Modeling stock index of Colombia, Peru, Mexico, Chile and United States between 2001 and 2011: Evidence against of informal efficiency.

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This article presents estimations of the conditional mean and variance of stock returns of the following indexes: IGBC (Colombia), IPC (México), IPSA (Chile), IGBVL (Perú) and S&P 500 (USA) between 2001 and 2011. With the goal of establishing the dependence of these financial time series and categorize stock markets using informational efficiency findings. The methodology was based in the estimation of ARIMA and APARCH models using assumptions of probability distribution in the tails like t student and asymmetric GED. The findings show United States as the most informational efficient market and the least efficient were México, Chile, Colombia and Peru.


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Introduction

The capital market is an instrument through which savings becomes investment. It is composed of intermediate and non intermediate capital market. In the first one there is an institution which works as an intermediary savers and borrowers such as banks, financial corporations and other agents in the market. In the latter one the relation among savers units and saving lacking units is direct through stock markets which are trading equities, bonds, forex and financial derivates.

Given the relevancy of this mechanism to the economy, the efficiency in these markets will have a positive effect over economic growth (King and Levine, 1993; Levine and Zervos; 1998; Wurgler, 2000; Levine, 2004). In that way, the financial markets had a good effect on the allocation of capital and this is possible through price mechanism. In economies with advanced financial development, the prices allow a better allocation of resources shifting investment to more productive sectors and reducing in the worst (Wurgler, 2000).

Nonetheless, after the last financial crisis, once more the hypothesis of efficient market (EMH) has been put in question, especially in the more developed economies such as the United States where EMH is suppose to be valid.

The proposition of Fama(1970) that prices in the financial markets always reflect the available information is not true because during last crisis in United States the prices overreacted and this is one of the reasons which explains the deep recession in US, the worst from Great Depression in 1929.

When prices do not reflect available information in the market, then someone who knows a relevant fact can get an extraordinary profit thanks to that informational advantage. Likewise this situation shift to an allocation of resources where valuations of assets are not based in the fundamentals of the economy and indeed is just speculation, as a consequence the price of assets increase and it helps growth of speculative burbbles.

In less developed economies such as in Latin-American the problem of informational efficiency (in the Fama’s sense) is a reality. However, during last decades level of financial development in Latin American countries has improved and also its financial systems have become more modern, integrated and bigger. At least this can be concluded after comparing findings about size of Wurgler(2000) and Uribe(2007). For instance, Colombia had a ratio of capitalization over nominal IBP of 3% in 1997 according to Wurgler(2000) and after ten years that measure has change to 41.61% according to estimations of Uribe(2007). The same exercise was made for México, Chile and Perú with similar conclusions.

In recent days, some Latin American countries have taken another important step toward regional integration of stock markets of Chile, Colombia and Perú with the launch of MILA (Mercado Integrado Latinoamericano). México wants become a member of this group and is expected to do so in the near future.

In this sense is important to make a new revision of EMH of Fama (1970) in the markets which are part of the MILA adding to México and US during a time where took place international financial crisis.
In that context, the main goal of this paper is to find the equations of conditional mean and variance of equities returns of the market in the MILA moreover México and US between 2001-2011 and classifies the markets from less to more efficient in Fama’s sense.

The organization of the document is the following. In the next section will present the theory framework which is an explanation of the conditional media models (ARIMA) and conditional variance models (APARCH: GARCH, TARCH and GJR GARCH) moreover a short comment about the informational efficiency concept. Then methodology is discussed and stylized facts of financial time series, findings and finally conclusions and recommendations.

Theory Framework Informational efficiency.

In the correlations analysis with the past of financial time series, like this one, is impossible to separate the findings of the discussion about informational efficiency. Then will make a short exposition of the concept.

Fama (1970) said “A market in which prices always fully reflect available information is called efficient”. Malkiel(1987, 120, quote by Uribe and Ulloa(2011), 130) said something similar “A capital market is said to be efficient if it fully and correctly reflect all relevant information in determining security prices. Formally, the market is said to be efficient with respect some information set, \( \varphi \), if security prices would be unaffected by relevant information to all participants. Moreover efficiency with respect to an information set, \( \varphi \), implies that it is impossible to make economic profits by trading on basis of \( \varphi \).”

