in Argentina, Chile, Mexico, India, Pakistan, the Philippines, and Taiwan.

Further, a number of recent studies have shown that there is often an asymmetry in the way innovations impact stock return volatility (e.g., Pagan and Schwert, 1990; Engle and Ng, 1993). The asymmetric effect refers to the situation where bad news tends to cause more volatility than good news. This asymmetric effect is attributed to the use of debt financing by firms and is known as the leverage effect (e.g., Black, 1976; Christie, 1982). There is a close connection between stock return volatility and leverage. The leverage effect argues that a negative stock return decreases the stock price thereby increasing the leverage of the firm, and increased leverage leads to more stock price volatility. On the other hand, a positive stock return decreases the leverage of the firm and the stock volatility. Thus, leverage causes negative shocks to have a greater impact on conditional volatility than do positive shocks, and leads to asymmetric changes in stock return volatility.

### 3. Liberalization process in Sri Lanka

The Sri Lankan stock market, in its present form, was established in 1984 with the formation of the Colombo Stock Exchange. The initial date of liberalization of the CSE to foreign investors was June 05, 1990 when the government abolished the 100% transfer of property tax on share purchases by non-nationals subject to the limitation that their aggregate shareholding shall not exceed 40% of the issued capital of a company. Non-nationals include both foreign institutional and individual investors. In the same year, the government relaxed exchange controls on inward remittances for share purchases and outward remittances of surpluses on dealings on listed shares.

Table 1 presents the trading statistics of the CSE during the study period. Accordingly, the initial liberalization led to tremendous increases in market turnover and returns. In 1990, the first year of liberalization, market turnover increased from 0.2 to 1.6 million rupees, and the market index rose by an unprecedented 114%. In 1991, the year after the initial liberalization, the turnover increased by 244%, and 40% of the turnover was attributable to trading by foreign investors. In the same year, the market index increased by 118%, which represents the largest annual increase ever.

The second key date of liberalization was March 31, 1992 when the 100% transfer of property tax on share purchases by non-nationals was completely removed except in certain companies where foreign ownership was restricted. The restricted companies included banks, insurance companies, housing and mining firms, plantations, and companies that had restrictive provisions in their Articles of Association. We consider this as the date of full liberalization. Since then, some of these ownership restrictions, particularly for banks and insurance companies, have been further relaxed. In 1993, the year after the

---

\(^3\) The countries studied were Greece, Turkey, India, Korea, Malaysia, Philippines, Taiwan/China, Thailand, Argentina, Brazil, Chile, Columbia, Mexico, and Venezuela.
## Table 1

<table>
<thead>
<tr>
<th></th>
<th>Pre-liberalization period</th>
<th>Liberalization window period</th>
<th>Post-liberalization</th>
</tr>
</thead>
<tbody>
<tr>
<td>Market capitalization</td>
<td>9.9/11.8/18.5/15.7/17.1</td>
<td>36.9/81.8/66.2/124.1/143.2</td>
<td>106.9/104.2/129.4/116.7/112.8</td>
</tr>
<tr>
<td>Turnover (Rs. Bn.)</td>
<td>0.1/0.1/0.3/0.4/0.2/0.2</td>
<td>1.6/5.5/6.2/22.1/34.5</td>
<td>11.2/7.4/18.3/18.2/14.8</td>
</tr>
<tr>
<td>Domestic turnover</td>
<td>na/na/na/na/na</td>
<td>3.4/4.7/14.4/20.7/5.8</td>
<td>3.4/10.5/11.8/9.3/7.9</td>
</tr>
<tr>
<td>Foreign turnover</td>
<td>na/na/na/na/na</td>
<td>2.2/1.5/7.7/13.8/5.4</td>
<td>4.0/7.9/6.4/5.5/3.1</td>
</tr>
<tr>
<td>Number of trades</td>
<td>4/9/15/13/17</td>
<td>48/92/110/113/424</td>
<td>404/186/98/206/329</td>
</tr>
<tr>
<td>Number of trades</td>
<td>(Thousands)</td>
<td>114/118/–28/62/1</td>
<td>–33/–9/17/–15/–4</td>
</tr>
<tr>
<td>Market return (%</td>
<td>b 27/16/55/–23/6</td>
<td>114/118/–28/62/1</td>
<td>–33/–9/17/–15/–4</td>
</tr>
</tbody>
</table>

na indicates that the data are not available.
Rs. Bn. stands for rupees billion, and Mn. stands for million.
Source: Colombo Stock Exchange Annual Reports.

a Turnover is the value of all the transactions.
b Annual change in the All Share Price Index (ASPI) of the CSE.
second liberalization initiative, the market turnover rose from 6.2 to 22.1 million rupees, and trading by foreign investors increased more than five times relative to the previous year. Furthermore, the market index rose by 62% in 1993. The foreign investor activity peaked in 1994, the second year after the full liberalization of the market. Thus, there was a substantial increase in turnover, both domestic and foreign, the number of shares traded, the number of trades, and market return following both the initial and second liberalization initiatives.

