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Did Equity Market Volatility Increase Following the Opening of Emerging Markets to Foreign Investors?

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In this paper, we empirically investigate whether deregulation and financial liberalisation resulted in increased equity market volatility, in a sample of eight very important 'emerging' markets. More specifically, the sample consists of Argentina, Chile, Mexico, South Korea, India, Pakistan, Philippines and Taiwan. Motivated by the observation of Ross (1989) and Lamoureux and Lastrapes (1990) that increased volatility could reflect increased information flow, we employ a methodology which allows us to (i) account for time variation in volatility, and (ii) examine changes in volatility persistence, i.e., changes in the *nature* of volatility rather than changes in volatility *per se*. The results suggest that, for most of the sample markets, the nature of volatility has not changed dramatically after liberalisation.

I. Introduction

The work of McKinnon (1973) and Shaw (1973) suggests that financial repression will result to indiscriminate distortions of financial prices and in reduced real rate of economic growth. Deregulation, development and liberalisation of financial markets is seen to affect economic growth by allowing interest rates to be raised to their *laissez-faire* competitive levels. The increased marginal productivity of capital will increase output growth, which, in turn, will further increase saving and investment (Fry (1997)).[1] This development process should also enhance the role of the stock market through increased research, production and dissemination of information in the market place, which should result in the reduction of volatility of equity prices. Tauchen and Pitts (1983) present a model which shows that volatility is inversely related to the number of traders in a market. Contrary to the above, the Keynesian view assumes imperfect markets (particularly in relation to the availability of information to all participants) and that investment is determined by "animal spirits". Therefore, deregulation could attract speculators and investors with short term strategies who can introduce financial crises and economic instability. Furthermore, volatility can induce even more volatility and, in this sense, financial liberalisation will increase volatility through increased liquidity. Keynes (1964), regards liquidity as having a destabilising effect on the market because of the assumption of market imperfection.

However, even if volatility increases after financial liberalisation, this may not be damaging

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1. For a review of recent evidence and a discussion on financial development and economic growth, see also Arestis and Demetriades (1997).

to the efficiency of a market. Ross (1989) and Lamoureux and Lastrapes (1990) show that volatility is related to the rate of information flow arriving in the market. Thus, increased volatility could reflect increased information flow. This is also consistent with the neo-classical theory which suggests that financial deepening should encourage increased production and dissemination of information because of the profit opportunities which will follow financial liberalisation.

The issue of Financial liberalisation and economic growth has naturally attracted the attention of many researchers. However, as Arestis and Demetriades (1997) argue, there are still issues such as the relationship of financial liberalisation and equity market volatility that need further investigation. In this paper we attempt to address this gap in the literature and empirically investigate the impact of financial liberalisation on equity market volatility in a sample of Emerging Stock Markets (ESMs, hereafter). Grabel (1995) presented some evidence that volatility increased in selected ESMs following financial liberalisation. Here, motivated by the observation of Ross (1989) and Lamoureux and Lastrapes (1990) we follow a different approach. More specifically we employ a methodology which allows us to (i) account for time variation in volatility, and (ii) examine changes in volatility persistence, i.e., changes in the *nature* of volatility rather than changes in volatility *per se*. The rest of the paper is arranged as follows: Section II describes the data and the testing methodologies, Section III presents the results, whilst Section IV concludes the paper.

II. Data and Testing Methodologies

For the empirical analysis, as a proxy for the stock markets, we use daily observations on the Korean S.E. Composite Price Index, Chile General Price Index, Bombay S.E. National Price Index, Mexico I.P.C. Price Index, Karachi S.E. 100 Price Index, Philippines S.E. Composite Price Index, Taiwan S.E. Weighted Price Index. For Argentina we used the Datastream Total Stock Market Index. All data are collected from Datastream and indices are expressed in local currency. The sample period begins at 5/1/88 for all markets and at 3/7/89 for India and Pakistan (due to data unavailability) and ends at 27/2/98. We employ daily observations because the GARCH models that we will utilise are estimated with the Maximum Likelihood (ML) approach and ML estimators are asymptotic; i.e., they are valid only in large samples.

