Financial Liberalisation and Breaks in Stock Market Volatility: Evidence from East Asia

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Abstract

This paper examines the short and medium term impact of financial reforms on stock market volatility in five East Asian emerging markets. Several newly proposed tests are employed to identify and verify the number and timing of structural breaks in the variance dynamics. The detected breakdates do not correspond to official liberalisation dates. The magnitude and direction of the change in volatility is estimated using parametric and non-parametric techniques. Our findings suggest that by taking into account the possibility of multiple breaks, a richer evolution of volatility is obtained than by focussing on official liberalisation dates. We also show that focussing on official liberalisation dates results in inaccurate inference.

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1. Introduction

The effects of financial liberalisation on stock market volatility have been the subject of controversy ever since emerging market economies began liberalising their financial markets in the 1980s and early 1990s. Following Keynes[1], several authors have argued that financial liberalisation could attract speculators and investors with short-term horizons, resulting in asset price bubbles and financial instability (e.g. Allen and Gale, 2000; Arestis and Demetriades, 1997, 1999; Singh, 1997, 2003). Other authors (e.g. Tauchen and Pitt, 1983; Fry, 1997) have in contrast argued that stock return volatility is inversely related to the number of traders in a market. Given that the relaxation of capital account restrictions may attract new investors to newly liberalised markets, stock market volatility may decline after liberalization. Empirical evidence is equally divided. Grabel (1995) and Nilsson (2002) find that market liberalisation creates excess stock market volatility while Bekaert and Harvey (1997), Li (2002) and Kassimatis (2002) demonstrate that stock market volatility declined after the sample countries opened up their stock market to foreign investors. De Santis and Imrohoroglu (1997) and Spyrou and Kassimatis (1999), on the other hand, find no obvious relationship between stock market liberalisation and volatility. Jayasuriya (2005) finds that volatility may decline, rise or stay the same following stock market liberalisation which, is argued, may reflect different market characteristics, such as market transparency and investor protection or institutions such as rule of law and corruption.

Empirical studies on this topic have so far treated the dates of structural breaks resulting from financial reforms as known, typically assuming that a breakdate coincides with the official liberalisation date. However, financial market participants may adjust their behaviour well before or even after the event, depending on when the news was disseminated, how credible the announcements were, and their assessment regarding the timing of any perceived impact on the market. Moreover, by using the official liberalisation date as the breakdate, previous studies implicitly assume that there is a single break, while in reality there may be more than one break, for example because of changes in the perceived credibility of the policy makers. Thus, the estimates of volatility obtained by previous studies may be biased or inefficient.[2] In order to have more accurate estimates of volatility changes due to financial liberalisation, this paper takes

[1] Keynes (1964) regards liquidity as having destabilising effect on the market because of the assumption of market imperfection, particularly in relation to the availability of information to all participants.
[2] It is an established fact that not taking into account structural breaks in the estimation of GARCH-type models may result in over-estimating volatility persistence (Lamoureux and Lastrapes, 1990).

care to identify both the number and the timing of structural breaks that occur around official liberalisation dates. This is done by first employing a number of CUSUM-type non-parametric tests to detect breaks in the unconditional variance of the returns process. Once the breaks have been identified, robustness tests are carried out using a set of more powerful tests to verify that the unconditional variance of each regime is statistically different. These breakdates are then compared to the official liberalisation dates. Subsequently, the best-fitting GARCH model is employed to provide an estimate of the long-run variance in each regime. As a result, a robust measure of the direction and level of the change in the long-run volatility of returns is obtained.

The empirical application focuses on five East Asian emerging markets all of which liberalised their financial markets in the late 1980s or early 1990s, namely (South) Korea, Malaysia, Philippines, Taiwan and Thailand. These countries have been extensively studied in the broader literature on financial reforms, not least because of their importance to the world economy and the availability of reliable data.[3] They can therefore provide an excellent platform from which to highlight the importance of correctly identifying the number and timing of structural breaks.

The paper is organised as follows. Section 2 sets out the econometric methodology. Section 3 describes the data and sources, including the official financial liberalisation dates in each of the five East Asian countries studied. Section 4 reports and discusses the empirical results while Section 5 summarises and concludes.

2. Econometric Methodology

2.1. The number and timing of breaks

The tests that are employed to detect the number and identify the timing of structural breaks are derived from Inclan and Tiao (1994) - henceforth I&T – Sansó, Aragó, and Carrion (2003) – henceforth SAC - Kokoszka and Leipus (2000) – henceforth K&L - and Lee, Maekawa and Tokutsu (2003) – henceforth LMT. These tests are essentially able to detect a single break. However I&T introduce an algorithm that sequentially searches for additional breaks by applying the tests iteratively in sub-samples until no break is found. This section first provides a brief overview of each of the tests and then introduces a variant of the I&T algorithm for multiple breaks.

[3] See, for example, Demetriades and Luintel (2001) and Demetriades, Devereux and Luintel (1998?).

I&T introduce the following statistic[4]:

$$I\&T = \sqrt{\tfrac{T}{2}} \cdot \max_k (D_k)$$

where

$$D_k = \tfrac{C_k}{C_T} - \tfrac{k}{T},\ k = 1,\ldots,T,\ D_0 = D_T = 0 \text{ and } C_k = \sum_{t=1}^{k} r_t^2$$

T is the sample size and r_t represents the return series, assumed to be *i.i.d.* $(0, \sigma_t^2)$. I&T show that for a fixed k, D_k can be written as a function of the standard F-statistic that is used to test for the equality of variances of two independent samples. They prove that the asymptotic distribution of the test is the supremum of a Brownian bridge. Andreou and Ghyssels (2003) show that the I&T test has power and only minor size distortions when applied to strongly dependent data.

SAC (2002) however, are sceptical to the use of the I&T test without a closer examination of the underlying process. Specifically, they suggest that the widely used test is not appropriate for financial time series since it suffers important size distortions for leptokurtic and platykurtic innovations that become more severe for heteroskedastic conditional variance processes. In the case of Integrated-GARCH disturbances, they show that the test diverges. For this reason, they introduce two new tests that explicitly consider the fourth moment properties of the disturbances and the conditional heteroskedasticity. Their first test is as follows:

$$SAC_1 = \tfrac{1}{\sqrt{T}} \cdot \max_k (B_k)$$

where

$$B_k = \frac{C_k - \frac{k}{T} \cdot C_T}{\sqrt{\hat{a}_4 - \hat{\sigma}^4}},\ k = 1,\ldots,T,\ C_k = \sum_{t=1}^{k} r_t^2,\ \hat{a}_4 = \frac{\sum_{t=1}^{k} r_t^4}{T},\ \text{and } \hat{\sigma} = \frac{C_T}{T}$$

while the second one by:

$$SAC_2 = \tfrac{1}{\sqrt{T}} \cdot \max_k (G_k)$$

where

$$G_k = \frac{C_k - \frac{k}{T} \cdot C_T}{\sqrt{\hat{\varpi}_4}},\ k = 1,\ldots,T,\ \text{and } C_k = \sum_{t=1}^{k} r_t^2$$

and ϖ_4 is the finite (but not necessarily constant) long-run fourth moment coefficient of r_t (also interpreted as the long-run variance of the zero-mean variable $\xi = r_t^2 - \sigma^2$) a consistent estimator of which could be the non-parametric statistic:

[4] The notation has been changed to accord better with financial series.

$$\hat{\varpi}_4 = \frac{1}{T} \cdot \sum_{t=1}^{k} (r_t^4 - \hat{\sigma}^2)^2 + \frac{2}{T} \cdot \sum_{l=1}^{m} w(l,m) \cdot \sum_{t=1}^{k} (r_t^4 - \hat{\sigma}^2) \cdot (r_{t-l}^4 - \hat{\sigma}^2)$$

where $\hat{\sigma}^2 = \frac{C_T}{T}$ and *w(l,m)* is a lag window such as the Bartlett, defined as *w(l,m)=1-l/(m+1)* , where m is the bandwidth and l the lag value, or the quadratic spectral, defined as $w(l,m) = \frac{3}{z^2}\left(\frac{\sin(z)}{z} - \cos(z)\right)$ where $z = 6\pi / 5 \cdot l / m$ [5]. The asymptotic distribution of both tests is the supremum of Brownian bridge[6].

