A test of the efficient market hypothesis with regard to the exchange rates and the yield to maturity in Colombia

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Abstract: - This article investigates the informational efficiency of the Colombian stock market with regard to the information contained in the exchange rates as well as the yield to maturity. Since the underlying data is non-normal with time-varying volatility we make use of tests that are based on bootstrap simulations with leverage adjustments in order to create reliable critical values. The results show that neither the exchange rates nor the yield to maturity is causing the stock price index. This is interpreted as empirical support for the efficient market hypothesis in that the Colombian stock market is with regard to these two main variables.

Key-Words: - EMH, Colombia Stock Market, Granger Causality.

1 Introduction

Since Fama (1970) established the weak, semi-strong and strong form of market efficiency, there have been numerous studies focused on empirically testing the weak and semi-strong forms. In the literature, autocorrelation in stock returns is the predominant method for testing weak-form market efficiency. Lim and Brooks (2011) provide a comprehensive survey of the literature about weak-form efficiency. In the case of the semi-strong form, many studies have focussed on how delays in stock prices responses to new information might create arbitrage opportunities that should not exist in an efficient market. There is an extensive body of knowledge on sources of information that affect the stock price dynamics such as new releases of firm fundamentals, macroeconomic news and announcements from other markets are just a few[1].

Our objective is to test the informational efficiency of Colombian Stock Market with regard to fixed income and foreign exchange markets. Specifically, we test if the stock market reacts unbiased and instantly to shocks in the fixed income and foreign exchanges markets as postulated by the EMH. Our argument relies in the assumption that there is a direct link among these three markets. We include the fixed income market as a proxy that includes expectations of inflation and monetary policy which are factors that also affect the foreign exchange and stock markets (see for example: Feldstein (1980), Bredin, Hyde, Nitzsche, and O'Reilly (2007) and Farka (2009)). The role of the fixed income markets is important because inflation targeting monetary policy in the nineties is a plausible explanation for the plunge in the cost of capital during the last decade (Bekaert & Harvey, 2000).
This paper is structured as follows: In Section 2 we present the relevant literature on testing the EMH hypothesis in Colombia and other emerging markets. Section 3 describes the data and methodology for or proposed setup. Section 4 presents the results and Section 5 concludes.

2 Literature review

2.1 Testing EMH in emerging markets

Although the Colombian Stock Market has experienced a recent development in terms of liquidity, size and number of listed firms, lack of efficiency seems to persist even in the weak-form (Agudelo Rueda, 2010, 2011). In fact, the presence of autocorrelation (inefficiency in the weak-form) is persistent in this market, even contemporaneously (see: Bekaert, Harvey, and Lundblad (2007); Harvey (1995); E. H. Kim and Singal (2000); Korajczyk (1996); Uribe Gil (2007); Urrutia (1995)). Nevertheless, autocorrelation is not a feature only found in Colombia or other developing markets, this characteristic is also reported in some developed markets (Griffin, Kelly, and Nardari (2010); Malkiel (2003)). Another sign of weak-form inefficiency is reported by a statistically significant "day of the week effect" in the Colombian Stock Market (Kristjanpoller, 2009).

As previous studies have extensively tested the weak-form efficiency, we focus our attention in the semi-strong form. This form has also been tested in a variety of ways in emerging markets. For example, the delay in price reaction to announcements about firm fundamentals like dividends and returns has been studied by Griffin et al. (2010). The authors examine post-earnings announcement drifts, and argue that there are no significant differences in the abnormal returns obtained in emerging and developed stock markets when using this trading strategy. Adelegan (2003) argues that the Nigerian Stock Market is not efficient in respect to dividend news. Alexakis, Patra, and Poshakwale (2010) assert that the Greek Stock Market is not informationally efficient in respect to accounting releases. Mandal and Rao (2010) find out that the Indian Stock Exchange Market is moderately efficient with regard to dividend news.

Other studies have focused on the price reaction to both macroeconomic news and shocks in other markets. Hanousek and Filer (2000) argue that in the case of Poland and Hungary it is possible to implement an arbitrage strategy given that there is a delay of the effect of economic announcements in stock prices. Hatemi-J (2002) finds that the Korean Stock Market is informationally efficient with respect to monetary policy. Hatemi-J (2004) tests the Japanese Equity Market in respect to the interest rates, consumer price index, industrial production, money supply and the real effective exchange rate, and he finds no violations to the semi-strong form efficiency. Hatemi-J and Bryan (2009) find delay in adjustment to the EMH in the Australian Equity Market with respect to shocks in interest rates and exchange rates. Al Janabi, Hatemi-J, and Irandoust (2010) find that the Gulf Cooperation Council Equity Markets are efficient in respect to oil and gold prices. In sum, there is still an ongoing debate about the informational efficiency of stock markets.

