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Causality and Cointegration Analysis: Evidence from the Brazilian Stock Market

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Abstract

Many studies have focused on examining the cointegration and causality between or among stock markets of different countries. This paper departs from these traditional inter-relationship studies through its investigation on the causality and cointegration between the Brazilian Stock Market (Bovespa) and a listed company (Petrobras) by employing the Granger causality test and error correction technique based on autoregressive distributed lag (ARDL) modelling approach to cointegration. We find empirical evidence of cointegration and that deviation from long-run equilibrium is corrected according to the speed of adjustment. In particular, a disequilibrium resulting from a shock to the stock market is corrected by 3.8% per week. Our findings also show a unidirectional causality running from Bovespa index to share price of Petrobras thus revealing the predictive power of the former. While our Granger causality finding is inconsistent with the preaching of efficient market hypothesis (EMH), it nonetheless fortifies the need for investors and financial analysts to closely monitor the movements of the Brazilian stock market index when investing (or analyzing changes) in Petrobras.

Keywords: Bovespa, Petrobras, Cointegration, Causality, Equilibrium, Short-run, Long-run

1.0 Introduction

Various studies have been done on the relationship between economic variables within or across countries (Adam & Tweneboah, 2008; Chen et. al., 1986; Hamao, 1988; Kaneko & Lee, 1995). Each in its own unique way tries to investigate the possible interdependence or impacts resulting from changes in other variables. These changes or interdependence of stock markets have pushed investors to diversify their portfolio in order to minimize risk. Causal relations between macro (and micro) economic indicators and stock markets have been rigorously pursued in the literature. This is particularly crucial in risk management as it provides information about indicators capable of predicting the behaviour of stock market returns. Such indicators include but not limited to stock prices, interest rates, exchange rates, macroeconomic performance and stock market variables.

Liu et. al. (2005) argue that, no single market is autarchic or completely exogenous and that no market based on its own innovations can fully account for its variance. Observing the dramatic changes in the world economic environment following trade liberalization and financial globalization, there have been vast and in-depth studies that seek to investigate and/or examine movements in stock prices. For instance, Chen et. al. (2002) analysed the dynamic interdependence of major Latin American stock markets and found that variations in Mexico market prices aided in explaining movements in other Latin American countries. This finding collaborates with Bessler & Yang (2003). By invoking cointegration vector approach, their results suggest that US has a consistent long-run impacts/effects on markets in other countries.[15]

While others have found evidence of possible correlation between or among stock markets across countries, Tabak & Lima (2002) analysed the cointegration of Latin American markets with US between January, 1995 and

[15] These countries are Australia, Japan, Hong Kong, UK, Germany, France, Switzerland, US and Canada.

March, 2001 and their test results however showed no cointegration between the series. They however found a short-term causality where causality flows from Brazilian stock market to other Latin American stock markets.

Confining the studies within national borders, by using Malaysian stock market, Ibrahim (1999) found that the influence of macroeconomic forces on the expected future cash flows has systematic impact on stock prices. Similarly, by using vector error correction model (VECM), Maysami & Koh (1990) examined the long-run relationships between the Botswana stock exchange and key macroeconomic variable for the period 1978 to 1989. After seasonally adjusting the variables, their results revealed a cointegrating vector among the returns on the stock exchange and growth in money supply, inflation, exchange rate changes as well as term structure of interest rates. After testing for the efficiency of Bovespa, Tabak (2003) argues that the Brazilian stock market has become much efficient following the collapse of capital controls and the apparent increase in capital flows. His bivariate error correction model showed causation between Bovespa and foreign capital inflows.

It is worth mentioning that the performance of individual stock market among other factors depends on the various listed companies. The surge of the Brazilian economy is naturally reflected in the behaviour of the Bolsa de Valores do Estado de Sao Paulo (Bovespa). This is where more than 50 of the most important companies including Petrobras are listed. Petrobras was a public Brazilian energy company until 1997 when the call for its privatisation became intensified. The government subsequently scrapped its monopoly on oil-related activities, abandoned state control of the oil prices and opened the sector to competition thus ending its monopoly power over the exploitation of the country's oil and natural gas (Goldstein, 2010). Nonetheless, Petrobras still remains one of the giant listed companies in the stock market forming 8% of Bovespa's portfolio from May to August, 2013.