K&L study the change-point problem for ARCH type models and suggest that the estimator $\hat{k}$ of a change point $\hat{k}^*$ is given by:

$$\hat{k} = \min\{k : |U_T(k)| = \max_{1 \le k \le T} |U_T(j)|\}$$

where

$$U_T(k) = \left(\frac{1}{\sqrt{T}} \cdot C_k - \frac{k}{T \cdot \sqrt{T}} \cdot C_T\right), \; k = 1, \ldots, T, \text{ and } C_k = \sum_{t=1}^{k} r_t^2$$

As noted by Andreou and Ghyssels under the null hypothesis of no break:

$U_T(k) \rightarrow_{D[0,1]} \sigma \cdot B(k)$ for B(k) a Brownian bridge and thus, for $\hat{\sigma}$ an estimator of σ then under the null which establishes a Kolmogorov-Smirnov type asymptotic $\sup\{|U_T(k)|\}/\hat{\sigma} \rightarrow_{D[0,1]} \sup\{B(k) : k \in [0,1]\}$ distribution[7].

However, when multiple breaks in the variance of an observed series may be present, it is necessary to incorporate the aforementioned test in an iterative scheme to sub-samples of the series, dividing the (sub-)sample consecutively after a possible change point is found. I&T propose a version of such an algorithm, which they name Iterative Cumulative Sums of Squares (ICSS) algorithm. This paper employs the modified version of this algorithm suggested by Karoglou (2006) which is in principle more robust to the existence of transitional periods between breaks. Karoglou's version of the algorithm comprises the following six steps:

[5] Note that these estimators depend on the selection of the bandwidth m, the level of which the authors suggest that can be chosen by employing the Newey-West (1994) automatic procedure.
[6] The test of Kokoszka and Leipus (2000) which is considered next, is quite similar to SAC_2. However, they depart from a different set of assumptions (they assume an ARCH(∞) process) and therefore, the SAC_2 can be regarded as more general.
[7] The same authors suggest the use of the VARHAC estimator for the computation of $\hat{\sigma}$

1. Calculate the CUSUM test statistic under consideration.
2. If it is above the critical value, split the particular data segment into two parts at the corresponding point.
3. Repeat steps 1 and 2 for the first segment until no more (earlier) change-points are found.
4. Mark this point as an estimated change-point of the whole series.
5. Remove the observations that precede this point (i.e. those of the first segment).
6. Consider the remaining observations as the new sample and repeat steps 1 to 5 until no more change-points are found.

This is applied for each of the test statistics described above, i.e. I&T, SAC_1, SAC_2^{Brt}, SAC_2^{QS}, K&L

2.2. Robustness Tests

After having detected the suggested breakdates and, consequently, the suggested segments of the stock returns of each country, we carry out some robustness tests in order to verify that the neighbouring segments have different variances. The tests are designed to test for the homogeneity of variances of different samples; in our case these samples are two successive segments. Apart from the standard F-test, which suffers from the assumption of normality of the samples, we also use three other tests[8].

The Siegel-Tukey test (Siegel and Tukey, 1960) tests the equality of variances of samples that it assumes independent and with equal medians. Essentially, the test-statistic derives after sorting all observations from lowest to highest and then ranking them according to a certain procedure. In this paper, we use the normal approximation to the Siegel-Tukey statistic with a continuity correction as suggested by Sheskin, 1997.

The Bartlett test (Snedecor and Cochran, 1983) is another test for the homogeneity of variances that we use. It compares the logarithm of the weighted average variance with the weighted sum of the logarithms of the variances and is approximately distributed as a χ^2 with one degree of freedom. Under the joint null hypothesis that the subgroup variances are equal and that the sample is normally distributed, the test statistic is approximately distributed as a $\chi 2$ with one degree of freedom. Note however that it

[8] These tests are calculated in Eviews.

assumes that the sample variances are normally distributed. For that reason we use the adjusted Bartlett statistic (for details see Sokal and Rohlf, 1995, and Judge, et al, 1985).

Finally, the Levene test (Levene, 1960), is the last test we consider to test the homogeneity of variance across the neighbouring segments. It is based on an analysis of variance of the absolute difference from the mean and it follows an approximate F-distribution with one numerator degrees of freedom and n-1 denominator degrees of freedom under the null hypothesis of equal variances in each sample. It has the additional advantage that it is less sensitive than the Bartlett test to departures from normality.

2.3. Volatility Estimators

The magnitude and direction of the change in volatility is proxied by the unconditional variance in each regime, utilising three alternative estimators: (i) the sample standard deviation; (ii) the square root of the VARHAC estimator of the variance (den Haan, 1997); (iii) the square root of the unconditional variance of the best fitting GARCH specification and calculating the unconditional variance that it suggests. This allows us to examine the evolution of volatility throughout the sample period.

3. The Data

The stock returns series of five East Asian emerging markets are constructed using continuous compounding[9]. It is widely accepted that the conditional mean of the returns exhibits little predictability from the past (Bekaert and Harvey, 1997). However, we also consider the possibility of moving average error terms induced by calendar effects. We therefore follow the procedure suggested by Pagan and Schwert (1990) to remove potential day-of-the-week effects.

The data in this study consists of daily closing stock price indexes, expressed in the local currency[10] of: (i) Korea Stock Price Index; (ii) Taiwan Weighted Stock Index; (iii) Kuala Lumpur Composite Index; (iv) Stock Exchange of Thailand Index and (v) the Philippines Stock Exchange Composite Index. The sample period starts from 4 years prior to and after financial liberalisation. The data is obtained from *Datastream*.

[9] The daily return stock price index series on day t (RPI_t) is generated as follows:

$$RPI_{,t} = (100) \times (\log PI_t - \log PI_{t-1})$$

where PI_t represents the closing value of the five East Asian emerging stock price indices on day t. The return series is therefore the time series of continuously compounded daily returns expressed as a percentage.

[10] US dollar indexes are not employed in order to avoid introducing exchange rate volatility effects.

Financial Liberalisation Dates of East Asian Emerging Markets

The official liberalisation dates for five Asian emerging markets are based on Bekaert and Harvey (2000), Santis and Imrohoroglu (1997), Bhattacharya and Daouk (2002) and Fuchs-Schundeln and Funke (2001). These are as follows: January 1992 for South Korea, January 1991 for Taiwan, December 1988 for Malaysia, September 1987 for Thailand and June 1991 for the Philippines. Liberalisation policies in the aforementioned economies have been implemented in other periods as well. However, we are concerned with those considered the main ones in opening up stock markets to foreign investment. Table 1 provides a comparison of the liberalisation dates in the literature.

Table 1: Comparisons of Official Financial Liberalisation Dates in East Asian Emerging Markets Across Authors

Work of / Country	*Santis & Imrohoroglu (1997)*	*Henry (2000)*	*Kim & Singal (2000)*	*Bekaert & Harvey (2000)*
Korea	Jan-92	Jun-87	Jan-92	Jan-92
Malaysia	Dec-88	May-87	Dec-88	Dec-88
Philippines	Oct-89	May-86	Jul-86	Jun-91
Taiwan	Jan-91	May-86	Jan-91	Jan-91
Thailand	Dec-88	Jan-88	Aug-88	Sep-87
Work of / Country	*Fuchs-Schundeln & Funke (2001)*	*Kassimatis (2002)*	*Bhattacharya & Daouk (2002)*	***ADOPTED***
Korea	Jan-92	Jan-92	Jan-92	***Jan-92***
Malaysia	Dec-88	NA	Dec-88	***Dec-88***
Philippines	Jun-91	Nov-91	Jun-91	***Jun-91***
Taiwan	Jan-91	Jan-91	Jan-91	***Jan-91***
Thailand	Sep-87	NA	Sep-87	***Sep-87***

Table 2 presents the descriptive statistics for stock returns of five East Asian emerging markets in full sample and sub-sample periods. The mean of stock return is increased in the cases Korea, Malaysia and the Philippines after liberalisation. The stock return volatility (measured by the standard deviation) declined after liberalisation in East Asian emerging markets, except for Thailand, where it appears to have increased considerably.