2.2 The relationship of the financial markets

The link between the foreign exchange and the stock markets is still an ongoing debate form either the theoretical and empirical perspective. There are two contradicting economic arguments about the

[1] See Fama (1991) for a review of empirical methods for testing the semi-strong form of market efficiency.

correct sign of this relationship. On one hand, the goods market approach asserts that security prices increase when the home currency goes down due to domestic relative prices, and it also diminishes comparatively with foreign competitors (Feldstein, 1980). On the other hand, the Portfolio Balance Model argues that security prices increase as the domestic currency increases because foreign capital is attracted to the local economy (Katechos, 2011).

The empirical behaviour of the relationship between stock markets and exchange rates has been empirically tested extensively without a consensus. For example, Hau and Rey (2006) find evidence that contradicts the Portfolio Balanced Model. They also find a strong negative correlation between stock and foreign exchange market. Chue and Cook (2008) state that after the currency crisis of the early nineties, stocks were negatively related with exchange rates, but this relationship fades away during the last decade. Bartram and Bodnar (2012) argue that the reaction of security prices is conditionally related with the specific net positions (net exporters or net importers) of the firms and exchange rates.

The empirical correlation between the stock and the fixed income markets is also contradicting. Baele, Bekaert, and Inghelbrecht (2010) found that the correlation between these two markets has varied by as much as -0.6 to 0.6, with some periods of negative correlations and others of positive correlations . The reasons for this behavior are abundant in the literature. For example, the early work from Fama and French (1989) argues that poor economic conditions create co-movements. Other authors attribute these phenomena to behavioral reasons such as the 'Flight to Quality' that tend to generate temporal illiquidity in both the stock and fixed income markets being the only exception the fixed income market of the high quality country (Chordia, Sarkar, and Subrahmanyam (2005); Massa, Goetzmann, and Rouwenhorst (1999)). Most recently, Baker and Wurgler (2012) argued that: *"Government bonds commove more strongly with bond-like stocks: stocks of large, mature, low-volatility, profitable, dividend-paying firms that are neither high growth nor distressed"* P (1).

In summary, all markets seem to be somehow related, although the level of this correlation as well as its direction is a matter still open for debate. In fact, Katechos (2011) asserts that this relationship is not only strong, but it also depends on the magnitude of interest rates. In the author's words: *"currencies with higher interest rates are positively related with global equity returns, whereas the value of currencies with lower interest rates is negatively related with global equity returns"* P(550). Under a Granger causality approach Abdalla and Murinde (1997) found that in the case of India, Korea and Pakistan the exchange rate does Granger cause the stock market, but the causality flows in the opposite direction in the case of the Philippines. Finally, S.-J. Kim et al. (2006) concluded that bonds markets Granger caused the segmentation of stock markets in Europe after the monetary union. In that sense, our paper is one of the few papers that uses a bivariate Granger causality levered approach into testing the direction of the relationship of sovereign bonds, exchange rate and stock exchanges in a multivariate setting. In the next section we give detail of the data and the methodology employed.

3 Dataset and the Methodology

The dataset contains daily information from 2001:07 to 2013:05 of Colombian Exchange Stock Index (IGBC), Colombian sovereign bond yield for a 2Y maturity (BOND) and the USD/COP exchange rate (ER). BOND is obtained from Bloomberg fair market value zero coupon USD denominated sovereign bond curves (FMCZCB) for Colombia. This proxy is derived from actual bond prices and provides a good approximation of what would be the theoretical price of a given maturity with constant duration. From the descriptive statistics (see Table 1) we can see that in all of the variables we reject the hypothesis of normality and there is evidence of asymmetry (high kurtosis and negative skewness in the case of the IGBC) which makes these variables a suitable candidate for a leveraged bootstrap test of causality.