We split the sample period for each market in two sub-periods, a pre-liberalisation and a post-liberalisation period. The cut-off point is the year when an important policy which opened the market to foreign investors was introduced: during 1989 in Argentina (December) all limits to foreign capital were abolished and in Mexico (May) all shares were made investable, while in India, Pakistan and Philippines all shares were made investable in November 1992, February 1991, and November 1991, respectively. In Chile, foreign exchange transactions were made free on April 1990, while in S. Korea and Taiwan foreign ownership levels increased in January 1992 and January 1991, respectively (see for details Bekaert (1995a)). It should be noted that these policies are not the only policies implemented in these markets nor are they of the same nature. However, they signify important policy shifts. Also, liberalisation is a long process and often markets adjust before a policy is introduced. In order to avoid estimation bias resulting from this adjustment process we dropped from the sample 200 observations before and 200 observations after the liberalisation policy was introduced.

Equity returns are estimated as the first differences of the logarithmic price levels. Since, in the present analysis, only the conditional variance is of interest we utilise the following procedure to obtain the unpredictable part of the stock returns (see also Pagan and Schwert (1990), and Engle and Ng (1993)): returns are regressed on a constant and four dummy variables, one for each day from Tuesday through Friday, to remove any day-of-the-week effect. Next, the residuals from this regression are regressed on their lagged values up to fifth order, to remove any predictable component of the return series. The residuals of this last regression are then used in the analysis.

The next step is to test for autoregressive conditional heteroscedasticity (ARCH) effects in the data. The ARCH model developed by Engle (1982) can account for the difference between the unconditional and the conditional variance of a stochastic process. While conventional econometric models operate under the assumption of constant variance, the ARCH process allows the conditional variance to vary over time, leaving the unconditional variance constant. In the ARCH(q) model the conditional variance is a function of past squared innovations (u_t) in the mean of some other stochastic process, thus allowing it to change over time:

$$y_t = \beta' x_t + u_t, \tag{1}$$

$$u_t \mid \Omega_{t-1} \sim N(0, h_t), \tag{2}$$

$$h_t^2 = \omega + \sum_{j=1}^{q} a_j u_{t-j}^2, \tag{3}$$

where x_t is a vector including the information set Ω_{t-1}, u_t is a random error, and h_t^2 is the conditional volatility of the stochastic process y_t.

A more general process is the Generalised ARCH (GARCH) process developed by Bollerslev (1986). The GARCH models are capable of capturing leptokurtosis, skewness and volatility clustering, which are the three of features most often observed in empirical analysis. Volatility clustering implies that large (small) price changes follow large (small) price changes of either sign. In the GARCH(q,p) model, the conditional volatility is specified as in Equation (3) with the addition of its past squared values, as in Equation (4):

$$h_t^2 = \omega + \sum_{j=1}^{q} a_j u_{t-j}^2 + \sum_{j=1}^{p} c_j h_{t-j}^2. \tag{4}$$

For a well defined GARCH(q,p) the following restrictions must be imposed, to ensure that the conditional variance does not take negative values: $\omega > 0$, $a_j \geq 0$ and $c_j \geq 0$. One of the appealing features of the GARCH model, is that it can be interpreted as an ARMA model. Bollerslev *et al*. (1992) review the empirical evidence on the ARCH modelling in finance and suggest that most financial series follow a GARCH(1,1) process.

To capture the time varying volatility, in this paper, Equation (4) is used.[2] The coefficient of the squared error term (a) measures the extent to which past news cause volatility today. In other words the size and significance of a implies the existence of volatility clustering in the data. The sum $(a+c)$ measures volatility persistence. As the sum $a+c$ approaches unity, the persistence of shocks to volatility becomes greater. If $a+c=1$ then any shock to volatility is permanent and the unconditional variance is infinite. In this case, the process is called an I-GARCH process (integrated in variance process, Engle and Bollerslev (1986)). The I-GARCH process implies that volatility persistence is permanent and therefore past volatility is significant in predicting future volatility over all finite horizons. If the sum $a+c$ is greater than unity, then volatility is explosive; i.e., a shock to volatility this period will result in even greater volatility during the next period (Chou (1988)).

