European Business Review

Cross-market dynamics and optimal portfolio strategies in Latin American equity markets

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Received 1 April 2013
Revised 10 August 2013
Accepted 3 December 2013

Abstract

Purpose – This paper aims to investigate the return links and volatility transmission between five major equity markets of the Latin American region and the USA over the period 1993-2012.

Design/methodology/approach – The authors employ a multivariate vector autoregressive moving average – generalized autoregressive conditional heteroskedasticity (VAR-GARCH) methodology which allows for cross-market transmissions in both return and volatility. Moreover, we show how the obtained results can be used to design internationally diversified portfolios involving the Latin American assets and to analyze the effectiveness of hedging strategies.

Findings – The results point to the existence of substantial cross-market return and volatility spillovers and are thus crucial for international portfolio management in the Latin American region. However, the intensity of shock and volatility cross effects varies across the studied markets.

Research limitations/implications – The optimal weights and hedging ratios that we compute from the observed return and volatility spillovers, suggest that adding the Latin American assets helps improve the risk-adjusted return of the internationally diversified portfolios as well as reduce their risk exposure. For policymakers and market authorities, an increase in the level of shock interactions and volatility transmission between the US and Latin American equity markets as well as among these Latin American markets implies that the stability of the financial system in one country can be deeply affected by the disturbances in another country.

Originality/value – The authors extend the previous works on Latin American emerging markets by examining the extent of shock and volatility transmission as well as portfolio design and management from the point of view of both the US (global) and Latin American investors.

Keywords Hedge ratios, Latin American equity markets, Portfolio designs, Shock and volatility transmission, VAR-GARCH models

Paper type Research paper

1. Introduction

Dynamic asset return linkages and volatility transmission across national capital markets are of greater and greater interest to the financial community with the increased

European Business Review
Vol. 27 No. 2, 2015
pp. 161-181

0955-534X
DOI 10.1108/EBR-04-2013-0069

globalization and financial integration throughout the world. If, for example, asset return and volatility are found to spread from one market to another, portfolio managers and policymakers would have to adjust their actions to essentially prevent contagion risks in the event of market crashes, financial turbulences or crises. This critical issue has been extensively investigated by numerous studies focusing on international asset markets (Forbes and Rigobon, 2002; Syriopoulos, 2007; Aloui *et al.*, 2011 for stock markets; Wang *et al.*, 2007 for monetary markets; and Skintzi and Refenes, 2006; Johansson, 2008 for bond markets). Using various methodologies, these studies generally find evidence of significant cross-market return and volatility spillovers. They also document that the degree of spillover is highly dependent on trade, economic and financial integration as well as on the international coordination of monetary policies. Moreover, market conditions and geographical proximity play a crucial role in explaining the intensity and nature of shock spillovers, as the latter tend to be more important during turbulent periods than during normal (or tranquil) ones, and more pronounced at regional level than at international level as well.

It is clear that a better understanding of the cross-market linkages in terms of asset return and volatility transmission is of paramount importance for building efficient business strategies and designing optimal portfolios. This article aims at providing comprehensive insights about this issue for major emerging equity markets in Latin American region which has received much attention from finance practitioners and academics since their openings in 1980s. While using the US equity markets as a reasonable proxy for the global markets, we address the investment problem of the global investors who seek diversification benefits by adding the Latin American market assets to their portfolios. At the empirical level, we make use of the vector autoregressive moving average – generalized autoregressive conditional heteroskedasticity (VAR-GARCH) model which is a multivariate econometric technique introduced by Ling and McAleer (2003). This model is particularly advantageous in that it allows us to investigate the conditional volatility dynamics of the asset returns as well as the conditional interdependence cross-effects and volatility transmission between them. For instance, Hammoudeh *et al.*, (2009) show the superiority of this model over several other multivariate specifications such as the full factor GARCH model through providing meaningful estimates of the parameters with less computational complication. In a more recent study, Arouri *et al.*, (2011) provide evidence that the VAR-GARCH model outperforms several competing multivariate GARCH models, including the dynamic conditional correlation (DCC)-GARCH, the constant conditional correlation (CCC)-GARCH and the BEKK-GARCH, in terms of accurate volatility estimates. Another important advantage of the VAR-GARCH model is the possibility of determining, from the obtained empirical results, the optimal weights of internationally diversified portfolios comprising simultaneously the assets issued by the Latin American and the US equity markets under consideration. We are also able to shed light on the optimal hedging strategies and to analyze the hedging effectiveness for these diversified portfolios.

In the related literature, a number of previous studies have investigated various issues for Latin American equity markets, but almost all studies focused on market comovement, economic and financial integration and international diversification benefits (Christofi and Pericli, 1999; Meric *et al.*, 2001; Susmel, 2001; Chen *et al.*, 2002; Johnson and Soenen, 2003; Barari, 2004; Diamandis, 2009; Lahrech and Sylwester, 2011;

Pablo, 2013). For example, Meric *et al.*, (2001) examine the stability of correlations and the benefits of international portfolio diversification through investment in the four largest Latin American markets (Argentina, Brazil, Chile and Mexico) from the point of view of a US investor. Considering three different subperiods around the stock market crash in 1987, their findings show that there are no significant gains to a well-diversified US investor from holding a well-diversified portfolio of Latin American stocks in the most recent sample period, owing to rising cross-market correlations. Barari (2004) estimates the integration scores for a sample of six Latin American markets over the period from January 1988 and December 2001, and finds a trend toward increased regional integration relative to global integration until the mid-1990s. The author also notes that the global integration of these markets proceeds faster than the regional integration during the second half of the 1990s. Diamandis (2009) investigates the long-run relationships between four Latin America stock markets (Argentina, Brazil, Chile and Mexico) and the US stock markets, using both the autoregressive and moving average representations of a VAR model. The obtained results indicate that the examined stock markets are partially integrated and that the four stock markets of Latin America together with the US stock markets share four significant common permanent components, which ultimately drive their long run links. Lahrech and Sylwester (2011) also study the integration process of the same four Latin American equity markets with the US equity market. They first infer the integration degree from dynamic conditional correlations of a multivariate DCC-GARCH model and then examine how these correlations evolve over time using a smooth transition model. Their results, drawn over the period 1988-2004, show an increase in the degree of return comovement between the Latin American and the US equity markets, even though the magnitude and speed of linkages vary substantially across these Latin American markets. From a distinct perspective, the more recent study of Pablo (2013) analyzes a database of 952 acquisitions in Latin America during the period 1998-2004 and shows that the cumulative abnormal returns for the acquiring firm are proportional to the gross domestic product (GDP) growth correlation between the countries where the target and the bidder operate their operations. More interestingly, Pablo (2013) finds that the acquiring firm benefits from buying firms located in countries whose governance environment differs significantly from that in the acquirer's country, regardless of the quality of the governance in the target country.