Fig. 1 illustrates the liberalization time line. Liberalization is a sequential process. It is likely that information leakages occur, and that market participants react to such information before the actual liberalization date. Hence, consistent with the literature, we define an approximately five-year liberalization window period (Lib) as the period from seven months prior to the initial liberalization to four-and-half years after the initial liberalization (11/89 to 12/94). Then, we define the five-year period before the liberalization window period as the pre-liberalization period (Prelib) and the six-year period after the liberalization window period as the post-liberalization (Postlib). Each sub-period covers approximately five years. Further, we also examine the liberalization and post-liberalization periods (LibPostlib) together as one sub-period.

4. Data

The main stock index of the CSE is the All Share Price Index (ASPI) which is a value-weighted index of stock prices of all listed companies. This study uses continuously compounded weekly returns of the ASPI for the 16-year period from January, 1985 to December, 2000. The total number of observations in the study period is 829. The index data are from the CSE and not adjusted for dividends.6 Insider trading is prohibited in Sri Lanka. Stock brokers act as intermediaries to transactions and do not engage in market making. There is no over-the-counter market and the CSE is the only place of share trading. The trading in the CSE is completely automated. Further, there are no derivatives, no short-selling, and no cross-listed stocks. Fig. 2 shows the daily movements of the market index. The market exhibited a boom during the liberalization period. The market index increased from 172 to 987 during the liberalization period representing a cumulative return of 474%.

4 Henry (2000) used a seven-month event window to investigate the effect of market liberalization in 12 emerging markets.
5 Kim and Singal (2000) split the sample period into two five-year sub-periods as before and after liberalization and argued that a five-year period is long enough to capture the effects of market liberalization.
6 An index with dividends is not available for the Sri Lankan market. French et al. (1987) suggested that since the ex-dividend days are different for different stocks in a stock price index excluding dividends should have little effect on the volatility estimates of an aggregate index. Nelson (1991) also pointed out that excluding dividends is not likely to result in important errors when forecasting volatility.
Fig. 2. Daily movements of the market index.

Fig. 3. Weekly market returns.

Fig. 3 shows weekly returns to the market index. The behaviour of weekly returns shows evidence of volatility increases in the period following the liberalization (1989–2000) relative to the pre-liberalization period. The weekly returns indicate two spikes, one positive spike in April 1990 and one negative spike April 1994, both of which fall into the liberalization window period. These two observations were winsorized by setting the value of the positive spike equal to the next highest positive value and the value of the negative spike equal to the next lowest negative value. The study uses the winsorized weekly returns series.

Table 2 provides the descriptive statistics on weekly returns. These returns appear to be stationary. The mean weekly return for the pre-liberalization period (Prelib) is 0.0344% and not very different from that in the full period (0.0386%). However, the mean return in the liberalization period is 0.1209% indicating that the period of market opening to foreign investors is associated with higher returns. The mean return in the post-liberalization period (Postlib) is negative (−0.0284%). The mean return in the combined period of liberalization and post-liberalization (LibPostlib) is not very different from the pre-liberalization period either. Thus, quite clearly the average returns are significantly higher in the liberalization period relative to both pre- and post-liberalization periods. The unconditional volatility,

---

7 All the results are qualitatively similar even without winsorizing these outliers.
Table 2
Descriptive statistics for weekly returns.

<table>
<thead>
<tr>
<th>Period</th>
<th>Mean (%)</th>
<th>Median (%)</th>
<th>Standard deviation (%)</th>
<th>Skewness(^a)</th>
<th>Kurtosis(^b)</th>
<th>Jarque-Bera(^c)</th>
<th>Q(12)(^d)</th>
<th>Q(24)(^e)</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full</td>
<td>0.0386</td>
<td>0.0128</td>
<td>0.6436</td>
<td>0.85</td>
<td>8.31</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>829</td>
</tr>
<tr>
<td>Prelib(^f)</td>
<td>0.0344</td>
<td>0.0245</td>
<td>0.4606</td>
<td>0.51</td>
<td>7.29</td>
<td>0.000</td>
<td>0.013</td>
<td>0.088</td>
<td>248</td>
</tr>
<tr>
<td>Lib(^g)</td>
<td>0.1209</td>
<td>0.0289</td>
<td>0.8002</td>
<td>1.11</td>
<td>7.67</td>
<td>0.000</td>
<td>0.000</td>
<td>0.048</td>
<td>268</td>
</tr>
<tr>
<td>Postlib(^h)</td>
<td>−0.0284</td>
<td>−0.0332</td>
<td>0.6106</td>
<td>0.06</td>
<td>4.69</td>
<td>0.000</td>
<td>0.041</td>
<td>0.059</td>
<td>313</td>
</tr>
<tr>
<td>LibPostlib(^i)</td>
<td>0.0404</td>
<td>0.0000</td>
<td>0.7078</td>
<td>0.85</td>
<td>7.55</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>581</td>
</tr>
</tbody>
</table>