Finally, we test for structural shifts in unpredictable return variance. Structural shifts mean that the constant in the variance equation of the GARCH model is not stable over time; i.e., the unconditional variance is non-stationary. Over long sample periods, it is likely that structural shifts will occur. These result in overestimation of the GARCH parameters, which could suggest an I-GARCH process. Here, we test for a structural shift between September 1997 and the end of the sample period in order to account for the financial crisis that disturbed the markets during this period. To test for structural shifts in the unconditional variance, we include dummy variables in the variance equation of the standard GARCH model, as in (5):

$$h_t^2 = \omega + dD_t + au_{t-1}^2 + ch_{t-1}^2, \tag{5}$$

where D_t is a dummy variable which corresponds to the period September 1997 to February 1998, i.e., takes the value of 1 for this period and 0 otherwise. If the dummy variable is significant, then the constant in the variance equation is not stable and the period for which it is unstable should be dropped from the analysis. The period used is the post-liberalisation period for every country. Then we proceed with the analysis as described above.[3]

III. Results

Table 1 presents some sample statistics for the unpredictable returns. The most extreme maximum and minimum return is observed in Argentina which is also the riskier market, with the highest standard deviation. However, skewness does not seem to be a big problem since all statistics are close to zero. Excess positive kurtosis is found for all countries indicating thicker tails than a normal distribution. The Jarque-Bera test for normality indicates significant

2. In estimating the GARCH parameters pre- and post-liberalisation we have to make an assumption about the distribution of returns. Because of the non-normality of the unpredictable returns, assuming a normal distribution for the GARCH models could be inappropriate and result in inaccurate estimates (although in most cases results obtained under both assumptions are similar, e.g., Choudhry (1996)). Therefore, all models are estimated assuming a normal distribution and alternatively a *t* distribution. Selection between the two models is based on the Akaike Information Criterion (AIC) and the Schwarz Bayesian Criterion (SBC).
3. Note that we also test for structural shifts in mean equation. These results are reported along the results for the variance.

departures from normality for all market returns. The Ljung-Box statistic for 5th order autocorrelation is not significant for any country. Testing for ARCH effects (Table 2) indicates that there are significant ARCH effects in all countries and for both sub-periods, except for the pre-liberalisation period in Argentina. Thus, there is evidence of time varying volatility in the sample markets.

Table 1 Sample Statistics

	Max	Min	StDev	Skew	Kurt	Norm	Ljung-Box Statistic (5)
Argentina	0.364	-0.652	0.038	-0.513	41.884	193,374.9	0.306
Chile	0.060	-0.124	0.009	-0.587	18.559	38,096.8	0.257
India	0.165	-0.091	0.016	0.755	12.784	15,570.0	0.082
Korea	0.100	-0.118	0.016	0.196	5.775	3,691.1	0.027
Mexico	0.143	-0.138	0.016	0.201	8.962	8,846.6	0.196
Pakistan	0.070	-0.097	0.012	0.019	6.464	3,926.4	0.056
Philippines	0.097	-0.096	0.016	0.044	4.357	2,092.1	0.222
Taiwan	0.130	-0.103	0.021	-0.078	2.768	846.61	0.029

Table 2 Lagrange Multiplier Statistic for ARCH Effects in the Conditional Volatility

$$h_t^2 = \omega + \sum_{j=1}^{q} \alpha_j u_{t-j}^2$$
$$H_0: \alpha_1 = \cdots = \alpha_q = 0$$
$$H_1: \alpha_1 \neq 0, \cdots, \alpha_q \neq 0$$