Table 2: Descriptive Statistics of Stock Returns

		Period	Mean	St. Deviation	Skewness	Kurtosis	Observations
Korea	*Full Sample*	(Jan 88 – Dec 95)	0.0108	0.5969	0.2929	2.9882	2086
	Pre-Lib	(Jan 88 – Dec 91)	0.0063	0.6231	0.1928	3.0126	1043
	Post-Lib	(Jan 92 – Dec 95)	0.0153	0.5694	0.4275	2.8626	1043
Malaysia	*Full Sample*	(Dec 84 – Nov 92)	0.0158	0.6326	-2.0698	24.6773	2086
	Pre-Lib	(Dec 84 – Nov 88)	0.0062	0.7442	-2.1061	21.6072	1043
	Post-Lib	(Dec 88 – Nov 92)	0.0254	0.4967	-1.4075	18.6465	1043
Philippines	*Full Sample*	(Jun 87 – May 95)	0.0314	0.8577	-0.1761	10.5878	2088
	Pre-Lib	(Jun 87 – May 91)	0.027	1.0506	-0.2043	8.5135	1045
	Post-Lib	(Jun 91 – May 95)	0.0357	0.6064	0.1088	2.2532	1043
Taiwan	*Full Sample*	(Jan 87 – Dec 94)	0.04	1.04	-0.0905	1.8429	2087
	Pre-Lib	(Jan 87 – Dec 90)	0.0613	1.2187	-0.1363	0.9397	1043
	Post-Lib	(Jan 91 – Dec 94)	0.0187	0.8237	-0.0161	2.8274	1044
Thailand	*Full Sample*	(Sept 83 – Aug 91)	0.0329	0.6073	-0.8298	11.5289	2087
	Pre-Lib	(Sept 83 – Aug 87)	0.0371	0.2689	0.1676	8.1141	1043
	Post-Lib	(Sept 87 – Aug 91)	0.0287	0.8157	-0.6779	5.8025	1044

4. Empirical Results

4.1. The number and timing of breaks

Table 3 reports the results of applying the Karoglou (2006) algorithm outlined in Section 2, utilising the five non-parametric tests also described in the same section. Not all the breakdates suggested by the algorithm are adopted because some of the tests may exaggerate the number of breakdates if there is volatility persistence or the innovation term is not Gaussian (SAC, 2002, Karoglou 2006).[11] In order for a breakdate to be adopted the following two conditions (Rule A) must be satisfied:

i) <u>Segment size:</u> The two derived segments (before and after the breakdate) contain at least 50 observations each.

[11] The I&T test for example has been found to diverge in such cases.

ii) Significance: Two or more statistics indicate the existence of the break at the 5% level

We also adopt the following subsidiary rule (Rule B) in cases where no breakdate has been detected in the pre or post liberalisation period by Rule A:

iii) Segment size: The two derived segments (before and after the breakdate) contain at least 50 observations each.

iv) Significance: One statistic indicates the existence of the break at the 1% level and it is the first (before) after the official liberalisation date suggested by this statistic.

Following Rule A, we adopt three breakdates in the case of Korea, 16 April 1990, 10 December 1992 and 1 March 1994. The first two are suggested by all five tests, with four of the statistics significant at the 1% level. The third breakdate is suggested by four tests, one of which at the 1% level.

Applying Rule A we adopt two breakdates in the case of Malaysia, 19 October 1987 and 19 January 1988. Both breakdates are suggested by four tests, of which three are significant at the 1% level. Rule B is applicable in the case of Malaysia because Rule A does not result in a breakdate being adopted after the official liberalisation date of 1 December 1988. This rule suggests a third breakdate of 26 August 1991, since the I&T test is significant at the 1% level and the derived segments contain more than 50 observations each.

In the case of the Phillipines, the application of Rule A results in four breakdates being adopted, 20 December 1987, 25 September 1991, 4 October 1993 and 6 May 1994. The first one is suggested by four statistics at the 1% level, the second one by all five at the 1% level, the third and fourth also by five tests, albeit only three at the 1% level.

The application of Rule A in the case of Taiwan results in three breakdates being adopted, 2 April 1990, 12 March 1991, and 29 October 1991. The first two are suggested by all five tests at the 1% level. The third is also suggested by all five tests, albeit only three at the 1% level.

Finally, the application of Rule A to the case of Thailand results in three breakdates being adopted, 28 August 1986, 1 August 1990 and 27 February 1991. The first two are suggested by all five tests at the 1% level, while the third is also suggested by all five tests, of which four at the 1% level. Three of the tests detect a fourth breakdate that is, however, not adopted because the resulting segment contains only 43 observations, hence condition (i) is not satisfied.

Table 3: Detected Structural Changes

	datapoint	I&T	SAC_1	SAC_2^{BT}	SAC_2^{QS}	K&L	adopted
korea	597	√	√	√*	√	√	yes (16-04-90)
	1291	√	√	√*	√	√	yes (10-12-92)
	1607	√	√*	-	√*	√*	yes (01-03-94)
	1828	√*	-	-	-	-	no
	1873	√*	-	-	-	-	no
malaysia	751	√	√	-	√	√*	yes (19-10-87)
	818	√	√	-	√	√*	yes (19-01-88)
	1756	√	-	-	-	-	yes (26-08-91)
	1818	√*	-	-	-	-	no
phillipines	110	√	-	-	-	-	no
	149	-	√	√	√	√	yes (20-12-87)
	1128	√	√	√	√	√	yes (25-09-91)
	1656	√	√	√*	√	√*	yes (04-10-93)
	1810	√	√	√*	√	√*	yes (06-05-94)
	1952	√	-	-	-	-	no
	2037	√*	-	-	-	-	no
taiwan	848	√	√	√	√	√	yes (02-04-90)
	1094	√	√	√	√	√	yes (12-03-91)
	1259	√	√	√*	√	√*	yes (29-10-91)
	1558	√	-	-	-	-	no
	1647	√	-	-	-	-	no
	1803	√	-	-	-	-	no
	1875	√	-	-	-	-	no
	2025	√	-	-	-	-	no
	2046	√	-	-	-	-	no
thailand	781	√	√	√	√	√	yes (28-08-86)
	1805	√	√	√	√	√	yes (01-08-90)
	1955	√	√	√*	√	√	yes (27-02-91)
	2044	√	√	-	√	-	no

Note: √ denotes statistical significance at 1% level, √* at 5% level, and - no statistical significance. Also, I&T refers to the Inclan and Tiao test, SAC_1 refers to the first test of Sansó, Aragó, and Carrion, SAC_2^{BT} and SAC_2^{QS} refer to the second test of Sansó, Aragó, and Carrion with the Bartlett and Quadratic Spectral kernel estimate correspondingly, and K&L refers to the Kokoszka and Leipus test.

4.2. Robustness Tests

Table 4 reports the results of carrying out the robustness tests outlined in Section 2. The same table also reports the results of applying the robustness tests to the segments defined by the official liberalisation dates. These tests confirm that the neighbouring segments resulting from the adopted breakdates have different variances, with the differences being significant at the 1% level. The same tests also suggest that with the exception of Korea the variances in the pre and post liberalisation periods are statistically different at the 1% level. In the case of Korea three of the tests suggest no variance change after the official liberalisation date. Thus, by focussing on the official liberalisation date, one may fail to detect the regime switches that have taken place before and after this date.

Table 4: Robustness Tests

		F-statistic	Siegel-Tukey	Bartlett	Levene	change in variance
korea	before & after liberalisation	1.19†	0.41†	7.69	0.95†	no
	Regime 1 & 2	2.21	4.94	96.03	38.85	yes
	Regime 2 & 3	1.93	2.56	42.94	15.02	yes
	Regime 3 & 4	1.50	2.58	15.92	10.70	yes
malaysia	before & after liberalisation	2.21	8.60	159.66	48.42	yes
	Regime 1 & 2	10.21	4.89	296.10	114.05	yes
	Regime 2 & 3	13.38	6.96	420.20	166.18	yes
	Regime 3 & 4	2.41	4.60	52.77	37.38	yes
phillipines	before & after liberalisation	3.02	5.97	303.13	68.56	yes
	Regime 1 & 2	6.75	8.61	344.44	176.72	yes
	Regime 2 & 3	2.27	5.50	103.82	42.33	yes
	Regime 3 & 4	2.41	4.60	52.77	37.38	yes
	Regime 4 & 5	2.13	3.15	29.69	18.67	yes
taiwan	before & after liberalisation	2.13	10.61	145.00	114.14	yes
	Regime 1 & 2	3.69	10.67	195.62	201.98	yes
	Regime 2 & 3	3.45	7.27	65.98	66.59	yes
	Regime 3 & 4	2.06	4.86	41.89	32.13	yes
thailand	before & after liberalisation	9.09	16.44	1072.55	265.60	yes
	Regime 1 & 2	9.51	16.13	873.02	224.07	yes
	Regime 2 & 3	5.55	8.31	278.93	170.04	yes
	Regime 3 & 4	4.11	4.53	62.88	30.82	yes

Note: † denotes statistical insignificance (i.e. not significant at 5% level). In all other cases, the statistical significance is found below 1% level.

