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Global and regional spillovers in emerging stock markets: a multivariate GARCH-in-mean analysis

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## Abstract

This paper examines global (mature market) and regional (emerging market) spillovers in local emerging stock markets. Tri-variate VAR GARCH(1,1)-in-mean models are estimated for 41 emerging market economies (EMEs) in Asia, Europe, Latin America, and the Middle East. The models capture a range of possible transmission channels: spillovers in mean returns, volatility, and cross-market GARCH-in-mean effects. Hypotheses about the importance of different channels are tested. The results suggest that spillovers from regional and global markets are present in the vast majority of EMEs. However, the nature of cross-market linkages varies across countries and regions. While spillovers in mean returns dominate in emerging Asia and Latin America, spillovers in variance appear to play a key role in emerging Europe. There is also some evidence of cross-market GARCH-in-mean effects. The relative importance of regional and global spillovers varies too, with global spillovers dominating in Asia, and regional spillovers in Latin America and the Middle East.

*JEL classifications:* F30; G15
*Keywords:* Volatility spillovers; contagion; stock markets; emerging markets

## 1. Introduction

The empirical finance literature abounds with studies of cross-border links in stock market returns. This is not surprising. Empirical modelling of such links is relevant for trading and hedging strategies and provides insights into the transmission of shocks (news) across

[1] Marianne Schulze-Ghattas was on sabbatical from the International Monetary Fund and visiting fellow at the Financial Markets Group, London School of Economics when the research was done. The views expressed in this paper are those of the authors and do not necessarily reflect those of the European Central Bank or the International Monetary Fund.

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markets. Informed by standard asset pricing models and supported by advances in the econometric modeling of volatility, research in the past two decades has focused on interdependencies in terms of both first and second moments of return distributions.

Early studies of spillovers across national stock markets primarily covered advanced countries. Prompted by the October 1987 stock market crash in the US, Hamao, Masulis and Ng (1990), King and Wadhwani (1990) and Schwert (1990) examined spillovers across major markets before and after the crash. Subsequent research refined and expanded the analysis of advanced market links by examining spillovers in high frequency (e.g., hourly) data (Susmel and Engle, 1994); asymmetry in the transmission of positive and negative shocks (Bae and Karolyi, 1994; Koutmos and Booth, 1995); differences in the transmission of global and local shocks (Lin, Engle and Ito, 1994), and interactions among larger sets of advanced markets (Theodossiou and Lee, 1993; Fratzscher, 2002).

Research into cross-border links in emerging stock markets was boosted by the growth and increasing openness of these markets, as well as the speed and virulence with which past financial crises in emerging market economies (EMEs) spread to other countries. Bekaert and Harvey (1995, 1997, 2000) and Bekaert, Harvey and Ng (2005) analyse the implications of growing integration with global markets for local returns, volatility, and cross-country correlations, covering a diverse set of EMEs in Africa, Asia, Latin America, and the Mediterranean. Most other studies of EME stock markets focus on specific regions. Scheicher (2001), Chelley-Steeley (2005), and Yang, Hsiao and Wang (2006) examine extent and effects of stock market integration in Central and Eastern Europe, both within the region and with advanced markets, while Chen, Firth and Rui (2002) look at evidence of regional linkages among Latin American stock markets. Floros (2008) focuses on the Middle East, while Ng (2000), Tay and Zhu (2000), Worthington and Higgs (2004), Caporale, Pittis and Spagnolo (2006), Engle, Gallo and Velucchi (2008), and Li and Rose (2008) examine stock markets in emerging Asia.

These studies generally point to increasing links among emerging stock markets, and between these markets and mature markets. However, results are difficult to compare across countries because they are based on different methodologies, time periods, and data frequencies. This paper seeks to remedy this problem by applying a uniform specification to a large set of EMEs - 41 in all - spanning four regions: Asia, emerging Europe, the Middle East and North Africa, and Latin America. A downside of this approach is that, given the large number of countries in each region, we cannot model simultaneously the links among all local markets, and between these markets and major mature markets. We focus on links between local emerging markets and aggregate global and regional markets as we are interested in the impact of the latter on the former.

The paper relies on a broad model framework that encompasses several channels through which news in global and regional markets may influence local emerging markets. More specifically, we apply a tri-variate VAR-GARCH-in-mean framework with the BEKK representation proposed by Engle and Kroner (1995) to model and test for cross-market spillovers in means and variances of stock returns as well as own and cross-market spillovers from second to first moments (GARCH-in-mean effects). This approach builds and expands on the methodologies adopted in earlier studies such as Hamao, Masulis and Ng (1990), Ng

(2000), and Bekaert, Harvey and Ng (2005). The global market in each tri-variate model is a GDP-weighted average of the US, Japan, and Europe (Germany, France, Italy, and the UK), [1] and the regional market is a weighted average of all emerging markets in the region included in our country sample, except for the model's local market.[2] Our analysis is based on weekly stock returns in local currency. Time series end in mid-March 2008 and start in 1993 for emerging Asia, and in 1996 for Latin America, most markets in emerging Europe, South Africa, the Middle East and North Africa.

We use Wald tests to examine several hypotheses about spillovers in means and variances, as well as GARCH-in-mean effects, from global and regional markets to local markets. The results suggest that spillovers from regional and global markets are present in the vast majority of EMEs. However, the nature of cross-market linkages varies across countries and regions. While spillovers in mean returns dominate in emerging Asia and Latin America, spillovers in variance appear to play a key role in emerging Europe. There is also some evidence of cross-market GARCH-in-mean effects. The relative importance of regional and global spillovers varies too, with global spillovers dominating in Asia, and regional spillovers in Latin America and the Middle East.