\(^a\) Skewness measures the asymmetry of the distribution of returns around its mean.  
\(^b\) Kurtosis measures the peakedness of the distribution of return.  \(K = 3\) for normal distribution; if \(K > 3\) the distribution is leptokurtic.  
\(^c\) \(p\)-Values of the Jarque-Bera statistic for testing the normality of returns.  
\(^d\) \(p\)-Value of the Ljung-Box Q-statistic at 12 lag.  
\(^e\) \(p\)-Value of the Ljung-Box Q-statistic at 24 lag.  

measured by the standard deviation of weekly returns, is 0.8002% in the liberalization period compared with 0.4606% before the liberalization. Further, the volatility is the highest in the liberalization period relative to all other periods considered. The returns are more volatile in the post-liberalization and LibPostlib periods relative to the pre-liberalization period as well. These statistics clearly point to higher returns and higher volatility in the liberalization window period.

The statistics given in Table 2 also show that returns are positively skewed and leptokurtic. This is more pronounced in the liberalization period. The Jarque-Bera test statistic strongly rejects the null hypothesis of normal distribution for all periods considered. The Ljung-Box Q-statistic rejects the null hypothesis of no autocorrelation up to 24 lags. This suggests the existence of linear dependency in returns indicating that it might be possible to predict returns from past returns.

5. Methodology

We employ autoregressive conditional heteroskedastic (ARCH), and generalized autoregressive conditional heteroskedastic (GARCH) models for modelling heteroskedastic conditional volatility. The ARCH (Engle, 1982) models assume that the variance of the error term in a given period depends on the squared error terms from previous periods. The volatility in past periods is captured by the lags of the squared residuals. The GARCH (Bollerslev, 1986) models extend the ARCH model to allow for the variance of the error term to depend on its own lags as well as lags of the squared errors. Therefore, the GARCH model can capture the volatility changes with less parameters than the ARCH models.

The autoregressive (AR) model for returns specifies the current returns as a function of lagged returns as follows:

\[
R_t = \beta_0 + \sum_{i=1}^{n} \beta_i R_{t-i} + \epsilon_t
\]

where \(R_t\) is the current return, \(R_{t-i}\) is the lagged return, and \(\epsilon_t\) is the error term. The residuals and the squared residuals of this equation are tested for both autocorrelation and heteroskedasticity. The weekly return series is adjusted for autocorrelation. The results of modelling the weekly return series as an AR process are presented in Table 3. An AR(1) process is sufficient to eliminate the serial correlation in all periods except in the post-liberalization period where an AR(2) process is required. Although the AR processes are able to adequately remove the linear dependence of the series, the Ljung-Box Q-statistic for squared residuals suggest the existence of non-linear dependence in all periods except in the pre-liberalization period. The ARCH-LM statistic shows clear evidence of ARCH effects in the errors in all periods. Hence, we use GARCH-type models as specified below.
Table 3
Box-Jenkins estimation and specification tests.

<table>
<thead>
<tr>
<th>Period</th>
<th>$\hat{\beta}_0$</th>
<th>$\hat{\beta}_1$</th>
<th>$\hat{\beta}_2$</th>
<th>$Q_{(12)}$</th>
<th>$Q_{(24)}$</th>
<th>$Q^2_{(12)}$</th>
<th>$Q^2_{(24)}$</th>
<th>ARCH-LM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full</td>
<td>0.030 (0.16)</td>
<td>0.215 (0.00)</td>
<td>22.94 (0.03)</td>
<td>33.14 (0.10)</td>
<td>236.42 (0.00)</td>
<td>246.64 (0.00)</td>
<td>128.30 (0.00)</td>
<td>128.30 (0.00)</td>
</tr>
<tr>
<td>Prelib</td>
<td>0.027 (0.35)</td>
<td>0.234 (0.00)</td>
<td>5.95 (0.92)</td>
<td>13.83 (0.95)</td>
<td>13.54 (0.33)</td>
<td>19.85 (0.71)</td>
<td>16.48 (0.03)</td>
<td>16.48 (0.03)</td>
</tr>
<tr>
<td>Lib</td>
<td>0.091 (0.06)</td>
<td>0.247 (0.00)</td>
<td>23.71 (0.02)</td>
<td>33.62 (0.09)</td>
<td>92.38 (0.00)</td>
<td>97.16 (0.00)</td>
<td>45.51 (0.00)</td>
<td>45.51 (0.00)</td>
</tr>
<tr>
<td>Postlib</td>
<td>-0.021 (0.53)</td>
<td>0.118 (0.04)</td>
<td>8.28 (0.60)</td>
<td>22.42 (0.57)</td>
<td>36.60 (0.00)</td>
<td>44.31 (0.00)</td>
<td>25.22 (0.00)</td>
<td>25.22 (0.00)</td>
</tr>
<tr>
<td>LibPostlib</td>
<td>0.032 (0.24)</td>
<td>0.212 (0.00)</td>
<td>21.04 (0.05)</td>
<td>30.66 (0.16)</td>
<td>170.46 (0.00)</td>
<td>176.52 (0.00)</td>
<td>96.10 (0.00)</td>
<td>96.10 (0.00)</td>
</tr>
</tbody>
</table>