An efficient market, according to Fama (1970) and Malkiel(1987), incorporates all available the information in the price, every player in the stock market gets the information and in this way is impossible make huge profits.

For example, when a relevant fact affects the price of one asset, it ups or down and after a short time the markets come back to equilibrium because if it would up (or down) indefinitely, one of the parties would not be able to trade with the other one. If it happens and exist relevant profits, this market is not efficient. When it happens the speculative burbbles take place.

That kind of efficiency is called informational efficiency or weak efficiency hypothesis. Campbell, Lo y Mackinlay (1997) did a classification of efficiency:

- Weak efficiency. Historical information is part of the financial time series. The best forecast he price for tomorrow is the actual price.
- Stronger efficiency. The price of the assets reflects all public available information.
- Strongest efficiency. In the market is known all the information even private information.

Using auto correlations analysis, especially ARIMA models, is possible to find out if one stock market is efficient or not (weak hypothesis). When autocorrelation coefficients are different of zero, is valid to say that stock market is not efficient in the Fama’s sense. This is the main goal of the present research.

In the next section will be present some theories about conditional media and variance models.
Conditional mean. The conditional mean of a time series is a combination of auto regressive process which order p and a moving average with order q (Box and Jenkins, 1978). It is called an ARMA process $(p,q)$:

$$r_t = \mu + \sum_{i=1}^{p} a_i r_{t-i} + \sum_{j=1}^{q} b_j e_{t-j} + e_t$$

Where is expected that $a_i > 0$ and $b_j > 0$. $r_t$, is a daily return of the financial times series in the time t. If it is a stationary process, $\sum_{i=1}^{p} a_i + \sum_{j=1}^{q} b_j$, one shock over the mean has decreasing effect until it goes toward zero. When alpha plus beta are bigger than one, $(\sum_{i=1}^{p} a_i + \sum_{j=1}^{q} b_j > 1)$, it is said that process does not toward to zero and its frenzied growth. If alpha plus beta are equal to one, any shock over the mean has a persistent effect.

When a time series needs to be differentiated respect to its lags to be forecast it, it is called integrated with order $d$ and the literal means number of times that series have been differentiated. In this case, ARMA model $(p,q)$ becomes in ARIMA model $(p,d,q)$.

Conditional variance. The concept is illustrated in the equation (1), $e_t$ is the stochastic term which is uncorrelated with the square innovations. The phenomena was analyzed by Engle(1982) who propose the ARCH models $(p,q)$ (Autoregressive Conditional Heteroskedastic). He defines ARCH process as follow:

$$e_t = \sigma_r$$

Where $z$ is an idd process (zero mean and unit variance) and $\sigma_r$ is not constant over the time showing volatility clusters (high volatility times are preceding by high volatility times). The conditional variance is explained by ARCH terms:

$$\sigma_r^2 = \varphi_0 + \sum_{i=1}^{q} a_i e_{t-i}^2$$

Where $0 < a_i < 1$, to ensure a non conditional variance finite Bollerslev (1986) proposed the generalization of ARCH models which him called GARCH $(p,q)$, and the principal difference respect to ARCH process was add a new term in the equation: volatility of the past. Next, it will be show:

$$\sigma_r^2 = \varphi_0 + \sum_{i=1}^{q} a_i e_{t-i}^2 + \sum_{j=1}^{p} \beta_j \sigma_r^2$$

$$\sum_{i=1}^{q} a_i + \sum_{j=1}^{p} \beta_j$$ (persistence) must be less than one to ensure the process toward zero. Otherwise any chock over variance would growth indefinitely.

After GARCH models new specifications have been proposed as such TARCH, GJR-GARCH, EGARCH, GARCH-M, among others. In this research will use GARCH, TARCH and GJR-GARCH models. The last ones have additional variables to capture the effect of positive and negative news over conditional mean (leverage effect).

GJR-GARCH models. The model proposed by Glosten, Jagannathan y Runkel (1993) adding a new term in the equation to capture leverage effects. The equation is:

$$\sigma_t = \omega + \sum_{i=1}^{q} [a_i e_{t-i}^2 + \gamma_i (\max(0,e_{t-i}))^2] + \sum_{i=1}^{p} \beta_i \sigma_{t-i}$$

Gamma ($\gamma_i$) is a term to capture leverage effect. If it is different to zero, is valid to affirm that variance is sensible to negative news more than positive ones. Negative news increase the volatility.
A similar model, EGARCH, was present by Nelson (1991) which specification is as follow:
\[
\log(\sigma_t) = \omega + \sum_{j=1}^{\infty} \beta_j \log(\sigma_{t-j}) + \sum_{j=1}^{Q} \left( \alpha_i \frac{e_{t-j}}{\sigma_{t-j}} + \gamma_i \frac{|e_{t-j}|}{\sqrt{\sigma_{t-j}}} \right)
\]

If \( \gamma_i \) is significant the variance presents asymmetry.