The paper is organised as follows. Section 2 describes the econometric model. Section 3 provides details on the data set and outlines the hypotheses tested. Section 4 discusses the results; and section 5 offers some concluding remarks.

## 2. Methodology

We represent the first and second moments of returns in local, regional and global stock markets by a tri-variate VAR-GARCH(1,1)-in-mean process.[3] In its general specification the model has the following form:

$$x_t = \alpha + B'x_{t-1} + \Gamma' h^*_t + u_t \qquad (1)$$

with $x_t$ a 3x1 vector of returns in local emerging markets, regional emerging markets, and mature markets; $x_{t-1}$ a corresponding vector of lagged returns; $h^*_t = (\sqrt{h_{11,t}}, \sqrt{h_{22,t}}, \sqrt{h_{33,t}})$ a vector of the conditional standard deviations in local, regional, and global markets; and $u_t = (e_{1,t}, e_{2,t}, e_{3,t})$ a residual vector. The parameters of the mean return equations (1) comprise the constant terms $\alpha = (\alpha_1, \alpha_2, \alpha_3)$; the parameters of the autoregressive terms $B = (\beta_{11}, 0, 0 \mid \beta_{21}, \beta_{22}, 0 \mid \beta_{31}, \beta_{32}, \beta_{33})$, which allow for mean return spillovers from mature markets to regional and local emerging markets, and from regional markets to local markets; and $\Gamma = (\gamma_{11}, 0, 0 \mid \gamma_{21}, 0, 0 \mid \gamma_{31}, 0, 0)$ the parameters of the GARCH-in-mean terms.

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[1] We used GDP weights because time series on market capitalisation were not available for all emerging markets in our sample.

[2] Bekaert, Harvey, and Ng (2005) adopt a similar approach.

[3] The model is based on the multivariate GARCH(1,1)-BEKK representation proposed by Engle and Kroner (1995).

The residual vector $u_t$ is tri-variate and normally distributed $u_t \mid I_{t-1} \sim (0, H_t)$ with its corresponding conditional variance-covariance matrix given by:

$$H_t \quad = \quad \begin{bmatrix} h_{11,t} & h_{12,t} & h_{13,t} \\ h_{21,t} & h_{22,t} & h_{23,t} \\ h_{31,t} & h_{32,t} & h_{33,t} \end{bmatrix} \tag{2}$$

In the multivariate GARCH(1,1)-BEKK representation proposed by Engle and Kroner (1995), which guarantees by construction that the variance-covariance matrices in the system are positive definite, $H_t$ takes the following form:

$$H_t = C'_0C_0 + \begin{bmatrix} a_{11} & 0 & 0 \\ a_{21} & a_{22} & 0 \\ a_{31} & a_{32} & a_{33} \end{bmatrix}' \begin{bmatrix} e_{1,t-1}^2 & e_{1,t-1}e_{2,t-1} & e_{1,t-1}e_{3,t-1} \\ e_{2,t-1}e_{1,t-1} & e_{2,t-1}^2 & e_{2,t-1}e_{3,t-1} \\ e_{3,t-1}e_{1,t-1} & e_{3,t-1}e_{2,t-1} & e_{3,t-1}^2 \end{bmatrix} \begin{bmatrix} a_{11} & 0 & 0 \\ a_{21} & a_{22} & 0 \\ a_{31} & a_{32} & a_{33} \end{bmatrix}$$

$$\begin{bmatrix} g_{11} & 0 & 0 \\ g_{21} & g_{22} & 0 \\ g_{31} & g_{32} & g_{33} \end{bmatrix}' \quad H_{t-1} \begin{bmatrix} g_{11} & 0 & 0 \\ g_{21} & g_{22} & 0 \\ g_{31} & g_{32} & g_{33} \end{bmatrix} \tag{3}$$

Equation (3) models the dynamic process of $H_t$ as a linear function of its own past values $H_{t-1}$ as well as own and cross products of past innovations $e_{1,t-1}$, $e_{2,t-1}$, $e_{3,t-1}$, allowing for own-market and cross-series influences in the conditional variances. The parameters of (3) are given by $C_0$, which is restricted to be upper triangular, and two matrices $A_{11}$ and $G_{11}$. Each of these two matrices has three zero restrictions as we are focusing on volatility spillovers (causality-in-variance) running from mature stock markets to regional and local emerging stock markets, and from regional to local emerging markets.

Given a sample of T observations, a vector of unknown parameters $\theta$[4] and a 3 x 1 vector of variables $x_t$, the conditional density function for the model (1)-(3) is:

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[4] Standard errors are calculated using the quasi-maximum likelihood method of Bollerslev and Wooldridge (1992), which is robust to the distribution of the underlying residuals – these are not reported for reasons of space. A residual vector $u_t$ following a t-student distribution has also been considered, but the results were qualitatively similar and therefore are not reported. The full set of results is available from the authors upon request.

$$f(x_t \mid I_{t-1}; \theta) = (2\pi)^{-1} \mid H_t \mid^{-1/2} \exp(- [u`_t (H_t^{-1}) u_t] / 2) \qquad (4)$$

The log likelihood function is:

$$\text{Log-Lik} = \Sigma_{t=1}^{T} \log f (x_t \mid I_{t-1}; \theta) \qquad (5)$$

## 3. Data and hypotheses tested

### *3.1. Data set*

The tri-variate VAR-GARCH-in-mean model outlined above is estimated for 41 emerging market economies (EMEs) in Asia, Latin America, Europe (including South Africa[5]), and the Middle East and North Africa. The following EMEs are included in the country sample:

*Emerging Asia*: China, Hong Kong, India, Indonesia, Korea, Malaysia, Pakistan, the Philippines, Singapore, Sri Lanka, Taiwan, and Thailand.

