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DYNAMIC CONDITIONAL CORRELATION IN LATIN-AMERICAN ASSET MARKETS

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Abstract

In this paper we reviewed the models of volatility for a group of five Latin American countries, mainly motivated by the recent periods of financial turbulence. Our results based on high frequency data suggest that Dynamic multivariate models are more powerful to study the volatilities of asset returns than Constant Conditional Correlation models. For the group of countries included, we identified that domestic volatilities of asset markets have been increasing; but the co-volatility of the region is still moderate.

1. Introduction

The volatility of returns is the main criterion used to take investment decisions, since is the simplest approximation to quantify the riskiness of an asset. But, this measure of returns variation is not directly observable in the markets, which imply that those interested in composing portfolios or studying the markets of assets have to quantify the observed levels of volatility and forecast their expected ranks. The measures of volatility have a dependence of correlation, whose computations and results are tied to the explicit assumptions concerning the statistical properties of returns. Under classical assumptions, the standard measures of volatility usually underestimate the observed and expected variations of returns during periods of financial stress.

The ever increasing relations of capital markets among countries and the recent periods of financial turbulence have warned about the necessity of improving the procedures used to measure the volatility, in order to properly quantify the transmission of shocks. But the estimation of the variations of the expected returns also require of measures able to capture the markets dynamics, as an integrated system.

From a quantitative standpoint, the estimations of volatility require of a positive definite matrix of returns correlations; since this condition guarantees that variances are strictly positives. This quantitative condition and that related to the estimation of volatility in an integrated system are both adequately captured by Multivariate GARCH models. This class of models might be classified into three groups. The first group is composed by models BEKK, VEC, and Factor models; and represents direct generalizations of univariate GARCH. The second group is based on linear combinations of univariate GARCH, and the third group by non linear combinations. This last group is represented by the model of Constant Conditional Correlation (Bollerslev, 1990) and the Dynamic Conditional Correlation model (Engle 2002, and Tse and Tsui 2002).

Amongst the broad range of multivariate models of volatility, the Dynamic Conditional Correlation is perhaps the most suitable class of model to assess estimations on financial data, since the correlations between the asset returns usually display time dependence. By this same reason, the Constant Conditional Correlation model could produce biased estimations of volatility, across time as well as across asset markets.

Dynamic Conditional Correlation (DCC) models have been used to study the crisis of the asset markets in Asia during 1998 (Tse and Tsui 2002, and Chiang, Jeon and Li 2007). From different perspectives, these studies coincided in that the conditional correlations increased during the crisis, and that asset markets were seriously affected by financial contagion. The systemic risk at that time caused strong reductions in the benefits from the diversification across countries of the same region, deepening even more the negative effects of the crisis.

The asset markets in Latin-America have also been impacted by different crises and shocks in the last two decades. According to some studies for the 1990's the evidence of financial contagion is weak, since the adoption of temporary policy measures in some countries and the underdevelopment of their market structures could have impeded that the returns in asset markets were more affected by shocks (Reinhart and Calvo 1996, Forbes and Rigobon 1999, and Martínez and Ramirez 2009). However, the sensitivity of these markets has been increasing, presumably by the strengthening in the financial and commercial relations among countries.

We used the multivariate DCC GARCH model to construct a comprehensive framework that allowed testing the volatility spillovers across Latin-American markets of equities and exchange rate. Our results suggest that despite that the volatility of domestic asset markets have been increasing, the co-volatility of the region is still moderate.

This paper is organized into three sections, additional to this Introduction. In Section 2 we presented the estimating procedure of DCC models. Section 3 contains a brief statistical analysis of data, and the main results from the multivariate models. Finally, we proposed a set of broad conclusions regarding the observed volatility of Latin-American asset markets, in Section 4.