**TARCH model (Threshold Autoregressive Heteroskedastic).**

The TARCH model was introduced by Zakoian(1994), the way as the model captures the asymmetry in variance is including dummies variable in the conditional variance equations:
\[
\sigma_t = \omega + \sum_{k=1}^{Q} \alpha_j e_{t-j}^2 + \sum_{k=1}^{P} \beta_j \sigma_{t-k} + \phi_1 e_{t-1}^2 d_{t-1}
\]

\( d_t = 1 \) si \( e_t < 0 \) y \( d_t = 0 \), otherwise (positive news). If \( \phi_1 \) is different to zero, the leverage effect is true.

APARCH model. The APARCH model (Assymetric Power ARCH Model) was proposed by Ding.

Granger and Engle (1993), it garners all the special cases of conditional variance in the models as GARCH, TARCH, EGARCH and GJR-GARCH.
\[
\sigma^\delta_t = \omega + \sum_{j=1}^{Q} \alpha_j (|e_{t-j}| - \gamma_j e_{t-j})^\delta + \sum_{i=1}^{P} \beta_i (\sigma_{t-i})^\delta
\]

\( \varepsilon_t = \sigma_t z_t \), \( z_t \sim D(0,1) \)

Where, \( \alpha_j, \gamma_j, \delta \) and \( \beta_i \) are terms to be estimated. If \( \gamma_i \) is positive and significative, variance is more sensible to negative news that positive ones.

The equation must to satisfy the follow conditions:
1. \( \omega > 0, \alpha_j \geq 0, j=1,2,...,q, \beta_i \geq 0, i=1,2,...,p, \)
2. \( \omega > 0, \delta > 0 \) non conditional variance exists.

Changing the value of the parameters \( \omega, \alpha_j, \gamma_i, \delta \) and \( \beta_i \) is possible to find especial cases of family GARCH models: “…”,
- When \( \delta = 2, \beta_i = 0 (i=1,...,p), \gamma_j = 0(j=1,...,q) \) APARCH model is an ARCH model.
- When \( \delta = 2, \alpha_j = 0 (i=1,...,p) \) APARCH model is a GARCH model.
- When \( \delta = 2, \) APARCH model becomes is a GJR-GARCH model.
- When \( \delta = 1, \) APARCH becomes is a TARCH …” (Ding-Ding, p. 7, 2011).

To estimate conditional variance model were running different specifications changing parameters.

**Methodology**

In the estimation of ARIMA models and different versions of GARCH was used maximum log likelihood method.

Considering the main goal of the present document is to find dependence respect to past of stock index´s returns only AR terms were specified in the mean equation and the identification of the process was carry out through Box and Jenkis methodology and analyzing the innovations with Box Pierce test to rule out serial auto correlation.
Once selected no correlated models, the best models was chosen with information criteria\(^8\).

Estimation of conditional mean needed to prove with different specifications, changing parameters in the APARCH model.

Eligible models were free of serial auto correlation and ARCH effects according to Lung Box test as single innovations as square innovations.

Finally, no correlated models and without ARCH effects were testing with Kolmogrov Smirnov test to prove if everyone follow a probability distribution t or asymmetric GED.

Once selected the best models according to desirable features of its errors, the model was chosen through information criteria.

Every index was run under assumptions of probability like t or asymmetric GED. The chosen had lower information criteria.

The information. All the information of the stock indexes corresponds to daily records of IGBC (Índice General de la Bolsa de Valores de Colombia), IGBVL (Índice General de la Bolsa de Valores de Lima), IGPA (Índice de la Bolsa de Comercio de Santiago), IPC (Índice General de la Bolsa de México) and S&P500 (Index of New York Stock Exchange) since 3 July of 2001 until 30 May of 2011 equal to 2419 observations. The information came from Banco de la República de Colombia, Banco Central de Chile, Banco Central del Perú, Bolsa de Comercio de Santiago and la Bolsa de Lima.