*Latin America*: Argentina, Brazil, Chile, Colombia, Ecuador, Mexico, Peru, and Venezuela.

*Emerging Europe*: Bulgaria, Croatia, the Czech Republic, Estonia, Hungary, Israel, Latvia, Poland, Romania, Russia, Slovakia, Slovenia, South Africa, and Turkey.

*Middle East and North Africa*: Egypt, Jordan, Kuwait, Lebanon, Morocco, Saudi Arabia, and Tunisia.

The model for each EME consists of returns in local, regional, and global markets. We use weekly returns, defined as log differences of local currency stock market indices for weeks running from Wednesday to Wednesday to minimize effects of cross-country differences in weekend market closures. Mature market returns are calculated as a weighted average of returns on benchmark indices in the US, Japan, and Europe (France, Germany, Italy, UK). Regional market returns are a weighted average of returns on benchmark indices for all sample EMEs in the region, except the local market. As time series on market capitalisation are not available for all EMEs in the sample, weights are based on US$-GDP data from the IMF's World Economic Outlook database.[6] All stock market indices were obtained from Datastream. Return time series run through 12 March 2008 and begin on the following dates:[7] *Emerging Asia*: 1 September, 1993. *Emerging Europe*: 12 June, 1996 (except Bulgaria: 1 November, 2000; Croatia: 15 January, 1997; Romania: 1 October, 1997). *Latin*

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[5] South Africa has been included under the heading "Europe", as this is the region with which it has the strongest economic and financial links.

[6] Annual GDP data were converted into weekly data and weights were calculated as 104-week moving averages.

[7] Dates refer to end of week.

*America*: 3 January, 1996. *Middle East and North Africa*: 31 January, 1996 (except Saudi Arabia and Tunisia: 1 July, 1998).

*3.2 Hypotheses tested*

We test for spillovers in means and variances, and GARCH-in-mean effects by placing restrictions on the relevant parameters and computing the following Wald test:

$$W = [R\hat{\theta}]'[RVar(\hat{\theta})R']^{-1}[R\hat{\theta}] \tag{6}$$

where $R$ is the q×k matrix of restrictions, with q equal to the number of restrictions and k equal to the number of regressors; $\hat{\theta}$ is a k×1 vector of the estimated parameters, and $Var(\hat{\theta})$ is the heteroscedasticity - robust consistent estimator for the covariance matrix of the parameter estimates. The tests involve joint hypotheses at one, two, three, four, and nine degrees of freedom (k). Specifically, a benchmark case that allows for no spillovers and three sets of null hypotheses about different spillover channels were tested:

*Benchmark case of no spillovers and GARCH-in-mean effects*

H01: No spillovers in mean, no spillovers in variance, and no GARCH-in-mean effects: $\beta_{21} = \beta_{31} = a_{21} = g_{21} = a_{31} = g_{31} = \gamma_{11} = \gamma_{21} = \gamma_{31} = 0$.

*Tests of spillovers in mean*

H02: No spillover in mean from regional to local markets: $\beta_{21} = 0$.
H03: No spillover in mean from global to local markets: $\beta_{31} = 0$.
H04: No spillover in mean from regional and global markets: $\beta_{21} = \beta_{31} = 0$.

*Tests of spillovers in variance*

H05: No volatility spillover from regional markets: $a_{21} = g_{21} = 0$.
H06: No volatility spillover from global markets: $a_{31} = g_{31} = 0$.
H07: No volatility spillover from regional and global markets: $a_{21} = g_{21} = a_{31} = g_{31} = 0$.

*Tests of GARCH-in-mean effects*

H08: No GARCH-in-mean effect from local volatility to local mean returns: $\gamma_{11} = 0$.

H09: No GARCH-in-mean effect from volatility in regional markets to local mean returns: $\gamma_{21} = 0$.
H10: No GARCH-in-mean effect from volatility in global markets to local mean returns: $\gamma_{31} = 0$.
H11: No GARCH-in-mean effects from regional or global volatility to local markets: $\gamma_{21} = \gamma_{31} = 0$.

H12: No GARCH-in-mean effects whatsoever: $\gamma_{11} = \gamma_{21} = \gamma_{31} = 0$.

## 4. Discussion of results

The tri-variate VAR-GARCH(1,1)-in-mean specification captures conditional means and variances of returns in local stock markets fairly well. On the basis of Ljung-Box portmanteau (LB) autocorrelations tests of ten lags the null hypothesis of no autocorrelation is rejected in only three cases (India, Latvia, and Slovenia) for the standardised residuals, and in six cases (Argentina, Mexico, Hungary, Poland, Morocco, and Saudi Arabia) for the standardised squared residuals (Table 1). Most of the estimated own-market parameters for the variance-covariance equations ($a_{11}$ and $g_{11}$) and a number of the spillover parameters are statistically significant (Table 2).

**Insert Tables 1 and 2 about here.**

Tests of the hypotheses about spillovers from regional and global stock markets to local emerging markets suggest that such linkages matter in the vast majority of the EMEs in our sample, particularly in Asia, emerging Europe, and Latin America. The benchmark case (H01), which cuts all linkages and implies a simple univariate VAR-GARCH(1.1) model for each EME local market, is rejected for all but eight of the 41 countries - in most cases at the one percent level (Tables 3 and 4).

**Insert Tables 3 and 4 about here.**

Spillovers from regional emerging and global mature markets to mean returns in local markets (H02-H04) appear to be present in all emerging regions. We reject the null hypotheses of no regional spillovers (H02) and/or no global spillovers (H03) for almost 90 percent of the countries in our sample. In emerging Asia, direct linkages with mature global markets dominate regional linkages, except in China, Korea, Sri Lanka, and Taiwan. By contrast, regional spillovers seem to be equally or more important than global spillovers in Latin America (except in Brazil and Mexico), emerging Europe (except in Hungary and Slovenia), and in the Middle East and North Africa (except in Saudi Arabia). We reject the joint hypothesis of no spillovers in mean from regional and global markets (H04) for three quarters of the sample EMEs in Asia, nearly two thirds of the Latin American countries, and half of the EMEs in Europe.

