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# The dynamics of the volatility – trading volume relationship: New evidence from developed and emerging markets

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## Abstract

This paper empirically investigates whether there is an evolution in the relation between stock market trading volume and volatility in 23 developed and 15 emerging markets. To answer this question, we develop a dynamic application of the TARCH (1, 1) model and first prove that the relationship is variable through time. Then, we focus our analysis on three major financial events, namely the Asian Crisis, the Dot Com bubble burst and the Subprime crisis. We find that the explanatory power of volume is greater during these periods. Finally, we show that the sign of the relationship cannot be clearly set for a specific country or sub group of developed or emerging markets.

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## 1. Introduction

The volatility – trading volume relationship has been the subject of a considerable amount of research over the past 30 years. Volatility is one of the key variables in finance, as it is often used as a proxy for the risk of holding an asset. However, volatility is not directly observable and has to be measured by choosing one of the numerous approaches proposed by an impressive amount of financial literature and practice. The only two variables that can be observed and quantified at each point in time are prices and volumes. It is therefore interesting to check for the link between volumes and price changes and, more generally, to analyze the role of trading volume in explaining volatility, in order to better picture the structure of financial markets in terms of information arrivals and dissemination among participants, i.e. informational efficiency of prices, but also to better describe speculative prices and hence, optimize portfolio allocation, derivatives pricing and risk management (Karpoff, 1987).

One of the first characterizations of the relationship between price changes and volume is the subordination model that goes back to Clark (1973). In this setting, also referred to as the Mixture of Distribution Hypothesis (MDH), the distribution of prices and volume is jointly subordinated to a latent mixing variable, namely the information flow, which allows a positive, contemporaneous correlation between the return variability and the unobservable directing process and explains the persistence of daily stock price movements. Furthermore, the trading volume is considered as the standard proxy for the mixing variable. This approach, very appealing from a market microstructure perspective as it makes assumptions about the underlying process that drives both price changes and volumes, focuses on the flow of information to the market and gave birth to an abundant literature (Tauchen and Pitts, 1983; Andersen, 1996; Bollerslev and Jubinski, 1999 among others)[1].

Another leading information-based model is the Sequential Information Model (SIM) developed by Copeland (1976) and based on the key assumption that information gets to traders in a sequential way; it also predicts positive correlation between volume and volatility, similarly to the MDH, but with different assumptions about the speed with which the equilibrium is achieved.

Empirical evidence on the MDH modeling reports mitigated results. Early studies, i.e. Clark (1973), Epps and Epps (1976), Tauchen and Pitts (1983), Harris (1986, 1987), confirm the main results of this theoretical framework. Gallant *et al.* (1992), Chen *et al.* (2001) and Andersen (1996) also find volatility and volume to be positively related.

In an attempt to explain the sources of volatility persistence, Lamoureux and Lastrapes (1990) use the MDH framework while introducing the contemporaneous trading volume directly into the conditional variance of a GARCH model[2] and find evidence that persistence in volatility is significantly reduced. Hence, they confirm that volume is driven by the same latent variable that drives return volatility, without providing a model for the joint process though. We will use and extended Lamoureux and Lastrapes modeling in our paper.

However, another strand of literature claims that volatility and trading volume exhibit different time structures and dynamics such as Heimstra and Jones (1994), Lamoureux and Lastrapes (1994), Richardson and Smith (1994) or Lobato and Velasco (2000). Moreover, Ané and Ureche-Rangau (2008) find evidence that the ability of volume to explain the volatility depends on the extent to which their long memory and intermittent behavior are similar and stress that if there is indeed common short run behavior of volatility and trading volume, this may not be the case on the long run.

More recent research even points out the possibility of a negative relation between volatility and trading volume[3] (Wang, 1994; Wang, 2004; Li and Wu, 2006). Li and Wu (2006) conclude that the positive relationship between volatility and volume is primarily driven by informed trading coming from information arrivals but once the effect of informed trading controlled, squared returns have a significant negative correlation with the trading volume, namely the liquidity volume.

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[1] Another approach is based on the heterogeneity of investors' opinions and expectations, i.e. Admati and Pfeiderer (1988), Harris and Raviv (1993), He and Wang (1995) among others.

[2] The Autoregressive Conditional Heteroskedasticity (ARCH) models introduced by Engle (1982) and Generalized by Bollerslev (1986) also allow coping with the persistence in stock return distributions without providing an economic explanation of the phenomena.

[3] This idea is not totally new, as already Tauchen and Pitts (1983) mention that there may be situations when volatility and trading volume are negatively related, namely in incipient markets, as they mature.

The most important part of the above quoted empirical studies focuses on developed markets mainly due to data limitations for the emerging ones. However, the tremendous development of emerging markets over the last ten to fifteen years and their important weight in international portfolios and capital flows nowadays has encouraged research on their peculiarities in terms of volatility and trading volume relation (e.g. Saatcioglu and Starks, 1998 for Latin America; Wang *et al.,* 2005 for China; Asai and Unite, 2008 for the Philippines; Ureche-Rangau and DeRorthays, 2009 for the Chinese A shares). The results are again rather mitigated.

Finally, Girard and Biswas (2007) analyze both developed and emerging stock markets and find evidence that the trading volume – volatility relationship is different between developed and emerging markets: the size and sign of the information shock have similar effects in developed markets while size is more important in emerging markets, volume is positively related to volatility when total volume is included in the conditional variance specification of the GARCH (1,1) model but GARCH effects persist. These effects vanish when volume is decomposed into Expected (EV) and Unexpected volume (UV). Finally, emerging markets are found to have larger responses to information shocks.

The objective of this paper is to perform a dynamic analysis of the volatility and trading volume relationship on a sample composed by both developed and emerging countries. To do so, we develop the framework used by Girard and Biswas (2007) and implement a sliding window TARCH with volume modeling on a time period stretching from January 1997 to June 2009, hence, comprising a diversity of market trends and turmoil. The development of the countries classified as emerging is fast; being emergent is not a permanent status. One can therefore wonder whether the dynamics of volatility and volume in emerging market stock exchanges has changed throughout the years. It could therefore be possible to study their evolution and development through the trading volume and volatility relationship.

The paper is structured as follows. The next section presents our methodology and data along with some preliminary statistics, section three provides the empirical results and their analysis on different countries and time periods while section four concludes and draws some lines for further research.

## 2. Methodology

In this paper we focus on the dynamics of the volatility and trading volume relationship for which potential structural changes are already studied by Balduzzi *et al.* (1997) and Wagner and Marsh (2005). One explanation is based on the Gennotte and Leland (1990) liquidity hypothesis which states that liquidity constraints may cause non informational traders to impact return variability. By misinterpreting non informational liquidity trading as being informational, these traders may contribute to an increase of the return variability while there are no common information releases and/or high trading activity. This may typically be the case of market crashes, the direct implication of this hypothesis being that the same trading volume may lead to different price changes and hence that the volatility – volume correlation changes during such market episodes.

For the specific case of emerging economies, market development, as represented for example by the introduction of derivatives trading, may change the informational role of trading volumes in terms of predicting the volatility. Following Subrahmanyan (1991) among others, derivative securities trading is likely to make informed and discretionary liquidity traders to change the number and composition of stocks traded, with impact on the volatility and trading volume relationship.

These arguments make us believe that the volatility and trading volume relationship may vary through time depending on the type of market under study and the time period used in the analysis, namely "normal" versus "stressed" market conditions.

In line with Girard and Biswas (2007), we use an asymmetric GARCH model also known as Threshold GARCH, i.e. TARCH model, as introduced by Glosten *et al.* (1993) and Zakoian (1994). Our contribution consists in applying this methodology in a dynamic setting, on sliding windows. We will thus be able to study the dynamics of the volatility – trading volume relationship within sub periods and the whole time frame under analysis. In a first part we will develop the specifications of a TARCH model and then detail, in a second part, our rolling TARCH method. Finally, we will describe our data set.

### 2.1 The TARCH specification

The TARCH specification models stock return volatility and captures the different stylized facts commonly reported on financial time series and their volatility. Among these empirical regularities, the TARCH model manages to reproduce the leverage effect, i.e. negative shocks having a greater impact on the conditional volatility than positive shocks of the same magnitude and volatility clustering, important (small) price fluctuations tend to be followed by fluctuations of the same magnitude.

A standard TARCH (1,1) model is defined as follows:

$$\begin{aligned} R_t &= \alpha + \varepsilon_t \\ \varepsilon_t / \varepsilon_{t-1}, \varepsilon_{t-2}, \ldots &\sim N\left(0, \sigma_t^2\right) \\ \sigma_t^2 &= \gamma + \omega \varepsilon_{t-1}^2 + \eta \varepsilon_{t-1}^2 d_{t-1} + \psi \sigma_{t-1}^2 \end{aligned} \quad (1)$$

In this setting, $R_t$ stands for the return of the stock and $\varepsilon_t$ for the conditionally Gaussian residual of zero mean and variance equal to $\sigma_t^2$. The conditional variance denoted $\sigma_t^2$ depends on the constant $\gamma$, the ARCH term $\varepsilon_{t-1}^2$, the GARCH term $\sigma_{t-1}^2$ and finally, the term that captures the asymmetry $\varepsilon_{t-1}^2 d_{t-1}$. The parameter $d_t$ accounts for the impact of good and bad market news arrivals on the volatility as $d_t = 1$ if $\varepsilon_t < 0$, and zero otherwise. Hence, good news have an impact of magnitude equal to $\omega$ while bad news have an impact of $\omega + \eta$. This is how the leverage effect within the conditional variance is taken into account, i.e. if $\eta > 0$ bad news have a greater effect compared to good news.