	$\chi^2(1)$		$\chi^2(12)$	
	Pre-liberalisation	Post-liberalisation	Pre-liberalisation	Post-liberalisation
Argentina	0.705 (0.401)	33.64*** (0.000)	7.82 (0.799)	197.64*** (0.000)
Chile	5.776** (0.016)	170.142*** (0.000)	7.863 (0.796)	285.811*** (0.000)
India	6.576*** (0.010)	42.402*** (0.000)	67.652*** (0.000)	78.805*** (0.000)
Korea	95.578*** (0.000)	79.336*** (0.000)	137.007*** (0.000)	378.162*** (0.000)
Mexico	0.284 (0.594)	312.994*** (0.000)	25.040** (0.015)	335.563*** (0.000)
Pakistan	27.586*** (0.000)	60.725*** (0.000)	30.755*** (0.002)	94.596*** (0.000)
Philippines	11.203*** (0.001)	71.868*** (0.000)	73.781*** (0.000)	144.357*** (0.000)
Taiwan	16.653*** (0.000)	20.470*** (0.000)	63.717*** (0.000)	82.672*** (0.000)

Notes: The Lagrange Multiplier Statistic is distributed as $\chi^2(q)$.
The null hypothesis is no ARCH effects, figures in parentheses are probabilities that the null is accepted.
***, ** and * reject the null hypothesis at the 1%, 5% and 10% significance level respectively.

Having established ARCH effects in the volatility of the sample data, we next turn our attention to the existence of GARCH effects. To this end, we estimate a GARCH(1,1) model for the whole sample period (Table 3). The results suggest that large (small) price changes follow large (small) price changes of either sign. The ARCH coefficient (α) is less than unity in every case indicating that volatility is not explosive. The sum $\alpha + c$ which measures persistence is significantly different from unity only for Korea, Mexico, and Taiwan at the 1% significance level. This suggest that any shock to volatility is permanent in the other countries. The Ljung-Box tests for serial correlation do not reject the null hypothesis of no autocorrelation, except for Argentina, Chile and India at the 1% significance level. However, these results should be interpreted with caution since, when ARCH is present in a series, the standard tests for autocorrelation tend to over-reject the null (Taylor (1986)).

Table 3 GARCH(1,1) Estimation for Daily Returns

$$h_t^2 = \omega + \alpha_1 u_{t-1}^2 + c_1 h_{t-1}^2$$

	ω	α	c	$\alpha + c$	Ljung-Box	Iter.
Argentina	0.512E-5*	0.122***	0.883***	1.005[.518]	28.53[.001]	32
	(0.289E-5)	(0.018)	(0.013)			
Chile	0.456E-5*	0.259***	0.709***	0.968[.105]	37.48[.000]	28
	(0.240E-5)	(0.036)	(0.022)			
India	0.301E-5	0.102***	0.894***	0.996[.482]	32.74[.000]	86
	(0.285E-5)	(0.014)	(0.01)			
Korea	0.96E-5***	0.126***	0.830***	0.956[.000]	14.09[.169]	43
	(0.240E-5)	(0.014)	(0.012)			
Mexico	0.16E-4***	0.151***	0.793***	0.944[.000]	6.38[.783]	28
	(0.262E-5)	(0.022)	(0.016)			
Pakistan	0.377E-5	0.147***	0.843***	0.990[.179]	13.87[.179]	128
	(0.264E-5)	(0.019)	(0.014)			
Philippines	0.159E-5	0.058**	0.938***	0.996[.293]	7.84[.645]	252
	(0.654E-5)	(0.023)	(0.020)			
Taiwan	0.557E-5**	0.071***	0.915***	0.986[.000]	16.00[.100]	122
	(0.283E-5)	(0.010)	(0.008)			

Notes: Numbers in parenthesis are standard errors.
***, ** and * indicate significance at the 1%, 5% and 10% level respectively.
Numbers in brackets are probabilities that $\alpha + c$ is not significantly different from unity, given by a Wald test. Ljung-Box St. is the Ljung-Box (10) statistics for serial correlation.
The last column reports the number of iterations after which convergence was reached.

Results from testing for structural shifts (Table 4) suggest that the only markets that became more volatile (statistically significant coefficient) during the 1997-1998 financial crisis are Korea and Pakistan. The coefficient of the dummy variable for Korea and Pakistan is also positive, suggesting an increase in the conditional variance of stock returns in both countries. Thus, for these markets, the sub-period September 1997 to February 1998, is excluded from the analysis.