The rest of the paper is organized as follows; Section 2 presents the theoretical perspective and a brief literature review while section 3 outlines our methodology. We present the results and discussions of our empirical findings in section 4 while section 5 concludes the study.

2.0 Theory and Brief Overview of the Literature

This paper is based on the catastrophe theory of which can be applied to analyzing the relationships and workings of macroeconomic variables and stock markets. This theory, also called the theory of morphogenesis was propounded by Rene Thom in the 1960s and became popular in the 1970s following the first oil shock and its associated intellectual discourse. It is a mathematical method for describing and analysing the evolution of forms in nature. The catastrophe theory is concerned with the interactions between the short-run equilibria and the long-run dynamics. Explicitly, it studies the movements of short-run equilibria as the long-run variables evolve. In particular, it investigates events where gradual changing forces/factors produce sudden effects (Zeeman, 1977). Zeeman replicated and modified the theory into a more helpful shape and thus provided benchmark illustrations for further applications. A subset of the catastrophe theory is Thom's delay rule. At its very core, it identifies the period of a relationship breakdown and a sudden catastrophic change in a form of structural break. As a precondition for the workings of the delay rule, it is crucial to believe in the presence of various different relationships across time and for the relationship to completely break down, it is imperative to identify where the correlations fail. Critics (Croll, 1976; Sussmann & Zahler, 1978; Zahler & Sussmann, 1977) have argued that the catastrophe theory has not been a well-suited analytical tool and at its best only serves as a heuristic tool in forming a theory (Lorenz, 1993). Jakimowicz (2010:642) however contends that the limited original applications of this theory robbed it of its importance and that "economics experienced fascination and a drop in interest in the catastrophe theory."

Investigating on the possible impact of changes in oil prices on 18 equity markets, Ferson & Harvey (1995) found evidence of the ability of oil prices fluctuations in transmitting itself onto equity markets. While some equity markets were highly sensitive to oil price changes, others showed less responsiveness to such changes suggesting a divergence in how individual markets respond to changes in oil prices.

Arguing along the same line, Chen et. al. (1986) examine the impact of changes in oil prices on stock markets. They formed an oil price series of first differences in the logarithm of Producer Price Index/Crude Petroleum series. Their simulation results suggest that, oil price risk does not have a separate reward in the stock market. They therefore conclude that changes in oil prices have no effect or impact on asset prices. Consistent with earlier findings, Hamao (1989) applied the same approach to the Japanese data and his results were not different from Chen et. al.'s findings. Interestingly, Kaneko & Lee (1995) found a significant degree of responsiveness of Japanese stock returns to changes in oil prices. In particular, Kaneko & Lee singled out changes in oil prices as the most important factor influencing the Japanese stock returns. Evidently, this is in sharp contrast to earlier findings which they attribute to the methodological differences coupled with the dramatic changes in the country's economic development.

After employing vector autoregression (VAR) and examining the relationship between macroeconomic variables (including oil prices), Papapetrou's (2001) empirical findings suggest that oil prices are crucial in explaining stock price movement. This is consistent with Sbeiti & Hadadd (2011). By invoking multivariate cointegration and Granger causality tests, Sbeiti & Hadadd investigated the relationship between stock prices and main macroeconomic variables (including oil prices) of the Gulf Cooperation Council (GCC) markets. Their results revealed that oil prices, interest rate and domestic credit were cointegrated with equity markets and thus have a long-term equilibrium effects on the stock markets of four GCC. More importantly, with the exception of Bahrain, they found that causality runs from oil prices to the stock price index in oil rich Kuwait, Saudi Arabia and Oman. Results from both their generalized variance decomposition and the generalized impulse response functions underscored the significance of oil prices in explaining a significant portion of the forecast error variance of the index in the above-mentioned oil rich nations. Arouri et. al. (2008) used the same approach to investigate the international stock return linkages of 6 major Latin American emerging markets with the rest of the world.[16] Their results suggest a significant correlation between/among these countries. In particular, market interdependence is much stronger for Brazil, Argentina and Colombia. Results from their VECM showed a negative error correction term for all markets implying the existence of a stronger reversion to long-run equilibrium.