Our study thus complements the above literature by addressing the question of return and volatility spillovers in a more efficient framework. Using monthly data over the period from January 1993 to December 2012 for the five selected Latin American equity markets (Argentina, Brazil, Chile, Colombia and Mexico) and the US equity market, we mainly find evidence of significant cross-market return and volatility spillovers. This result is indeed expected, given the relatively high degree of market openings of the sample Latin American equity markets. The direct spillover of conditional volatility across equity markets is, however, more apparent from the US markets to the emerging Latin America, suggesting the important role of the US markets in international shock transmission. Our empirical results from the analysis of optimal weights and hedge ratios indicate that both the local and global (US) investors may benefit from adding the assets issued by the Latin American markets into a diversified portfolio of the Latin American and US stocks. International hedging strategies are also necessary to manage the risk of investing in local equity markets more effectively.

The remaining part of the article is structured as follows. Section 2 describes the empirical methodology we use to quantify shock transmission and volatility spillover effects between Latin American and US equity markets. We also show how our results can be used to build optimal portfolios and efficient hedging strategies. Section 3 presents the data and their stochastic properties. Section 4 discusses the obtained results and their implications on international portfolio investments toward Latin American assets. Section 5 concludes the article.

2. Empirical method

This section first presents the empirical framework of the VAR-GARCH model. It then derives the implications for international portfolio management from the estimation results.

2.1 VAR-GARCH model for modeling shock and volatility transmission

GARCH-type models have received a particular interest from the majority of previous works that focus on volatility modeling of stock markets. It is now common in the finance literature that multivariate volatility models such as the CCC-GARCH of Bollerslev (1990), the BEKK-GARCH (full parameterization) of Engle and Kroner (1995) or the DCC-GARCH of Engle (2002) provide more insightful results than univariate volatility models. While the first model assumes constant conditional correlations, the last two models accommodate dynamic conditional correlations. The superior ability of these models comes from the fact that they account for dynamic covariances and conditional correlations among different variables in the system, which allow the computation of portfolio's optimal weights and minimum-variance hedge ratios. Nevertheless, the estimation of multivariate volatility models often becomes extremely difficult, especially when the number of variables considered is important owing to the rapid proliferation of coefficients to be estimated. Moreover, they do not enable to capture cross-market volatility spillover effects, while the latter are likely to occur with the increasing integration of markets.

This article proposes the use of the newly developed VAR-GARCH model to avoid the empirical limitations of the above multivariate specifications. As stated earlier, the VAR-GARCH model permits to explore the joint evolution of conditional returns, volatility and dynamic correlations among the equity markets. Introduced by Ling and McAleer (2003), this modeling approach has been applied by, among others, Chan *et al.* (2005) to tourism demand variations, Hammoudeh *et al.* (2009) to stock markets, Chang *et al.* (2011) to crude oil spot and futures markets and Arouri *et al.* (2011) to oil and stock markets. These studies show that this model provides meaningful and interpretable coefficients.

In its formal representation, the VAR-GARCH model described in Ling and McAleer (2003) includes the multivariate CCC-GARCH model of Bollerslev (1990) as a special case when there is absence of return and volatility cross-effects. The correlations between different shocks of the system variables are assumed to be constant to make the estimation and inference procedure easier. While most of previous contributions adopted the bivariate specification, we develop the multivariate extension of this model to investigate the interdependence between the US and the five Latin American equity markets. The specification we consider is thus a six-variable VAR(1)-GARCH(1,1) where the conditional mean is given by[1]:

$$\begin{cases} Y_t = \mu + \Phi Y_{t-1} + \varepsilon_t \\ \varepsilon_t = D_t \eta_t \end{cases} \tag{1}$$

where,

$Y_t = (r_t^a, r_t^b, r_t^{ch}, r_t^{co}, r_t^m, r_t^{usa})'$ with $r_t^a, r_t^b, r_t^{ch}, r_t^{co}, r_t^m$ and r_t^{usa} being the returns on equity markets of Argentina, Brazil, Chile, Colombia, Mexico and the USA at time t, respectively;

F = (6 ′ 6) matrix of coefficients of the form $\Phi = \begin{pmatrix} \phi_{11} & \phi_{12} & \dots & \phi_{16} \\ \phi_{21} & \phi_{22} & \dots & \phi_{26} \\ \vdots & \vdots & \dots & \vdots \\ \phi_{61} & \phi_{62} & \dots & \phi_{66} \end{pmatrix}$;

$\varepsilon_t = (\varepsilon_t^a, \varepsilon_t^b, \varepsilon_t^{ch}, \varepsilon_t^{co}, \varepsilon_t^m, \varepsilon_t^{usa})'$ with $\varepsilon_t^a, \varepsilon_t^b, \varepsilon_t^{ch}, \varepsilon_t^{co}, \varepsilon_t^m$ and ε_t^{usa} being the error terms from the mean equations of the respective equity markets;

$\eta_t = (\eta_t^a, \eta_t^b, \eta_t^{ch}, \eta_t^{co}, \eta_t^m, \eta_t^{usa})'$ refers to a (6×1) vector of independently and identically distributed errors; and