2. The Dynamic Conditional Correlation model

Multivariate GARCH models, composed by non linear combinations of univariate GARCH, strongly depend on the definition of the matrix of conditional correlations. Under the assumption of correlations independent of time (R) the models of Constant Conditional Correlations (CCC) allows a straightforward computation of the correlation matrix. But, if correlations vary over time(R_t), the models of Dynamic Conditional Correlations (DCC) (Engle 2002, and Tse and Tsui 2002), are more appropriate to compute the returns variations. For high frequency data, DCC models are preferred over CCC since their structure allow an adequate estimation of the continuous changes in correlations, and also because DCC are more parsimonious than other multivariate GARCH models.

According to Engle (2002) the covariance matrix in a DCC model requires that:

$$H_t = D_t R_t D_t \qquad (1)$$

H and R be both positive definite with probability of one, to avoid that linear dependencies on asset returns may produce variances negative or equal to zero. In equation (1) the matrix of variance is given by $D_t^2 = diag\{H_t\}$.

DCC models are estimated in two stages. The first entails the selection of appropriate univariate GARCH models, in order to obtain the standard deviations$\left(\sqrt{h_{ii,t}}\right)$ required to adjust the residuals $\left(u_{i,t} = \frac{\varepsilon_{i,t}}{\sqrt{h_{ii,t}}}\right)$ [1]. This stage is characterized by its flexibility, since any univariate GARCH model can be used to estimate the individual volatility.

In the second stage the multivariate model is estimated based on the suitable dynamic quasi-correlation matrix Q_t. For temporary stochastic processes with mean reverting changes in correlations (like those observed in asset returns) the matrix Q_t is defined by:

$$Q_t = (1-\alpha-\beta)\overline{Q} + \alpha u_{t-1}u'_{t-1} + \beta Q_{t-1} \qquad (2)$$

The $n \times n$ covariance matrix of u_t is given by $\overline{Q} = E[u_t u'_t]$; and positive definiteness of the quasi-correlation matrix requires that the parameters α, β and (1-α-β) be all positive. Alternative approaches for processes with unit root and asymmetric adjustments are provided by the Integrated DCC and Asymmetric DCC version models, respectively.

Lastly the Mean Reverting DCC approach requires the re-escalation of the matrix Q_t in order to guarantee that all the elements in the diagonal be equal to one. This stage finally leads us to the conditional correlation matrix, explained by the following equation:

$$R_t = diag\{Q_t\}^{-1/2} Q_t \, diag\{Q_t\}^{-1/2} \qquad (3)$$

Where $diag\{Q_t\}^{-1/2} = diag\left(1/\sqrt{q_{11,t}}, \dots, 1/\sqrt{q_{nn,t}} \right)$

Assuming that asset returns are multivariate normal, this approach permits the maximization of the log-likelihood function:

$$\ell_t(\theta,\phi) = \left[-\frac{1}{2}\sum_{t=1}^{T}\left(nlog(2\pi) + 2log|D_t| + \varepsilon'_t D_t^{-2}\varepsilon_t\right) \right] + \left[-\frac{1}{2}\sum_{t=1}^{T}\left(log|R_t| + u'_t R_t^{-1} u_t - u'_t u_t\right) \right] \qquad (4)$$

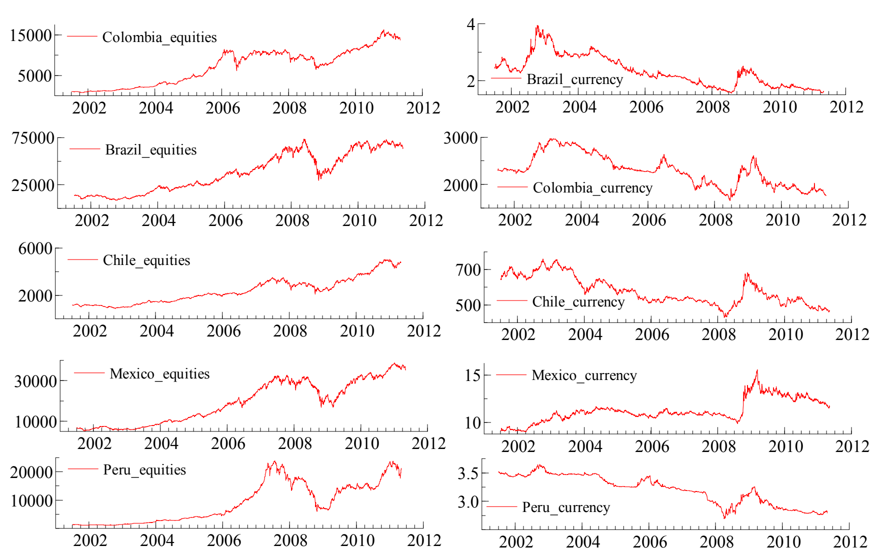
[1] This stage consists in estimating the diagonal elements of matrix H. The residuals standardization solves the problem of heteroskedasticity present in our data.