$Q_{(12)}$ and $Q_{(24)}$ indicate the Ljung-Box $Q$-statistic at lags 12 and 24, respectively. $Q^2_{(12)}$ and $Q^2_{(24)}$ represent Ljung-Box $Q$-statistic of squared residuals at lags 12 and 24, respectively. ARCH-LM test statistic at lag 4. $p$-Values are in parentheses.

$$R_t = \hat{\beta}_0 + \sum_{i=1}^{n} \beta_i R_{t-i} + \epsilon_t$$ (1)
5.1. The GARCH model of volatility

The GARCH (p,q) process is specified as follows:

\[
R_t = \phi_0 + \phi_1 R_{t-1} + \varepsilon_t \\
\varepsilon_t / \psi_{t-1} \sim N(0, h_t) \\
h_t = \alpha_0 + \sum_{i=1}^{q} \alpha_i \varepsilon^2_{t-1} + \sum_{j=1}^{p} \beta_j h_{t-1}
\]

(2)

(3)

where \( R_t \) is the current return, \( R_{t-1} \) is the lagged return, and \( \varepsilon_t \) is the error term. \( h_t \) is the current conditional volatility, and \( h_{t-1} \) is the lagged conditional volatility. The coefficients \( \alpha_0 > 0, \alpha_i \geq 0 \) and \( \beta_j \geq 0 \) for all \( i \) and \( j \), and \( (\sum_{i=1}^{q} \alpha_i + \sum_{j=1}^{p} \beta_j) < 1 \). The sum of the slope coefficients \( (\sum_{i=1}^{q} \alpha_i + \sum_{j=1}^{p} \beta_j) \) measures the persistence of volatility. The Maximum Likelihood (ML) method is used to estimate the parameters of the conditional mean (Eq. (2)), and the variance equation (Eq. (3)). The best model is chosen on the basis of the minimum values of Akaike Information Criterion (AIC) and Schwarz Criterion (SC). Various ARCH(p) and AR(s)-GARCH(p,q) models were estimated, and the AR(1)-GARCH(1,1) model produced better estimations. Accordingly, the model is specified as follows:

\[
R_t = \phi_0 + \phi_1 R_{t-1} + \phi_2 R_{t-2} + \varepsilon_t \\
\varepsilon_t / \psi_{t-1} \sim N(0, h_t) \\
h_t = \alpha_0 + \alpha_1 \varepsilon^2_{t-1} + \beta_1 h_{t-1} + \lambda_1 Lib_t + \lambda_2 Postlib_t \\
h_t = \alpha_0 + \alpha_1 \varepsilon^2_{t-1} + \beta_1 h_{t-1} + \lambda_2 Postlib_t
\]

(4)

(5)

(6)

To examine the effect of liberalization on volatility, two dummy variables, Lib and Postlib, are included in the conditional variance equation (5). The variable Lib takes the value 1 in the liberalization period and zero otherwise, and Postlib equals 1 in the post-liberalization period and zero otherwise. A statistically significant \( \lambda_1 \) will indicate that liberalization has had a significant impact on the volatility of returns, while a significant \( \lambda_2 \) will imply that the volatility in the post-liberalization period is reliably different from that in the pre-liberalization period. We also investigate whether the volatility has changed in the entire period after the initial liberalization (liberalization plus post-liberalization period or LibPostlib) relative to the pre-liberalization period when the market was closed. This is accomplished through the specification of the alternative conditional variance equation (6) where LibPostlib takes the value of 1 in the liberalization and post-liberalization periods and 0 otherwise.