$D_t = diag(\sqrt{h_t^a}, \sqrt{h_t^b}, \sqrt{h_t^{ch}}, \sqrt{h_t^{co}}, \sqrt{h_t^m}, \sqrt{h_t^{usa}})$ with $h_t^a, h_t^b, h_t^{ch}, h_t^{co}, h_t^m$ and h_t^{usa} being the conditional variances of $r_t^a, r_t^b, r_t^{ch}, r_t^{co}, r_t^m$ and r_t^{usa}, respectively. Their time-series dynamics are modeled in equations (2) and (3) as:

$$h_t^i = C_i^2 + \beta_{ii}^2 h_{t-1}^i + \alpha_{ii}^2 (\varepsilon_{t-1}^i)^2 + \sum_{j=1}^{5} \beta_{ij}^2 h_{t-1}^j + \sum_{j=1}^{5} \alpha_{ij}^2 (\varepsilon_{t-1}^j)^2 \tag{2}$$

where $i \in \{Argentina, Brazil, Chile, Colombia, Mexico, USA\}$ and j indicates other equity markets of the sample excluding the market i.

As it can be seen, the conditional variance of stock market i depends not only on its own past volatility and return innovations, but also on those of the remaining five stock markets. This particular feature thus permits the direct transmission of volatility and shocks from one market to another. We can also express the conditional covariance between markets i and j, h_t^{ij} , as follows:

$$h_t^{ij} = \rho \sqrt{h_t^i} \sqrt{h_t^j} \tag{3}$$

where ρ is the conditional constant correlation. Note that the assumption of constant correlation coefficient may be viewed as restrictive because the latter tends to vary through time with respect to changes in market conditions and investor expectations. Unfortunately, the VAR-GARCH model with dynamic conditional correlations has not been analyzed theoretically yet.

Overall, the proposed model allows us to examine both return and volatility spillover cross-effects between the US and Latin American equity markets. As the normality condition is rejected for the return series we consider (see, Table I), we make use of the quasi-maximum likelihood (QML) method to estimate the model's parameters. For further details about the asymptotic properties of the VAR-GARCH model and its estimation procedure, see Ling and McAleer (2003).

Table I.
Statistic properties of the data

	Argentina	Brazil	Chile	Colombia	Mexico	USA
Panel A: Descriptive statistics						
Mean (%)	0.312	1.316	0.825	1.412	0.874	0.66
Maximum (%)	42.472	31.319	18.341	26.696	17.514	10.424
Minimum (%)	−53.919	−47.207	−34.389	−33.078	−0.41.932	−18.756
Standard deviation	0.115	0.114	0.071	0.091	0.090	0.044
Skewness	−0.762***	−0.785***	−0.929***	−0.471***	−1.423***	−0.838***
Kurtosis	2.987***	2.369***	3.465***	1.159***	4.332***	1.596***
JB	112.049+++	80.438+++	153.939+++	22.233+++	267.558+++	53.374+++
McLeod-Li (7)	18.595++	18.076++	18.338++	25.923+++	14.565++	40.102+++
Panel B: Unconditional correlations						
Argentina	1.000	0.554	0.530	0.324	0.604	0.447
Brazil		1.000	0.652	0.417	0.652	0.604
Chile			1.000	0.456	0.587	0.563
Colombia				1.000	0.351	0.324
Mexico					1.000	0.641
USA						1.000

Notes: JB is the Jarque-Bera test for normality based on skewness and kurtosis. McLeod-Li (7) is the empirical statistics of the McLeod-Li test for nonlinearity (ARCH effects), applied to seven lags; *; **; ***indicate significance of coefficients at the 1, 5 and 10% levels, respectively; +; ++; +++indicate rejection of the null hypotheses of normality and non-ARCH effects at the 1, 5 and 10% levels, respectively

2.2 Optimal designs of portfolio investments

Once the estimation results of our six-variable VAR(1)-GARCH(1,1) model become available, we can use them to build optimal and minimum-variance hedged portfolios by computing the optimal weights and hedge ratios of the constituent composite assets (market indices). Several studies have suggested significant gains from diversification within the Latin American markets or by investing simultaneously in the US and Latin American stock markets (Susmel, 2001; Arouri *et al.*, 2010). The return and volatility spillovers between the US and Latin American markets that we will establish empirically later in the article require portfolio managers to quantify the optimal weights and hedging ratios to adequately deal with the risk associated with these markets.

To illustrate this purpose, we now consider a portfolio composed of two composite assets (i.e. two Latin American markets or a Latin American market and the US market) for which we attempt to minimize the risk without reducing the expected returns. According to Kroner and Ng (1998), the optimal weight of holdings of the two assets is given by:

$$w_{ij,t} = \frac{h_t^j - h_t^{ij}}{h_t^i - 2h_t^{ij} + h_t^j} \tag{4}$$

and,

$$w_{os,t} = \begin{cases} 0, & if \quad w_{ij,t} < 0 \\ w_{ij,t}, & if \quad 0 \le w_{ij,t} \le 1 \\ 1, & if \quad w_{ij,t} > 1 \end{cases} \tag{5}$$

where $w_{ij,t}$ refers to the weight of the first asset i in a one-dollar two-asset portfolio at time t and h_t^{ij} the conditional covariance between the returns on the two assets at time t. Therefore, the optimal weight of the second asset j in the considered portfolio is $(1 - w_{ij,t})$.

Concerning the minimum-variance hedge ratios, Kroner and Sultan (1993) consider a portfolio of two assets and show that the risk of this portfolio is minimal if a long position of one dollar in the asset i can be hedged by a short position of β_t dollars in the asset j. That is:

$$\beta_{ij,t} = \frac{h_t^{ij}}{h_t^j} \tag{6}$$

In terms of the obtained results, the lower the beta, the higher the degree of hedging effectiveness and the more important the necessity to pursue an international diversification strategy.