In which the parameters in D_t (θ) and R_t $(\phi)$are estimated simultaneously. The separate estimation of the volatility (first part of the equation) and the correlation component (the remaining part) is computationally easier than the simultaneous maximization. However, this separate estimation alternative represents limited information parameters that are not fully efficient. Besides, the maximization of the function requires of further assumptions on the data generating process, given that the multivariate density of returns usually differs from the Gaussian density. According to Bollerslev and Wooldridge (1992), consistent pseudo maximum likelihood estimators of equation (4) could be obtained under the correct specification of the conditional mean and variance equations.

3. Data and Results

For the estimating procedure we used daily observations of the Stock Exchange index and the nominal Exchange rate, of Brazil, Chile, Colombia, Mexico and Peru. Our data consists of closing quotes, from July 4^{th} of 2001 to May 5^{th} of 2011; which represents 2567 observations per market. As usual, the differences across countries in the number of observations resulting from holidays were solved reproducing the data observed in the previous trading day.

Graph 1 Exchange rate and Stock Exchange data, 2001-2011



All of these countries experienced increasing trends in the markets of equities in the mid of 2000 that became even more pronounced a year later, presumably by the investors' expectations of further capital gains based on the increasing commodity prices at that time. The United Nations document of Capital flows shows that the annual growth rates of equity prices in Latin-American markets at the end of 2007 were outstanding in Peru (86%) and Brazil (75.3%); and moderate but still remarkable in Chile (20.8%) and Colombia (12.64%). These bullish markets lasted until late 2008 when the sub-prime bubble in U.S exploded, prompting the most recent global financial crisis. In Latin-America the effects of this crisis were rapidly absorbed by the markets of assets, and in some cases like Brazil and Colombia, were accompanied by temporary capital controls measures.

For the same years, the dynamics of the currency markets tells a different story. In Brazil, Chile, Colombia and Peru the nominal exchange rates exhibited increasing trends that reached a peak in 2003, when the quotations of the U.S dollar in terms of the domestic currency exhibited strong revaluations. This downward trend in domestic currencies was enlarged during the global financial crisis of 2008-2009; which coincided with considerable increments in the capital inflows received by these countries (Table 1). The revaluation trend of the currencies of Brazil, Colombia and Peru was partially stopped by means of governments interventions in the exchange rate markets (Edwards, 2011). However, the downward trends continued forming bearish markets, still present nowadays.

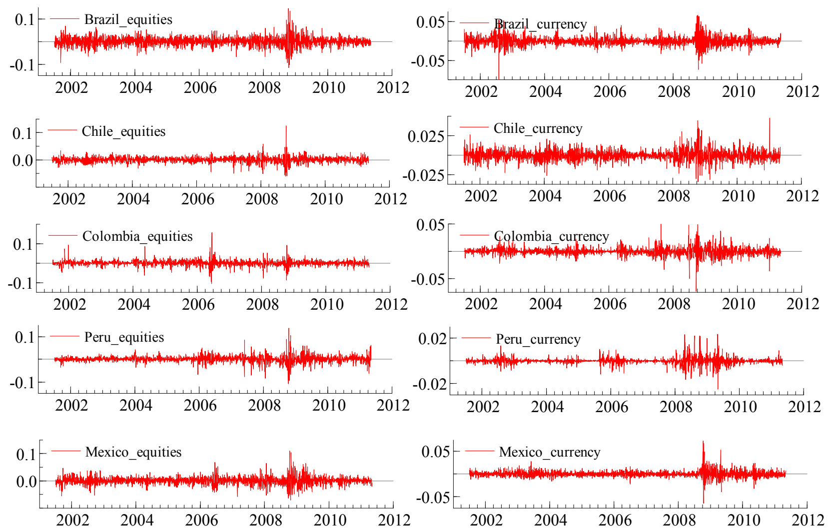
Table 1 Capital inflows (Millions of dollars)