Using slightly different approaches, some studies have concentrated on investigating for any possible relationship between stock markets of two different countries. For instance, by employing cointegration test to analysing the interdependence of Bovespa and Istanbul Stock Exchange (ISE) for the period 29/12/1995 to 26/08/2005, Onay (2007) found no support for pairwise cointegration – indicating no long-run relationship between the two financial markets. His results thus suggest the presence of no common stochastic trend in these markets. Conversely, his causality test results showed that Bovespa granger causes ISE in a unidirectional order suggesting a short-run lead-lag relationship.

By respectively using the monthly and daily closing stock price series of Bovespa and ISE, Onay & Unal (2012) subsequently investigated the long-run financial integration and the bivariate extreme dependence between these markets. Their static cointegration results showed no evidence of long-run cointegration. This finding collaborates with Onay's (2007) earlier study. However, following the introduction of structural break into their model, Onay & Unal found that Bovespa and ISE were cointegrated in the aftermath of the Turkey crisis in 2000. Their dynamic cointegration and DCC-GARCH showed that equity prices in the two emerging markets can move together even in the absence of significant trade and financial linkages suggesting the existence of other underlying factors affecting equity prices other than trade, foreign direct investments, financial linkages and macroeconomic relations.

De Oliveira & De Medeiros (2009) provided a diagnostic analysis of equity markets by using data of 12 companies with greatest weight in Bovespa (with Petrobras having the highest weight). They examined the

[16] Their study covered Argentina, Brazil, Chile, Colombia, Mexico and Venezuela.

existence of lead-lag effects between Bovespa and New York Stock Exchange (NYSE) where the Dow Jones Industrial Average (DJIA) and Bovespa index were used as proxies for the performance of NYSE and Bovespa respectively. Cointegration as well as the existence of bidirectional causality was found between the markets. In particular, their econometric models revealed market segmentation and that changes in the returns of Bovespa index are largely accounted for by stock price variations in the Dow Jones index.

Basher & Sadorsky (2004) employed an international multi-factor model which allows for both conditional and unconditional risk factors in investigating the relationship between changes oil prices and stock markets returns of 21 emerging economies including Brazil. While noticing that oil prices do affect stock markets returns, Basher & Sadorsky argue that the overall impact on emerging market stock prices of changes in oil prices largely depend on whether or not the company in question in a net consumer or producer of oil. The logic is that, all things being equal, rising oil prices benefit oil producing companies while adversely affecting (via rising cost of production) companies using oil as a major input in production. This undoubtedly has crucial implications for Bovespa index where Petrobras is a giant listed oil company. As an oil producing company, it would be highly sensitive to adjustments in oil prices thus affecting the rest of the index. Further, given its market share, performance of Bovespa is heavily skewed towards the performance of Petrobras. It is noteworthy that, until recently Brazil became self-sufficient in oil production and subsequently a net exporter of oil. This undoubtedly has favourably impact on its economy following the recent increases in world demand for oil and its associated rising oil prices. However, empirical findings on the impact of oil price changes on stock prices have been mixed and inconclusive. Kilian (2009) criticizes earlier studies and argues that economists treat oil price shocks as exogenous and thus oil prices respond to other factors that also affect stock prices (Hamilton, 2005; Kilian, 2008).

Many studies (Sbeiti & Hadadd, 2011; Kwon & Shin, 1999; Maysami & Koh, 2000; Onay & Unal, 2012; Kurihara & Nezu, 2006; Faff & Brailsford, 1999) have used various techniques to investigate and analyse long-run relationships between or among macroeconomic variables and stock markets of developed, developing and emerging markets. Existence of a long-run relationship means that short-term variations away from equilibrium would revert to the long-run equilibrium according to the speed of adjustment and that the series will not drift away from each other. While most studies have concentrated on investigating inter-relationships of stock markets between or among countries, study on intra-relationship within a stock market in fast-growing emerging markets is almost non-existent.

None of these studies have investigated for an intra-relationship (between the stock market itself and a listed company) where the short and long-run elasticity/equilibrium is determined. In addition to bridging this gap in literature, the aim of this paper is to investigate the intra-relationship between our series using the error correction model (ECM) and Granger causality test by relying on time series data on Bovespa index and share price of Petrobras stock.

3.0 Data and Methodology

The data which was obtained from the School of Oriental and African Studies (SOAS) Datastream consists of 729 observations from 31 December 1997 to 14 December 2011 of weekly time series data on both the logarithm of Bovespa index (LBO) and the share price of Petrobras (LBAP) where Bovespa index is the main indicator of the Brazilian stock markets average performance. Because monthly data may not adequately capture short-term effects of capital adjustments hence the use of the weekly data. Below is the graphical representation of our time series variables (LBO and LBAP) in log levels.