3. Data

Our data set is collected on a monthly basis and consists of the Morgan Stanley Capital International total return indices for five major emerging equity markets in Latin America (Argentina, Brazil, Chile, Colombia and Mexico) and for the US stock market. The sample period runs from January 1993 to December 2012. All the total return indices are obtained from Datastream International, which are expressed in US dollars to preserve homogeneity across studied markets. We compute the return series by calculating the differences in natural logarithm of the two consecutive index prices.

The basic statistics and stochastic properties of the monthly returns are presented in Table I. Panel A indicates that the monthly average return of the Latin American markets ranges from 0.31 per cent in Argentina to 1.41 per cent in Colombia. Except Argentina, the monthly returns of Latin American equity markets are consistently higher than those provided by the US equity market (0.66 per cent). However, it is important to note that the entire sample emerging markets experienced a very high level of unconditional volatility, with Argentina being the most volatile market followed by Brazil. Thus, Argentina has the lowest average returns and highest volatility, suggesting the fact that some emerging markets may not be attractive in terms of risk-return tradeoff. Skewness and kurtosis coefficients are all significant at the conventional levels. The Jarque-Bera test for normality based on the third and fourth moments strongly rejects the hypothesis of normally distributed returns, thus supporting our decision to employ the QML approach of Bollerslev and Wooldridge (1992) to estimate the empirical model.

Panel B of Table I reports the unconditional correlations among the studied markets. As expected, there are positive but relatively weak bilateral correlations between them. The highest unconditional correlation is between Brazil and Chile, and between Brazil and Mexico (0.652) and the lowest one is between Argentina and Colombia (0.324). These low levels of correlation suggest that there are still benefits from international diversification across Latin American emerging markets. The bilateral correlation with the US equity markets is still moderate and ranges from 0.324 (Colombia) to 0.641 (Mexico).

We depict, in Figure 1, the time-variations market indices, and in Figure 2, the time-variations in return series for the sample equity markets. Unsurprisingly, these series are quite unstable and reveal several periods of high volatility, especially during times of crisis. If we look closely at each market, we see that the Mexican equity market was particularly sensitive to the Tequila debt crisis of 1994-1995, while the equity markets in Argentina and Brazil responded strongly to their market-opening events during the years from 1989 to 1993 (Bekaert and Harvey, 2000). All the markets experienced sharp declines in returns at the time of the Asian financial crisis of 1997-1998 and the global financial crisis of 2007-2008.

Table II presents some key financial indicators for the stock markets in the Latin American countries we consider in our paper as well as in the USA for comparison purpose. We observe that Latin American markets are too small compared to the US market. Brazil leads the region in terms of market capitalization followed by Mexico, while Argentina has the smallest stock market followed by Colombia. However, notice that the capitalization of the Chilean stock market exceeds the country’s GDP, while it represents only 45 and 55 per cent of GDP in Mexico and Brazil, respectively. In terms of the number of listed companies, Brazil is the leading market followed by Chile.

Unsurprisingly, Latin American stock markets are clearly less liquid than the US market according to the turnover ratio. Again, Brazil leads the region in terms of market liquidity followed by Mexico, while Argentina is the less liquid market followed by Colombia. On the other hand, trade openness ratio shows that Mexico has the highest