As stated in the literature review, to investigate the relationship between trading volume and volatility, Lamoureux and Lastrapes (1990) introduced the volume parameter directly into the conditional variance of the GARCH model. According to them, the trading volume may proxy the daily number of information arrivals driving the price process. Hence, assuming that the daily number of information arrivals is serially correlated, the previous setting can then be modified as follows:

$$\begin{aligned} R_t &= \alpha + \varepsilon_t \\ \sigma_t^2 &= \gamma + \omega \varepsilon_{t-1}^2 + \eta \varepsilon_{t-1}^2 d_{t-1} + \psi \sigma_{t-1}^2 + \zeta_0 V_{t-1} \end{aligned} \quad (2)$$

with $V_t$ standing for the detrended trading volume[4]. Based on the mixture model, $\zeta_0$ should be significantly positive and the persistence of the volatility should therefore become negligible if the trading volume explains the presence of GARCH effects in the data.

### 2.2 Rolling TARCH method

As we are concerned by the evolution of the significance of volume in explaining stock return volatility, we develop a sliding windows framework that computes several TARCH models at different points in time and finally shows the evolution of the conditional variance coefficients through the time period under study.

The window on which the TARCH estimation is performed can be modified within the program; the results we present in the next part are obtained with a standard window of 200 observations. Our programming setting provides the estimations of the conditional variance parameters for each specific 200-observation window.

### 2.3 Data and some preliminary statistics

The sample period of our study goes from January 1st, 1997 to June 30, 2009. For each country we use the Datastream Market Index as provided by Thomson Reuters Datastream.

Our data set comprises daily prices and volume for 38 equity indices corresponding to 23 developed (Panel A) and 15 emerging economies (Panel B). The classification of the markets is based on the MSCI International Equity indices definitions and criteria. Following Chen *et al.* (2001) we define trading volume as the total number of shares traded on an exchange on a particular day. As such, we have a maximum of 3,226 observations (for Netherlands) and a minimum of 2,253 observations (for Ireland).

[4] Lagged volume is preferred to contemporaneous volume to avoid simultaneity problems. The detrending procedure is $Vol_t = a + b_1 t + b_2 t^2 + e_t$ with $Vol_t$ stating for the trading volume at time $t$.

The daily index returns are calculated as the logarithmic first difference of the stock price indices. Most of our stock returns series are significantly negatively skewed (13/15 for emerging countries and 19/23 for developed countries) as illustrated by Table 1. As the majority of financial time series, they are also highly leptokurtic except for Chile, whose return series is platykurtic. The trading volumes, described in Table 2, are also taken in logarithm and roughly show the same characteristics in terms of asymmetry as the returns series but less tail thickness, i.e. more often they are platykurtic. The hypothesis of normality is clearly rejected by the Jarque-Bera test for both return and volume series on developed and emerging markets, as its associated p-values are all far below the conventional 5% confidence level.

**Table 1: Descriptive statistics of the logarithmic return series for both the developed (Panel A) and emerging (Panel B) equity indices.**

| *Panel A:* | Number of | Equity Indices (USD) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ***Developed Countries*** | **observations** | **Mean** | **Maximum** | **Minimum** | **Std. Dev.** | **Skewness** | ***t-stat*** | **Kurtosis** | ***t-stat*** | **Jarque-Bera** | ***p-value*** |
| **AUSTRALIA** | 3204 | 0.0001 | 0.0364 | -0.0694 | 0.0066 | -0.9721 * | *-22.4638* | 14.9890 * | *138.5233* | 19693.34 * | *0.0000* |
| **AUSTRIA** | 3136 | 0.0001 | 0.0446 | -0.0451 | 0.0059 | -0.4435 * | *-10.1382* | 12.2664 * | *105.9242* | 11322.72 * | *0.0000* |
| **BELGIUM** | 3220 | 0.0001 | 0.0386 | -0.0406 | 0.0057 | -0.2702 * | *-6.2604* | 9.1110 * | *70.7840* | 5049.57 * | *0.0000* |
| **CANADA** | 3190 | 0.0001 | 0.0525 | -0.0588 | 0.0062 | -0.7330 * | *-16.9008* | 13.7100 * | *123.4752* | 15531.76 * | *0.0000* |
| **DENMARK** | 3168 | 0.0001 | 0.0485 | -0.0600 | 0.0061 | -0.4547 * | *-10.4490* | 11.5213 * | *97.9026* | 9694.11 * | *0.0000* |
| **FINLAND** | 3173 | 0.0001 | 0.0625 | -0.0807 | 0.0095 | -0.3277 * | *-7.5370* | 8.7057 * | *65.6046* | 4360.78 * | *0.0000* |
| **FRANCE** | 3218 | 0.0001 | 0.0462 | -0.0464 | 0.0063 | -0.0627 | *-1.4522* | 9.3975 * | *74.0791* | 5489.82 * | *0.0000* |
| **GERMANY** | 3211 | 0.0001 | 0.0706 | -0.0374 | 0.0063 | 0.2374 * | *5.4913* | 11.8562 * | *102.4385* | 10523.82 * | *0.0000* |
| **GREECE** | 3158 | 0.0001 | 0.0516 | -0.0483 | 0.0079 | -0.1764 * | *-4.0466* | 6.9966 * | *45.8451* | 2118.15 * | *0.0000* |
| **HONG KONG** | 3121 | 0.0000 | 0.0676 | -0.0590 | 0.0077 | 0.0332 | *0.7578* | 11.0016 * | *91.2468* | 8326.55 * | *0.0000* |
| **IRELAND** | 2253 | 0.0000 | 0.0405 | -0.0632 | 0.0071 | -0.7872 * | *-15.2543* | 11.3136 * | *80.5495* | 6720.92 * | *0.0000* |
| **ITALY** | 3209 | 0.0001 | 0.0489 | -0.0473 | 0.0064 | -0.1061 * | *-2.4536* | 9.5560 * | *75.8081* | 5752.88 * | *0.0000* |
| **JAPAN** | 3116 | 0.0000 | 0.0492 | -0.0379 | 0.0068 | 0.0258 | *0.5881* | 6.0547 * | *34.8062* | 1211.82 * | *0.0000* |
| **NETHERLANDS** | 3226 | 0.0000 | 0.0443 | -0.0499 | 0.0065 | -0.2698 * | *-6.2567* | 10.3903 * | *85.6818* | 7380.53 * | *0.0000* |
| **NEWZEALAND** | 3182 | 0.0000 | 0.0402 | -0.0534 | 0.0056 | -0.5699 * | *-13.1243* | 10.8992 * | *90.9556* | 8445.17 * | *0.0000* |
| **NORWAY** | 3176 | 0.0001 | 0.0603 | -0.0590 | 0.0081 | -0.5233 * | *-12.0396* | 10.6854 * | *88.4094* | 7961.17 * | *0.0000* |
| **PORTUGAL** | 3189 | 0.0001 | 0.0438 | -0.0557 | 0.0055 | -0.2533 * | *-5.8405* | 12.6303 * | *111.0103* | 12357.40 * | *0.0000* |
| **SINGAPORE** | 3179 | 0.0000 | 0.0461 | -0.0414 | 0.0064 | -0.0443 | *-1.0187* | 8.4178 * | *62.3538* | 3889.03 * | *0.0000* |
| **SPAIN** | 3186 | 0.0001 | 0.0450 | -0.0415 | 0.0062 | -0.1172 * | *-2.7010* | 8.5664 * | *64.1340* | 4120.46 * | *0.0000* |
| **SWEDEN** | 3175 | 0.0001 | 0.0579 | -0.0447 | 0.0083 | 0.0493 | *1.1340* | 7.5213 * | *52.0029* | 2705.59 * | *0.0000* |
| **SWITZERLAND** | 3184 | 0.0001 | 0.0393 | -0.0306 | 0.0053 | -0.0303 | *-0.6971* | 7.8358 * | *55.6987* | 3102.83 * | *0.0000* |
| **UK** | 3198 | 0.0000 | 0.0513 | -0.0451 | 0.0060 | -0.1369 * | *-3.1607* | 12.6029 * | *110.8504* | 12297.81 * | *0.0000* |
| **USA** | 3186 | 0.0001 | 0.0473 | -0.0409 | 0.0059 | -0.1856 * | *-4.2773* | 10.0020 * | *80.6747* | 6526.71 * | *0.0000* |
| ***Panel B:*** | **Number of** | **Equity Indices (USD)** | | | | | | | | | |
| ***Emerging Countries*** | **observations** | **Mean** | **Maximum** | **Minimum** | **Std. Dev.** | **Skewness** | ***t-stat*** | **Kurtosis** | ***t-stat*** | **Jarque-Bera** | ***p-value*** |
| **BRAZIL** | 2640 | 0.0003 | 0.0610 | -0.0705 | 0.0098 | -0.3481 * | *-7.3010* | 8.9514 * | *62.4183* | 3949.35 * | *0.0000* |
| **CHILE** | 3158 | 5.0112 | 6.8457 | 3.6349 | 0.5563 | 0.0556 | *1.2755* | 1.9082 * | *-12.5242* | 158.48 * | *0.0000* |
| **CHINA** | 3060 | 0.0001 | 0.0410 | -0.0411 | 0.0077 | -0.1168 * | *-2.6375* | 6.9874 * | *45.0238* | 2034.10 * | *0.0000* |
| **COLOMBIA** | 3075 | 0.0001 | 0.0550 | -0.0512 | 0.0099 | -0.1145 * | *-2.5930* | 12.8877 * | *111.9211* | 12533.05 * | *0.0000* |
| **CZECHREPUBLIC** | 3178 | 0.0002 | 0.0992 | -0.0680 | 0.0077 | 0.0797 | *1.8335* | 19.2230 * | *186.6816* | 34853.35 * | *0.0000* |
| **HUNGARY** | 3161 | 0.0001 | 0.0789 | -0.0827 | 0.0093 | -0.4880 * | *-11.2007* | 13.2756 * | *117.9269* | 14032.22 * | *0.0000* |
| **INDIA** | 3145 | 0.0002 | 0.0788 | -0.0542 | 0.0083 | -0.2797 * | *-6.4046* | 8.9774 * | *68.4254* | 4723.06 * | *0.0000* |
| **ISRAEL** | 3097 | 0.0001 | 0.0337 | -0.0451 | 0.0065 | -0.4589 * | *-10.4255* | 6.1363 * | *35.6272* | 1377.99 * | *0.0000* |
| **MALAYSIA** | 3121 | 0.0000 | 0.1401 | -0.1597 | 0.0086 | -0.5408 * | *-12.3345* | 79.4169 * | *871.4264* | 759536.10 * | *0.0000* |
| **MEXICO** | 3182 | 0.0002 | 0.0597 | -0.0586 | 0.0074 | -0.1176 * | *-2.7079* | 10.2359 * | *83.3174* | 6949.13 * | *0.0000* |
| **PERU** | 3078 | 0.0001 | 0.0308 | -0.0379 | 0.0049 | -0.6257 * | *-14.1719* | 10.3817 * | *83.5955* | 7354.88 * | *0.0000* |
| **POLAND** | 3171 | 0.0001 | 0.0578 | -0.0538 | 0.0086 | -0.2220 * | *-5.1037* | 7.1024 * | *47.1551* | 2249.65 * | *0.0000* |
| **SOUTHAFRICA** | 3034 | 0.0001 | 0.0525 | -0.0629 | 0.0081 | -0.6207 * | *-13.9584* | 9.1763 * | *69.4431* | 5225.54 * | *0.0000* |
| **TAIWAN** | 3109 | 0.0000 | 0.0352 | -0.0532 | 0.0079 | -0.1066 * | *-2.4258* | 5.3682 * | *26.9536* | 732.38 * | *0.0000* |
| **TURKEY** | 3154 | 0.0002 | 0.0962 | -0.1170 | 0.0146 | -0.1257 * | *-2.8818* | 8.3503 * | *61.3339* | 3770.15 * | *0.0000* |