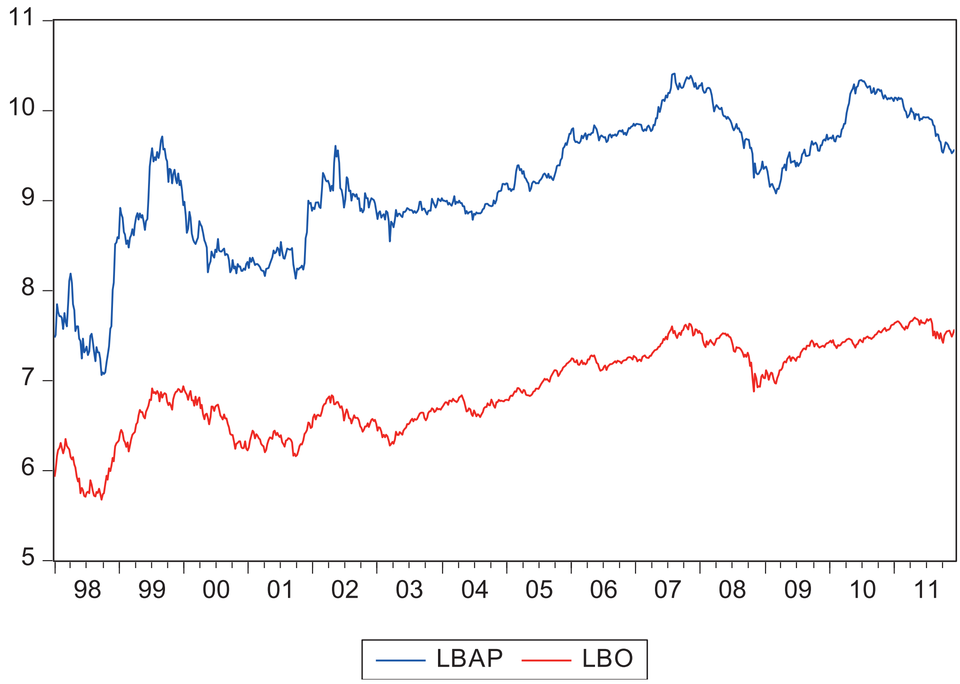

Figure 1: Graphical Representation of LBO and LBAP

Figure 1 above shows the line plot of LBO and LBAP. It is clear from the graph that, both series trend upwards (positive) albeit minor fluctuations that tend to smooth out overtime. Notably there are minor fluctuations around the trend except with the sharp falls in 1998 and 2008. These falls could be attributed to the high volatilities and contagion resulting from the Mexican crisis that spread across Latin American emerging markets and the global economic crisis respectively. The strong macroeconomic stabilization programmes undertaken by the Brazilian macroeconomic policymakers coupled with increases in both domestic and world demand for oil and other related energy products undoubtedly led to a rise in the share price of Petrobras as well as Bovespa stock price index. The graph suggests that the two time series are nonstationary and thus have unit roots. By nonstationarity, we mean the distribution of the time series variables change over time hence the mean, variance and covariance of each variable is time variant otherwise the series is stationary. Many economic time series are nonstationary causing misleading results in the traditional ordinary least square (OLS) estimators. In stationarity, the use of graphs and correlograms could be deceptive and this calls for more formal tests of the order of integration. The purpose for this stationarity tests therefore is to determine the order of integration of each variable (LBO and LBAP).

3.1 Formal Unit Root Tests

We performed Phillips-Perron test for unit root in the series. This is necessary in examining the order of integration because cointegration between nonstationary series requires both series to be of the same order of integration.