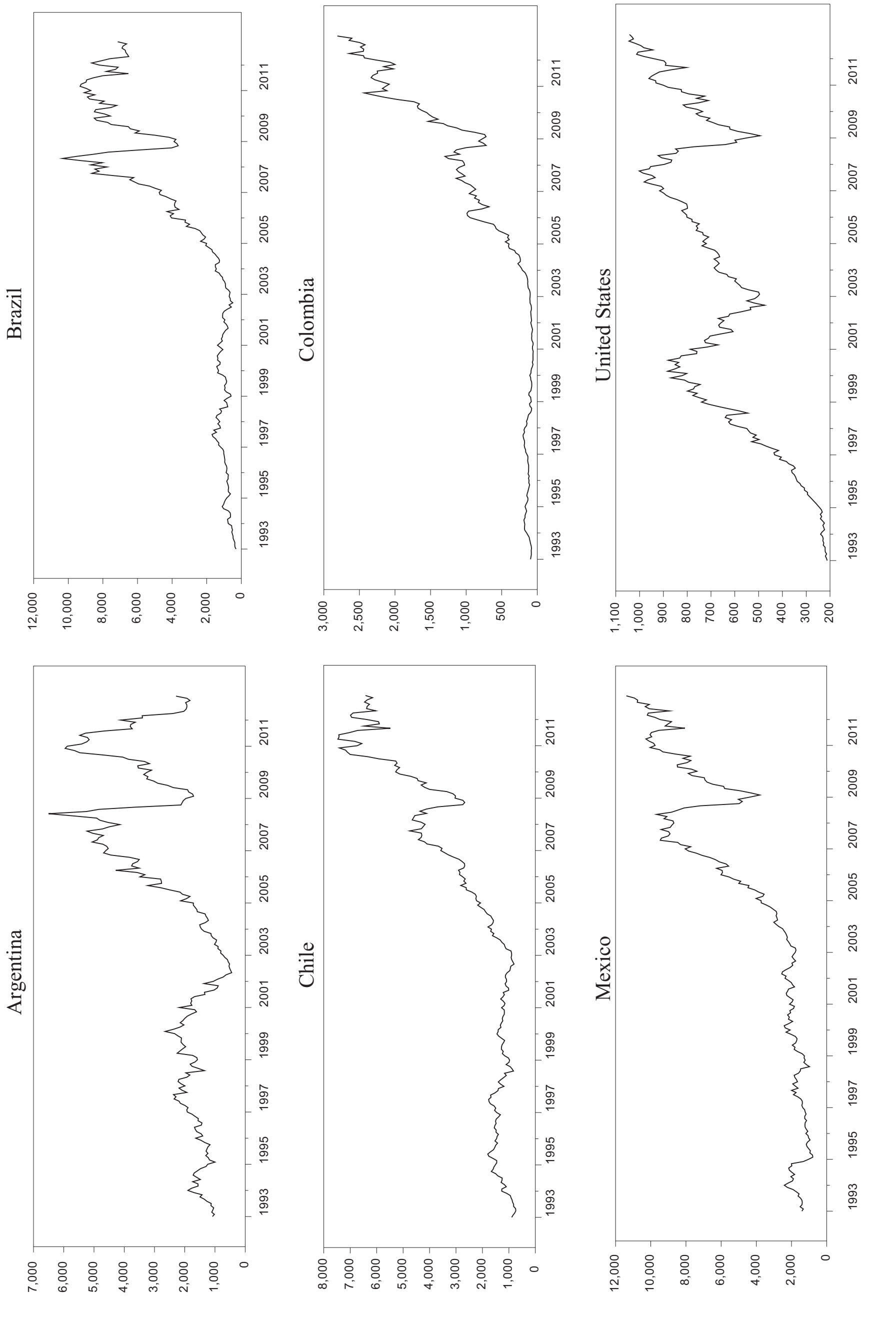

Figure 1. Dynamics of stock market prices

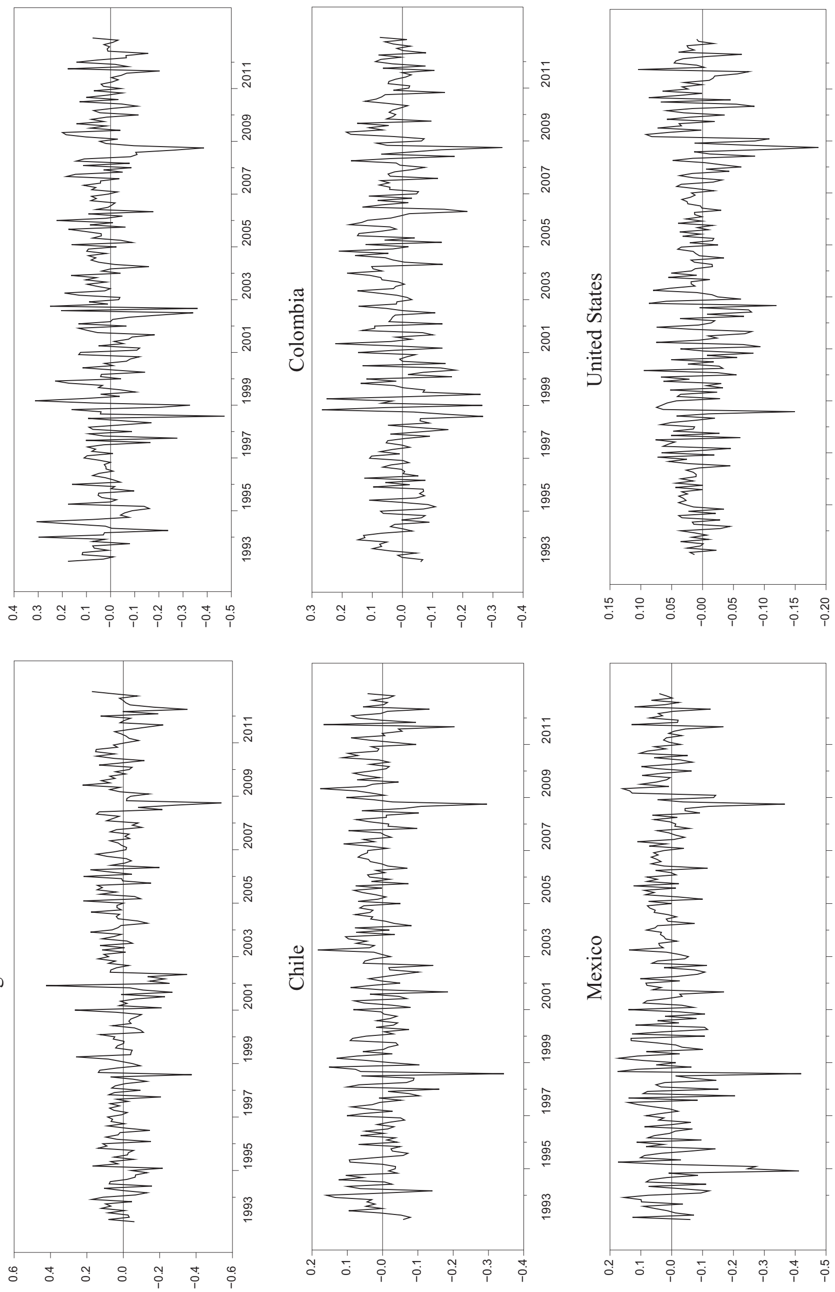

Figure 2.
Dynamics of equity markets returns

Table II. Stock markets in Latin American countries in 2012

Market	No. of listed companies	Market capitalization ($ billions)	Market capitalization (% GDP)	Turnover ratio (%)	Trade openness (exports + imports in % GDP)	Strength of legal rights index (between 0 and 10)
Argentina	101	34	7.2	3.8	36	4
Brazil	353	1,229	54.6	67.9	27	3
Chile	225	313	116.8	16.0	67	6
Colombia	76	262	70.9	11.2	37	5
Mexico	131	525	44.6	25.3	70	6
USA	4,102	18,668	119.0	124.6	32[a]	9

Notes: All the figures are obtained from the World Bank's World Development Indicators; [a] numbers in 2011; strength of legal rights index measures the degree to which collateral and bankruptcy laws protect the rights of borrowers and lenders and thus facilitate lending; the index ranges from 0 to 10, with higher scores indicating that these laws are better designed to expand access to credit trade openness degree followed by Chile, while Argentina and Colombia are the two markets in the region that trade less with the rest of the world.

Finally, as for the institutional framework, legal rights index, which measures the degree to which collateral and bankruptcy laws protect the rights of borrowers and lenders, is relatively weak in Latin America compared to the USA. Chile and Mexico have the highest index, while Brazil and Argentina have the lowest one.