	2005	2006	2007	2008	2009
Brazil	13,807	16,299	89,086	29,352	70,551
Chile	1,591	-4,202	-10,223	7,329	-2,455
Colombia	3,236	2,890	10,347	9,492	6,359
Mexico	17,360	667	21,352	26,952	16,153
Peru	-99	718	8,330	8,609	970

Correspond to the summation of the Balances of Capital and Financial Accounts
Source: IMF

Despite of the differences in the long term trends of the markets of equities and currencies, in the mid of 2008 the returns of both markets experienced similar clusters of volatility. In the graphs presented below we identified two features that describe the markets dynamics at that time. First, within the group, the strongest changes in the asset returns were observed in Brazil, Chile and Mexico. And second, the volatility for the markets of equities was leaded by Brazil; while for the markets of currencies this role was played by Peru.

Graph 2 Returns of Exchange rate and Stock Exchange data



Calculations of the authors

An initial look at the distributional properties of data suggests that all series strongly differ from the standard normal. The descriptive statistics presented in Table 2 reveal that the unconditional distributions of the returns are skewed, besides displaying considerable excess of kurtosis. This last feature is especially strong in the Stock exchange and Exchange rate markets of Colombia and Peru.

Table 2- Summary Statistics of Data

	Mean	Variance	Skewness	Kurtosis
Stock exchange				
Brazil	0.00076	0.00036	0.07	8.05
Chile	0.00060	0.00011	0.28	14.57
Colombia	0.00112	0.00019	0.11	17.43
Mexico	0.00073	0.00019	0.23	8.94
Peru	0.00118	0.00023	-0.11	13.19
Exchange rate				
Brazil	-0.00008	0.00013	0.30	9.89
Chile	-0.00010	0.00004	0.45	7.34
Colombia	-0.00008	0.00005	-0.01	13.50
Mexico	0.00012	0.00005	1.08	20.75
Peru	-0.00008	0.00001	0.70	19.44

Calculations of the authors

Consistently with both characteristics, in all our estimations we assumed a multivariate Student t distribution; which represented the degrees of freedom as an extra parameter (df) that indicates the number of statistical moments in the multivariate distribution. Since all of the estimated df parameters exceeded the value of four, is evidently that fourth order moments exist. In Tables 3 and 4 we present our DCC results for Stock Exchange and Exchange rate data, respectively. Previously we evaluated the existence of constant conditional correlation in the asset returns; and both, the tests of LMC and Engle and Sheppard (2001), rejected this assumption. Besides, our estimated parameters are consistent and efficient, since they were obtained from the simultaneous maximization of the components of volatility and correlation.

The results for the markets of equities are based on univariate GARCH (1, 1), with constant in the Mean and Variance equations. All our results are significant at traditional levels, besides satisfying the expected conditions in terms of strictly positive variances. This condition requires that the quasi-correlation matrix be positive definite, which in our results of the multivariate GARCH is satisfied with positives α, β and (1-α-β) parameters.