Table 4 Testing for Structural Shifts in Unpredictable Returns and Unconditional Variance

	$d_{mean\ equation}$	$d_{variance\ equation}$	Iterations
Argentina	0.1108E-3 (0.001349)	0.768E-5 (0.110E-4)	39
Chile	-0.001038** (0.5262E-3)	0.859E-6 (0.829E-5)	22
India	-0.9122E-4 (0.0011251)	0.271E-5 (0.966E-5)	27
Korea	-0.0026678 (0.0022386)	0.48E-4*** (0.122E-4)	27
Mexico	0.1640E-3 (0.0012442)	0.142E-4 (0.106E-4)	37
Pakistan	-0.2940E-3 (0.0012302)	0.38E-4*** (0.107E-4)	49
Philippines	-0.4569E-4 (0.0017680)	0.215E-4 (0.877E-4)	38
Taiwan	-0.3682E-3 (0.0015970)	0.737E-5 (0.102E-4)	28

Notes: Number in parentheses are standard errors.
***, ** and * indicate significance at the 1%, 5% and 10% levels respectively.

We now have to determine which distributional assumption is appropriate for the sample data. All models are estimated assuming a normal distribution and alternatively a *t* distribution. Although the results obtained from the two assumptions are similar, in every case both the AIC and the SBC favour the assumption of a *t* distribution (see Table 5). The only exception is the pre-liberalisation period for Taiwan where the model can only be estimated assuming a normal distribution (it will not converge with a *t* distribution). Thus, for comparability, we also use the same assumption for the post-liberalisation period.[4]

Table 5 Selection Criteria Values for Different Distributional Assumptions for the GARCH Models Estimated

		Pre-liberalisation		Post-liberalisation	
		Normal	t-distr.	Normal	t-distr.
Argentina	AIC	541.7379	557.3095*	4897.8	4935.1*
	SBC	534.3982	548.1314*	4886.7	4921.2*
Chile	AIC	1190.0	1250.1*	6117.3	6145.5*
	SBC	1182.1	1240.3*	6106.4	6131.8*
India	AIC	1905.2	1945.2*	3634.0	3679.0*
	SBC	1896.2	1933.9*	3623.9	3666.0*

4. Also note that testing for the correct lag structure suggests that the nature of volatility has not changed dramatically after liberalisation: the lag structure of the GARCH process used remains the same in both subperiods, (1,1). These results are not reported here but are available from the authors upon request.

Table 5 (Continued)

		Pre-liberalisation		Post-liberalisation	
		Normal	t-distr.	Normal	t-distr.
Korea	AIC	2431.1	2460.8*	3849.8	3863.2*
	SBC	2421.6	2449.0*	3839.5	3850.3*
Mexico	AIC	309.1702	315.3677*	5956.3	6034.4*
	SBC	303.3448	308.0496*	5944.9	6020.3*
Pakistan	AIC	805.5275	820.4169*	4601.6	4676.8*
	SBC	798.8333	812.0491*	4591.0	4663.4*
Philippines	AIC	2131.8	2182.6*	4319.6	4367.3*
	SBC	2122.5	2171.0*	4309.0	4354.1*

Notes: The first line for every country reports the Akaike Information Criterion and the second line is the Schwarz Bayesian Criterion. The models with the highest AIC and SBC values are chosen.
* indicates the highest values.

Tables 6 and 7 report the results from the GARCH(1,1) estimation for the pre- and post-liberalisation period. We can see that the ARCH effect is statistically insignificant for Mexico and Pakistan in the pre-liberalisation period but becomes significant during the second period. The opposite happens in Philippines where the significant pre-liberalisation ARCH effect becomes insignificant during the second period. The volatility persistence indicator is higher in the second period for four countries (Chile, Korea, Philippines and Taiwan) and lower for the remaining four. However, a Wald test suggests that, *for both sub-periods*, the volatility persistence indicator equals unity for Argentina, Chile, India, Pakistan and Philippines. For Korea and Taiwan, $(a+c)$ is less than unity for both sub-periods, while for Mexico the null hypothesis of an I-GARCH is accepted only for the period before liberalisation, not after. So, in terms of volatility persistence, Mexico is the only country which benefited from liberalising its stock market (since any shock to volatility is absorbed by the market at a faster pace than before). What these results mean for Mexico is that, while during the first period a shock to volatility decays at the rate of 0.991 per day, during the second period it decays at the rate of 0.927 per day; after six weeks the proportion of the shock remains at 0.7624 (0.991^{30}) during the first period, while it remains at 0.1029 (0.927^{30}) during the second period.