We also find evidence of volatility spillovers from regional and/or global markets to local emerging markets (H05-H07). These linkages appear to be somewhat less important than linkages in mean returns, except in emerging Europe. Our tests reject the hypotheses of no volatility spillovers from regional markets (H05) and/or global markets (H06)—as well as the joint hypothesis of no volatility spillovers whatsoever (H07)—for 85 percent of the EMEs in Europe and South Africa, but only for about half of the EMEs in Asia and Latin America, and for just over a quarter of the EMEs in the Middle East and North Africa. In Asia, regional spillovers appear to have been a more important source of volatility in local markets than global spillovers, while in other regions, global and regional spillovers have been equally important.

Volatility in regional and global markets may affect not only the volatility of local emerging markets but also expected returns in these markets (H09-H12). While such cross-market variance-to-mean spillovers (GARCH-in-mean effects) appear to be less prominent than spillovers in mean and variance, our results suggest that they do play a role as a transmission channel between regional and local emerging markets and, in particular, between global and local markets. We reject the hypothesis of no GARCH-in-mean effects from regional to local emerging markets (H09) for over a third of the EMEs in our sample. The null hypothesis of no variance-to-mean spillovers from global mature markets to local emerging markets (H10) is rejected for nearly half of the EMEs in Asia, Europe, the Middle East and North Africa. By contrast, own-market GARCH-in-mean effects seem to become negligible when the full range of possible spillover channels from regional and global markets are modeled. We reject the restriction of no such effects (H08) for only four EMEs in our sample.

## 5. Conclusions

The main objective of this study was to examine regional and global spillovers in emerging stock markets using a uniform model for a large set of EMEs to facilitate cross-country comparisons. A trivariate VAR GARCH(1,1)-in-mean model was chosen to capture a broad range of possible spillover channels in means and variances. We carried out a series of Wald tests involving restrictions on various spillover parameters to analyse the importance of different transmission channels.

Starting with a benchmark case that rules out any spillovers from regional or global stock markets to local emerging markets, we found that such spillovers are present in the vast majority of EMEs. The benchmark restrictions are rejected for all but a few countries in our sample. However, the nature of cross-market linkages varies across countries and regions. While spillovers in mean returns dominate in emerging Asia and Latin America, spillovers in variance appear to play a key role in emerging Europe. There is also some evidence of cross-market GARCH-in-mean effects. The relative importance of regional and global spillovers varies too, with global spillovers dominating in Asia, and regional spillovers in Latin America and the Middle East.

Our results offer a first stab at a comprehensive comparative analysis of cross-market linkages in emerging stock markets. Further research is no doubt needed. An important question is whether transmission channels and the relative importance of regional and global spillovers have changed over time, in particular in the run-up to, and course of, the present crisis.

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Table 1. Parameter Estimates for Mean Equations and LB Test Statistics: Local Markets