5.2. The TGARCH model and asymmetric shocks

In Eqs. (5) and (6) above, the conditional variance is specified as a linear function of past squared errors and past conditional volatility. This linear GARCH model does not capture the asymmetric changes in stock return volatility. As discussed previously, some studies have shown that negative return shocks cause more volatility than positive return shocks, and this has been interpreted as due to a leverage effect (e.g., Black, 1976; Christie, 1982). The leverage effect suggests that when stock prices decline due to negative shocks, the leverage of the firm increases leading to higher stock price volatility. In order to accommodate this asymmetric response, we employ the Threshold-GARCH (TGARCH) model proposed by Glosten et al. (1993), and Zakoian (1994). The TGARCH model incorporates a dummy variable to capture the effect of unexpected returns on the conditional variance of returns. The conditional variance of the TGARCH model is specified as follows:

\[
h_t = \alpha_0 + \sum_{i=1}^{q} \alpha_i \varepsilon^2_{t-1} + \sum_{j=1}^{p} \beta_j h_{t-1} + \gamma \varepsilon^2_{t-1} d_{t-1} + \lambda_1 Lib_t + \lambda_2 Postlib_t
\]

(7)
where \( d_{t-1} = 1 \) if \( \varepsilon_{t-1} < 0 \) and 0 otherwise. If \( \gamma > 0 \) and significant, then there is evidence of a leverage effect. It means that adverse market conditions or negative shocks cause more volatility than positive shocks. We estimate both the GARCH and TGARCH models and discuss the results below.

6. Empirical results

The parameters of the GARCH and TGARCH models are estimated using the Maximum Likelihood method. Table 4 summarizes the estimates of the GARCH(1,1) model, and Table 5 provides the results of the TGARCH(1,1) model.

6.1. Impact of liberalization on volatility

First, we assess the impact of past volatility on current volatility by examining the GARCH coefficient \((\beta_1)\). During the full period, the coefficient is estimated as 0.233 and 0.248, respectively, in the two conditional variance equations. They are statistically significant at 1% indicating that current volatility is affected by past volatility. The GARCH coefficient takes the highest value in the liberalization period (0.558) and is more than two times the coefficient in the post-liberalization period. These results clearly suggest that past volatility has had the largest impact on current volatility during the liberalization period.

The key to understanding the impact of market liberalization on volatility is to examine the coefficients on the dummy variables Lib, Postlib and LibPostlib which represent the liberalization, post-liberalization, and liberalization plus post-liberalization periods, respectively. The Lib coefficient is 0.166 in the GARCH model (Eq.(5)), and 0.167 in the TGARCH model (Eq.(7) in Table 5), both of which are significant at 1%. These results indicate that volatility is significantly higher during the liberalization period. The coefficient for Postlib is much smaller and not significant in the GARCH model and significant at 10% in the TGARCH model. Thus, there is no convincing evidence to suggest that the volatility in the post-liberalization period is very different from that in the pre-liberalization period. Therefore, the results indicate that past volatility has had the largest impact on current volatility during the liberalization period suggesting that market liberalization resulted in a reliable increase in volatility.

The LibPostlib coefficient is used to assess if the volatility in the combined period of liberalization and post-liberalization is different relative to the pre-liberalization period. The coefficient is 0.085 in the GARCH model and 0.096 in the TGARCH model, and both are significant at 1%. This suggests that there has been an increase in return volatility following liberalization reforms compared with the period when the market was not open to foreign investors. However, this higher volatility in the LibPostlib period is attributable to the higher volatility in the five-year liberalization window period.

6.2. Asymmetric shocks and volatility

Next we turn to the results on the impact of asymmetric shocks on volatility in the TGARCH model, which are reported in Table 5. The asymmetric coefficient \((\gamma)\) captures the impact of negative vs. positive shocks on volatility. An asymmetric coefficient that is reliably greater than zero will indicate that negative shocks cause more volatility than positive shocks. However, we find the opposite. In the full period, the asymmetric coefficient is \(-0.168\) in Eq. (7) and \(-0.266\) in Eq. (8), both of which are significantly less than zero. This asymmetric effect is much more negative in the liberalization period \((-0.446)\). Thus, negative shocks are significantly negatively related with volatility suggesting that negative shocks in fact have made the market less volatile in both the full and liberalization periods.

---

8 The two dummy variables (Lib and Postlib) in the mean equation (Eq. (4)) are not significant.
Table 4  
Maximum likelihood estimates for the AR(s)-GARCH(1,1).