4.3. Volatility Estimates

For each country we present the results using two figures, which report and illustrate the three alternative measures of volatility in (i) the pre and post liberalisation periods and (ii) each of the identified regimes. In addition we also plot the stock returns in a separate figure, alongside one of the volatility estimates, to illustrate the evolution of stock returns in each regime.[12]

{Figure 1}

Figure 1 shows that the estimated measures of volatility before and after the official liberalisation date of 1 January 1992 have declined slightly. The GARCH-

[12] In this type of figure we include just one of the volatility estimates, for clarity of exposition. It turns out that the three estimates are similar, so that the choice of estimator does not matter.

derived estimate shows a decline of 9.8%, the standard deviation a decline of 8.3% and the VARHAC estimate shows a marginal decline of 0.3%.[13]

{Figure 2}

In contrast, Figure 2 illustrates a much richer evolution of volatility in the pre and post liberalisation periods. The volatility measures in the first segment, which covers the period 1 January 1988 – 15 April 1990, was, in fact considerably lower than suggested by Figure 1. In the second segment, which covers a twenty month period before the official liberalisation data and an eleven month period after the official liberalisation date, volatility increased substantially: the GARCH measure shows an increase of 51.6%, the standard deviation an increase of 48.7% and the VARHAC an increase of 33.3%. The third segment, however, which starts almost a year after the official liberalisation date is one of decreasing volatility, with the three measures decreasing by 29.5%, 28% and 20% respectively. Finally, the fourth segment which starts twenty six months after the liberalisation date exhibits a further decline in volatility of 18.5% in both the first two measures and 18.0% in the third. As a result, a comparison of the first and fourth segment shows that volatility has declined by around 12.7% (12.9%, 12.7% and 12.5%, respectively). Figure 3 illustrates the evolution of volatility through time, alongside the stock returns.

{Figure 3}

A plausible interpretation of the Korean results is as follows. The first regime is likely to correspond to the period before any news regarding financial liberalisation has reached the market. The second regime may correspond to the period in which information about liberalisation reached market participants, creating uncertainty. It is interesting, however, that the second regime continues well after the official liberalisation date. Even in the third regime, which begins eleven months after the liberalisation date, uncertainty appears to be higher than in the first regime. It takes more than two years after the official liberalisation date before uncertainty is reduced to pre-liberalisation levels. Thus, focusing on the regimes that are based on the official liberalisation dates completely masks this rich volatility pattern.

A similar conclusion, if more pronounced, emerges by analysing the results for Malaysia that are presented in Figures 4-6. Figure 4 suggests that liberalisation led to a

[13] Note, however, that the tests reported in Table 4 suggest that these changes may not be statistically significant in this particular case.

decline in volatility of between 28.4% and 40.3%, depending on which measure is used. Figure 5, on the other hand, reveals a much more striking evolution of volatility. Volatility increases very substantially, for a period of three months, about a year before the official liberalisation date. The standard deviation suggests an increase in volatility of 219.7% while VARHAC shows an increase of 128.1% and GARCH a smaller increase of 53.1%, which is nevertheless also rather large. About a year before the liberalisation date of 1 December 1988 volatility declines quite substantially and remains low for a period of three and a half years: the GARCH measure shows a decline of 45.1%, the standard deviation a decline of 72.6% and the VARHAC a decrease of 61.8%. A further decline in volatility, in the range of 35-40% depending on the measure used, occurs in the fourth regime, which starts approximately two years and nine months after the official liberalisation date. As a result, volatility exhibits a decline in the range of 45.3-47.5%, depending on measure used, when the first and the last (fourth) regimes are compared.

The Philippines exhibits an even richer evolution of volatility, given that there are five different regimes. Figure 7 shows a decline in volatility in the post liberalisation period that ranges from 34.9% in the case of the GARCH measure to 42.5% for the standard deviation. This masks a much more considerable drop in volatility when one compares the first regime with the last (fifth) one, that ranges between 69.2% and 73.4% depending on the measure used. In between the first and fifth regimes there are two consecutive periods of declining volatility, followed by a period of increasing volatility, ending with a period of declining volatility. The official liberalisation date falls three months before the end of the second regime. The period of increased volatility, which lasts for about seven months, occurs more than two years after the official liberalisation date.

The case of Taiwan is very similar to that of Malaysia and to some extent, Korea. The pre-liberalisation period includes a regime of substantially increased volatility which starts about nine months before the official liberalisation date and ends three months after. The increase in volatility ranges from 35.3% in the case of the GARCH measure to 51.4% for the standard deviation. This period is then followed by two regimes of declining volatility, lasting about seven months and more than three years, respectively. The decline in volatility between the first and fourth regimes ranges from 43.3% to 51.6% depending on which measure is used. Comparing the pre and post liberalisation periods shows a decline in volatility in the range of 31.4% to 42.8%, which masks all the aforementioned changes.

Thailand presents a sharp contrast to the other countries in that the results suggest an increase in volatility, following the financial liberalisation of 1 September 1987. The comparison of the pre and post liberalisation periods in Figure 13 shows an increase of 201.5% for the standard deviation and 140.8% for the VARHAC measure. The GARCH measure indicates a change to an infinite unconditional variance, which further illustrates the limitations of artificially imposing a single breakdate in the sample period. The measures in Figure 14 show that volatility more than trebled about a year before the official liberalisation date. This regime continues for almost three years after the liberalisation date. Moreover, it is followed by a seven-month period where volatility increases by 91.8%-135.4%, depending on the measure used. In the final period, which lasts about six months, volatility declines by about 50%, but this is not sufficient to bring it back to its pre-liberalisation level. In fact, comparison of the first and last regimes suggests that volatility increased by 189.1%-257.6%, depending on the measure employed. Once again, a before and after comparison masks several important volatility swings.

5. Conclusions

This paper highlights the importance of correctly identifying the number and timing of structural breaks when analysing changes in stock market volatility due to financial liberalisation. The volatility dynamics that emerge when breakdates are carefully extracted from the data are much richer than those suggested by studying the pre and post liberalisation periods. In three of the five countries analysed - Korea, Malaysia and Taiwan – volatility increases before the official liberalisation date and subsequently declines below its original level. Analysing the pre and post liberalisation periods altogether fails to detect pick up the period of increased volatility, which in the case of Korea exceeds two years. In the case of the Philippines, analysing the pre and post liberalisation periods, masks an initial marked decline in volatility and fails to pick up a period of substantially increased volatility that occurs more than two years after the official liberalisation date. In the case of Thailand, focussing on the official liberalisation date fails to pick up a decline in volatility that occurs in the fourth (final) regime, which nevertheless is not sufficient to reduce volatility to its pre-liberalisation level. In all cases the analysis of pre and post liberalisation periods results in an 'averaging-out' of volatility patterns. Thus, important changes in volatility may not be detected resulting in inaccurate inference and potentially misleading policy implications. To end on a more positive note, our findings would suggest that the analysis of the effects of financial liberalisation on stock market uncertainty remains fertile ground for further research.

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Appendix I – the GARCH models

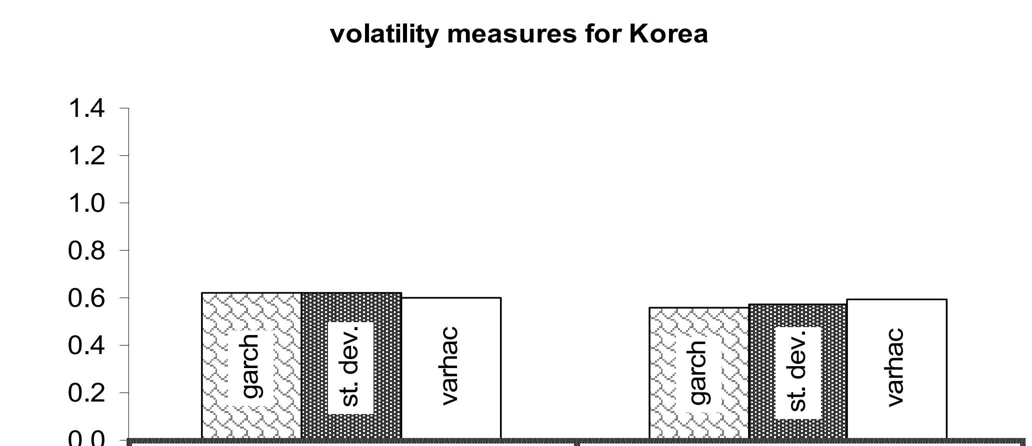
The table that follows presents the GARCH model that best fits the data of each segment.

Note that * denotes insignificance at 10% level; in its place the standard deviation is used.