Table 3- Stock Exchange markets

	LMC-TEST	Engle & Sheppard TEST		UNIVARIATE MODELS, GARCH(1,1)		DCC		
				ALPHA	BETA	ALPHA	BETA	df
Brazil				0.054	0.928			
				(0.008)***	(0.011)***			
Chile				0.098	0.860			
				(0.012)***	(0.016)***			
Colombia				0.208	0.710			
				(0.040)***	(0.059)***			
Mexico				0.055	0.924			
				(0.010)***	(0.014)***			
Peru				0.168	0.811			
				(0.027)***	(0.031)***			
	44.501	E-S Test(5)	62.28			0.008	0.989	8.415
	[0.000]		[0.000]			(0.002)**	(0.005)***	(0.599)***
		E-S Test(10)	71.24					
			[0.000]					

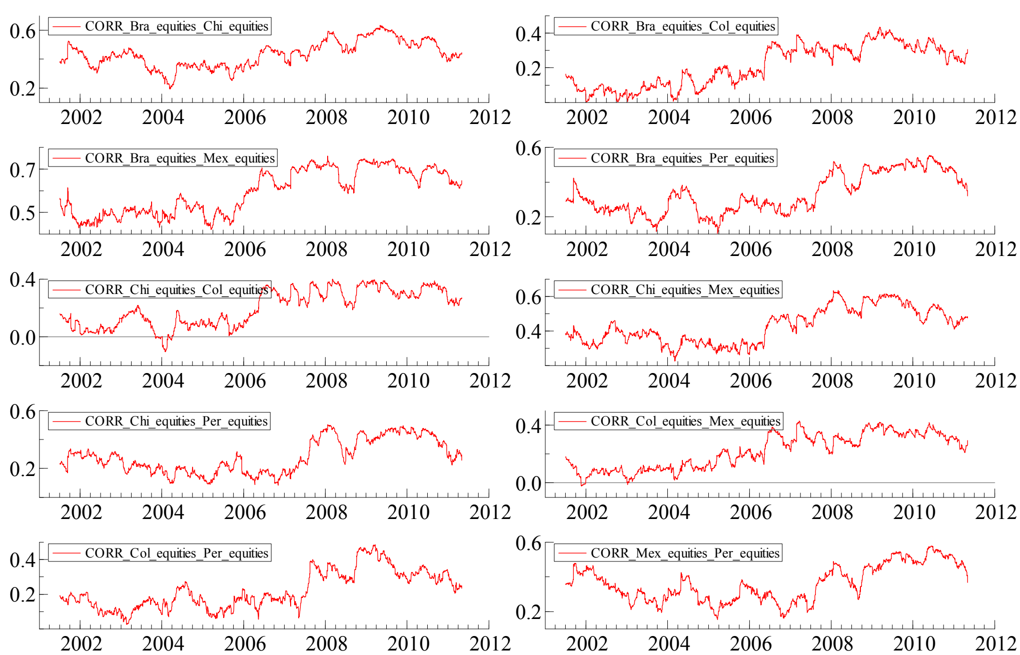
Calculations of the authors
LMC and Engle-Sheppard statistics test under the null of Constant Conditional Correlations of returns.
Significant at 1% (***) , 5% (**) and 10% (*) respectively. Standard errors in parenthesis.

The univariate models presented in Table 3, evidence a high persistency in volatility since in all estimations the summations of the parameters alpha and beta are very close to the unity. Per country, the highest volatility persistency is observed in the Brazilian market

(0.98), while the lowest is particular to Colombia (0.92). These differences in the sensitivity may be attributed to the size of the markets, and the amount of foreign capital involved in the transactions. Likewise, the estimated parameters in the multivariate DCC GARCH also display a high persistency of deviations from the unconditional level.

The pair-wise conditional correlations, in Graph 3, exhibit upward trends in 2006, followed four years later by strong and sustained downward trends. This asymmetric response in equity markets may come from increases in the conditional covariance, originated by negative shocks in asset returns.

Graph 3- Conditional correlations among Stock Exchange markets



Calculations of the authors

For the markets of exchange rate we adjusted univariate integrated GARCH (1, 1) models, with a constant in the equation of the mean. The results of these models of unitary persistency indentify that Peru (12%) and Colombia (10.7%) strongly react to shocks , but when considering the entire group of countries, the reaction though remains significant, is extremely small(0.8%).