The estimation method was log likelihood to run ARIMA and GARCH models. In this research was use the econometric software R project i386 and packages like FGarch functions.

### Findings

Stylized facts. In the graphic 1, see the daily prices of the stock index of Colombia, Chile, México, US and Peru.

Is evident the inexistence of constant mean, in other words these process are non stationary in mean.

To resolve this problem and to forecast every time series, the solution was become them stationeris. The new time series was continuously composed return equivalent to logarithmic difference respect to price (watch graphic 2) between t and t-1 periods.

In the graphic 2, the returns had a stable mean or they were stationary in mean albeit non in variance.

\[^8\] Information criteria: 

\[
\begin{align*}
A_kaike & = -2 \frac{\ln L}{T} + \frac{2k}{T} \\
B_{ayesian} & = -2 \ln L + \frac{k \ln T}{T} \\
S_{chwarz} & = \sqrt{T} \frac{\text{SCR}}{T} \\
H_{ann Quinn} & = \frac{\ln(\sigma^2)}{T} + \frac{2K}{T} \ln(\ln(T))
\end{align*}
\]

Where L is the likelihood, T is number of observations; K is number of parameter to be estimated in every model, SCR is the Square Residual Sum and \(\sigma^2\) is residual variance. The election was done, looking for a model with the lower information criteria.
In the other side, descript statistics of every stock return are shown in the picture 1. The mean of the returns was less than zero, Kurtosis was bigger than 3(leptokurtic) and returns presented negative asymmetry except for IGBC from Colombia. It means that in Colombian stock market had best daily opportunities to make profits respect others in the Region.

These facts bring to think about no normality of analyzed stock returns.

As a consequence was run Kolmogrov-Smirnov test. Null hypothesis of the test is that time series follow a normal distribution and the alternative is that the last affirmation is not true. Findings are shown in the picture 1.

After test the conclusion was rule out null hypothesis with significance level of 1%. The stock return did not follow a normal distribution.

In the picture 2 are shown no correlated models under assumption of probability distribution of errors t-student. Conditional mean model with less information criteria was ARIMA (40, 0, 0), with 40 auto regressive terms (AR).
In variance the GJR GARCH models (with probability distribution t-student) were free of serial correlation, without ARCH effects and overcome KS test. Among these models, the best one was (1, 1).

Moreover was run a model with GED assumption of probability in tails (watch pictures 1 and 2). The best mean model was ARIMA (40, 0, 0) with variance GARCH (1, 1) under GED distribution.

Finally, the selected model was an ARIMA (40, 0, 0) and GJR GARCH (1,1) with conditional probability distribution t student. This finding is in the same direction of research as such Alonso and García (2008), Alonso and Serna (2009), and Uribe(2007). They found dependence in the returns of IGBC albeit using different methodologies and research fields.

IGPA

In this index, an ARIMA model (20, 0, 0) with t distribution was chosen because models with higher lags had lower information criteria (watch picture 4). Selected models were least parsimonious.

In variance, the eligible models were GARCH (1, 1), GJR GARCH (1,1) and TARCH (2,1). Among them the best was TARCH (2, 1) (watch pictures 5, 6 and 7).

Then the same exercise was done with assumption of probability GED. The best model in mean was ARIMA (20, 0, 0) and eligible models of variance were GARCH (1,1) and GJR GARCH (1,1), the best was GJR GARCH (1,1). (See pictures 4 and 5)

Among models with t-student and GED assumptions, the best model according to information criteria was an ARIMA (20, 0, 0) with a TARCH (2, 1) model in variance under t-student assumption.

<table>
<thead>
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<th>Models of GJR GARCH with distribution GED</th>
<th>Models of GJR GARCH with distribution t</th>
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IPC

The conditional mean of the IPC’s returns can be estimated using a ARIMA (30, 0, 0) under assumption of probability distribution t student (see picture 8). In the conditional variance, eligible models were GJR GARCH (1, 1), GARCH (2, 1) and TARCH (1, 1), the best was last one (see pictures 9, 10 and 11).