| | $\beta_{11}$ | $\beta_{21}$ | $\beta_{31}$ | $\gamma_{11}$ | $\gamma_{21}$ | $\gamma_{31}$ | $LB_{(10)}$ | $LB_{(10)}^2$ |
|---|---|---|---|---|---|---|---|---|
| *Emerging Asia* | | | | | | | | |
| China | 0.055 | 0.047 | 0.073 | 0.146 | 0.001 | -0.372 ** | 12.70 | 5.67 |
| Hong Kong | -0.039 | -0.023 | 0.026 | -0.095 ** | 0.290 | 0.001 | 13.33 | 6.46 |
| India | 0.017 | 0.069 | 0.167 ** | 0.023 *** | -0.199 | 0.101 | 18.01 * | 4.38 |
| Indonesia | 0.025 | 0.009 | 0.244 *** | -0.093 | 0.068 | 0.137 | 14.98 | 14.59 |
| Korea | -0.074 | 0.053 | 0.108 | 0.011 | 0.210 | 0.195 | 14.62 | 15.53 |
| Malaysia | -0.015 | 0.079 * | 0.051 | 0.018 | 0.163 | 0.111 | 13.87 | 7.82 |
| Pakistan | 0.146 *** | 0.057 | 0.128 ** | -0.174 ** | -0.802 ** | 0.284 * | 14.54 | 15.72 |
| Philippines | -0.014 | 0.037 | 0.183 *** | 0.309 | -0.089 | -0.036 | 8.77 | 9.02 |
| Singapore | -0.005 | 0.017 | 0.145 *** | 0.007 | 0.093 | 0.086 | 11.19 | 13.44 |
| Sri-Lanka | 0.229 *** | 0.018 | 0.032 | -0.009 | 0.007 | -0.157 | 5.36 | 8.75 |
| Taiwan | -0.033 | 0.092 ** | 0.084 | 0.219 | -0.246 | -0.002 | 6.81 | 8.12 |
| Thailand | 0.030 | 0.019 | 0.092 | -0.311 | 0.404 | 0.526 *** | 6.67 | 4.71 |
| *Latin America* | | | | | | | | |
| Argentina | -0.010 | 0.116 ** | -0.150 * | 0.084 ** | -0.198 | 0.235 | 12.50 | 18.99 ** |
| Brazil | -0.113 *** | 0.050 | 0.238 ** | 0.018 | -0.050 | 0.079 | 13.63 | 12.89 |
| Chile | 0.160 *** | 0.090 ** | -0.105 ** | -0.237 | 0.027 | 0.080 | 12.05 | 12.67 |
| Colombia | 0.136 *** | 0.095 ** | -0.039 | -0.028 | -0.328 *** | 0.076 | 7.65 | 2.84 |
| Ecuador | 0.062 | 0.019 | -0.012 | 0.082 ** | -0.278 | 0.405 | 13.44 | 10.24 |
| Mexico | -0.036 | 0.060 | -0.126 ** | 0.354 | -0.155 | -0.110 | 8.58 | 21.99 ** |
| Peru | 0.114 *** | 0.108 *** | -0.048 | 0.161 *** | -0.178 | 0.064 | 4.49 | 5.48 |
| Venezuela | 0.141 *** | 0.157 * | -0.168 | -0.008 | -0.281 | 0.201 | 12.55 | 8.80 |
| *Emerging Europe* | | | | | | | | |
| Bulgaria | 0.097 | 0.059 | -0.066 | -0.115 ** | -0.873 *** | 0.449 *** | 2.71 | 8.38 |
| Croatia | 0.002 | 0.109 ** | 0.156 ** | -0.344 * | 0.163 | -0.187 | 3.51 | 3.86 |
| Czech Republic | -0.027 | 0.052 | -0.005 | 0.197 | -0.288 * | 0.136 | 5.81 | 5.94 |
| Estonia | 0.061 | 0.185 *** | 0.019 | 0.075 | -0.282 * | 0.351 ** | 12.42 | 12.62 |
| Hungary | -0.032 | 0.070 | 0.084 | 0.191 | -0.153 | -0.069 | 13.10 | 16.20 * |
| Israel | -0.084 ** | 0.025 | 0.066 | 0.169 ** | -0.094 | -0.089 | 9.43 | 7.36 |
| Latvia | 0.190 *** | 0.259 *** | 0.024 | -0.004 ** | -0.262 ** | -0.032 | 16.80 * | 3.28 |
| Poland | -0.067 * | 0.080 * | 0.050 | 0.183 *** | -0.235 ** | 0.053 | 7.87 | 17.02 * |
| Romania | 0.113 ** | 0.092 | 0.055 | -0.092 | 0.034 | 0.151 | 2.75 | 14.64 |
| Russia | 0.036 | 0.100 | -0.107 | 0.000 | 0.154 | 0.186 | 6.42 | 12.38 |
| Slovakia | 0.055 | 0.015 | 0.001 | 0.147 | -0.356 *** | 0.138 | 9.78 | 4.75 |
| Slovenia | 0.086 | -0.003 | 0.101 ** | 0.082 *** | 0.016 | -0.027 | 18.12 * | 15.96 |
| South Africa | -0.004 | -0.026 | 0.007 | -0.596 *** | 0.057 | 0.318 | 7.48 | 7.54 |
| Turkey | 0.010 | 0.217 * | 0.165 | -0.074 | 0.160 | 0.124 | 13.13 | 12.11 |
| *Middle East and North Africa* | | | | | | | | |
| Egypt | 0.043 | 0.170 ** | 0.104 | -0.088 | 0.077 | -0.153 | 14.66 | 13.08 |
| Jordan | 0.149 *** | 0.098 ** | 0.033 | -0.144 *** | 0.131 | 0.024 | 12.04 | 15.53 |
| Kuwait | 0.140 *** | 0.146 *** | -0.006 | 0.025 ** | 0.086 | 0.045 | 10.26 | 15.10 |
| Lebanon | 0.031 | 0.137 * | 0.039 | -0.134 | -0.058 | -0.007 | 6.03 | 8.40 |
| Morocco | 0.184 *** | 0.030 | 0.068 | -0.187 ** | 0.281 * | -0.138 | 9.74 | 18.40 ** |
| Saudi Arabia | 0.163 *** | 0.007 | 0.081 * | -0.394 *** | -0.215 | -0.265 ** | 5.35 | 21.81 ** |
| Tunisia | 0.132 | 0.009 | 0.015 | -0.184 | 0.101 | -0.169 ** | 9.53 | 5.66 |

Notes: Standard errors (S.E.) were calculated using the quasi-maximum likelihood method of Bollerslev and Wooldridge (1992), which is robust to the distribution of the underlying residuals. Rejection of the null hypothesis at 1%, 5%, and 10% levels is denoted by ***, **, and * respectively. The $LB_{(10)}$ and $LB^2_{(10)}$ are, respectively, the Ljung-Box autocorrelations test (1978) of ten lags in the local market standardised and standardised squared residuals. The covariance stationary condition is satisfied by all the estimated models with all the eigenvalues of $A \otimes A + G \otimes G$ being less than one in modulus. A residual vector $u_t$ following a t-student distribution has also been considered, but the results were qualitatively similar and therefore are not reported. The full set of results (including results for regional and global markets) is available from the authors upon request.