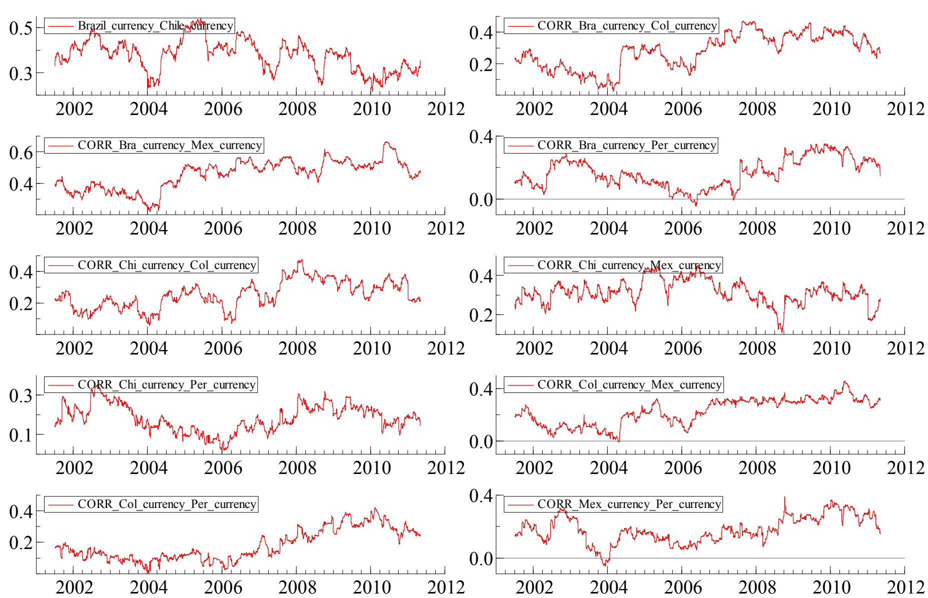
Table 4- Exchange rate markets

	LMC-TEST	Engle & Sheppard TEST		UNIVARIATE, IGARCH	DCC		
				ALPHA	ALPHA	BETA	df
Brazil				0.069			
				(0.08)***			
Chile				0.052			
				(0.01)***			
Colombia				0.107			
				(0.013)***			
Mexico				0.045			
				(0.045)***			
Peru				0.120			
				(0.019)***			
	34.42	E-S Test(5)	90.08		0.008	0.988	7.36
	[0.000]		[0.000]		(0.002)***	(0.003)***	(0.378)***
		E-S Test(10)	106.37				
			[0.000]				

Calculations of the authors
LMC and Engle-Sheppard statistics test under the null of Constant Conditional Correlations of returns.
Significant at 1% (***) , 5% (**) and 10% (*) respectively. Standard errors in parenthesis.

The pair-wise conditional correlations between the exchange rate markets of Brazil, Colombia, Mexico and Peru are above the average level since 2004, exhibiting an upward shift that might be suggesting that markets are more closely integrated.

Graph 4 -Conditional correlations among Exchange rate markets



Calculations of the authors

Consistently with the analysis of data, our empirical results suggest the presence of bears in the markets of exchange rate; since the conditional correlations on large negative returns have been increasing since 2006, especially for Brazil, Colombia and Peru.

4. Conclusions

In this paper we extended the analysis of Latin- American asset returns to a multivariate dimension, by means of multivariate GARCH models, given that their structure allows measure variations in the asset returns of the region. The high frequency data usually exhibit strong dependence of time, which invalidate the models of Constant Conditional Correlation as a proper mean to estimate volatilities of returns. Our empirical results for the entire region, based on DCC models allowed us identified a moderate reaction to shocks with high persistency, suggesting a long term memory of asset markets. The conditional correlations and volatilities exhibited different trends among markets since the mid of 2005. The stock exchange markets exhibited bullish trends, while the markets of currencies in terms of the U.S dollar revealed bearish trends. However, for the mid of 2008 and coinciding with the U.S housing crisis, we identified some clusters of volatility for the markets of equities as well as for the exchange rate markets.

According to our results, the volatility reactions differ among countries, and they were especially strong in Brazil, Peru and Mexico. For the group of countries included in our models, we noticed that Brazil leads the reactions in the markets of equities, while Peru fills this role in the exchange rate markets.

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