3.2 Phillips-Perron (1988) Test

The Phillips-Perron (PP) test which uses nonparametric methods, as a consequence, suffers less from distributional problems and also adjusts for the serial correlation as well the endogeneity of the regressors hence avoiding the loss of observations implied by the traditional augmented Dickey-Fuller (ADF) test. Further, the PP test is consistent even in the presence of heteroskedastic error terms (Hamilton, 1994). This test differs from the traditional ADF tests mainly in how they deal with serial correlation and heteroskedasticity in the errors. The distribution of the ADF test assumes that the error terms are homoskedastic and independent statistically (Asteriou & Hall, 2011). This assumption is rather strong. We thus use the PP test which has relatively less restrictive assumption regarding the distribution of the error terms. In particular, it corrects for any serial correlation and heteroskedasticity in the errors terms of the regression by directly modifying the t (= τ) test statistic. This is the main rationale for the use of this test. Two (2) set of regressions were ran. We first estimate the regression with an intercept and no trend. To investigate for possible change in unit root results, we estimated a second regression with an intercept and a trend. This was done for each series. The regression equations estimated followed the form;

$$\Delta LBO_t = \varphi_0 + \delta LBO_{t-1} + \varepsilon_t \quad (1a)$$
$$\Delta LBO_t = \varphi_0 + \delta LBO_{t-1} + \varphi_2 t + \varepsilon_t \quad (1b)$$
$$\Delta LBAP_t = \varphi_0 + \delta LBAP_{t-1} + \varepsilon_t \quad (2a)$$
$$\Delta LBAP_t = \varphi_0 + \delta LBAP_{t-1} + \varphi_2 t + \varepsilon_t \quad (2b)$$

where φ_0 are constant; φ_2 are the coefficients of the time trend, δ are coefficients of the autoregressive process while ε_t are the error terms.

The unit root is performed under the;
Null hypothesis, H_o: δ = 0 [The series has a unit root]
Alternative hypothesis, H_1: δ < 0 [The series has no unit root]

We reject H_o if the computed PP test statistic is less than the critical t (= τ) value otherwise we do not reject H_o. The series is stationary (no unit root) if we reject H_o and nonstationary (existence of unit root) if we fail to reject H_o.

3.3 Cointegration and Error Correction Model (ECM)

After establishing that our series are I(1), Kremers et. al. (1992) proposed the use of MacKinnon critical values for the ECM t test when the series are individually I(1) process. Thus, under the null hypothesis (H_o) that the series are not cointegrated, the ECM t test together with the MacKinnon's critical values performs better than the Dickey-Fuller (DF) t test (De Boef & Granato, 1999). In this light, we use the ECM t test for cointegration and our model estimated takes the form;

$$\Delta LBAP_t = \partial + \Phi \Delta LBO_t + \lambda(LBAP_{t-1} - LBO_{t-1}) + \varepsilon_t \quad (3)$$

The distance between $LBAP_{t-1}$ and LBO_{t-1}in equation (3) would be irrelevant in determining the nature of change in LBAP if its coefficient (that is the error correction rate) $\lambda = 0$, implying no error correction and therefore no cointegration. Thus testing H_o of no cointegration and testing H_o that $\lambda = 0$ are two sides of the same coin.

The existence of cointegration shows a long-run relationship or equilibrium between economic variables (Gujarati & Porter, 2009). In other words, our time series variables are said to be cointegrated if the linear combination of LBO_t and $LBAP_t$ is stationary yet considered in isolation, each variable is integrated of order one [That is, $\{LBO_t, LBAP_t\} \sim I(1)$] (Asteriou & Hall, 2011). The aim of this is to identify stationary linear combinations between our nonstationary variables such that the I(1) series can be remodelled in stationary variables. In this quest, we invoke the error correction model (ECM). This approach is based on running OLS regression where the choice of the regressor or regresand is not of much relevance (Engle & Granger, 1987). To this end, we estimate the regression;

$$LBAP_t = \beta_1 + \beta_2 LBO_t + e_t \quad (4)$$

but $\hat{e}_{t-1} = LBAP_{t-1} - \hat{\beta}_1 - \hat{\beta}_2 LBO_{t-1}$

where β_2 is the long-run elasticity. To ensure that this regression model is not spurious, we difference the series and following the Granger representation theorem, we express a general autoregressive distributed lag (ARDL) ECM of the form;

$$\Delta LBAP = \lambda_0 + \alpha_1 \Delta LBO_t + \sum_{i=1}^{p} \beta_i \Delta LBAP_{t-i} + \sum_{i=1}^{p-1} \gamma_i \Delta LBO_{t-i} - \pi EC_{t-1} + \varepsilon_t \quad (5)$$

where ε_t is white noise and π is the coefficient of the error correction term which measures the speed of adjustment or the feedback effect while $\alpha_1$is the short-run elasticity.