Table 6 GARCH(1,1) Estimation for Daily Returns (Pre-liberalisation period)

$$h_t^2 = \omega + a_1 u_{t-1}^2 + c_1 h_{t-1}^2$$

	ω	a	c	DF	$a+c$	Ljung-Box	I
Argentina	0.4592E-4***	0.133**	0.868***	3.6385	1.001[.970]	16.34[.090]	24
	(0.1127E-4)	(0.054)	(0.037)	(1.0830)			
Chile	0.23E-4***	0.387**	0.480***	3.6787	0.867[.240]	17.69[.060]	30
	(0.575E-5)	(0.142)	(0.082)	(0.6358)			
India	0.1056E-4	0.11230**	0.872***	3.0496	0.984[.688]	23.19[.010]	38
	(0.6061E-5)	(0.053)	(0.033)	(0.5081)			
Korea	0.48E-4***	0.282***	0.512***	4.4486	0.800[.000]	11.41[.326]	27
	(0.403E-5)	(0.060)	(0.047)	(0.7564)			

Table 6 (Continued)

	ω	a	c	DF	$a+c$	Ljung-Box	I
Mexico	0.135E-4 (0.2051E-4)	0.145 (0.157)	0.846*** (0.070)	3.6184 (1.619)	0.991[.939]	18.38[.049]	27
Pakistan	0.437E-5 (0.870E-5)	0.399 (0.245)	0.577*** (0.100)	3.4272 (1.0306)	0.976[.907]	15.34[.120]	30
Philippines	0.32E-4*** (0.432E-5)	0.250*** (0.061)	0.700*** (0.039)	3.6902 (0.5421)	0.950[.295]	10.74[.378]	25
Taiwan	0.39E-4*** (0.5895E-5)	0.168** (0.041)	0.753*** (0.032)	- -	0.922[.000]	16.56[.084]	27

Notes: Numbers in parenthesis are standard errors.
***, ** and * indicate significance at the 1%, 5% and 10% levels respectively.
Numbers in the brackets in the fifth column are probabilities that $a+c$ is not significantly different from unity, given by a Wald test. Ljung-Box St. is the Ljung-Box (10) statistics for serial correlation.
DF: degrees of Freedom; I: iterations

Table 7 GARCH(1,1) Estimation for Daily Returns (Post-liberalisation period)

$$h_t^2 = \omega + a_1 u_{t-1}^2 + c_1 h_{t-1}^2$$

	ω	a	c	DF	$a+c$	Ljung-Box	I
Argentina	0.641E-5** (0.314E-5)	0.128*** (0.021)	0.866*** (0.016)	7.024 1.0789	0.994[.441]	11.57[.353]	24
Chile	0.258E-5 (0.324E-5)	0.204*** (0.038)	0.768*** (0.027)	7.4141 1.3300	0.973[.083]	23.08[.020]	23
India	0.511E-5 (0.509E-5)	0.122** (0.041)	0.854*** (0.029)	4.7275 0.8292	0.978[.180]	14.72[.142]	24
Korea	0.103E-4** (0.401E-5)	0.091*** (0.026)	0.840*** (0.023)	8.1975 1.942	0.931[.000]	11.16[.345]	20
Mexico	0.19E-4*** (0.273E-5)	0.152*** (0.025)	0.775*** (0.020)	5.0716 0.577	0.927[.000]	11.87[.294]	34
Pakistan	0.13E-4*** (0.326E-5)	0.222*** (0.047)	0.746*** (0.029)	3.660 0.418	0.968[.319]	6.92[.733]	33
Philippines	0.385E-5 (0.940E-5)	0.102 (0.071)	0.885*** (0.055)	4.9394 0.8859	0.987[.441]	7.88[.640]	40
Taiwan	0.94E-5*** (0.321E-5)	0.057*** (0.010)	0.9015*** (0.009)	- -	0.966[.000]	13.67[.189]	27