<table>
<thead>
<tr>
<th>Period</th>
<th>Model</th>
<th>$\phi_0$</th>
<th>$\phi_1$</th>
<th>$\phi_2$</th>
<th>$\omega_0$</th>
<th>$\omega_1$</th>
<th>$\beta_1$</th>
<th>$\lambda_1$</th>
<th>$\lambda_2$</th>
<th>$\lambda_3$</th>
<th>$\text{LL}^a$</th>
<th>$\text{AIC}^b$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full</td>
<td>AR(1)-GARCH(1,1)</td>
<td>0.015</td>
<td>0.310</td>
<td>0.012</td>
<td>0.324</td>
<td>0.233</td>
<td>0.166</td>
<td>0.030</td>
<td>0.12</td>
<td>-703.8</td>
<td>1.72</td>
<td></td>
</tr>
<tr>
<td>Full</td>
<td>AR(1)-GARCH(1,1)</td>
<td>0.018</td>
<td>0.310</td>
<td>0.109</td>
<td>0.325</td>
<td>0.248</td>
<td></td>
<td></td>
<td></td>
<td>0.085</td>
<td>-712.3</td>
<td></td>
</tr>
<tr>
<td>Profit</td>
<td>AR(1)-ARCH(1)</td>
<td>0.028</td>
<td>0.305</td>
<td>0.103</td>
<td>0.179</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>-143.5</td>
<td>1.19</td>
<td></td>
</tr>
<tr>
<td>Profit</td>
<td>AR(1)-GARCH(1,1)</td>
<td>0.067</td>
<td>0.304</td>
<td>0.135</td>
<td>0.219</td>
<td>0.558</td>
<td></td>
<td></td>
<td></td>
<td>-285.4</td>
<td>2.24</td>
<td></td>
</tr>
<tr>
<td>Postlib</td>
<td>AR(1)-GARCH(1,1)</td>
<td>-0.015</td>
<td>0.262</td>
<td>0.114</td>
<td>0.414</td>
<td>0.230</td>
<td></td>
<td></td>
<td></td>
<td>-255.3</td>
<td>1.67</td>
<td></td>
</tr>
<tr>
<td>LibPostlib</td>
<td>AR(1)-GARCH(1,1)</td>
<td>-0.008</td>
<td>0.298</td>
<td>0.002</td>
<td>0.354</td>
<td>0.409</td>
<td></td>
<td></td>
<td></td>
<td>-561.5</td>
<td>1.95</td>
<td></td>
</tr>
</tbody>
</table>

$^a$ $p$-values are in parentheses.  
$^b$ Value of the log-likelihood function.  
$^c$ Akaike Information Criteria.

\[ R_t = \phi_0 + \phi_1 R_{t-1} + \phi_2 R_{t-2} + \varepsilon_t \]  
\[ h_t = \omega_0 + \omega_1 \varepsilon_{t-1}^2 + \beta_1 h_{t-1} + \lambda_1 Lib_t + \lambda_2 Postlib_t \]  
\[ h_t = \omega_0 + \omega_1 \varepsilon_{t-1}^2 + \beta_1 h_{t-1} + \lambda_3 LibPostlib_t \]
Table 5
Maximum likelihood estimates for the AR(s)-TGARCH(1,1).

<table>
<thead>
<tr>
<th>Period</th>
<th>Model</th>
<th>$\delta_0$ (p-value)</th>
<th>$\delta_1$ (p-value)</th>
<th>$\delta_2$ (p-value)</th>
<th>$\omega_0$ (p-value)</th>
<th>$\omega_1$ (p-value)</th>
<th>$\beta_1$ (p-value)</th>
<th>$\lambda_1$ (p-value)</th>
<th>$\lambda_2$ (p-value)</th>
<th>$\gamma$ (p-value)</th>
<th>LL</th>
<th>AIC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full</td>
<td>AR(1)-TGARCH(1,1)</td>
<td>0.022 (0.30)</td>
<td>0.319 (0.00)</td>
<td></td>
<td>0.117 (0.00)</td>
<td>0.420 (0.00)</td>
<td>0.200 (0.00)</td>
<td>0.167 (0.00)</td>
<td>0.017 (0.07)</td>
<td>−0.168 (0.07)</td>
<td>−702.7</td>
<td>1.71</td>
</tr>
<tr>
<td>Full</td>
<td>AR(1)-TGARCH(1,1)</td>
<td>0.028 (0.18)</td>
<td>0.320 (0.00)</td>
<td></td>
<td>0.119 (0.00)</td>
<td>0.479 (0.00)</td>
<td>0.187 (0.00)</td>
<td>0.096 (0.00)</td>
<td></td>
<td>−0.266 (0.00)</td>
<td>−709.6</td>
<td>1.73</td>
</tr>
<tr>
<td>Lib</td>
<td>AR(1)-TGARCH(1,1)</td>
<td>0.073 (0.13)</td>
<td>0.310 (0.00)</td>
<td></td>
<td>0.272 (0.00)</td>
<td>0.595 (0.00)</td>
<td>0.260 (0.07)</td>
<td></td>
<td></td>
<td>−0.446 (0.01)</td>
<td>−293.4</td>
<td>2.23</td>
</tr>
<tr>
<td>PostLib</td>
<td>AR(2)-TARCH(1,1)</td>
<td>−0.018 (0.56)</td>
<td>0.264 (0.00)</td>
<td>0.138 (0.01)</td>
<td>0.116 (0.00)</td>
<td>0.476 (0.00)</td>
<td>0.214 (0.06)</td>
<td></td>
<td></td>
<td>0.074 (0.72)</td>
<td>−255.2</td>
<td>1.68</td>
</tr>
<tr>
<td>LibPostLib</td>
<td>AR(1)-TARCH(1,1)</td>
<td>0.017 (0.55)</td>
<td>0.206 (0.00)</td>
<td></td>
<td>0.089 (0.00)</td>
<td>0.434 (0.00)</td>
<td>0.489 (0.00)</td>
<td></td>
<td></td>
<td>−0.150 (0.11)</td>
<td>−560.5</td>
<td>1.95</td>
</tr>
</tbody>
</table>