After establishing a relationship/correlation between the two variables, we proceeded to test the causality of these variables since correlation does not necessary imply causality. This was done by employing the Granger causality test.

3.4 Granger Causality Test

Causality is an important concept in econometric analysis and refers to the ability of one variable to predict or cause the other. Granger (1969) developed a test to help determine this causal relation. According to Granger, Y causes X if the past values of Y can be used to predict X more accurately than simply using the past values X. Intuitively, we test for the ability of LBO to predict or Granger cause LBAP or vice versa. In doing this, we estimated the Granger causality equations below;

$$LBAP_t = \sum_{i=1}^{n} \lambda_i LBAP_{t-i} + \sum_{j=1}^{m} \delta_j LBO_{t-j} + u_{1t} \quad (6)$$

$$LBO_t = \sum_{i=1}^{n} \alpha_i LBAP_{t-i} + \sum_{j=1}^{m} \beta_j LBO_{t-j} + u_{2t} \quad (7)$$

where m and n are the number of lagged LBO and LBAP terms respectively. u_{1t} and u_{2t} are random errors ~ N (0, σ^2). Equation (6) postulates that current LBAP is related to past values of itself as well as that of LBO and equation (7) also postulates similar behaviour for LBO.

$$From\ equations\ (6)\ and\ (7), our\ H_o: \sum_{j=1}^{m} \delta_j = 0\ and\ H_0: \sum_{i=1}^{n} \alpha_i = 0\ respectively.$$

We reject the H_o if the computed $F^* > F^{m}_{n-k}$ (k is the number of parameters estimated in equations (6) and (7)) otherwise we do not reject H_o.

4.0 Empirical Results and Discussions

4.1 Unit Root Test Results

Table 1: PP Unit Root Test Results for LBO

Equation 1a: $\Delta LBO_t = \varphi_0 + \delta LBO_{t-1} + \varepsilon_t$ **Null Hypothesis: D(LBO) has a unit root**

		1% critical value	-3.439105
PP test statistic	**-1.730498**	5% critical value	-2.865294
		10% critical value	-2.568825

Variable	Coefficient	Std. Error	t-Statistic	Prob
LBO(-1)	**-0.005494**	**0.003263**	**-1.683611**	**0.0927**
Constant	**0.040126**	**0.022584**	**1.776759**	**0.0760**

Equation 1b: $\Delta LBO_t = \varphi_0 + \delta LBO_{t-1} + \varphi_2 t + \varepsilon_t$ **Null Hypothesis: D(LBO) has a unit root**

		1% critical value	-3.970708
PP test statistic	**-2.984647**	5% critical value	-3.416001
		10% critical value	-3.130278

Variable	Coefficient	Std. Error	t-Statistic	Prob
LBO(-1)	**-0.019385**	**0.007186**	**-2.697606**	**0.0071**
Constant	**0.122858**	**0.044310**	**2.772714**	**0.0057**
@TREND(12/31/1997)	**3.61E -05**	**1.67E -05**	**2.168236**	**0.0305**

Table 2: PP Unit Root Test Results for LBAP

Equation 2a: $\Delta LBAP_t = \varphi_0 + \delta LBAP_{t-1} + \varepsilon_t$ **Null Hypothesis: D(LBAP) has a unit root**

		1% critical value	-3.439105
PP test statistic	**-2.420537**	5% critical value	-2.865294
		10% critical value	-2.568825

Variable	Coefficient	Std. Error	t-Statistic	Prob
LBAP(-1)	**-0.009273**	**0.003920**	**-2.365400**	**0.0183**
Constant	**0.088141**	**0.036166**	**2.437122**	**0.0150**

Equation 2b: $\Delta LBAP_t = \varphi_0 + \delta LBAP_{t-1} + \varphi_2 t + \varepsilon_t$ **Null Hypothesis: D(LBAP) has a unit root**

		1% critical value	-3.970708
PP test statistic	**-2.803439**	5% critical value	-3.416001
		10% critical value	-3.130278

Variable	Coefficient	Std. Error	t-Statistic	Prob
LBAP(-1)	**-0.017243**	**0.006850**	**-2.517237**	**0.0120**
Constant	**0.149151**	**0.056181**	**2.654841**	**0.0081**
@TREND(12/31/1997)	**3.37E -05**	**2.38E -05**	**1.418407**	**0.1565**

From Tables 1 and 2, the pre-condition of the series being integrated of the same order is verified with the PP tests. Each variable is first tested with a constant and no trend followed by a constant and a trend. The appropriate number of lags is picked according to the modified Akaike Information Criterion (MAIC) and the critical values are obtained from MacKinnon (1990) one-sided p-values. For all series the presence of a unit root cannot be rejected at any reasonable level of significance - indicating that all the series are integrated of order one, I(1). Having shown that the series are I(1), the next logical step is the test of cointegration using the ECM t test.