		μ	ω	$(\varepsilon_{t-1})^2$	$(\varepsilon_{t-2})^2$	$(\sigma_{t-1})^2$	$(\sigma_{t-2})^2$	$(\sigma_{t-3})^2$
Korea	before liberalization	-	0.0263	0.2296	-0.1140	0.8165	-	-
		-	(0.0052)	(0.04)	(0.0435)	(0.0261)	-	-
	after liberalization	-	0.0093	0.0537	-	2.1200	-1.8877	0.6843
		-	(0.0025)	(0.0094)	-	(0.0738)	(0.1238)	(0.0655)
	segment 1	-	0.0776	0.1474	-	0.5569	-	-
		-	(0.0289)	(0.0431)	-	(0.1347)	-	-
	segment 2	-	0.0487	0.1811	-	0.7380	-	-
		-	(0.0109)	(0.0273)	-	(0.0305)	-	-
	segment 3	-	0.2975	0.0070	-	-	-	-
		-	(0.0220)	(0.0463)	-	-	-	-
	segment 4	-	0.1820	0.0844	-	-	-	-
		-	(0.0121)	-0.0508	-	-	-	-
Malaysia	before liberalization	-	0.0104	0.1649	-0.1147	0.9279	-	-
		-	(0.0021)	(0.0226)	(0.019)	(0.0107)	-	-
	after liberalization	-	0.0913	0.2758	-	0.3470	-	-
		-	(0.0094)	(0.0446)	-	(0.0705)	-	-
	segment 1	-	0.0149	0.0439	-	0.9172	-	-
		-	(0.0058)	(0.0128)	-	(0.0244)	-	-
	segment 2	-	0.2805	-	-	-0.1165	0.8029	-
		-	(0.0678)	-	-	(0.018)	(0.0297)	-
	segment 3	-	0.0878	0.2045	-	0.4695	-	-
		-	(0.0149)	(0.0377)	-	(0.0876)	-	-
	segment 4	-	0.0865	0.2413	-	-	-	-
		-	(0.0061)	(0.0716)	-	-	-	-
The Phillipines	before liberalization	-	0.0127	0.1546	-0.0883	0.9193	-	-
		-	(0.003)	(0.035)	(0.0359)	(0.0098)	-	-
	after liberalization	-	0.0090	0.0625	-	0.9133	-	-
		-	(0.0028)	(0.0125)	-	(0.0167)	-	-
	segment 1	-	2.6168	0.3842	-	-	-	-
		-	(0.2608)	(0.1102)	-	-	-	-
	segment 2	-	0.0285	0.0713	-	0.8806	-	-
		-	(0.007)	(0.0112)	-	(0.0201)	-	-
	segment 3	-	0.0244	0.1563	-	0.1821	0.5788	-
		-	(0.0101)	(0.0423)	-	(0.0829)	(0.0991)	-
	segment 4	-	0.6700*	-0.0437*	-	-	-	-
		-	(0.074)	(0.0646)	-	-	-	-
	segment 5	-	0.0075	-	-	1.9538	-0.9788	-
		-	(0.0025)	-	-	(0.0175)	(0.0175)	-
Taiwan	before liberalization	0.1301	0.0250	0.1190	-	0.8665	-	-
		(0.0278)	(0.0081)	(0.0235)	-	(0.0247)	-	-
	after liberalization	-	0.0152	0.0579	-	0.9156	-	-
		-	(0.0032)	(0.0083)	-	(0.0104)	-	-
	segment 1	0.1267	0.0220	0.1107	-	0.8777	-	-
		(0.0277)	(0.007)	(0.0208)	-	(0.0212)	-	-
	segment 2	-	0.0308	-0.0285	-	1.0196	-	-
		-	(0.0045)	(0.0017)	-	(0.0027)	-	-
	segment 3	-	0.0497	-0.0701	-	0.1443	0.8825	-
		-	(0.0117)	(0.029)	-	(0.0026)	(0.0247)	-
	segment 4	-	0.0120	0.0344	-	1.3999	-0.4589	-
		-	(0.0045)	(0.0125)	-	(0.2336)	(0.2145)	-
Thailand	before liberalization	-0.0174	0.0011	0.2546	-0.1260	0.8689	-	-
		(0.0049)	(0.0002)	(0.0405)	(0.0429)	(0.0136)	-	-
	after liberalization	0.0455	0.0073	0.2019	-0.0687	0.8695	-	-
		(0.0154)	(0.0016)	(0.0277)	(0.0311)	(0.0116)	-	-
	segment 1	-0.0224	0.0037	0.1981	-	0.7190	-	-
		(0.0051)	(0.0009)	(0.0248)	-	(0.0402)	-	-
	segment 2	0.0694	0.0076	0.1274	-	0.8579	-	-
		(0.0133)	(0.0018)	(0.0134)	-	(0.0125)	-	-
	segment 3	-	1.5078	0.2117	-	-	-	-
		-	(0.1943)	(0.1242)	-	-	-	-
	segment 4	-	0.3125	0.2273	-	-	-	-
		-	(0.0353)	(0.0935)	-	-	-	-

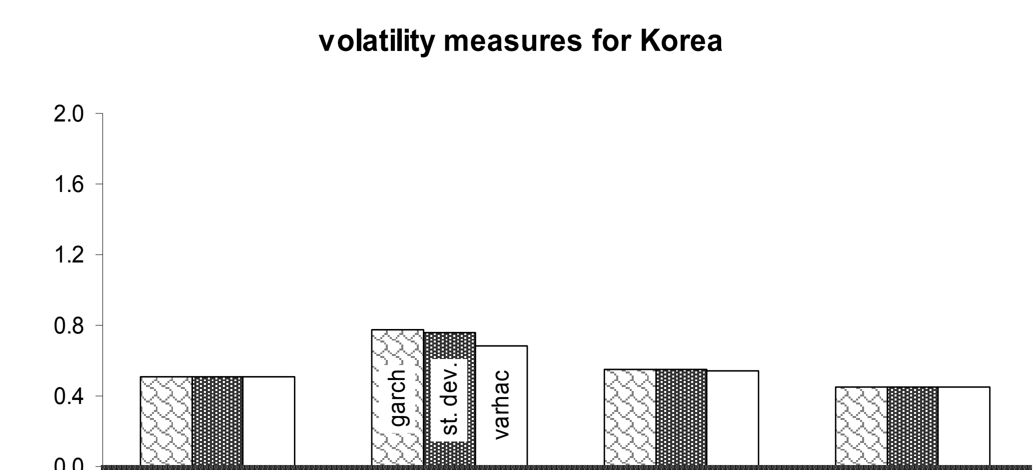
Appendix II - Figures

Figure 1



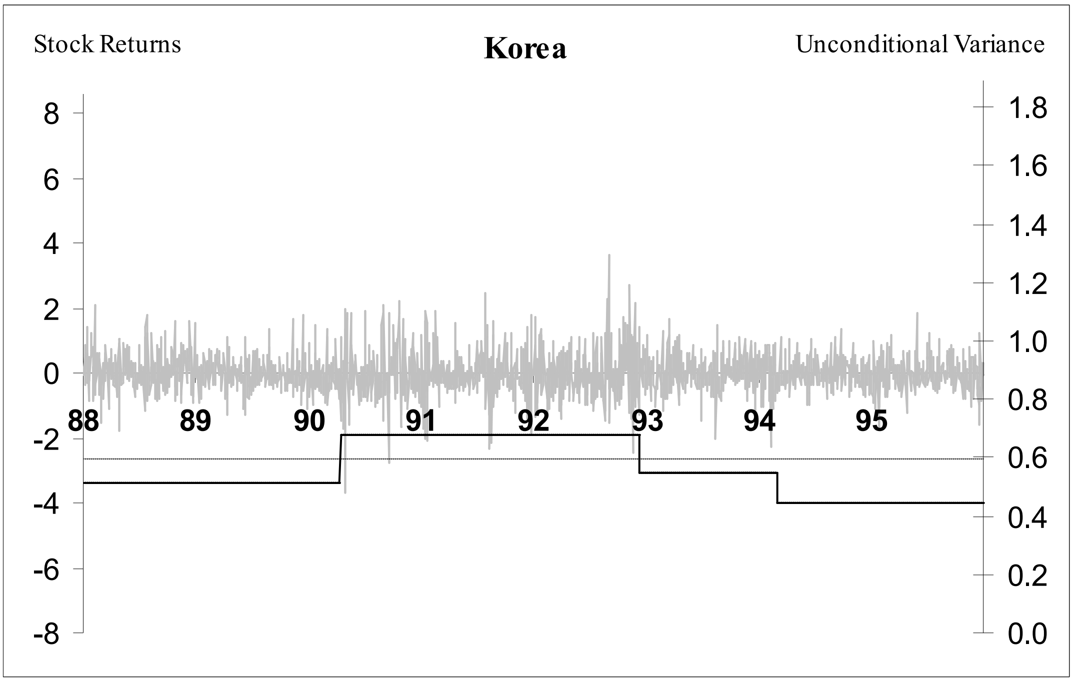
	before liberalisation 01/01/88 - 31/12/91	*after liberalisation 01/01/92 - 29/12/95*
garch	*0.622*	*0.561*
st. dev.	*0.624*	*0.572*
varhac	*0.597*	*0.595*