* denotes significance at the 5% conventional risk level

**Table 2: Descriptive statistics of the trading volume series for both the developed (Panel A) and emerging (Panel B) equity indices.**

| *Panel A: Developed Countries* | Number of observations | LogVolumes | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Mean | Maximum | Minimum | Std. Dev. | Skewness | *t-stat* | Kurtosis | *t-stat* | Jarque-Bera | *p-value* |
| AUSTRALIA | 3204 | 5.5000 | 6.7119 | 4.3427 | 0.2565 | -0.1342 * | *-3.1000* | 2.9790 | *-0.2423* | 9.67 * | *0.0079* |
| AUSTRIA | 3136 | 3.4406 | 4.8017 | 2.1790 | 0.4642 | 0.4240 * | *9.6934* | 2.0204 * | *-11.1980* | 219.36 * | *0.0000* |
| BELGIUM | 3220 | 3.7166 | 5.0382 | 0.3010 | 0.4695 | -0.2675 * | *-6.1965* | 3.9570 * | *11.0851* | 161.28 * | *0.0000* |
| CANADA | 3190 | 5.0225 | 5.7759 | 1.4914 | 0.2765 | -1.5793 * | *-36.4149* | 18.0055 * | *172.9978* | 31254.26 * | *0.0000* |
| DENMARK | 3168 | 3.7370 | 4.6948 | 2.1673 | 0.3465 | -0.5468 * | *-12.5638* | 2.5122 * | *-5.6043* | 189.26 * | *0.0000* |
| FINLAND | 3173 | 4.4080 | 6.0445 | 2.7767 | 0.5076 | -0.8811 * | *-20.2619* | 2.6742 * | *-3.7463* | 424.58 * | *0.0000* |
| FRANCE | 3218 | 4.9874 | 5.9466 | 3.5857 | 0.3871 | -0.6333 * | *-14.6668* | 2.3253 * | *-7.8132* | 276.16 * | *0.0000* |
| GERMANY | 3211 | 4.0097 | 6.2527 | 0.6021 | 0.6504 | 0.8571 * | *19.8276* | 2.5097 * | *-5.6707* | 425.29 * | *0.0000* |
| GREECE | 3158 | 3.8953 | 5.3114 | 1.8261 | 0.3607 | -0.3242 * | *-7.4376* | 3.5990 * | *6.8709* | 102.53 * | *0.0000* |
| HONG KONG | 3121 | 5.9494 | 6.7165 | 5.1203 | 0.2216 | -0.0981 * | *-2.2373* | 3.1256 | *1.4324* | 7.06 * | *0.0293* |
| IRELAND | 2253 | 4.4101 | 5.2583 | 1.4472 | 0.2662 | -1.6533 * | *-32.0373* | 13.2854 * | *99.6540* | 10957.31 * | *0.0000* |
| ITALY | 3209 | 5.7573 | 6.3724 | 4.9703 | 0.1936 | -0.4809 * | *-11.1206* | 3.5327 * | *6.1599* | 161.61 * | *0.0000* |
| JAPAN | 3116 | 5.9302 | 6.5860 | 1.0414 | 0.3181 | -2.9164 * | *-66.4620* | 42.8930 * | *454.5589* | 211041.00 * | *0.0000* |
| NETHERLANDS | 3226 | 5.0023 | 5.7006 | 4.0300 | 0.2063 | -0.7231 * | *-16.7661* | 4.0260 * | *11.8951* | 422.60 * | *0.0000* |
| NEWZEALAND | 3182 | 4.3549 | 5.6386 | 0.9031 | 0.2043 | -1.3229 * | *-30.4651* | 30.5333 * | *317.0313* | 101436.90 * | *0.0000* |
| NORWAY | 3176 | 4.5317 | 5.7131 | 3.4007 | 0.4625 | 0.0575 | *1.3219* | 2.0234 * | *-11.2339* | 127.95 * | *0.0000* |
| PORTUGAL | 3189 | 4.3277 | 5.4687 | 2.8561 | 0.4612 | -0.5138 * | *-11.8450* | 2.5831 * | *-4.8053* | 163.39 * | *0.0000* |
| SINGAPORE | 3179 | 5.2360 | 6.1682 | 4.0579 | 0.3759 | -0.4402 * | *-10.1336* | 2.6447 * | *-4.0897* | 119.41 * | *0.0000* |
| SPAIN | 3186 | 5.0688 | 6.0470 | 3.2711 | 0.3357 | -0.5483 * | *-12.6352* | 3.1296 | *1.4930* | 161.88 * | *0.0000* |
| SWEDEN | 3175 | 5.0607 | 6.3731 | 3.8337 | 0.4396 | -0.6810 * | *-15.6665* | 2.3905 * | *-7.0107* | 294.59 * | *0.0000* |
| SWITZERLAND | 3184 | 4.3092 | 5.5065 | 2.7404 | 0.5842 | -0.4762 * | *-10.9701* | 1.7534 * | *-14.3584* | 326.51 * | *0.0000* |
| UK | 3198 | 6.1854 | 6.7539 | 4.8482 | 0.2504 | -0.9480 * | *-21.8857* | 3.5730 * | *6.6143* | 522.73 * | *0.0000* |
| USA | 3186 | 6.3135 | 7.0505 | 5.2681 | 0.2732 | -0.4338 * | *-9.9954* | 2.9185 | *-0.9389* | 100.79 * | *0.0000* |
| *Panel B: Emerging Countries* | Number of observations | LogVolumes | | | | | | | | | |
| | | Mean | Maximum | Minimum | Std. Dev. | Skewness | *t-stat* | Kurtosis | *t-stat* | Jarque-Bera | *p-value* |
| BRAZIL | 2640 | 4.7248 | 5.4778 | 3.3086 | 0.2954 | 0.0734 | *1.5400* | 2.6891 * | *-3.2609* | 13.00 * | *0.0015* |
| CHILE | 3158 | 5.0112 | 6.8457 | 3.6349 | 0.5563 | 0.0556 | *1.2755* | 1.9082 * | *-12.5242* | 158.48 * | *0.0000* |
| CHINA | 3060 | 5.7684 | 7.2740 | 2.6522 | 0.7479 | 0.2531 * | *5.7161* | 1.8627 * | *-12.8416* | 197.58 * | *0.0000* |
| COLOMBIA | 3075 | 4.1117 | 6.8747 | 1.0414 | 1.2131 | 0.1322 * | *2.9929* | 1.7253 * | *-14.4290* | 217.15 * | *0.0000* |
| CZECHREPUBLIC | 3178 | 3.2198 | 4.4194 | 0.4771 | 0.6073 | -1.7539 * | *-40.3650* | 5.7369 * | *31.4938* | 2621.19 * | *0.0000* |
| HUNGARY | 3161 | 3.5923 | 5.7234 | 1.0000 | 0.3001 | -0.2778 * | *-6.3763* | 8.1576 * | *59.1909* | 3544.22 * | *0.0000* |
| INDIA | 3145 | 4.6752 | 5.5452 | 0.3010 | 0.3224 | -5.5527 * | *-127.1280* | 68.9427 * | *754.8691* | 585988.80 * | *0.0000* |
| ISRAEL | 3097 | 4.2139 | 5.6868 | 1.5185 | 0.5303 | -1.8471 * | *-41.9654* | 9.6501 * | *75.5423* | 7467.74 * | *0.0000* |
| MALAYSIA | 3121 | 4.9495 | 5.8106 | 4.0977 | 0.2915 | 0.2198 * | *5.0121* | 2.5120 * | *-5.5647* | 56.09 * | *0.0000* |
| MEXICO | 3182 | 4.9565 | 5.9805 | 3.6403 | 0.2613 | -0.4282 * | *-9.8610* | 4.3076 * | *15.0569* | 323.95 * | *0.0000* |
| PERU | 3149 | 3.5804 | 5.7442 | 1.5441 | 0.4634 | -0.8214 * | *-18.6046* | 6.7185 * | *42.1113* | 2168.38 * | *0.0000* |
| POLAND | 3171 | 3.8251 | 5.4129 | 2.6263 | 0.4814 | 0.4079 * | *9.3778* | 2.2294 * | *-8.8583* | 166.41 * | *0.0000* |
| SOUTHAFRICA | 3160 | 4.7632 | 5.4931 | 2.3729 | 0.3158 | -1.1920 * | *-26.8055* | 5.0806 * | *23.3936* | 1318.36 * | *0.0000* |
| TAIWAN | 3109 | 6.0868 | 6.7837 | 5.3057 | 0.1952 | -0.0120 | *-0.2721* | 3.1074 | *1.2222* | 1.57 | *0.4566* |
| TURKEY | 3154 | 6.5370 | 8.8545 | 4.5271 | 1.1782 | 0.0619 | *1.4184* | 1.4830 * | *-17.3903* | 304.44 * | *0.0000* |