Notes: Numbers in parenthesis are standard errors.
***, ** and * indicate significance at the 1%, 5% and 10% levels respectively.
Numbers in the brackets in the fifth column are probabilities that $a+c$ is not significantly different from unity, given by a Wald test. Ljung-Box is the Ljung-Box (10) statistics for serial correlation.
DF: degrees of Freedom; I: iterations

Furthermore, comparing the two coefficients (a and c) before and after liberalisation we see that in most cases the ARCH coefficient has decreased and the lagged conditional volatility coefficient has increased. More specifically, for all markets except Mexico and India (where a very small increase is observed), the ARCH coefficient is lower in the second period, while the lagged conditional volatility coefficients are lower in the second period only for Argentina, India and Mexico. Furthermore, the constant in the variance equation is lower post-liberalisation for Argentina, Chile, India, Korea, Philippines and Taiwan and higher for Mexico and Pakistan.

Table 8 reports Wald statistics that test the null hypotheses, for all markets, that (i) the volatility persistence indicator, $(\alpha + c)$, after liberalisation is equal to the volatility persistence indicator before liberalisation; (ii) the constant term, (ω), after liberalisation is equal to the constant term before liberalisation; (iii) the α coefficient after liberalisation is equal to the α coefficient before liberalisation; (iv) the c coefficient after liberalisation is equal to the c coefficient before liberalisation; (v) the degrees of freedom (DF) coefficient after liberalisation is equal to the degrees of freedom coefficient before liberalisation.

Table 8 Wald Tests for Equality of V*olatility Persistence*, α, c, and *Degrees of Freedom* (*DF*) Coefficients, before Liberalisation (BL) and after Liberalisation (AL)

	$(\alpha+c)_{AL} = (\alpha+c)_{BL}$	$\omega_{AL} = \omega_{BL}$	$\alpha_{AL} = \alpha_{BL}$	$c_{AL} = c_{BL}$	$DF_{AL} = DF_{BL}$
Argentina	1.0080 [.315]	158.38 [.000]	0.72008 [.788]	0.16447 [.898]	9.8515 [.002]
Chile	47.853 [.000]	40.791 [.000]	23.0808 [.000]	112.118 [.000]	7.8874 [.005]
India	0.1704 [.680]	1.1193 [.290]	0.06235 [.803]	0.35975 [.549]	4.0947 [.043]
Korea	240.43 [.000]	88.284 [.000]	55.3376 [.000]	203.052 [.000]	3.7248 [.054]
Mexico	23.062 [.000]	3.9720 [.046]	0.81188 [.776]	12.77720 [.000]	6.3307 [.012]
Pakistan	0.0672 [.795]	6.8222 [.009]	14.2366 [.000]	34.2768 [.000]	0.3091 [.578]
Philippines	4.3393 [.037]	8.7175 [.003]	4.34400 [.037]	11.1878 [.001]	1.9881 [.159]
Taiwan	103.03 [.000]	84.700 [.000]	114.863 [.000]	4531.10 [.000]	-

Notes: The Wald test is a chi-square (1) test.
Numbers in brackets are probabilities that the null hypothesis of equality of coefficients is accepted.

The results suggest that the ARCH coefficient is statistically different (i.e., reduced) following liberalisation in Chile, Korea, Pakistan, Philippines and Taiwan, while it is the same as before liberalisation in Argentina, India and Mexico. The coefficient of lagged conditional volatility is statistically different for Chile, Korea, Mexico, Pakistan, Philippines and Taiwan (with the exception of Mexico, it has increased in every case). Furthermore, the DF coefficient is the same for both sub-periods for India (at the 1% level), Korea, Pakistan and Philippines and different (increased) for Argentina, Chile and Mexico. Finally, testing for equality between sub-periods of the volatility persistence indicators suggests that $(\alpha + c)$ remains the same only for Argentina, India, and Pakistan, while it is statistically different for all other markets.