4. Empirical results and discussions

In this section, we first present the empirical results from estimating our six-variable VAR(1)-GARCH(1,1) model for the sample markets. We discuss, in particular, the extent of volatility transmission between the US and Latin American equity markets, and also within the Latin American region. We then report and discuss the results related to the optimal weights and hedge ratios of diversified portfolios including Latin American markets as well as compare the diversification potential and hedging effectiveness of each Latin American market from a US (global) investor's point of view.

4.1 VAR-GARCH estimates

Table III shows the estimation results of our multivariate VAR(1)-GARCH(1,1) model and the results of statistical tests applied to standardized residuals. A close look at mean equations indicates that Mexico plays a major role in the Latin American region because its one-period lagged returns significantly affect the current returns of all other markets. As shown in Table II, Mexico is the second-ranked country among the selected Latin American countries in terms of total market capitalization and liquidity, but it has the highest degree of economic openness as measured by the relative importance of trade sector to GDP. Our findings are thus consistent with those of previous works, suggesting that real trade increases financial contagion effects between involved countries (e.g. Johnson and Soenen, 2003; Caramazza *et al.*, 2004). For example, Johnson and Soenen (2003) use the Geweke feedback measures to evaluate the comovement between seven Latin American equity markets and the stock market in the USA, and find that a high share of trade with the USA positively affects stock market comovements. On the other hand, the lagged returns in Argentina also have significant effects on the current returns in four of five cases. The past returns in the US markets help to predict the future returns in Argentina, Colombia and Mexico. These findings thus indicate some evidence of short-term return predictability in Latin American equity markets and reinforce the conclusions of some recent papers, according to which the weak-form informational efficiency of Latin American equity markets is rejected most of the time (see, Arouri *et al.*, 2010; and references therein).

Regarding the estimates of ARCH and GARCH coefficients which capture the shock dependence and volatility persistence in the conditional variance equations, common patterns can be observed for both emerging and developed equity markets. These coefficients appear to be highly significant in almost all cases. The sensitivity of conditional volatility to past own volatility (GARCH terms) is significant for all the return series at the 1 per cent level. The results also suggest that changes in the current conditional volatility of stock returns depend on past own shocks affecting return dynamics as well, owing to the high significance of the coefficients related to the ARCH terms. We notice, however, that, in general, the estimated conditional volatilities do not change very rapidly under the impulsion of return innovations, given the small size of

Table III. Estimates of the multivariate VAR(1)-GARCH(1,1)

	Argentina	Brazil	Chile	Colombia	Mexico	USA
Mean equation						
Constant	0.014*** (0.004)	0.016*** (0.004)	0.008*** (0.003)	0.007* (0.004)	0.019*** (0.003)	0.009*** (0.001)
Argentina(1)	0.005 (0.045)	0.101*** (0.029)	0.092*** (0.029)	0.124*** (0.030)	0.036* (0.021)	0.019 (0.013)
Brazil(1)	0.027 (0.037)	−0.027 (0.039)	0.036 (0.029)	0.087*** (0.035)	0.008 (0.033)	−0.009 (0.015)
Chile(1)	0.073 (0.057)	0.037 (0.050)	−0.001 (0.056)	0.098 (0.064)	−0.040 (0.047)	−0.087*** (0.024)
Colombia(1)	0.082 (0.052)	−0.005 (0.041)	−0.017 (0.040)	0.032 (0.037)	0.029 (0.037)	0.048*** (0.014)
Mexico(1)	−0.110***(0.041)	0.190*** (0.041)	0.093** (0.041)	0.241*** (0.048)	−0.040*** (0.007)	−0.022 (0.016)
USA(1)	0.352*** (0.013)	−0.101 (0.074)	−0.024 (0.077)	−0.174* (0.097)	0.209*** (0.054)	0.150*** (0.002)
Variance equation						
Constant	0.002*** (0.0002)	0.003*** (0.0003)	0.004*** (0.0003)	0.002*** (0.0001)	0.0004*** (0.00005)	0.00007*** (0.000001)
$(\varepsilon_{t-1}^{Argentina})^2$	0.182*** (0.019)	−0.085*** (0.028)	0.116*** (0.035)	0.150*** (0.051)	0.024*** (0.008)	0.001 (0.002)
$(\varepsilon_{t-1}^{Brazil})^2$	0.071*** (0.025)	0.318*** (0.024)	−0.031 (0.034)	0.098*** (0.004)	0.047*** (0.009)	−0.008*** (0.001)
$(\varepsilon_{t-1}^{Chile})^2$	0.083* (0.047)	−0.0009 (0.041)	0.079 (0.066)	−0.092*** (0.002)	−0.149*** (0.020)	−0.070*** (0.003)
$(\varepsilon_{t-1}^{Colombia})^2$	−0.291*** (0.048)	−0.139*** (0.043)	0.054 (0.069)	0.020*** (0.0007)	−0.112*** (0.019)	−0.056*** (0.001)
$(\varepsilon_{t-1}^{Mexico})^2$	−0.053* (0.030)	−0.111*** (0.032)	−0.043 (0.057)	−0.250*** (0.003)	0.263*** (0.011)	0.025*** (0.001)
$(\varepsilon_{t-1}^{USA})^2$	−0.067 (0.074)	−0.117* (0.060)	−0.081 (0.084)	0.269*** (0.111)	−0.109*** (0.022)	0.245*** (0.014)
$h_{t-1}^{Argentina}$	0.687*** (0.019)	0.341*** (0.071)	−0.255 (0.184)	0.002 (0.008)	−0.086*** (0.015)	0.088*** (0.003)
h_{t-1}^{Brazil}	−0.059 (0.048)	0.456*** (0.031)	0.063 (0.070)	0.132*** (0.002)	0.554*** (0.032)	−0.231*** (0.023)
h_{t-1}^{Chile}	−0.043 (0.123)	−0.060 (0.083)	−0.215*** (0.064)	−0.072 (0.095)	−0.311 (0.258)	−0.296*** (0.009)
$h_{t-1}^{Colombia}$	0.016 (0.154)	−0.033 (0.121)	−0.388*** (0.136)	0.449*** (0.017)	0.030 (0.105)	0.254*** (0.044)
h_{t-1}^{Mexico}	−0.107** (0.045)	0.225 (0.178)	0.651 (1.145)	0.902*** (0.006)	0.684*** (0.009)	0.032*** (0.009)
h_{t-1}^{USA}	0.291* (0.168)	−1.921 (2.660)	3.509 (3.599)	−4.219*** (0.158)	−0.005 (0.033)	0.790*** (0.007)
Cross-market correlation						
Brazil	0.444*** (0.043)					
Chile	0.380*** (0.048)	0.615*** (0.029)				
Colombia	0.217*** (0.047)	0.360*** (0.040)	0.414*** (0.042)			
Mexico	0.498*** (0.031)	0.256*** (0.015)	0.232*** (0.025)	0.188*** (0.007)		
USA	0.427*** (0.100)	0.573*** (0.084)	0.479*** (0.066)	0.291** (0.124)	0.667*** (0.067)	–
Log-lik				1927.887		
AIC				1−15.066		
SIC				1−13.097		