* denotes significance at the 5% conventional risk level

## 3. Empirical evidence

This section summarizes the results of our estimations on the whole period as well as on our rolling windows, for both developed and emerging markets.

The results of the TARCH (1,1) model for the whole dataset, i.e. from 1997 to 2009, without and with the inclusion of the trading volume are provided in Tables 3 and 4. Panel A of the table shows the estimations performed on the developed markets sample while Panel B focuses on the emerging markets.

First we observe that volatility persistence, measured by $\psi$ is generally quite high. It ranges from 0.8704 (Norway) to 0.9447 (Finland) for developed countries and from 0.7975 (Israel) to 0.9399 (Malaysia) for emerging countries when volume is not included, i.e. equation “(1)”. We can also notice that developed countries have a slightly higher level of volatility persistence as the average value for $\psi$ is 0.8976 for this panel of countries while the average value for emerging economies amounts to 0.8621.

When the trading volumes are included in the conditional variance specification, i.e. equation “(2)”, the volatility persistence ranges from 0.8567 (Norway) to 0.9435 (Finland) for developed countries and from 0.5838 (Malaysia) to 0.9075 (Taiwan) for emerging countries. Furthermore, the average value for the volatility persistence is marginally reduced as the average values for $\psi$ equal 0.8971 (with respect to 0.8976 in the setting without volume) for developed markets and 0.8321 (as compared to 0.8621 without volume) for emerging markets. The inclusion of trading volume in the conditional variance estimation therefore poorly reduces the persistence of volatility for both developed and emerging markets. These results are in line with Chen *et al.* (2001), Girard and Biswas (2007) and Ureche-Rangau and DeRorthays (2009) among others while they contrast with Lamoureux and Lastrapes (1990). Developed countries still present a higher level of volatility persistence compared to emerging markets even with the inclusion of the trading volume in the specification. Finally, the results are clearly mitigated regarding the sign and significance of the trading volume coefficient. This coefficient is significant at the 5% confidence level in only 15 out of 23 developed markets and 8 out of 15 emerging ones, while its signs are both positive and negative.

Another observation we can make is that volatility clustering, measured by $\omega$, is more important in emerging markets, i.e. they are more responsive to larger size shocks. Indeed, the volatility clustering parameter ranges from 0.01207 (Netherlands) to 0.08018 (Greece) and averages 0.03302 in developed markets while it ranges from 0.02372 (Colombia) to 0.19056 (Malaysia) and averages 0.07419 in emerging markets.

Finally, the asymmetry parameter, i.e. $\eta$, is always significant and positive for both panels of countries (except for Chile for which it is significantly negative). Moreover, on average, $\eta$ is higher than $\omega$ for the developed as well as emerging markets, i.e. an average of 0.09652 and 0.08467 respectively, suggesting that the direction of news is more important than their magnitude in explaining the volatility.

**Table 3: The TARCH(1,1) without trading volume (equation "(1)") estimated coefficients for the whole time period, i.e. 1997 – 2009.**