Another way of measuring volatility persistence is the half life of a shock. This measurement indicates how many periods it takes for a shock in volatility to reach its half life. This statistic is calculated as: $\frac{\log(0.5)}{\log(\alpha+c)}$. Note that the statistic applies only when volatility is not explosive or permanent, $[\alpha + c < 1]$, i.e., we cannot apply it for Argentina in the pre-liberalisation period. From Table 9 we see that the statistic has been reduced for India, Mexico, and Pakistan, with the most dramatic change in Mexico where the half life of a shock becomes from approximately 138 days in the pre-liberalisation period, only 9 days in the post-liberalisation period.

Table 9 Half Life of a Shock Pre- and Post-liberalisation

The statistic is calculated as: $\frac{\log(0.5)}{\log(\alpha+c)}$

	Pre-liberalisation	Post-liberalisation
Argentina		115
Chile	5	24
India	43	28
Korea	3	10
Mexico	76	9
Pakistan	29	21
Philippines	14	53
Taiwan	9	16

Notes: The statistics are expressed in days.
All numbers have been rounded to the integer.

To summarise the results, for India no change in either the GARCH coefficients or the volatility persistence is observed. For Argentina everything is the same except the unconditional volatility, which appears reduced following liberalisation. Past unexpected news have a lesser impact on volatility than before liberalisation in Chile, Korea, Pakistan, Philippines and Taiwan. *This suggest that news in any of these five markets induce a lower level of volatility than before liberalisation*. However, the impact of past conditional volatility seems increased in these countries.[5] This suggests that *older news have an increased effect on volatility after liberalisation*.

Also, the unconditional volatility appears reduced following liberalisation in Chile, Korea, Philippines and Taiwan and has not changed in Argentina, India, and Pakistan. As regards to the persistence of shocks the results are somewhat mixed: for Argentina, India and Pakistan all tests indicate that $(\alpha+c)$ remains equal to unity and the same for both sub-periods; for Korea and Taiwan $(\alpha+c)$ is different from unity and is increased following liberalisation; for Mexico $(\alpha+c)$ is reduced following liberalisation; while for Chile and Philippines one test indicates that $(\alpha+c)$ is statistically indifferent from unity for both sub-periods (Tables 6 and 7), while another test indicates that the indicator is statistically different for the two

5. The past conditional volatility can be interpreted as an infinite order geometrically declining ARCH process. Therefore, this parameter captures the weight of the markets memory.

sub-periods (Table 8).

IV. Conclusion

In this paper we tried to examine the impact of financial liberalisation on stock market volatility. We take the view that the analysis of the changes in the *nature* of volatility rather than the *level* of volatility can provide us with a better insight on the effects of liberalisation. Thus, the methodology employed here not only accounts for the time varying element of volatility, but also for other problems often encountered in financial data, such as skewness and leprokurtosis.

The results suggest that the nature of volatility has not changed dramatically after liberalisation. The lag structure of the GARCH process used remains the same (i.e., (1,1)) in both subperiods. Also, volatility persistence remains pretty much the same; for Argentina, India, and Pakistan and I-GARCH process is suggested for both subperiods, indicating that any shocks to volatility are permanent. The ARCH coefficient, which expresses the significance of past news on volatility, has been reduced for Argentina, Chile, Korea, Pakistan, Philippines and Taiwan post-liberalisation. This suggests that the markets are becoming less volatile after liberalisation; i.e., news of the same importance induce less volatility in the market post-liberalisation than pre-liberalisation. The coefficient of the lagged conditional volatility has been reduced in Argentina, India and Mexico suggesting that older news induce proportionately less volatility after liberalisation than before. This evidence seems to indicate that volatility is more likely to be unaffected or reduced following liberalization. Certainly more research is needed in the area, both in terms of the relationship between financial liberalisation and stock market volatility as well as the inferences based on the econometric tools used for examining volatility.

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