Under assumption of conditional probability distribution GED was estimated an ARIMA (30, 0, 0) because it was only model without no serial correlation. In the side of variance were run GJR GARCH models because they were only ones without no serial correlation and ARCH effects. The best among GJR GARCH models were (1,1). (See picture 9)

The best model was an ARIMA (30, 0, 0) and TARCH (1,1) under assumption of probability t student in tails.

This finding is similar to findings like Lopez (2004) who found as best model to the TARCH (1, 1).  

Table 8

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Table 9

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Table 10

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Table 11

IGVBL

Conditional mean of the IGBVL’s return was estimated under different specifications as shown in the picture 12. Using assumption of t student, the best model was an ARIMA (70, 0, 0) with conditional variance models as such GJR GARCH, GARCH and TARCH models.

Eligible models were GJR GARCH (1, 1), GARCH (1, 1) and TARCH (1,1) (see pictures 13,14 and 15). The selected model was a GJR GARCH.

When assumption of probability distribution changed to GED, the model with best behavior was an ARIMA (30, 0, 0) according to its parsimony. Meanwhile, conditional variance was calculated with GJR GARCH models because these specifications were no correlated and free of ARCH effects. The best model was GJR GARCH (1, 1).

In this sense, the decision was choose an ARIMA (70, 0, 0) and GJR GARCH (1,1) with assumption of conditional probability in fats t student.
Under assumption of conditional probability distribution GED only models with 10, 15 and 16 AR terms in the conditional mean were relevant. The ARIMA (10, 0, 0) was chosen because it was least parsimony.

The decision was chosen an ARIMA (10, 0, 0) in the conditional mean and GARCH (2, 1) with GED assumption of probability according to information criteria.

Table 12

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Table 13

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Table 14

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Table 15

S&P500

S&P 500’s returns were forecast with ARIMA models of 10, 15, 16 and 17 lags in their conditional means. They were eligible models without auto correlation serial. In the conditional variance was estimated one model, GARCH (2, 1), it was only one without serial correlation and ARCH effects, moreover it overcome KS test. (See pictures 16 and 17).

Conclusions

In the present research was found that all analyzed stock returns indexes exhibits dependence from its past.

In other words they do not collect relevant information in the asset prices so quickly (inefficiency informational). It means that if one stochastic event increases (decrease) the prices of assets in the Latin American stock markets, its effect will take some time to be assimilated.
As a consequence, it would be possible to forecast the price of one asset using models like ARIMA or GARCH and improve their behavior adding new variables to capture “day effect” and “hour effect”, it has been done by Montenegro (2007) and, Alonso and García (2009) analyzing IGBC from Colombia, Bravo (2004) with his structural model to IGBVL from Peru, Garcés and Calle (2007) using ARCH models and different versions of GARCH models in Peru and Sanchez-Vinnelli (2008) with time series models to explain daily returns of a group of nine companies from Peru.

This finding has one important repercussion: growing of speculative burbles if it does not controlled on time.

The stock markets more efficient according to numbers of lags in the conditional mean equation are: United Stated and Chile. While México, Colombia and Peru are slower that first ones.

Especially Peru stock market is the slowest in the group because it is affected by events from two months ago.

To conclude that stock markets in Latin America and specially in the analyzed markets are inefficient in the informational sense is nothing new because the same argument has been found by researchers in Colombia by Alonso and García (2008 and 2009).


Findings of this paper could be useful to get new risk premiums (correlations term) in the CAPM model to MILA´s markets through vanguard methods like Copulas.

It could be a new topic for researching.

Also is important to talk about the existence of leverage effect in the mean equation of the regional index´s returns. In this sense is valid to affirm that all analyzed stock indexes are more sensible to negative news than positive ones with exception of US market which is the most efficient in the informational sense.

Finally, in the present document was evident how important is to estimate financial time series models using assumptions of probability different to normal distribution like asymmetric t student or asymmetric GED to forecast or make VaR analyses.

The recommendations are as follows:

- Toward regulatory authorities and Central Banks: They should consider to take measures like proposed by Uribe and Ulloa (2011) to prevent speculative burbles which has terrible consequences over economies.

- In the same way should be important to design mechanism to improve the access PYME companies to regional stock markets. It requires a great effort to formalization of the companies.

- Is necessary to continue the integration process of the regional stock markets to increase trade volumes, investments options and deep of the market.

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9 This phenomenon has been studied by a recent work written by Uribe and Ulloa (2011) about informational efficiency using copulas.
References