| *Panel A: Devolped Countries* | Number Of Observations | $\alpha$ | | $\gamma$ | | $\omega$ | | $\eta$ | | $\psi$ | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Value | *t-stat* | Value | *t-stat* | Value | *t-stat* | Value | *t-stat* | Value | *t-stat* |
| AUSTRALIA | 3204 | 0,000168 * | *1,98* | 0,00000073 * | *7,38* | 0,019225 * | *2,39* | 0,109590 * | *10,28* | 0,901665 * | *96,66* |
| AUSTRIA | 3136 | 0,000258 * | *3,31* | 0,00000066 * | *7,14* | 0,041816 * | *4,45* | 0,072527 * | *6,35* | 0,893548 * | *91,95* |
| BELGIUM | 3220 | 0,000216 * | *2,93* | 0,00000054 * | *7,24* | 0,028401 * | *3,25* | 0,110216 * | *8,35* | 0,892961 * | *98,74* |
| CANADA | 3190 | 0,000292 * | *3,58* | 0,00000060 * | *8,65* | 0,027002 * | *2,84* | 0,085139 * | *7,70* | 0,906141 * | *109,98* |
| DENMARK | 3168 | 0,000263 * | *3,07* | 0,00000093 * | *6,76* | 0,033074 * | *3,34* | 0,091445 * | *7,03* | 0,887826 * | *81,99* |
| FINLAND | 3173 | 0,000414 * | *3,34* | 0,00000032 * | *6,01* | 0,037735 * | *7,48* | 0,030003 * | *4,14* | 0,944798 * | *324,45* |
| FRANCE | 3218 | 0,000189 * | *2,32* | 0,00000053 * | *5,92* | 0,020375 * | *2,41* | 0,109574 * | *9,17* | 0,906961 * | *106,08* |
| GERMANY | 3211 | 0,000176 * | *2,14* | 0,00000058 * | *7,14* | 0,029810 * | *3,25* | 0,100813 * | *8,64* | 0,900870 * | *95,20* |
| GREECE | 3158 | 0,000271 * | *2,53* | 0,00000098 * | *6,42* | 0,080022 * | *8,23* | 0,079529 * | *6,88* | 0,867941 * | *100,67* |
| HONG KONG | 3121 | 0,000154 | *1,62* | 0,00000048 * | *5,91* | 0,034094 * | *4,75* | 0,094129 * | *9,46* | 0,910418 * | *117,96* |
| IRELAND | 2253 | 0,000256 * | *2,42* | 0,00000071 * | *6,85* | 0,049449 * | *3,74* | 0,083954 * | *5,91* | 0,887751 * | *87,97* |
| ITALY | 3209 | 0,000186 * | *2,27* | 0,00000052 * | *5,17* | 0,068732 * | *6,74* | 0,072598 * | *6,48* | 0,880532 * | *81,58* |
| JAPAN | 3116 | -0,000045 | *-0,43* | 0,00000140 * | *5,62* | 0,043990 * | *4,38* | 0,100617 * | *7,00* | 0,875973 * | *68,52* |
| NETHERLANDS | 3226 | 0,000127 | *1,59* | 0,00000052 * | *6,24* | 0,022230 * | *2,59* | 0,121193 * | *9,64* | 0,898838 * | *99,69* |
| NEWZEALAND | 3182 | 0,000172 * | *2,07* | 0,00000079 * | *8,06* | 0,054860 * | *5,83* | 0,068677 * | *7,12* | 0,882688 * | *121,47* |
| NORWAY | 3176 | 0,000327 * | *3,24* | 0,00000129 * | *7,17* | 0,059646 * | *5,39* | 0,080580 * | *5,74* | 0,870404 * | *84,42* |
| PORTUGAL | 3189 | 0,000231 * | *3,05* | 0,00000049 * | *6,70* | 0,044015 * | *5,68* | 0,084986 * | *8,07* | 0,893811 * | *103,57* |
| SINGAPORE | 3179 | 0,000125 | *1,46* | 0,00000049 * | *7,25* | 0,057508 * | *7,38* | 0,090396 * | *7,71* | 0,887577 * | *118,53* |
| SPAIN | 3186 | 0,000226 * | *2,65* | 0,00000054 * | *6,50* | 0,026909 * | *3,19* | 0,084847 * | *8,52* | 0,912349 * | *119,83* |
| SWEDEN | 3175 | 0,000246 * | *2,32* | 0,00000071 * | *6,25* | 0,028884 * | *4,73* | 0,094293 * | *8,94* | 0,910511 * | *125,71* |
| SWITZERLAND | 3184 | 0,000140 | *1,90* | 0,00000058 * | *6,34* | 0,015684 | *1,61* | 0,124197 * | *9,00* | 0,896910 * | *80,61* |
| UK | 3198 | 0,000095 | *1,30* | 0,00000046 * | *6,89* | 0,012504 | *1,35* | 0,121848 * | *8,63* | 0,907229 * | *95,54* |
| USA | 3186 | 0,000052 | *0,70* | 0,00000029 * | *8,67* | -0,014197 * | *-2,32* | 0,148212 * | *15,26* | 0,929051 * | *159,80* |
| *Panel B: Emerging Countries* | Number Of Observations | $\alpha$ | | $\gamma$ | | $\omega$ | | $\eta$ | | $\psi$ | |
| | | Value | *t-stat* | Value | *t-stat* | Value | *t-stat* | Value | *t-stat* | Value | *t-stat* |
| BRAZIL | 2640 | 0,000448 * | *2,88* | 0,000003 * | *6,83* | 0,030458 * | *3,13* | 0,102191 * | *6,98* | 0,877368 * | *71,28* |
| CHILE | 3158 | 4,695015 * | *584,13* | 0,007022 * | *4,24* | 0,159555 * | *6,86* | -0,045720 * | *-2,85* | 0,828014 * | *33,06* |
| CHINA | 3060 | -0,000043 | *-0,41* | 0,000001 * | *5,96* | 0,075867 * | *11,03* | 0,046397 * | *4,85* | 0,894804 * | *185,26* |
| COLOMBIA | 3075 | 0,000047 | *0,28* | 0,000007 * | *19,60* | 0,017483 * | *7,87* | 0,069977 * | *11,76* | 0,870956 * | *161,23* |
| CZECHREPUBLIC | 3178 | 0,000437 * | *4,08* | 0,000002 * | *6,90* | 0,063856 * | *5,72* | 0,081783 * | *6,17* | 0,855211 * | *64,49* |
| HUNGARY | 3161 | 0,000345 * | *2,75* | 0,000003 * | *9,12* | 0,086859 * | *8,84* | 0,126845 * | *10,01* | 0,816988 * | *100,93* |
| INDIA | 3145 | 0,000496 * | *4,42* | 0,000002 * | *10,23* | 0,088820 * | *8,09* | 0,097166 * | *7,00* | 0,830342 * | *77,36* |
| ISRAEL | 3097 | 0,000249 * | *2,40* | 0,000003 * | *7,43* | 0,057619 * | *4,21* | 0,130200 * | *7,88* | 0,797505 * | *42,52* |
| MALAYSIA | 3121 | 0,000124 | *1,75* | 0,000000 * | *4,54* | 0,039575 * | *13,25* | 0,050557 * | *10,41* | 0,939912 * | *642,29* |
| MEXICO | 3182 | 0,000309 * | *3,09* | 0,000001 * | *8,68* | 0,029928 * | *3,77* | 0,133242 * | *12,27* | 0,876969 * | *109,70* |
| PERU | 3078 | 0,000252 * | *3,62* | 0,000001 * | *11,83* | 0,102261 * | *9,66* | 0,085414 * | *6,71* | 0,809354 * | *78,17* |
| POLAND | 3171 | 0,000227 | *1,78* | 0,000001 * | *6,18* | 0,044082 * | *5,29* | 0,066042 * | *6,81* | 0,903287 * | *112,33* |
| SOUTHAFRICA | 3034 | 0,000362 * | *3,30* | 0,000001 * | *7,92* | 0,062131 * | *6,08* | 0,093505 * | *7,52* | 0,867749 * | *94,85* |
| TAIWAN | 3109 | 0,000105 | *0,87* | 0,000001 * | *5,37* | 0,037006 * | *4,85* | 0,079774 * | *7,60* | 0,906874 * | *103,09* |
| TURKEY | 3154 | 0,000442 * | *2,08* | 0,000005 * | *7,36* | 0,089113 * | *10,49* | 0,064306 * | *5,01* | 0,856931 * | *102,88* |

* denotes significance at the 5% conventional risk level

**Table 4: The TARCH(1,1) with trading volume (equation "(2)") estimated coefficients for the whole time period, i.e. 1997 – 2009.**