p-values are in parentheses.

* Value of the log-likelihood function.

** Akaike Information Criteria.

\[ R_t = \delta_0 + \delta_1 R_{t-1} + \delta_2 R_{t-2} + \epsilon_t \]  

\[ h_t = \omega_0 + \sum_{i=1}^{\delta} \alpha_i \epsilon_{t-i}^2 + \sum_{j=1}^{\gamma} \beta_j h_{t-j} + \gamma h_{t-1} \]  

\[ h_t = \omega_0 + \sum_{i=1}^{\delta} \alpha_i \epsilon_{t-i}^2 + \sum_{j=1}^{\gamma} \beta_j h_{t-j} + \gamma h_{t-1} \]  

\[ h_t = \omega_0 + \sum_{i=1}^{\delta} \alpha_i \epsilon_{t-i}^2 + \sum_{j=1}^{\gamma} \beta_j h_{t-j} + \gamma h_{t-1} + \lambda_1 \text{LibPostLib} + \lambda_2 \text{LibPostLib} \]
Table 6
Summary statistics on leverage in Sri Lankan companies.

<table>
<thead>
<tr>
<th>Year</th>
<th>Leverage ratio (%)</th>
<th>Standard deviation of leverage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1994</td>
<td>11.6</td>
<td>18.3</td>
</tr>
<tr>
<td>1997</td>
<td>11.3</td>
<td>19.0</td>
</tr>
<tr>
<td>2000</td>
<td>13.8</td>
<td>21.1</td>
</tr>
</tbody>
</table>

* Leverage ratio is equal to the long-term debt as a percent of total assets, and is based on the 30 largest companies in terms of market capitalization each year.

This evidence of positive shocks leading to higher volatility does not mirror recent findings of the existence of a leverage effect in other international stock markets. The premise in the leverage effect argument is that negative shocks increase firms’ leverage leading to more stock price volatility. Therefore, finding the opposite effect in Sri Lanka raises the question as to whether the companies in Sri Lanka utilize no or insignificant levels of leverage. To answer this question, we examine the leverage ratio of Sri Lankan companies.

Table 6 reports the summary statistics for leverage for three points in the sample period for which capital structure data are available. The leverage, defined as the long-term debt to total assets ratio, was 11.6% in 1994, 11.3% in 1997, and 13.8% in 2000 for the 30 largest firms in terms of market capitalization. Thus, Sri Lankan companies indeed employ very low leverage. Further, Samarakoon (1999), based on a sample of 118 firms in Sri Lanka for the period 1993–1998 reports an average leverage ratio of 8.7%. He also finds that firm size is positively related to leverage suggesting that large firms use more leverage. Thus, the results of this paper which show that positive shocks lead to subsequent higher volatility seem to reflect this use of very low levels of debt by companies in Sri Lanka.

6.3. Volatility persistence and implied unconditional volatility

We also examine the persistence of volatility as well as the implied unconditional volatility to see if they are different in the liberalization period. The results are reported in Table 7. Volatility persistence is measured by \( \alpha_1 + \beta_1 \) in the GARCH model, and by \( \alpha_1 + \beta_1 + \gamma/2 \) in the TGARCH model. In the two GARCH equations, the volatility persistence is larger during and following liberalization. In the TGARCH model, there is evidence of higher volatility persistence in the period following liberalization. The volatility persistence parameters in the GARCH model suggest that the proportion of shocks that remain after a month is 0.37 in the liberalization period and 0.50 in the LibPostlib period. This means that after one month approximately 40% of the shocks remain in the liberalization period, and 50% of the shocks remain in the LibPostlib period.

Table 7 also reports the implied unconditional volatility (IUV), which is measured by \( \alpha_0 /[1 - (\alpha_1 + \beta_1)] \) in the GARCH model, and by \( \alpha_0 /[1 - (\alpha_1 + \beta_1 + \gamma/2)] \) in the TGARCH model. In the GARCH model, it ranges from 0.25 in the full sample period to 0.61 in the liberalization period, and in the TGARCH model the IUV ranges from 0.25 in the full period to 0.64 in the liberalization period. The IUV for the liberalization period is more than two times larger than that in the full period. This is further evidence of higher volatility in the liberalization period.