Figure 2



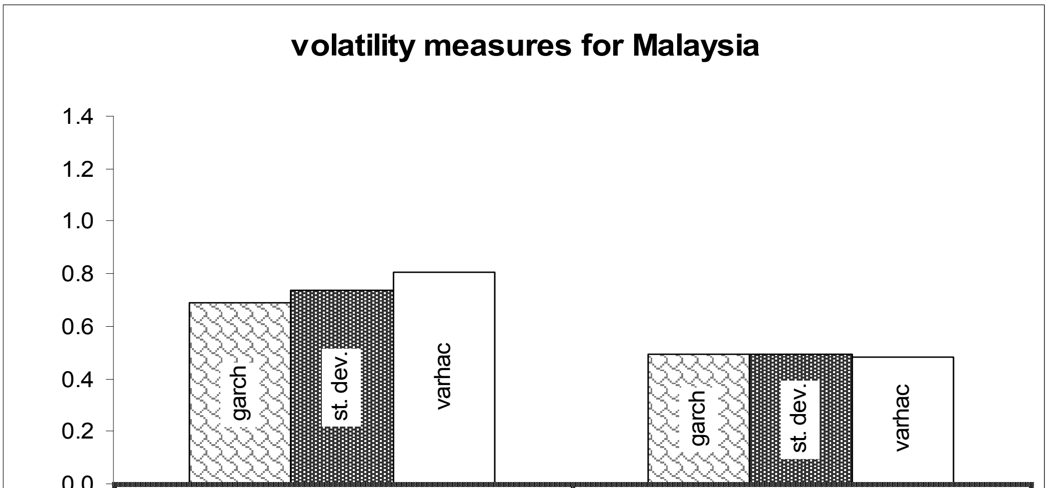
	segment 1 01/01/88 - 15/04/90	*segment 2 16/04/90 - 09/12/92*	*segment 3 10/12/92 - 28/02/94*	*segment 4 01/03/94 29/12/95*
garch	*0.512*	*0.776*	*0.547*	*0.446*
st. dev.	*0.511*	*0.760*	*0.547*	*0.446*
varhac	*0.511*	*0.681*	*0.545*	*0.447*

Figure 3



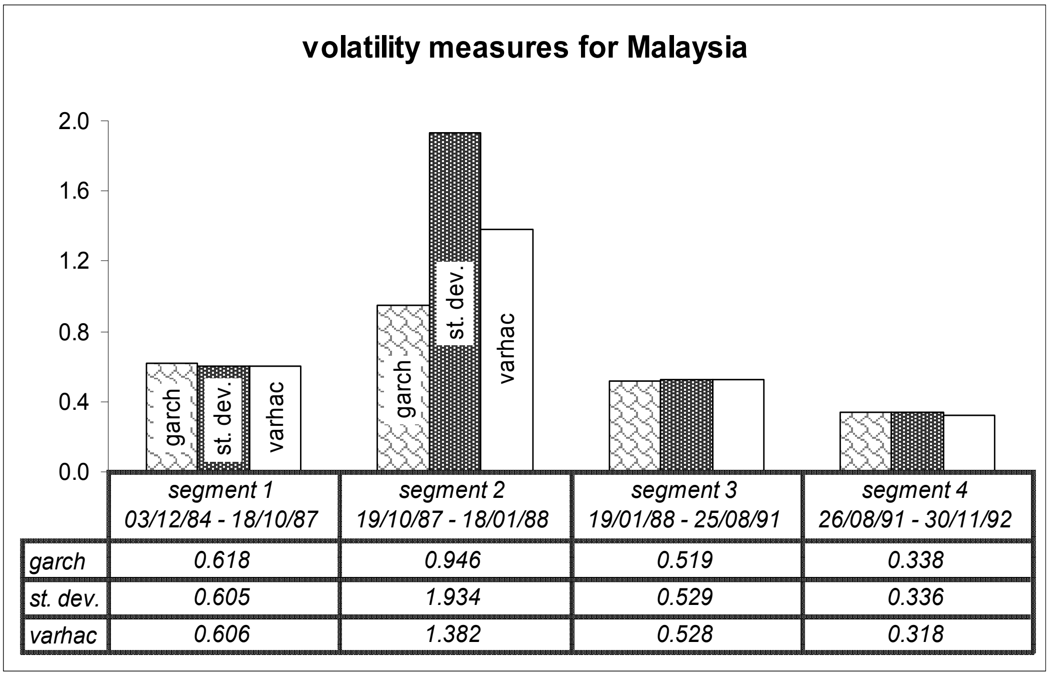
Note: the magnitude of the volatility that is depicted in all cases is the VARHAC estimate of den Haan. Also, the dashed line presents the volatility as given by the two segments defined by the official liberalisation date. The continuous line presents the volatility as given by the segments identified by the procedure of Section 2.

Figure 4



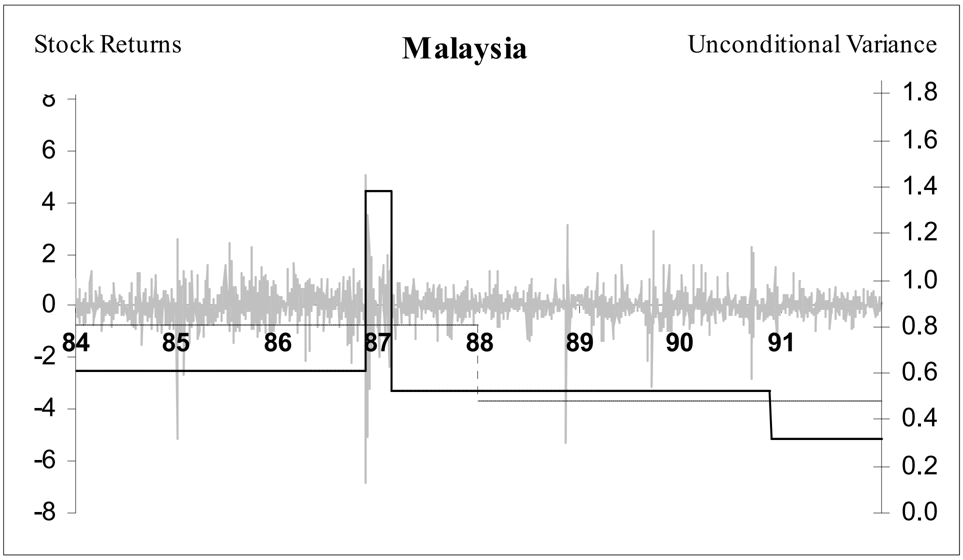
	before liberalisation 03/12/84 - 30/11/88	*after liberalisation 01/12/88 - 30/11/92*
garch	*0.687*	*0.492*
st. dev.	*0.736*	*0.495*
varhac	*0.808*	*0.482*

Figure 5



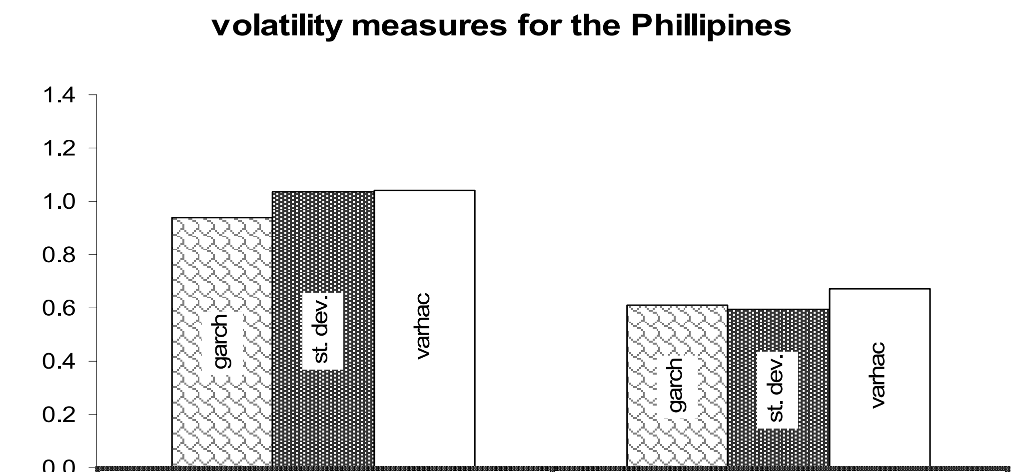
	segment 1 03/12/84 - 18/10/87	segment 2 19/10/87 - 18/01/88	segment 3 19/01/88 - 25/08/91	segment 4 26/08/91 - 30/11/92
garch	*0.618*	*0.946*	*0.519*	*0.338*
st. dev.	*0.605*	*1.934*	*0.529*	*0.336*
varhac	*0.606*	*1.382*	*0.528*	*0.318*