| Panel A: Devolped Countries | Number Of Observations | $\alpha$ | | $\gamma$ | | $\omega$ | | $\eta$ | | $\psi$ | | $\zeta_0$ | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Value | *t-stat* | Value | *t-stat* | Value | *t-stat* | Value | *t-stat* | Value | *t-stat* | Value | *t-stat* |
| AUSTRALIA | 3204 | 0.000162 | *1.91* | -0.0000017 | *-1.59* | 0.017381 * | *2.17* | 0.113332 * | *10.44* | 0.900689 * | *95.34* | 0.00000044 * | *2.29* |
| AUSTRIA | 3136 | 0.000254 * | *3.27* | -0.0000008 * | *-2.09* | 0.038277 * | *4.07* | 0.077781 * | *6.63* | 0.887465 * | *84.06* | 0.00000048 * | *3.69* |
| BELGIUM | 3220 | 0.000215 * | *2.91* | 0.0000010 * | *3.12* | 0.027057 * | *3.09* | 0.110814 * | *8.29* | 0.894524 * | *100.64* | -0.00000013 | *-1.57* |
| CANADA | 3190 | 0.000292 * | *3.56* | 0.0000006 | *1.00* | 0.027014 * | *2.83* | 0.085131 * | *7.22* | 0.906137 * | *105.50* | 0.00000000 | *-0.01* |
| DENMARK | 3168 | 0.000263 * | *3.05* | 0.0000014 * | *2.40* | 0.032641 * | *3.27* | 0.091766 * | *7.06* | 0.888386 * | *81.99* | -0.00000013 | *-0.84* |
| FINLAND | 3173 | 0.000412 * | *3.35* | 0.0000014 * | *2.40* | 0.035443 * | *6.90* | 0.034363 * | *4.56* | 0.943586 * | *309.07* | -0.00000024 | *-1.89* |
| FRANCE | 3218 | 0.000187 * | *2.30* | 0.0000030 * | *4.33* | 0.012262 | *1.43* | 0.117465 * | *9.50* | 0.907691 * | *100.92* | -0.00000047 * | *-3.74* |
| GERMANY | 3211 | 0.000168 * | *2.02* | -0.0000006 | *-1.87* | 0.020065 * | *2.09* | 0.105597 * | *9.00* | 0.904930 * | *97.09* | 0.00000031 * | *3.50* |
| GREECE | 3158 | 0.000266 * | *2.44* | 0.0000048 * | *4.63* | 0.080183 * | *7.89* | 0.083788 * | *7.06* | 0.862214 * | *92.97* | -0.00000094 * | *-3.79* |
| HONG KONG | 3121 | 0.000170 | *1.76* | -0.0000039 | *-1.86* | 0.031427 * | *4.63* | 0.097035 * | *9.70* | 0.911911 * | *121.80* | 0.00000074 * | *2.09* |
| IRELAND | 2253 | 0.000259 * | *2.44* | 0.0000023 | *1.89* | 0.051165 * | *3.72* | 0.087104 * | *5.62* | 0.883602 * | *74.34* | -0.00000034 | *-1.33* |
| ITALY | 3209 | 0.000191 * | *2.30* | 0.0000023 | *1.51* | 0.067929 * | *6.60* | 0.072716 * | *6.36* | 0.881118 * | *79.29* | -0.00000031 | *-1.19* |
| JAPAN | 3116 | -0.000049 | *-0.46* | 0.0000078 * | *3.20* | 0.041656 * | *4.02* | 0.104972 * | *7.10* | 0.870440 * | *64.16* | -0.00000105 * | *-2.73* |
| NETHERLANDS | 3226 | 0.000114 | *1.43* | 0.0000051 * | *3.88* | 0.012073 | *1.36* | 0.131546 * | *10.06* | 0.903238 * | *100.81* | -0.00000092 * | *-3.54* |
| NEWZEALAND | 3182 | 0.000172 * | *2.06* | -0.0000003 | *-0.21* | 0.056141 * | *5.94* | 0.066453 * | *6.84* | 0.882309 * | *119.12* | 0.00000025 | *0.76* |
| NORWAY | 3176 | 0.000326 * | *3.20* | -0.0000027 * | *-2.72* | 0.055790 * | *5.11* | 0.096117 * | *6.36* | 0.856709 * | *74.95* | 0.00000098 * | *3.96* |
| PORTUGAL | 3189 | 0.000237 * | *3.16* | 0.0000017 * | *4.69* | 0.039905 * | *5.10* | 0.085121 * | *8.28* | 0.896481 * | *106.55* | -0.00000027 * | *-3.62* |
| SINGAPORE | 3179 | 0.000125 | *1.46* | 0.0000017 * | *2.13* | 0.058671 * | *7.22* | 0.087658 * | *7.42* | 0.887262 * | *114.56* | -0.00000022 | *-1.55* |
| SPAIN | 3186 | 0.000225 * | *2.62* | 0.0000025 * | *3.14* | 0.022247 * | *2.57* | 0.091569 * | *8.35* | 0.911542 * | *111.39* | -0.00000037 * | *-2.57* |
| SWEDEN | 3175 | 0.000246 * | *2.32* | 0.0000013 | *1.91* | 0.028140 * | *4.38* | 0.094646 * | *8.94* | 0.911145 * | *124.51* | -0.00000012 | *-0.93* |
| SWITZERLAND | 3184 | 0.000143 | *1.95* | 0.0000012 * | *3.37* | 0.015087 | *1.56* | 0.123814 * | *9.04* | 0.897380 * | *81.34* | -0.00000014 | *-1.86* |
| UK | 3198 | 0.000103 | *1.40* | 0.0000024 * | *2.91* | 0.013031 | *1.40* | 0.121292 * | *8.76* | 0.907448 * | *96.30* | -0.00000031 * | *-2.41* |
| USA | 3186 | 0.000028 | *0.38* | 0.0000029 * | *6.21* | -0.024069 * | *-3.81* | 0.151853 * | *15.03* | 0.937533 * | *152.57* | -0.00000042 * | *-5.82* |
| **Panel B: Emerging Countries** | **Number Of Observations** | $\alpha$ | | $\gamma$ | | $\omega$ | | $\eta$ | | $\psi$ | | $\zeta_0$ | |
| | | Value | t-stat | Value | t-stat | Value | t-stat | Value | t-stat | Value | t-stat | Value | t-stat |
| BRAZIL | 2640 | 0.00045 * | *2.87* | 0.00000 | *-0.28* | 0.03063 * | *3.15* | 0.10200 * | *6.88* | 0.87568 * | *70.17* | 0.00000083 | *1.16* |
| CHILE | 3158 | 4.69721 * | *536.18* | 0.02130 | *1.36* | 0.16212 * | *7.19* | -0.05737 * | *-2.88* | 0.82980 * | *32.70* | -0.00304653 | *-0.90* |
| CHINA | 3060 | -0.00004 | *-0.42* | 0.00000 | *-1.40* | 0.06944 * | *10.25* | 0.05375 * | *5.73* | 0.89462 * | *188.86* | 0.00000030 * | *2.80* |
| COLOMBIA | 3075 | 0.00026 | *1.64* | 0.00002 * | *14.51* | 0.02372 * | *6.36* | 0.10182 * | *10.01* | 0.80884 * | *76.20* | -0.00000329 * | *-12.29* |
| CZECHREPUBLIC | 3178 | 0.00044 * | *4.07* | 0.00000 * | *2.70* | 0.06329 * | *5.44* | 0.08291 * | *6.06* | 0.85492 * | *63.69* | 0.00000007 | *0.47* |
| HUNGARY | 3161 | 0.00035 * | *2.77* | 0.00000 | *-1.72* | 0.08419 * | *8.37* | 0.13617 * | *10.39* | 0.80822 * | *91.70* | 0.00000181 * | *3.19* |
| INDIA | 3145 | 0.00049 * | *4.36* | 0.00000 * | *-3.07* | 0.07929 * | *7.41* | 0.10517 * | *7.52* | 0.83054 * | *77.64* | 0.00000126 * | *5.02* |
| ISRAEL | 3097 | 0.00025 * | *2.40* | 0.00000 * | *2.71* | 0.05770 * | *4.20* | 0.13001 * | *7.78* | 0.79765 * | *42.47* | -0.00000002 | *-0.07* |
| MALAYSIA | 3121 | 0.00018 | *1.11* | 0.00017 * | *44.19* | 0.19056 * | *9.40* | 0.06720 * | *2.39* | 0.58383 * | *51.90* | -0.00003081 * | *-45.53* |
| MEXICO | 3182 | 0.00031 * | *3.09* | 0.00000 | *1.44* | 0.03075 * | *3.84* | 0.13366 * | *12.21* | 0.87609 * | *109.39* | -0.00000023 | *-0.69* |
| PERU | 3078 | 0.00025 * | *3.61* | 0.00000 * | *5.37* | 0.10282 * | *9.06* | 0.08441 * | *6.61* | 0.81037 * | *76.99* | -0.00000004 | *-0.68* |
| POLAND | 3171 | 0.00022 | *1.76* | 0.00000 | *0.84* | 0.04313 * | *5.16* | 0.06655 * | *6.85* | 0.90413 * | *113.24* | 0.00000014 | *0.59* |
| SOUTHAFRICA | 3034 | 0.00035 * | *3.22* | 0.00000 * | *-2.88* | 0.05903 * | *5.62* | 0.09983 * | *7.81* | 0.86096 * | *90.12* | 0.00000094 * | *3.94* |
| TAIWAN | 3109 | 0.00012 | *0.98* | -0.00001 * | *-2.69* | 0.02985 * | *3.82* | 0.09003 * | *8.22* | 0.90759 * | *103.54* | 0.00000165 * | *3.00* |
| TURKEY | 3154 | 0.00046 * | *2.12* | 0.00000 * | *-2.30* | 0.08633 * | *9.78* | 0.07679 * | *5.56* | 0.83915 * | *86.12* | 0.00000193 * | *5.44* |

* denotes significance at the 5% conventional risk level

Table 5 shows the results that we obtain with our rolling TARCH procedure. We report the percentage of significant TARCH (1,1) parameters with the inclusion of volumes in the conditional variance for developed markets in Panel A and emerging markets in Panel B at a 5% confidence level for each country, according to the number of TARCH windows (conditional variance estimators).

Volatility persistence is observed on almost all the estimation widows (on average, between 85-90% of the cases) both for developed and emerging markets. The leverage effect is also a stylized fact that appears in about half of our sliding windows while the volatility clustering seems to be less frequently present (about one third of the cases).

The volume coefficient $\zeta_0$ is reported as the total percentage of significant estimators and, for illustrative purposes, is also split into positive and negative significant values. In Panel A, the percentage of significant $\zeta_0$ coefficients ranges from 33.51% (Norway) to 59.97% (Italy). Moreover, 15 countries out of 23 show a greater proportion of significant and positive volume coefficients. In Panel B, the percentage of significant $\zeta_0$ coefficients ranges from 31.26 % (Brazil) to 60.80% (Colombia). Furthermore, 10 countries out of 15 show a greater proportion of significant and positive volume coefficients. Hence, the results are quite comparable between the two panels and it seems difficult to clearly differentiate between developed and emerging countries in terms of the volatility - trading volume relationship as previously reported by empirical evidence, i.e. mostly positive relationship on mature, developed markets versus mostly negative on more incipient, emerging ones (see Asai and Unite, 2008 or Ureche-Rangau and DeRorthays, 2009 among others) which can be explained by the considerable changes experienced by emerging markets over the past decade.