Table 1-Descriptive Statistics

	BOND	ER	IGBC
Mean	4.070	2210.678	8333.649
Median	4.015	2248.855	9443.430
Maximum	13.595	2980.000	16278.880
Minimum	0.548	1655.030	776.540
Std. Dev.	2.226	351.966	4787.375
Skewness	0.697	0.454	-0.239
Kurtosis	3.844	2.105	1.662
Jarque-Bera	344.142	210.648	261.344
Probability	0.000	0.000	0.000
Observations	3108	3108	3108

Source: Data from Bloomberg, author calculations

We test for Granger causality between the underlying variables by using a leveraged bootstrap test developed by Hacker and Hatemi-J (2006, 2012). This test is based on a vector autoregressive model of order p, VAR(p), as the following:

$$X_t = \nu + A_1 X_{t-1} + \ldots + A_p X_{t-p} + e_t \quad (1)$$

where X is a three dimensional vector consisting of the variables. The optimal lag order p is selected carefully by minimizing the following information criterion, which is suggested by Hatemi-J (2003, 2008):

$$\text{HJC} = \ln\left(\det \hat{\Omega}_j\right) + j\left(\frac{n^2 \ln T + 2n^2 \ln(\ln T)}{2T}\right) \quad (2)$$
$$j = 0, \cdots, p.$$

Here $det\,\hat{\Omega}_j$ is the determinant of the variance-covariance matrix of the residuals in the VAR(j) model. The letter n represents the number of the variables and T is the sample size and ln is the natural logarithm.

The null hypothesis that kth element of X_t does not Granger-cause the mth element of X_t can be expressed as the following:

H_0: the row m, column k element in A_r equals zero for $r = 1,\ldots, p$. (3)

By utilizing some additional mathematical denotations it is possible represent the VAR model compactly as the following:

$$Y = DZ + \varepsilon . \quad (4)$$

The null hypothesis of non-Granger causality is then presented as

$$H_0: \quad C\beta = 0. \quad (5)$$

which can be tested via the following Wald statistic:

$$Wald = (C\beta)'\left[C\left((Z'Z)^{-1} \otimes S_U\right)C'\right]^{-1}(C\beta) \sim \chi_p^2 \quad (6)$$

Here $\beta = vec(D)$, where vec is the column-stacking operator; ⊗ is the Kronecker product and C is a $(p\times n)(1+p\times n)$ indicator matrix that has elements of ones and zeros. The variance-covariance matrix from VAR model that is restricted, is defined as $S_U = \frac{\hat{\varepsilon}_U' \hat{\varepsilon}_U}{T-b}$. Note that b represents the number of estimated parameters in the model. Assuming normal distribution, the Wald statistic of equation (6) is distributed as χ^2 asymptotically with degrees of freedom equal to the lag order p. However, if the normal assumption is not fulfilled and the volatility is time-varying, then the asymptotic critical values based on the χ^2 distribution are not accurate. The remedy this shortcoming, we apply a bootstrap test with leverage adjustments as developed by Hacker and Hatemi-J (2006, 2012). The simulations conducted by the mentioned authors show that this test has good size and power properties even if the lag order is selected endogenously. For conducting this test, the following steps need to be taken:

i) Estimate the VAR model in equation (1) based on the optimal lag order, p, and obtain the residuals ($\hat{e}_t$).

ii) Next, produce the simulated data, denoted by X_t^*, by the following expression:

$$X_t^* = \hat{A}_0 + \hat{A}_1 X_{t-1} + \ldots + \hat{A}_p X_{t-p} + \hat{e}_t^* \quad (7)$$

Note that the circumflex above any variable indicates the estimated value of that variable. The denotation $\hat{e}_t^*$ represents the bootstrapped residuals, which are obtained via T random draws with replacement from the regression's modified residuals (to be defined below), each with drawn whit the equal likelihood of $1/T$. These residuals are mean adjusted in each replication in order to make sure that the expected value of the residuals is equal to zero. The original residuals from the regression are adjusted via *leverages* in order to fulfill that assumption of constant variance. Before presenting the leverages, we need to introduce additional denotations. Let $Y_{-p} = (X_{1-L}, \cdots, X_{T-p})$ and let $Y_{i,-p}$ to be the ith row of Y_{-p}. Therefore, $Y_{i,-p}$ is created as a row vector of the lag p values for variable X_{it} across the sample period t = 1, . . ., T. Let also $V = (Y_{-1}', \cdots, Y_{-p}')$ and $V_i = (Y_{i,-1}', \cdots, Y_{i,-p}')$ for i = 1, 2. Note that in the equation that is defined by X_{1t}, the independent variable matrix in the estimated regression is W_1. This equation is the restricted one. In the equation that is defined by X_{2t}, the independent variable matrix for the regression is W. This equation is the unrestricted one. By using these denotations, the $T\times 1$ *leverages* vectors for X_{1t} and X_{2t} are defined as the following:

$$l_1 = \text{diag}\left(W_1\left(W_1'W_1\right)^{-1}W_1'\right)$$

and $$l_2 = \text{diag}\left(W\left(W'W\right)^{-1}W'\right) \quad (8)$$

By using these leverages to modify the residuals, we will account for the potential effect of time-varying volatility. The modified residual for X_{it} is produced as:

$$\hat{e}_{it}^m = \frac{\hat{e}_{it}}{\sqrt{1-l_{it}}} \quad (9)$$

here l_{it} represents the tth element of l_i, and $\hat{e}_{it}$ signifies the raw residual from the regression for X_{it}.