Table 2. Parameter Estimates for Variance-Covariance Equations: Local Markets

| | $a_{11}$ | $a_{21}$ | $a_{31}$ | $g_{11}$ | $g_{21}$ | $g_{31}$ |
|---|---|---|---|---|---|---|
| *Emerging Asia* | | | | | | |
| China | 0.319 ** | 0.088 | -0.006 | 0.937 *** | -0.012 | -0.002 |
| Hong Kong | 0.247 *** | 0.098 | -0.097 | 0.963 *** | -0.009 | 0.019 |
| India | 0.326 *** | -0.049 | -0.034 | 0.918 *** | 0.138 | 0.013 |
| Indonesia | 0.182 *** | -0.039 | -0.037 | 0.977 *** | 0.013 | 0.009 |
| Korea | 0.237 *** | 0.005 | -0.089 | 0.968 *** | 0.004 | 0.019 |
| Malaysia | 0.330 *** | -0.039 | -0.011 | 0.948 *** | 0.011 | 0.004 |
| Pakistan | 0.438 *** | -0.111 | 0.115 | -0.835 *** | 0.310 *** | 0.223 * |
| Philippines | 0.222 *** | 0.063 | -0.143 * | 0.954 *** | 0.002 | 0.033 * |
| Singapore | 0.362 *** | -0.026 | -0.045 | 0.923 *** | 0.016 | 0.022 |
| Sri-Lanka | 0.433 *** | 0.008 | 0.145 * | 0.888 *** | -0.001 | -0.026 * |
| Taiwan | 0.136 *** | -0.111 ** | 0.115 * | 0.984 *** | 0.034 *** | -0.019 * |
| Thailand | 0.203 *** | -0.047 | 0.001 | 0.974 *** | 0.017 | 0.001 |
| *Latin America* | | | | | | |
| Argentina | 0.227 *** | -0.096 | 0.303 *** | -0.966 *** | 1.470 *** | 0.556 *** |
| Brazil | 0.274 *** | 0.087 | -0.284 ** | 0.931 *** | 0.014 | 0.071 ** |
| Chile | 0.336 *** | 0.001 | 0.080 | 0.873 *** | 0.022 | -0.011 |
| Colombia | 0.456 *** | 0.030 | 0.024 | 0.673 *** | 0.038 | 0.009 |
| Ecuador | -0.534 *** | 0.031 | -0.112 | -0.892 *** | -0.032 | 0.011 |
| Mexico | 0.047 | 0.369 ** | -0.100 | 0.148 | 0.309 *** | 0.554 *** |
| Peru | 0.312 *** | -0.044 | 0.091 ** | 0.922 *** | 0.021 | -0.015 |
| Venezuela | 0.566 *** | -0.112 | -0.056 | -0.575 | 0.576 | 0.039 |
| *Emerging Europe* | | | | | | |
| Bulgaria | 0.693 *** | 0.124 | -0.759 *** | -0.008 | 0.080 | 0.172 |
| Croatia | -0.078 * | -0.005 | 0.102 ** | -0.989 *** | 0.635 *** | 0.311 *** |
| Czech Republic | 0.195 | 0.312 * | -0.077 | 0.617 *** | 0.042 | 0.129 |
| Estonia | -0.386 *** | 0.010 | 0.159 | 0.917 *** | 0.013 | 0.003 |
| Hungary | -0.381 *** | 0.197 | 0.082 | -0.773 *** | 0.864 *** | 0.778 *** |
| Israel | -0.048 | -0.027 * | 0.234 *** | 0.994 *** | 0.011 *** | -0.026 *** |
| Latvia | -0.685 *** | 0.318 *** | 0.047 | 0.796 *** | 0.016 | -0.019 |
| Poland | -0.188 *** | 0.532 *** | -0.277 * | 0.599 *** | 0.034 | 0.266 *** |
| Romania | 0.570 *** | 0.030 | -0.079 | -0.780 *** | 0.484 *** | -0.134 |
| Russia | 0.390 *** | -0.323 | -0.132 | -0.906 *** | 0.147 *** | 0.329 |
| Slovakia | 0.593 *** | -0.029 | 0.096 | 0.493 *** | 0.016 | -0.029 |
| Slovenia | 0.420 *** | 0.197 *** | -0.050 | 0.709 *** | -0.008 | 0.018 |
| South Africa | 0.252 ** | 0.314 *** | -0.395 *** | -0.470 | 0.265 *** | 0.861 *** |
| Turkey | 0.431 * | 0.778 *** | -0.707 * | 0.017 | 0.428 *** | -0.581 *** |
| *Middle East and North Africa* | | | | | | |
| Egypt | 0.235 | 0.114 | 0.023 | 0.949 *** | -0.026 | -0.001 |
| Jordan | 0.490 *** | -0.041 | 0.037 | 0.502 *** | 0.096 ** | 0.017 |
| Kuwait | 0.491 *** | 0.114 | 0.013 | 0.368 | 0.062 | 0.012 |
| Lebanon | 0.566 *** | 0.242 | 0.103 | 0.565 *** | -0.189 * | 0.007 |
| Morocco | 0.298 *** | -0.211 *** | -0.018 | 0.912 *** | -0.049 ** | 0.010 |
| Saudi Arabia | -0.265 *** | -0.134 * | -0.004 | 0.944 *** | 0.512 *** | 0.192 *** |
| Tunisia | 0.655 *** | 0.019 | -0.091 | 0.489 | 0/047 | 0.023 |

Notes: ***, **, and * denote significance at the 1%, 5% and 10% levels respectively. Standard errors (S.E.), not reported, are calculated using the quasi-maximum likelihood method of Bollerslev and Wooldridge (1992), which is robust to the distribution of the underlying residuals. A residual vector $u_t$ following a t-student distribution has also been considered, but the results were qualitatively similar and therefore are not reported. The full set of results is available from the authors upon request.