(*continued*)

Table III.

	Argentina	Brazil	Chile	Colombia	Mexico	USA
Robust tests for model standardized residuals						
Mean	−0.104	−0.039	−0.011	0.051	−0.136	−0.079
SD	1.080	1.047	1.013	1.042	1.118	1.028
Skewness	−0.271*	−0.533***	−0.950***	−0.402**	−1.069***	−0.634***
Kurtosis	0.946***	1.105***	2.916***	0.824**	2.545***	0.452
JB	11.795+++	23.394+++	120.164+++	13.153+++	109.562+++	17.971+++
Q(12)	5.616	2.518	8.114	9.127	7.485	6.418
ARCH(12)	12.126	12.868	15.423	13.552	4.742	9.056

Notes: Bollerslev and Wooldridge's (1992) robust standard errors are given in parentheses; JB is the Jarque-Bera test for normality based on excess skewness and Kurtosis; Q(12) is the Ljung-Box test for autocorrelation of order 12; ARCH(12) is the Engle (1982) test for conditional heteroscedasticity; *; **; *** indicate significance of coefficients at the 1, 5 and 10%, respectively; +++ indicates rejection of the null hypotheses of no autocorrelation, normality and homoscedasticity at the 1, 5 and 10% levels, respectively the ARCH coefficients. They tend, instead, to develop gradually over time with respect to the substantial effects of past volatility, advocated by the large values of the GARCH coefficients. Therefore, investors and fund managers seeking profit from trading in Latin America equity markets may consider active investment strategies based on volatility persistence and current market trends. It would be advisable, for example, to increase the portfolio investment if the markets under consideration are actually rising and to decrease it if they are falling, all while keeping in mind that the viability of such strategies depends on the stability and the strength of performance between successive periods.

We now discuss our results regarding the extent of volatility transmission within the Latin American region and between the US and Latin American markets. In general, the findings show that, in most cases, the conditional volatility of the Latin American markets is significantly affected by unexpected changes in the returns of at least one other market in the region. Thus, a shock in a particular Latin American market, regardless of its sign, implies an increase in the volatility of other Latin American markets. On the other hand, the past volatility of a particular Latin American market has, in many cases, significant effects on the current volatility of other equity markets of the region. There is also evidence of shock and volatility spillover effects between the US and Latin American equity markets. Indeed, the past return innovations of the US market exert significant effects on the conditional volatility of three Latin American equity markets (Brazil, Colombia and Mexico), while its past volatility significantly affects the volatilities of Argentina and Colombia.

This above-mentioned evidence of volatility spillovers among the sample markets reflects the relatively high levels of trade openness of Latin American countries (Table II). Indeed, tight economic linkages between countries make a particular country more sensitive and vulnerable to shocks occurred in the other countries. The structural economic reforms and financial liberalization policies that have been undertaken by governments of almost all Latin American countries since the early 1980s have also promoted significant growth in size and activities of their capital markets as well as rendered them more open to international capital flows (Bellalah and Nguyen, 2008). The relatively high strength of legal rights index in Table II also reveals that Latin American markets are attractive from the perspective of international investors and lenders. Accordingly, the free movements of capital inflows and outflows involving the Latin American markets are the main roots of increasing volatility and volatility spillovers with world capital markets. The increased transmission of shocks and volatility across our sample markets thus raises the question of contagion risks in extreme market conditions such as the last global financial crisis, which ultimately requires portfolio managers to reduce their international holdings and policymakers of contaminated countries to coordinate with each other to diminish the probability of co-crash.

As expected, the estimates of the constant conditional correlations among the Latin American equity markets, and between these markets and the US market are all positive, but still remain small and moderate in general. This finding, confirming the unconditional correlations, suggests the existence of potential gains from investing in the region.

Lastly, the results of the specification tests based on standardized residuals show that the departure from normality is greatly reduced compared to test statistics we report for the raw returns in Table I. Furthermore, autocorrelation and ARCH effects are no longer present in the standardized residuals. The multivariate VAR(1)-GARCH (1,1) model we use is thus flexible enough to capture the dynamics of stock returns in the US and Latin American equity markets as well as to model their volatility spillover cross effects.

4.2 Optimal designs of international portfolios

Our previous findings suggest that the potential gains from diversification are substantial by investing in the Latin American equity markets. Their return and volatility spillovers naturally require portfolio managers to quantify the optimal weights and hedging ratios to build more efficient portfolios. We calculate these indicators for a one-dollar portfolio invested in different pairs of Latin American equity markets or in different pairs of the US and a Latin American market, following the equations (5) and (6). Here, it is opportune to consider the market indices as well-diversified portfolios of the local markets.