iii) The additional step is to repeat the bootstrap simulations 10000 times and calculate the Wald test each time. In this way an approximate distribution for the Wald test statistic is estimated based on the sample data. After implementing these 10000 replications, we find the (α)th upper quantile of the distribution of bootstrapped Wald test. This quantile provides the α-level of significance "bootstrap critical value" (c_α^*).

iv) Finally, we compare the estimated Wald statistic based on the original simulated with the bootstrap critical. If the estimated Wald statistic is higher than the bootstrap critical value c_α^*, it means that the null hypothesis of non-causality can be rejected at the α level of significance. The bootstrap simulations are implemented via a module that is written in Gauss by Hacker and Hatemi-J (2010). This statistical software component is available online.

4 Results

In this section we discuss the results of our proposed asymmetric causality test applied to the Colombian Stock Market. Before testing for causality among the underlying variables we tested for unit roots. The results showed that each variable has a unit root. We also conducted the test for multivariate normality in the VAR model by using the Doornik and Hansen (2008) test[2]. The test results showed that the null hypothesis of no multivariate normality could be rejected. In addition, we tested for multivariate ARCH effects in the VAR model by using the Hacker and Hatemi-J (2005) test. The results showed that the null hypothesis of no multivariate ARCH could be strongly rejected. Thus, using the leveraged bootstrap simulations procedure is necessary in this case in order to obtain reliable inference. The results of the leveraged bootstrap causality tests are presented in Table 2 (panel A), which shows the null hypothesis that the exchange rate is not causing the stock prices as well as the null hypothesis that the yield to maturity is not causing the stock prices cannot be rejected at any conventional significance level as compared with a traditional VAR model in Table 2 (panel B) where the null hypothesis that the that the exchange rate is not causing the stock prices is rejected at the 10% confidence level which shows the additional robustness provided by the leveraged bootstrap method. Based on these empirical findings we can conclude that the Colombian stock market index is informationally efficient with regards to both the exchange rates and the yield to maturity.

[2] These results are available from the authors upon request.

Table 2: Panel A-The Results of Leveraged Bootstrap Causality Test.

H_0	The Estimated Test Value	1% Bootstrap Critical Value
ER does not cause *IGBC*	0.527	9.485
BOND does not cause *IGBC*	1.490	11.212
H_0	The Estimated Test Value	5% Bootstrap Critical Value
ER does not cause *IGBC*	0.527	6.114
BOND does not cause *IGBC*	1.490	6.320
H_0	The Estimated Test Value	10% Bootstrap Critical Value
ER does not cause *IGBC*	0.527	4.944
BOND does not cause *IGBC*	1.490	4.809

Source: Data from Bloomberg, author calculations

Notes: *BOND* is the yield to maturity, *IGBC* is the stock price index and *ER* is the exchange rate. The optimal lag in the VAR was set to be two by minimizing the Hatemi-J (2003) information criterion. An additional lag was included in the model in order to account for one unit root following the suggestion by Toda and Yamamoto (1995).

Table 2: Panel B-The Results of a Two Lag VAR pairwise Causality test

H_0	The Estimated Test Value	1% Bootstrap Critical Value
ER does not cause *IGBC*	5.086	9.21
BOND does not cause *IGBC*	2.479	9.21
H_0	The Estimated Test Value	5% Bootstrap Critical Value
ER does not cause *IGBC*	5.086	5.991
BOND does not cause *IGBC*	2.479	5.991
H_0	The Estimated Test Value	10% Bootstrap Critical Value
ER does not cause *IGBC*	5.086	4.605
BOND does not cause *IGBC*	2.479	4.605

Source: Data from Bloomberg, author calculations

5 Conclusions

This paper tests the semi-strong form of market efficiency in the Colombian Stock Market using daily data for the period 2001:07-2013:05. Since the underlying data is found to be non-normally distributed and the volatility is time-varying, volatility standard tests cannot perform accurately as shown in Table 2 Panel B. As a remedy, we make use of tests that are based on bootstrap simulations with leverage adjustments that can produce reliable critical values. The results show that neither the exchange rates nor the yield to maturity is causing the stock price index. This is interpreted as empirical support for the efficient market hypothesis in that the Colombian stock market is with regard to these two main variables. Thus, our results show that the Colombian stock market is informationally efficient to shocks in the foreign and fixed income market exchange.

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