**Table 5: Percentage of significant TARCH(1,1) conditional variance estimators with volumes at the 5% confidence level (rolling TARCH estimations).**

| *Panel A: Developed countries* | Number of TARCH windows | $\alpha$ | $\gamma$ | $\omega$ | $\eta$ | $\psi$ | $\zeta_0$ | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Total | + | - |
| AUSTRALIA | 3001 | 18.13% | 52.15% | 33.39% | 67.58% | 90.87% | 52.08% | 16.26% | 35.82% |
| AUSTRIA | 2935 | 30.43% | 36.35% | 31.65% | 51.21% | 78.94% | 37.99% | 27.05% | 10.94% |
| BELGIUM | 3021 | 30.82% | 52.93% | 20.13% | 43.13% | 90.40% | 56.01% | 39.72% | 16.29% |
| CANADA | 2989 | 22.05% | 45.03% | 24.96% | 42.09% | 91.94% | 45.67% | 22.32% | 23.35% |
| DENMARK | 2969 | 23.75% | 47.66% | 34.89% | 50.19% | 94.98% | 49.88% | 22.70% | 27.18% |
| FINLAND | 2974 | 21.89% | 38.80% | 29.29% | 54.57% | 76.56% | 39.58% | 22.33% | 17.25% |
| FRANCE | 3010 | 22.86% | 57.41% | 37.24% | 50.40% | 87.87% | 58.47% | 27.87% | 30.60% |
| GERMANY | 3008 | 21.44% | 51.60% | 32.55% | 53.06% | 94.48% | 51.80% | 30.95% | 20.84% |
| GREECE | 2958 | 24.10% | 39.66% | 26.94% | 49.53% | 89.82% | 40.60% | 30.70% | 9.91% |
| HONG KONG | 2921 | 32.87% | 53.65% | 48.03% | 65.90% | 89.90% | 54.98% | 29.68% | 25.30% |
| IRELAND | 2053 | 32.49% | 56.55% | 13.49% | 42.23% | 91.87% | 59.72% | 32.49% | 27.23% |
| ITALY | 3010 | 25.02% | 59.40% | 23.12% | 44.72% | 92.49% | 59.97% | 39.93% | 20.03% |
| JAPAN | 2917 | 19.57% | 41.17% | 23.55% | 46.01% | 87.52% | 42.82% | 26.50% | 16.32% |
| NETHERLANDS | 3026 | 14.74% | 43.82% | 37.38% | 60.71% | 96.70% | 45.01% | 19.70% | 25.31% |
| NEWZEALAND | 2983 | 21.02% | 48.27% | 23.84% | 35.00% | 85.05% | 47.64% | 13.24% | 34.39% |
| NORWAY | 2975 | 22.25% | 32.03% | 26.32% | 51.03% | 79.16% | 33.51% | 21.92% | 11.60% |
| PORTUGAL | 2988 | 39.79% | 44.68% | 28.82% | 45.58% | 79.32% | 46.55% | 37.92% | 8.63% |
| SINGAPORE | 2980 | 39.60% | 43.72% | 22.72% | 47.42% | 84.87% | 45.37% | 33.09% | 12.28% |
| SPAIN | 2897 | 26.72% | 52.86% | 33.41% | 49.48% | 93.00% | 54.37% | 34.58% | 19.79% |
| SWEDEN | 2975 | 22.25% | 43.90% | 30.02% | 54.86% | 89.92% | 45.48% | 17.11% | 28.37% |
| SWITZERLAND | 2985 | 13.77% | 52.36% | 40.57% | 49.41% | 92.19% | 53.13% | 32.76% | 20.37% |
| UK | 2999 | 17.21% | 54.55% | 26.81% | 45.32% | 88.70% | 57.39% | 27.74% | 29.64% |
| USA | 2985 | 14.51% | 53.27% | 61.31% | 75.38% | 95.81% | 54.41% | 33.57% | 20.84% |
| *Panel B: Emerging countries* | Number of TARCH windows | $\alpha$ | $\gamma$ | $\omega$ | $\eta$ | $\psi$ | $\zeta_0$ | | |
| | | | | | | | Total | + | - |
| BRAZIL | 2441 | 30.48% | 29.91% | 33.06% | 58.42% | 91.11% | 31.26% | 14.01% | 17.25% |
| CHILE | 2959 | 100.00% | 31.70% | 17.88% | 13.79% | 51.00% | 41.97% | 24.43% | 17.54% |
| CHINA | 2860 | 25.10% | 48.57% | 32.87% | 42.80% | 92.83% | 47.41% | 21.50% | 25.91% |
| COLOMBIA | 2875 | 6.05% | 57.32% | 51.27% | 52.42% | 93.67% | 60.80% | 24.94% | 35.86% |
| CZECHREPUBLIC | 2979 | 30.85% | 31.12% | 26.96% | 37.36% | 91.31% | 31.45% | 25.28% | 6.18% |
| HUNGARY | 2962 | 21.34% | 35.45% | 32.78% | 53.41% | 84.40% | 37.98% | 25.39% | 12.59% |
| INDIA | 2946 | 41.79% | 45.69% | 27.56% | 61.20% | 89.51% | 47.08% | 34.83% | 12.25% |
| ISRAEL | 2898 | 10.28% | 36.16% | 26.78% | 48.31% | 82.47% | 39.82% | 32.64% | 7.18% |
| MALAYSIA | 2922 | 32.14% | 40.62% | 27.00% | 45.62% | 76.39% | 43.84% | 27.28% | 16.56% |
| MEXICO | 2982 | 35.14% | 38.63% | 37.63% | 67.67% | 89.84% | 39.20% | 17.47% | 21.73% |
| PERU | 2879 | 33.07% | 51.23% | 47.31% | 47.69% | 85.52% | 55.12% | 44.22% | 10.91% |
| POLAND | 2969 | 13.84% | 44.09% | 40.89% | 45.98% | 86.97% | 48.00% | 28.63% | 19.37% |
| SOUTHAFRICA | 2833 | 17.97% | 39.53% | 28.77% | 48.39% | 92.38% | 40.24% | 12.18% | 28.06% |
| TAIWAN | 2910 | 16.32% | 53.44% | 37.29% | 49.55% | 91.62% | 56.29% | 39.97% | 16.32% |
| TURKEY | 2955 | 7.45% | 46.43% | 32.25% | 46.97% | 90.02% | 48.12% | 36.45% | 11.68% |

Our dataset comprises data from January 1997 to July 2009. The evolution of macroeconomic fundamentals and the financial events characterizing the time period under study along with investors' behavior and access to information may explain these variations. A number of significant macroeconomic events have impacted the financial industry over this time period, such as the 1997 Asian crisis, the burst of the dotcom bubble in 2000 and the subprime crisis of 2007, among others. Hence, we will first consider the impact of stress periods on the relationship between volatility and volumes, and then the evolution of this relation in bull and bear periods.

Table 6 summarizes the observed movements in the relationship between volatility and trading volumes. The left part of the table depicts this relation over specific periods of financial crisis, while the right part reports the movements of the same relation in periods of market growth ("Bull") and burst ("Bear"). "0" implies that no significant change is observed in the relation between volatility and volume (their relationship neither enforces nor relaxes), while a "+" or a "–" shows that the link between the two variables is enforced, either as a positive or as negative correlation. Finally, a "+/-" indicates a stronger impact of volume on the volatility of returns without any clear direction regarding the sign of this impact.

**Table 6: Impact of chosen macroeconomic events on the relationship between trading volume and volatility.**

| | CRISIS (Peak) | | | Bull & Bear | |
|---|---|---|---|---|---|
| | 1997 - 1998 | 2000 - 2001 | 2007 - 2008 | Bull | Bear |
| AUSTRALIA | 0 | 0 | +/- | - | - |
| AUSTRIA | 0 | + | +/- | +/- | + |
| BELGIUM | 0 | 0 | +/- | +/- | + |
| CANADA | 0 | - | - | +/- | + |
| DENMARK | 0 | - | + | 0 | - |
| FINLAND | 0 | - | + | +/- | + |
| FRANCE | 0 | - | + | +/- | +/- |
| GERMANY | 0 | - | + | 0 | + |
| GREECE | 0 | + | + | 0 | + |
| HONG KONG | +/- | - | + | 0 | - |
| IRELAND | 0 | 0 | + | - | - |
| ITALY | 0 | - | +/- | +/- | +/- |
| JAPAN | 0 | 0 | + | +/- | +/- |
| NETHERLANDS | 0 | + | - | - | 0 |
| NEWZEALAND | 0 | - | - | - | - |
| NORWAY | 0 | 0 | +/- | +/- | 0 |
| PORTUGAL | 0 | 0 | +/- | 0 | 0 |
| SINGAPORE | +/- | - | +/- | + | +/- |
| SPAIN | 0 | + | + | +/- | +/- |
| SWEDEN | 0 | - | + | +/- | +/- |
| SWITZERLAND | 0 | - | + | +/- | +/- |
| UK | 0 | - | + | - | +/- |
| USA | 0 | - | + | - | +/- |
| BRAZIL | +/- | - | +/- | +/- | - |
| CHILE | 0 | + | - | +/- | + |
| CHINA | - | - | +/- | 0 | - |
| COLOMBIA | +/- | +/- | 0 | + | +/- |
| CZECHREPUBLIC | 0 | 0 | + | 0 | 0 |
| HUNGARY | 0 | 0 | + | +/- | +/- |
| INDIA | 0 | 0 | + | + | + |
| ISRAEL | 0 | +/- | + | + | +/- |
| MALAYSIA | +/- | 0 | + | 0 | 0 |
| MEXICO | +/- | - | +/- | +/- | - |
| PERU | +/- | 0 | +/- | +/- | + |
| POLAND | 0 | - | +/- | + | - |
| SOUTHAFRICA | 0 | - | +/- | - | - |
| TAIWAN | 0 | 0 | +/- | + | +/- |
| TURKEY | 0 | - | - | + | +/- |

**The Asian crisis: 1997 – 1998**

Financial markets of East and Southeast Asia experienced a similar downward move during late 1997 and early 1998 after the collapse of the Thai baht at the beginning of July 1997. As reported by Baig and Goldfajn (1999), intense foreign exchange and stock market turmoil spread in the entire region. We can analyze the impact of financial markets operating in a shocked environment on the relationship between volatility and trading volume.