Table IV reports the average optimal weights of holdings of the two assets (Market 1 and Market 2) in a one-dollar portfolio. A glance at the estimates shows that the optimal weights are substantially different for portfolios of emerging markets and for portfolios of the US and an emerging market. To maximize the risk-adjusted return of a one-dollar portfolio constructed from two well-diversified portfolios in two different Latin American markets, investors should invest, on average, 39 per cent in the second Latin American market. For instance, an Argentinian investor needs to invest about 55 cents in Brazil, 24 cents in Chile, 38 cents in Colombia or 30 cents in Mexico to maximize the expected return of his one-dollar portfolio combining his own country stocks and another foreign market's stocks of the same region. When we consider an American (global) investor who wants to minimize the risk of his portfolio without lowering the expected return, he needs only to invest, on average, 16 per cent in one of the Latin American markets. More precisely, a US investor obtains optimal weights for a one-dollar portfolio by investing only about 9 cents in Argentina, 14 cents in Brazil, 25 cents in Chile, 22 cents in Colombia or 9 cents in Mexico.

	Brazil	Chile	Colombia	Mexico
Portfolios of emerging markets				
Optimal weight of Argentinean market	0.552	0.237	0.380	0.302
Optimal weight of Brazilian market		0.108	0.334	0.324
Optimal weight of Chilean market			0.635	0.558
Optimal weight of Colombian market				0.468

	Argentina	Brazil	Chile	Colombia	Mexico
Portfolios of the US – emerging markets					
Optimal weight of the US market	0.090	0.140	0.246	0.218	0.094

Notes: The table reports the average optimal weights of one-dollar portfolios of market indices; each market index represents a synthetic portfolio of stocks in a particular country

Table IV.
Portfolio's optimal weights

We now turn to the hedging strategies suggested by our multivariate VAR-GARCH estimations. Table V indicates that the cross-market hedging for considered portfolios, which is obtained by minimizing the portfolio risk, is more effective between the US and Latin American emerging markets than among the Latin American markets. Indeed, the average hedge ratios for portfolios of the US market and an emerging market attain a maximum value of 0.549 (USA–Chile), while they reach a maximum value of 0.958 (Brazil–Chile) for portfolios of Latin American markets. For the pair of USA and Chile, the obtained hedge ratio suggests that a one-dollar-long (buy) in the US market index should be hedged by selling about 55 cents of the Chilean equity market. On the other hand, a Brazilian investor who also invests in Chile should be short about 96 cents of the Chilean market index to minimize the risk of his one-dollar domestic portfolio.

Summarizing all the findings from the optimal weights and hedge ratios indicate that there is still room for the global investors to gain diversification benefits from investing in the assets issued by Latin American markets and that optimal portfolio designs can be built from using our VAR-GARCH modeling approach.

5. Conclusion

The main purpose of this article was to investigate dynamic interactions among the five major Latin American equity markets, and also between them and the US market. We focus on the period from 1993 to 2012, which is characterized by the gradual market liberalizations and the recurrence of financial crises in both emerging and developed markets. We extend the previous works on Latin American emerging markets by examining the extent of shock and volatility transmission as well as portfolio design and management from the point of view of both the US and Latin American investors.

Through making the use of the multivariate VAR-GARCH modeling approach, we show that dynamic correlations between the studied markets still remain low or at most moderate, suggesting that global (US) investors still have diversification opportunities from investing in Latin America emerging markets. The diversification benefits are also valuable at regional level for portfolios of stocks across the Latin American equity markets, at least for the short and middle run. This diversifying potential may be substantially reduced in the long run, as the increasing level of economic and financial linkages over the recent decades will lead to a convergence process, i.e. Latin American equity markets will respond more to regional and international common factors.

We also find evidence of significant shock and volatility interactions among the Latin American markets, and also between these markets and the USA. The intensity of shock and volatility cross-effects varies, however, across the studied markets. In addition, the optimal weights and hedging ratios, which account for the return and volatility spillovers across markets, suggest that the inclusion of the Latin American stocks help improve the risk-adjusted return of internationally diversified portfolios as well as reduce their risk exposure.

Overall, our results are not only useful for the understanding of the interrelationships between the Latin American and US equity markets, but also they are of interest to investors, portfolio managers and investment funds that are active in our sample emerging markets. Indeed, buying stocks in different Latin American markets lead to a reduction of portfolio risk, as compared with a portfolio of a single country's stocks. For policymakers and market authorities, an increase in the level of shock interactions and volatility transmission between the US and Latin American equity markets as well as

Table V.
Minimum-variance hedge ratios

	Brazil (short position)	Chile (short position)	Colombia (short position)	Mexico (short position)
Hedge ratios for portfolios of emerging markets				
Argentina (long position)	0.450	0.583	0.372	0.718
Brazil (long position)		0.958	0.489	0.367
Chile (long position)			0.315	0.218
Colombia (long position)				0.209

	Argentina (short position)	Brazil (short position)	Chile (short position)	Colombia (short position)	Mexico (short position)
Hedge ratios for portfolios of the US market and an emerging market					
USA (long position)	0.174	0.374	0.549	0.237	0.430

Note: The table reports the average hedge ratios for a one-dollar portfolio of representative portfolios in two countries among these Latin American markets implies that the stability of the financial system in one country can be deeply affected by the disturbances in another country. For instance, any change in the US equity markets would require a close watch and careful follow-up from policymakers in Latin American countries if they want to avoid adverse consequences from contagious shocks. Our study can be extended in some ways. First, the same methodology can be applied to the issue of cross-country stock-bond return comovements to explore the relationships in different asset classes both at the country and regional levels. This kind of study is of great importance because any portfolio optimization strategy hinges on the concept of correlation, shock and volatility spillovers. Second, the same model is suitable for the investigation of the determinants of shock and volatility transmission between emerging and developed stock markets, of which macroeconomic announcements, economic and financial integration factors as well as herding and speculation might be relevant candidates. Such research allows, for example, to determine the roots of shock and volatility spillovers and to answer the question of whether they result from economic fundamentals or other factors. Finally, it is also possible to extend our model to account for structural breaks and asymmetries which may characterize the dynamics of financial series.

Note

1. We use the commonly used information criteria (AIC and SIC) to select the optimal lag order for the VAR-GARCH system (both conditional mean and variance equations).

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Further reading

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