Table 3. Wald Test Statistics for Hypotheses Tested: Asia and Latin America

| | No spillovers | No spillovers in mean | | | No spillovers in variance | | | No GARCH-in-mean effects | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $\gamma_{11}=\gamma_{21}=\gamma_{31}=a_{21}=g_{21}=a_{31}=g_{31}=\beta_{21}=\beta_{31}=0$ | $\beta_{21}=0$ | $\beta_{31}=0$ | $\beta_{21}=\beta_{31}=0$ | $a_{21}=g_{21}=0$ | $a_{31}=g_{31}=0$ | $a_{21}=g_{21}=a_{31}=g_{31}=0$ | $\gamma_{11}=0$ | $\gamma_{21}=0$ | $\gamma_{31}=0$ | $\gamma_{21}=\gamma_{31}=0$ | $\gamma_{11}=\gamma_{21}=\gamma_{31}=0$ |
| *Emerging Asia* | | | | | | | | | | | | |
| China | 15.565 * | 4.439 ** | 1.174 | 5.771 * | 2.557 | 0.288 | 2.997 | 0.305 | 0.004 | 3.930 ** | 4.579 | 6.81 * |
| Hong Kong | 7.094 | 0.303 | 0.212 | 0.414 | 4.828 * | 1.817 | 3.883 | 0.449 | 0.730 | 0.479 | 0.808 | 0.83 |
| India | 17.086 ** | 1.666 | 5.155 ** | 9.929 *** | 4.629 * | 0.902 | 5.315 | 0.039 | 2.815 * | 0.569 | 1.513 | 1.519 |
| Indonesia | 23.218 *** | 0.044 | 13.817 *** | 15.559 *** | 2.142 | 0.509 | 3.886 | 0.206 | 0.101 | 0.666 | 0.731 | 0.736 |
| Korea | 328.358 *** | 4.934 ** | 0.626 | 6.735 ** | 41.791 *** | 20.615 *** | 38.939 *** | 1.639 | 1.332 | 3.977 ** | 4.589 | 5.189 |
| Malaysia | 236.498 *** | 3.61 * | 10.188 *** | 4.925 * | 91.987 *** | 27.655 *** | 23.829 *** | 0.027 | 0.117 | 2.368 | 2.368 | 3.593 |
| Pakistan | 48.906 *** | 1.787 | 4.442 ** | 7.654 ** | 8.531 ** | 4.834 * | 23.727 *** | 1.285 | 4.457 ** | 2.994 * | 12.743 *** | 14.825 *** |
| Philippines | 20.141 ** | 1.539 | 10.062 *** | 11.146 *** | 4.463 | 3.191 | 4.544 | 1.215 | 0.061 | 2.063 | 0.092 | 1.542 |
| Singapore | 20.982 ** | 0.269 | 14.262 *** | 14.285 *** | 2.106 | 1.413 | 2.109 | 0.001 | 0.064 | 0.322 | 0.333 | 1.225 |
| Sri-Lanka | 5.907 | 0.129 | 0.273 | 0.868 | 0.024 | 3.909 | 4.957 | 0.005 | 0.003 | 2.740 * | 1.151 | 1.168 |
| Taiwan | 34.695 *** | 4.504 ** | 2.097 | 6.045 ** | 17.451 *** | 3.917 | 20.257 *** | 1.134 | 0.016 | 2.008 | 2.016 | 2.7 |
| Thailand | 25.333 *** | 2.205 | 3.259 * | 3.456 | 2.161 | 0.006 | 2.583 | 3.579 * | 2.369 | 10.463 *** | 12.512 *** | 12.512 *** |
| *Latin America* | | | | | | | | | | | | |
| Argentina | 19.941 ** | 12.593 *** | 2.608 | 4.341 | 4.149 | 8.113 ** | 13.767 *** | 0.772 | 0.797 | 0.478 | 1.149 | 1.793 |
| Brazil | 16.366 * | 0.517 | 6.135 ** | 8.741 ** | 1.795 | 5.312 * | 6.735 | 0.006 | 0.027 | 0.133 | 0.186 | 0.254 |
| Chile | 10.951 | 5.737 ** | 4.361 ** | 6.746 ** | 2.148 | 2.216 | 3.282 | 1.259 | 0.083 | 0.902 | 1.462 | 2.248 |
| Colombia | 27.519 *** | 4.567 ** | 0.546 | 4.619 * | 3.916 | 0.458 | 6.949 | 0.017 | 8.125 *** | 0.421 | 8.425 ** | 8.523 ** |
| Ecuador | 9.143 | 4.164 ** | 2.038 | 2.173 | 10.616 *** | 8.517 *** | 1.631 | 1.579 | 1.889 | 2.662 | 2.697 | 3.924 |
| Mexico | 67.34 *** | 2.083 | 5.146 ** | 6.609 ** | 19.905 *** | 28.734 *** | 29.676 *** | 0.889 | 1.072 | 0.435 | 1.104 | 1.104 |
| Peru | 20.287 ** | 7.333 *** | 1.08 | 7.338 ** | 1.908 | 4.02 | 4.598 | 0.399 | 2.493 | 0.217 | 2.509 | 2.709 |
| Venezuela | 58.881 *** | 3.252 * | 2.603 | 4.169 | 6.928 ** | 0.095 | 47.207 *** | 0.002 | 9.634 *** | 0.970 | 2.665 | 3.925 |

Note: Rejection of the null hypothesis at the 1%, 5% and 10% is denoted by ***, **, and * respectively. The chi-squared critical values at 1%, 5% and 10% respectively are as follows; 1 degree of freedom: 6.635, 3.841, and 2.706; 2 degrees of freedom: 9.210, 5.991, and 4.605; 3 degrees of freedom: 11.345, 7.815, and 6.251; 4 degrees of freedom: 13.277, 9.488, and 7.779; 9 degrees of freedom: 21.666, 16.919, and 14.648.