Figure 6



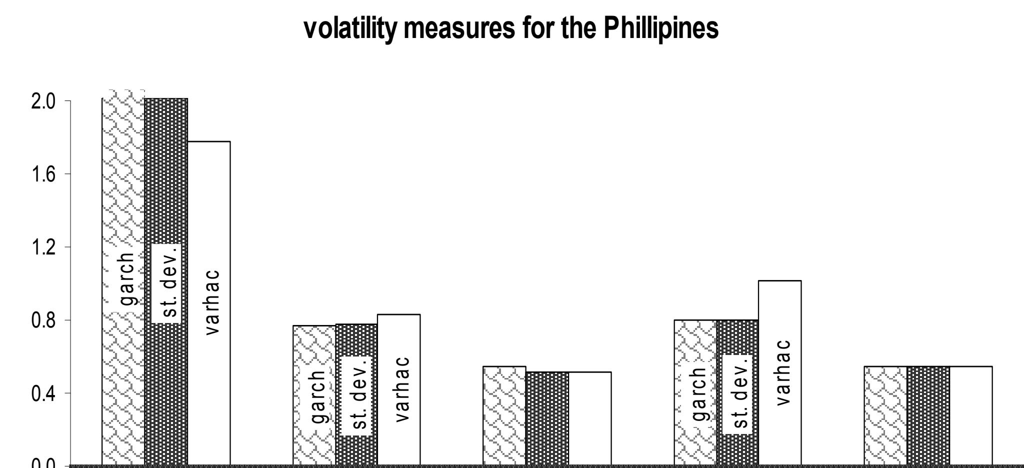
Note: the magnitude of the volatility that is depicted in all cases is the VARHAC estimate of den Haan. Also, the dashed line presents the volatility as given by the two segments defined by the official liberalisation date. The continuous line presents the volatility as given by the segments identified by the procedure of Section 2.

Figure 7



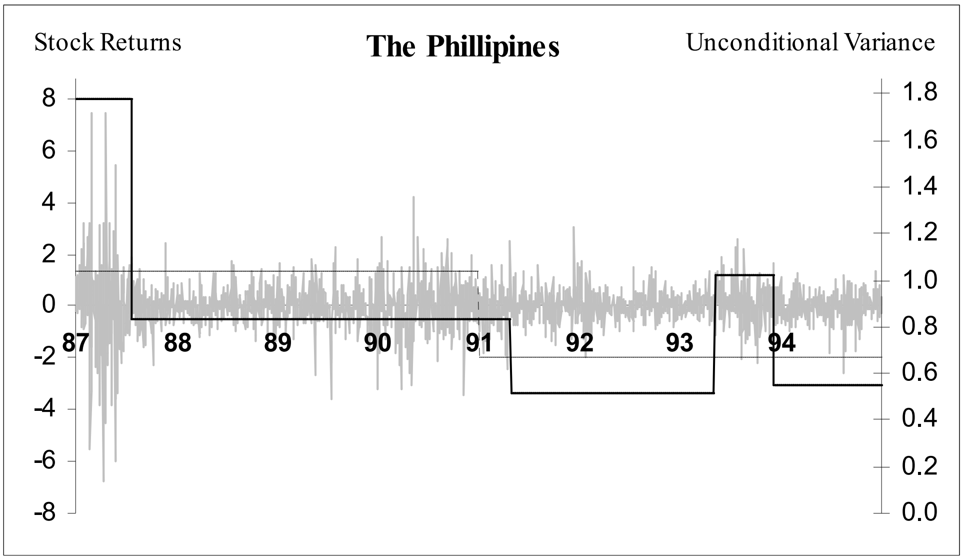
	before liberalisation 01/06/87 - 31/05/91	after liberalisation 01/06/91 - 31/05/95
garch	*0.939*	*0.611*
st. dev.	*1.038*	*0.597*
varhac	*1.039*	*0.671*

Figure 8



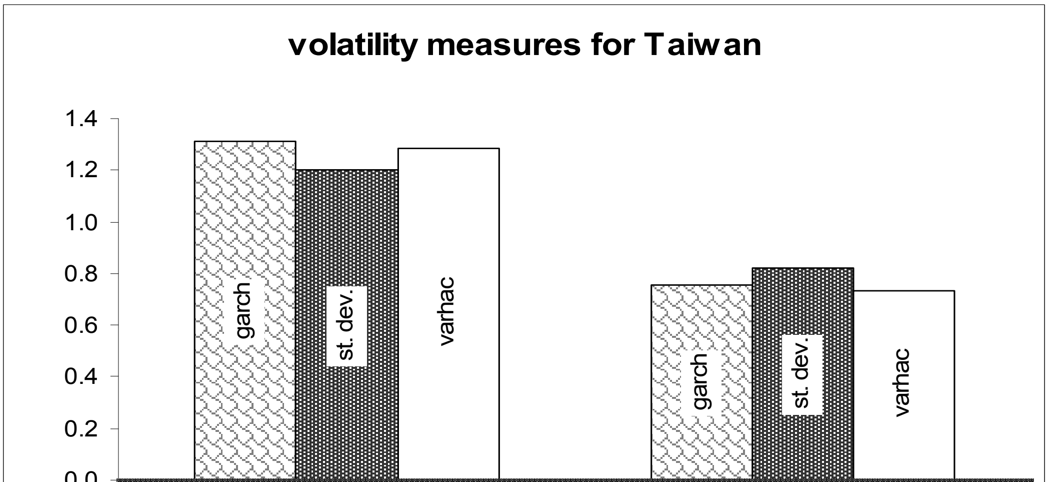
	segment 1 01/06/87 - 19/12/87	segment 2 20/12/87 - 24/09/91	segment 3 25/09/91 - 03/10/93	segment 4 04/10/93 - 05/05/94	segment 5 06/05/94 - 31/05/95
garch	*2.061*	*0.770*	*0.543*	*0.801*	*0.548*
st. dev.	*2.014*	*0.776*	*0.515*	*0.800*	*0.548*
varhac	*1.781*	*0.831*	*0.516*	*1.019*	*0.548*

Figure 9



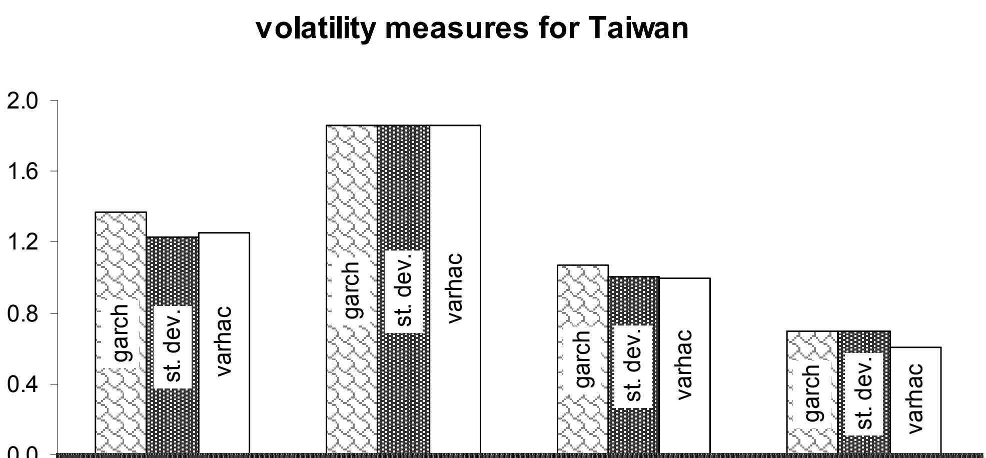
Note: the magnitude of the volatility that is depicted in all cases is the VARHAC estimate of den Haan. Also, the dashed line presents the volatility as given by the two segments defined by the official liberalisation date. The continuous line presents the volatility as given by the segments identified by the procedure of Section 2.