---

9 Using daily data, Huang and Yang (2000) found support for the existence of a leverage effect for Mexico, the Philippines, Thailand, Taiwan, South Korea, Malaysia and Argentina. However, they did not find such evidence for Brazil, Chile and Turkey. Kassimatis (2002) also showed that good news caused more volatility in India and Argentina before the liberalization.

10 We thank the referee for this suggestion.

11 This is estimated as the persistence coefficient to the power four.

12 For example see De Santis and Imrohoroglu (1997), and Huang and Yang (2000).
Table 7
Persistence of volatility and implied unconditional volatility\textsuperscript{a}.

<table>
<thead>
<tr>
<th>Model</th>
<th>Period</th>
<th>Volatility persistence</th>
<th>Implied unconditional volatility</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>$\alpha_1 + \beta_1$</td>
<td>$\alpha_0/[1 - (\alpha_1 + \beta_1)]$</td>
</tr>
<tr>
<td>GARCH</td>
<td>Full\textsuperscript{b}</td>
<td>0.57</td>
<td>0.26</td>
</tr>
<tr>
<td></td>
<td>Full\textsuperscript{c}</td>
<td>0.56</td>
<td>0.25</td>
</tr>
<tr>
<td></td>
<td>Lib</td>
<td>0.78</td>
<td>0.61</td>
</tr>
<tr>
<td></td>
<td>Postlib</td>
<td>0.73</td>
<td>0.43</td>
</tr>
<tr>
<td></td>
<td>LibPostlib</td>
<td>0.84</td>
<td>0.59</td>
</tr>
<tr>
<td>TGARCH</td>
<td>Full\textsuperscript{d}</td>
<td>0.53</td>
<td>0.26</td>
</tr>
<tr>
<td></td>
<td>Full\textsuperscript{e}</td>
<td>0.54</td>
<td>0.25</td>
</tr>
<tr>
<td></td>
<td>Lib</td>
<td>0.58</td>
<td>0.64</td>
</tr>
<tr>
<td></td>
<td>Postlib</td>
<td>0.73</td>
<td>0.43</td>
</tr>
<tr>
<td></td>
<td>LibPostlib</td>
<td>0.85</td>
<td>0.59</td>
</tr>
</tbody>
</table>

\textsuperscript{a} The series for the pre-liberalization period is modelled with AR(1)-ARCH(1). Therefore, persistence of volatility and IUV are not calculated for that period.

\textsuperscript{b} Based on estimates of Eq.(5).

\textsuperscript{c} Based on estimates of Eq.(6).

\textsuperscript{d} Based on estimates of Eq.(7).

\textsuperscript{e} Based on estimates of Eq.(8).

6.4. Model diagnostics

We carried out a series of diagnostic checks\textsuperscript{13}. The Ljung-Box Q-statistics indicated no evidence of serial correlation in the GARCH and TGARCH models. The skewness and kurtosis have been reduced dramatically compared with the return series, and the normality of the residual is not rejected for the post-liberalization period. The results of the diagnostic tests confirmed the validity of the models used. The models are well specified and the standardized residuals satisfy the condition of zero mean and unit variance. Also, the fact that no serial dependence is observed in the squared standardized residuals is evidence that the data is free of ARCH effects.

7. Conclusions

We examine the impact of liberalization of the Sri Lankan stock market to foreign investor on return volatility. We specify GARCH and TGARCH models of volatility and estimate them using 16 years of weekly data from the Colombo Stock Exchange. The empirical results show that market liberalization significantly increased the return volatility. Both conditional and unconditional volatility measures are the highest in the liberalization period. We also find that positive return shocks caused more volatility than negative shocks indicating no leverage effects. The capital structure data show that Sri Lankan companies use very low levels of debt. The lack of leverage effects most likely reflects this low level of leverage.

This increased volatility was more likely a result of both new information and trading behaviour of investors. The market liberalization was followed by further measures that made stock market investments more attractive. There were also more listings on the stock exchange. The arrival of foreign investors was also considered a signal of good market prospects which increased confidence among local investors. Foreign investors provided a new counterparty to transactions which enabled the domestic investors to engage in more trading than before. Thus, market liberalization set in motion a multitude of factors that would have contributed to higher market volatility.

\textsuperscript{13} The results relating to model diagnostics are not reported here for parsimony.
Acknowledgement

We would like to thank Daehoon Nahm, Kim Hawtrey, and an anonymous referee for valuable suggestions and comments on the paper.

References