Two specific dynamics can be drawn from Table 6. We can observe that in 2 developed countries out of 23, i.e. Hong Kong and Singapore, and 5 emerging countries out of 15, the volatility and trading volume relationship is modified following the Asian financial turmoil. Not surprisingly, we notice that Asian, both developed and emerging markets, and South American emerging countries developed specific dynamics during this period (1997-1998).

**The burst of the Dotcom bubble: 2000 – 2001**

The Dotcom bubble refers to the rise and fall of internet stock prices in the late 20th century. The bubble was fuelled by investors' overconfidence in new economy companies and translated into overvalued prices driven by "irrational euphoria" (Shiller, 2000).

17 developed countries out of 23 and 9 emerging countries out of 15 develop a specific dynamic in the volatility – trading volume relation during this particular period. Overall, 19 countries show a significant increase in the explanatory power of the volume parameter which is negatively linked to the volatility, while only 5 countries show a significant increase in the explanatory power of their volume parameter when this last is positively related to the volatility. Finally, for 2 countries the volume coefficients are statistically significant, however without any particular sign, while 12 countries do not show any particular pattern in the relationship between the two variables.

**The subprime crisis**

In the summer of 2007 major banks in the United States and Europe faced a collapse in the value of their mortgage backed securities which they had spread through the industry. The diffusion of these poisonous securities created a major credit crunch and led to the default of many financial institutions. It created a major worldwide financial distress followed by a collapse in stock market capitalization across the world and one of the most important economic recessions of our history. This crisis therefore affected both developed and emerging countries.

Table 6 shows that the relationship between trading volume and volatility has been impacted in the majority of developed and emerging economies. We find that 37 countries out of the 38 that compose our whole sample present a specific dynamic starting at the beginning of 2007. A first conclusion at this point is that the subprime crisis seems to have impacted Panel A and Panel B countries to the same extent.

Table 7 shows how the subprime crisis impacted the relationship between trading volume and volatility in developed (Panel A) and emerging (Panel B) countries. We can observe that more than 1 developed country out of 2 has a significant positive rise in the explanatory power of its volume parameter. Moreover, we can notice that emerging countries are also strongly impacted but for almost 1 out of 2 emerging countries the impact has no clear direction in time.

**Table 7: Impact of the subprime crisis on the relationship between trading volume and volatility**

| | Mixed impact +/- | Positively impacted + | Negatively impacted - | Not impacted 0 |
|---|---|---|---|---|
| Panel A | 30% | 57% | 13% | 0% |
| Panel B | 47% | 33% | 13% | 7% |

### 3.2 Bull and Bear period analysis

An important amount of empirical research on GARCH/TARCH estimations has focused on bull and bear markets, as defined by financial analysts and stock market commentators. It is likely that investors' confidence and behavior is affected by the longer-term direction of the market. This part of our analysis will therefore analyze the changes in the relationship between volatility of returns and volumes depending on the market trend. Although there is no formal consensus, a bull market can be defined as a long-term upward price movement characterized by a series of higher intermediate highs interrupted by a series of intermediate lows, and a bear market as a long-term downtrend characterized by lower intermediate lows interrupted by lower intermediate highs.

For convenience, we focus our analysis on the bearish period (2001-2003) following the Dotcom bubble burst in 2000, and the bullish period (2003-2007) preceding the subprime crisis in 2007. Our sliding window model will enable us to decrypt movements in the volatility-volume relationship during such periods.

**Bear period analysis**

Four specific dynamics can be drawn from Table 6. Overall, we can observe that the relationship between returns volatility and volume is not affected for 5 countries out of 38. Table 8 reports the impact of the bearish period on the coefficient of volume estimated *via* the TARCH(1,1) model. Panel A, corresponding to the developed markets dataset, shows a greater proportion of cases where the coefficient of volume is significantly positive during bear periods with respect to Panel B, i.e. emerging countries sub sample, while Panel B seems to have a greater proportion of cases for which the same coefficient is significantly negative when compared to Panel A. For both developed and emerging economies we can see that for one third of the countries no clear trend can be identified, as we obtain mixed results, both positive and negative, for the coefficient of volume.

**Table 8: Impact of the bearish period of 2001 - 2003 on the relationship between trading volume and volatility**

| | Mixed impact +/- | Positively impacted + | Negatively impacted - | Not impacted 0 |
|---|---|---|---|---|
| Panel A | 39% | 26% | 22% | 13% |
| Panel B | 33% | 20% | 33% | 13% |

**Bull period analysis**

Concerning the dynamics of the volatility and trading volume relation over the bull period, Table 6 shows that overall this relation is not affected for 7 countries out of 38. Table 9 reports the impact of the bullish period on the TARCH(1,1) estimator of the trading volume coefficient. We can notice that for Panel A, the impact of the bullish period is mainly mixed; it is therefore hard to rely on volume to predict volatility of returns as the sign and the proportion of the volume parameter are very unstable. In contrast, for Panel B, we observe that in 40% of the cases, the volume coefficient in the conditional variance equation is positive and significant. This implies that for emerging economies, in periods of growth, the volume parameter explains the volatility of returns to a greater extent.

**Table 9: Impact of the bullish period of 2003 - 2007 on the relationship between trading volume and volatility**

| | Mixed impact +/- | Positively impacted + | Negatively impacted - | Not impacted 0 |
|---|---|---|---|---|
| Panel A | 48% | 4% | 26% | 22% |
| Panel B | 33% | 40% | 7% | 20% |

Our findings are consistent with Ané and Ureche-Rangau (2008) who suggest that there is common short run behavior of volatility and trading volume, but this may not be the case on the long run. The sliding windows model that we use in this paper allows us to study these short run dynamics through time. Our results prove that the explanatory power of volume is indeed variable through time. Returns volatility and trading volume therefore share common short term dynamics as macroeconomic events and investors' behavior impact this relationship. However, on the long run, this relation is unstable, which renders the task of deriving a general pattern characterizing the dynamics between trading volume and volatility through time almost impossible. One empirical regularity can be stressed though, namely that the relationship between the two variables strengthens during periods of market stress, which is in line with Galati (2000), or Wagner and Marsh (2005) among others. Moreover, the relationship is mainly negative during such periods, suggesting that the MDH might hold in normal market conditions, i.e. when volatility is low, but be violated during periods of financial turmoil, i.e. when volatility reaches very high levels and investors might quit the market. As Galati (2000) highlights it, a positive relation between volatility and volume may thus be an indicator of liquid markets while a negative link between the two may be a sign of inadequate liquidity.

However, contrary to Girard and Biswas (2007), our results do not allow us to state that the behavior of the volatility and trading volume relationship is completely different in emerging markets compared to the developed ones. One potential explanation might be the important progresses made by emerging markets in imposing new market regulations that limit price manipulation and insider trading, that allow better liquidity, transparency and investor protection.

## 4. Conclusion

This paper examines the evolution of the relationship between trading volume and volatility in 23 developed and 15 emerging markets from January 1997 to July 2009. Our study uses an original approach by applying the TARCH(1,1) methodology in a dynamic sliding windows model. This allows us to study the evolution of this relationship over time, while trying to link these variations to macroeconomic events or changes in investors' behavior. The results provided above are computed with a window of 200 daily observations[5]. We then focus on three major macroeconomic events: the Asian crisis (1997-1998), the Dot Com bubble (2000-2001) and the Subprime crisis (2007).

First we find evidence that the relationship between trading volume and volatility is unstable through time. Moreover, we can identify specific dynamics during the three major financial crises mentioned above, i.e. we observe that the relationship is impacted by these events that can be linked to the economic environment or investor behavior. We observe that even though each country presents a specific dynamic, we are able to find common trends among the markets in our dataset. There seems to be a common short run behavior between trading volume and volatility, but that this may not be the case on the long run.

Second, we show that the explanatory power of volumes in the conditional variance strongly increases in stress periods when a country is directly exposed to a critical environment. Indeed, an increase in the explanatory power of volumes is always observed in such periods. The arrival of new information, uncertainty and increased price risk might explain the intensified relation between the two variables. However, the sign of the relationship cannot be set for a group of developed or emerging countries. This implies that we cannot identify common dynamics for developed or emerging markets. This is also true for bull and bear periods where no clear sign in the relationship can be found for the two defined sub groups.

Finally, we can conclude that there is indeed a strong relationship between trading volume and volatility. However, this relationship is unstable and does not totally explain volatility's main stylized facts, namely persistence. Hence, volume may not be enough to explain the returns volatility. The next step of our research is to take into account expected and unexpected trading volume separately and analyze their individual ability to explain volatility persistence. As the variation in the relation between volume and volatility depends on the time period and the market conditions it would also be interesting to model the volatility of the trading volume and volatility relationship.

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