Figure 10



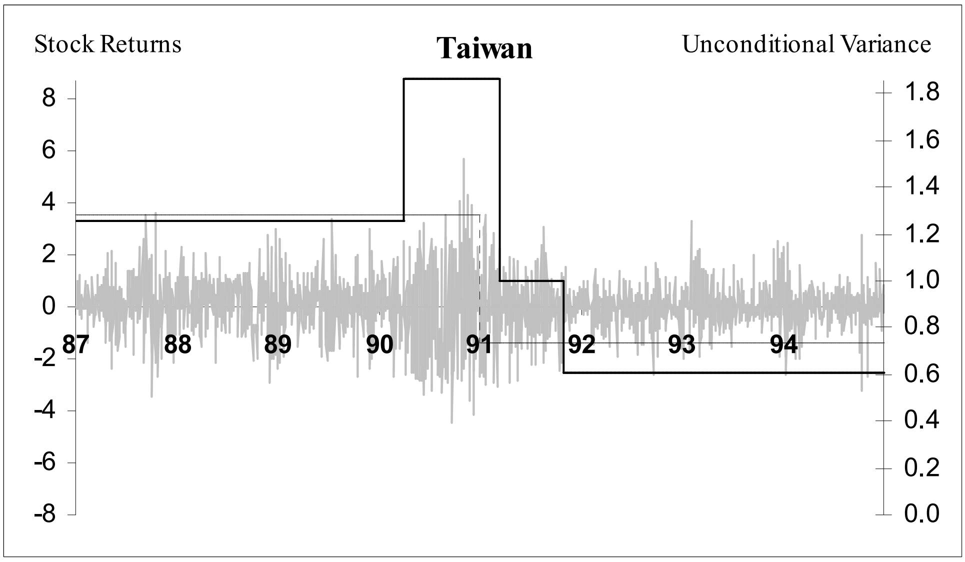
	before liberalisation 01/01/87 - 31/12/90	*after liberalisation 01/01/91 - 31/12/94*
garch	*1.314*	*0.756*
st. dev.	*1.202*	*0.824*
varhac	*1.284*	*0.735*

Figure 11



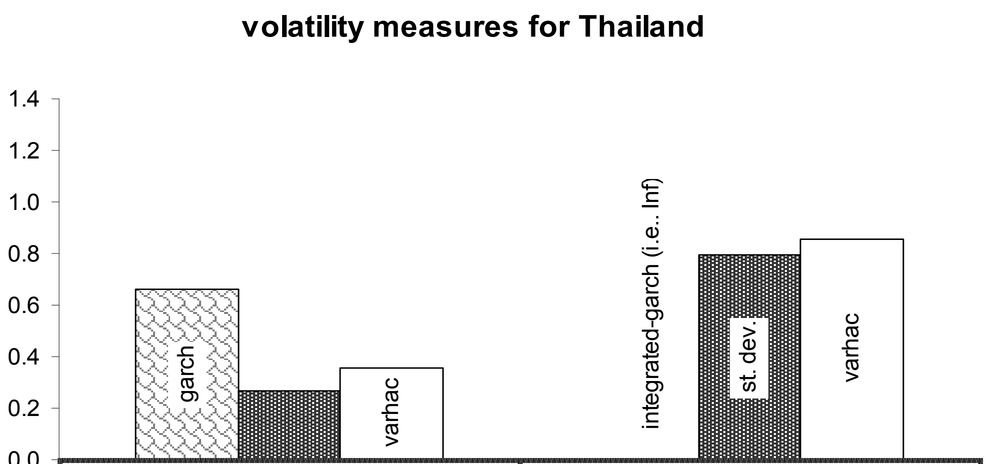
	segment 1 01/01/87 - 01/04/90	segment 2 02/04/90 - 11/03/91	segment 3 12/03/91 - 28/10/91	segment 4 29/10/91 - 30/12/94
garch	*1.372*	*1.857*	*1.072*	*0.697*
st. dev.	*1.228*	*1.859*	*1.000*	*0.696*
varhac	*1.255*	*1.862*	*1.000*	*0.607*

Figure 12



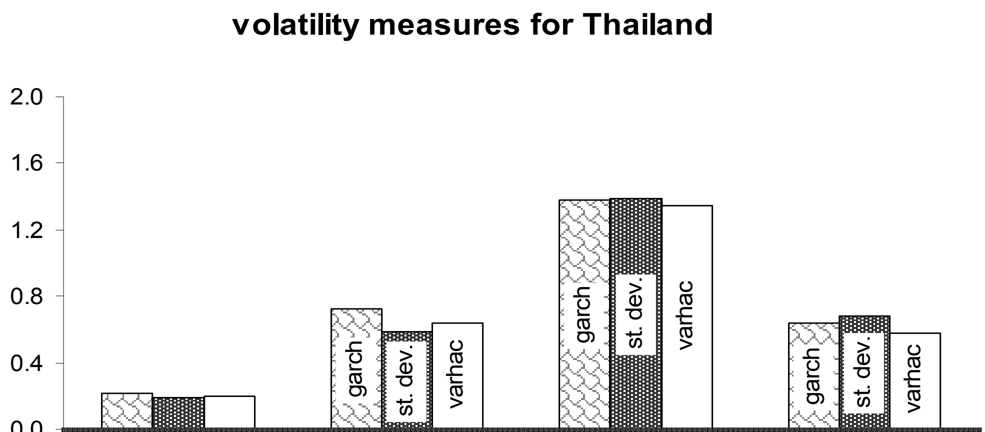
Note: the magnitude of the volatility that is depicted in all cases is the VARHAC estimate of den Haan. Also, the dashed line presents the volatility as given by the two segments defined by the official liberalisation date. The continuous line presents the volatility as given by the segments identified by the procedure of Section 2.

Figure 13



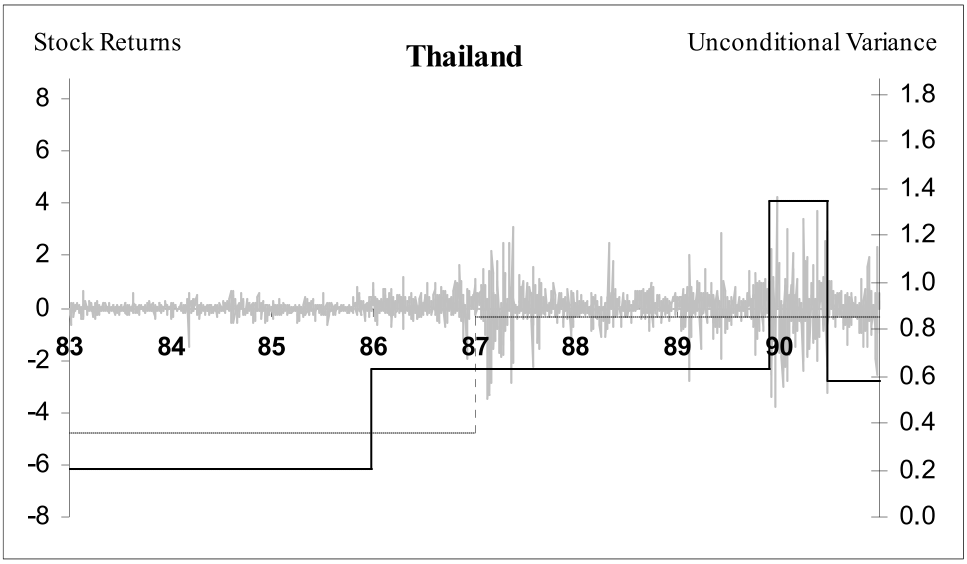
	before liberalisation 01/09/83 - 31/08/87	after liberalisation 01/09/87 - 31/08/91
garch	0.661	
st. dev.	0.264	0.796
varhac	0.355	0.855

Figure 14



	segment 1 01/09/83 - 27/08/86	segment 2 28/08/86 - 31/07/90	segment 3 01/08/90 -26/02/91	segment 4 27/02/91 - 30/08/91
garch	0.212	0.721	1.383	0.636
st. dev.	0.191	0.588	1.384	0.683
varhac	0.201	0.634	1.342	0.581

Figure 15



Note: the magnitude of the volatility that is depicted in all cases is the VARHAC estimate of den Haan. Also, the dashed line presents the volatility as given by the two segments defined by the official liberalisation date. The continuous line presents the volatility as given by the segments identified by the procedure of Section 2.