Table 4. Wald Test Statistics for Hypotheses Tested: Emerging Europe, Middle East and North Africa

| | No spillovers | No spillovers in mean | | | No spillovers in variance | | | No GARCH-in-mean effects | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $\gamma_{11}=\gamma_{21}=\gamma_{31}=a_{21}=g_{21}=a_{31}=g_{31}=\beta_{21}=\beta_{31}=0$ | $\beta_{21}=0$ | $\beta_{31}=0$ | $\beta_{21}=\beta_{31}=0$ | $a_{21}=g_{21}=0$ | $a_{31}=g_{31}=0$ | $a_{21}=g_{21}=a_{31}=g_{31}=0$ | $\gamma_{11}=0$ | $\gamma_{21}=0$ | $\gamma_{31}=0$ | $\gamma_{21}=\gamma_{31}=0$ | $\gamma_{11}=\gamma_{21}=\gamma_{31}=0$ |
| *Emerging Europe* | | | | | | | | | | | | |
| Bulgaria | 33.205 *** | 2.793 * | 2.898 * | 3.300 | 22.51 *** | 7.591 ** | 12.827 ** | 2.459 | 6.601 ** | 9.923 *** | 13.526 *** | 11.919 *** |
| Croatia | 138.304 *** | 4.143 ** | 7.125 *** | 17.838 *** | 3.688 | 7.961 ** | 119.581 *** | 0.549 | 0.062 | 3.952 ** | 3.962 | 3.946 |
| Czech Republic | 13.769 | 1.056 | 0.009 | 1.120 | 3.057 | 1.727 | 4.204 | 0.522 | 2.870 * | 0.848 | 3.027 | 3.206 |
| Estonia | 75.377 *** | 8.720 *** | 0.046 | 16.155 *** | 6.308 ** | 5.134 * | 42.874 *** | 0.062 | 2.694 | 5.670 ** | 5.671 * | 6.841 * |
| Hungary | 70.154 *** | 1.773 | 3.483 * | 6.376 ** | 15.509 *** | 57.831 *** | 43.606 *** | 0.878 | 0.305 | 5.101 ** | 0.316 | 1.725 |
| Israel | 91.964 *** | 1.200 | 2.627 | 3.217 | 39.292 *** | 39.157 *** | 90.621 *** | 0.302 | 5.341 ** | 0.145 | 1.470 | 1.594 |
| Latvia | 41.443 *** | 30.295 *** | 10.230 *** | 34.456 *** | 11.217 *** | 0.964 | 13.043 ** | 0.007 | 4.807 ** | 0.073 | 6.462 ** | 8.084 |
| Poland | 275.742 *** | 5.132 ** | 3.581 * | 10.052 *** | 77.027 *** | 58.432 *** | 67.918 *** | 0.147 | 1.869 | 7.233 *** | 2.631 | 3.436 |
| Romania | 34.205 *** | 5.069 ** | 8.133 *** | 5.885 * | 2.499 | 10.635 *** | 21.725 *** | 3.641 * | 2.004 | 0.288 | 0.306 | 6.507 * |
| Russia | 52.562 *** | 6.126 ** | 4.100 ** | 0.128 | 138.731 *** | 10.521 *** | 93.633 *** | 0.003 | 0.059 | 1.510 | 3.026 | 11.897 *** |
| Slovakia | 138.542 *** | 4.119 ** | 0.101 | 0.246 | 0.336 | 0.361 | 0.682 | 1.236 | 9.759 *** | 0.916 | 18.102 *** | 72.518 *** |
| Slovenia | 20.268 ** | 0.008 | 3.013 * | 3.323 | 12.331 *** | 0.459 | 14.695 *** | 0.834 | 0.033 | 0.061 | 0.076 | 1.144 |
| South Africa | 145.446 *** | 0.519 | 0.019 | 0.519 | 47.938 *** | 18.715 *** | 99.08 *** | 6.814 *** | 0.357 | 3.115 * | 2.819 | 7.309 * |
| Turkey | 68.478 *** | 3.885 ** | 3.782 ** | 13.421 *** | 18.947 *** | 15.074 *** | 28.504 *** | 0.129 | 0.242 | 0.159 | 0.509 | 0.546 |
| *Middle East and North Africa* | | | | | | | | | | | | |
| Egypt | 14.821 * | 5.242 ** | 2.683 | 8.923 ** | 3.606 | 0.121 | 5.663 | 0.018 | 0.250 | 0.794 | 1.003 | 1.031 |
| Jordan | 11.608 | 4.515 ** | 3.585 * | 5.818 * | 4.099 | 1.467 | 4.939 | 0.255 | 0.534 | 0.057 | 0.562 | 0.590 |
| Kuwait | 26.093 *** | 6.905 *** | 0.519 | 7.951 ** | 5.897 * | 3.812 | 16.711 *** | 0.521 | 4.158 ** | 0.028 | 4.174 | 4.326 |
| Lebanon | 10.456 | 3.366 * | 0.549 | 3.719 | 4.377 | 2.229 | 7.813 * | 0.988 | 0.273 | 0.002 | 0.290 | 1.374 |
| Morocco | 9.840 | 3.116 * | 2.329 | 2.447 | 0.713 | 0.211 | 1.196 | 0.043 | 2.083 | 3.574 * | 5.679 * | 5.816 |
| Saudi Arabia | 47.962 *** | 2.611 | 3.305 * | 3.342 | 14.822 *** | 5.251 * | 28.856 *** | 5.710 ** | 0.171 | 3.956 ** | 4.297 | 8.243 ** |
| Tunisia | 19.439 *** | 3.086 * | 4.227 ** | 1.333 | 1.498 | 2.291 | 4.195 | 1.366 | 1.999 | 4.295 ** | 9.232 *** | 12.475 *** |

Note: Rejection of the null hypothesis at the 1%, 5% and 10% is denoted by ***, **, and * respectively. The chi-squared critical values at 1%, 5% and 10% respectively are as follows; 1 degree of freedom: 6.635, 3.841, and 2.706; 2 degrees of freedom: 9.210, 5.991, and 4.605; 3 degrees of freedom: 11.345, 7.815, and 6.251; 4 degrees of freedom: 13.277, 9.488, and 7.779; 9 degrees of freedom: 21.666, 16.919, and 14.648.