Table 3: ECM t Test
Dependent Variable: D(LBAP)
Null hypothesis: Series are not cointegrated

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.010881	0.036408	0.298867	0.7651
D(LBO)	0.841429	0.058980	14.26641	0.0000
LBAP(-1)-LBO(-1)	-0.038654	0.010411	-3.712894	0.0002

From Table 3, our null hypothesis of no cointegration is clearly rejected at -3.23 MacKinnon critical value. Thus the coefficient of the distance between LBAP(-1) and LBO(-1) is statistically different from zero – implying cointegration between the series. This proves the existence of a long-run relationship between LBAP and LBO. Having shown that the series are in fact cointegrated, we present our bivariate ARDL ECM analysis first by running an OLS estimation of LBAP on LBO.

Table 4: OLS Estimation of LBO on LBAP

Equation (4): $\boldsymbol{LBAP_t = \beta_1 + \beta_2 LBO_t + e_t}$

Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob**
Constant	**-0.542574**	**0.128132**	**-4.234484**	**0.0000**
LBO	**1.410701**	**0.018512**	**76.20409**	**0.0000**
R^2	**0.888737**			
Adjusted R^2	**0.888584**			

Table 4 above depicts the case where LBAP is the independent variable while LBO is the dependent variable. From the Table, it is clear that the coefficient of LBO is 1.410701. Since the variables are in logs, their coefficients are the long-run elasticities. This implies that, the degree of responsiveness of LBAP to changes in LBO is 1.411. Thus, the (log) share price of Petrobras is increased by 1.411% if the (log) Bovespa stock index is increased by 1%. This clearly shows an elastic elasticity. After adjusting for the degrees of freedom, the results suggest that, about 89% of the variation in LBAP is explained by variations in LBO ceteris paribus.

From Table 4, the coefficient of LBO (1.41071) is the long run elasticity. The residuals from the long-run estimates in equation (4) are used as the error correction (EC) term that explains the short-run dynamics. ECM was established in order to investigate the adjustment of variables acting together towards attaining long-run equilibrium. Results from the ECM are presented in Table 5.

4.2 Error Correction Model (ECM)

Table 5: Error Correction Representation of the Autoregressive Distributed Lag (ARDL) Model

Equation 5: $\Delta LBAP = \lambda_0 + \alpha_1 \Delta LBO_t + \sum_{i=1}^{p} \beta_i \Delta LBAP_{t-i} + \sum_{i=1}^{p-1} \gamma_i \Delta LBO_{t-i} - \pi EC_{t-1} + \varepsilon_t$

Variable	Coefficient	Std. Error	t-Statistic	Prob
Constant	0.000392	0.002494	0.157283	0.8751
D(LBO)	0.823337	0.058852	13.98989	0.0000
D(LBO(-1))	0.190113	0.066546	2.856859	0.0044
D(LBO(-2))	-0.079497	0.066471	-1.195968	0.2321
D(LBAP(-1))	-0.026941	0.037138	-0.725442	0.4684
D(LBAP(-2))	0.116564	0.036753	3.171514	0.0016
EC_{t-1}	-0.038287	0.010508	-3.643537	0.0003

Our results from Table 5 suggest that the series are cointegrated with -0.038287 as the speed of adjustment and a short-run elasticity of 0.824304. As cointegration theory suggests, the presence of a cointegration relation implies that LBAP and LBO do share long-run equilibrium from which short-term divergence can be forecasted and to which the series will eventually converge to long-run equilibrium. Consistent with priori, the coefficient of the EC term (EC_{t-1}) which measures the speed of adjustment or the feedback effect is negative and statistically significant (at any level of significance) towards attaining the long-run equilibrium resulting from a shock to the stock market. During periods of negative shock and disequilibrium to the system, LBO_t increases less rapidly than is consistent with equation (4) thus moving LBO_{t-1} below its long-run steady-state path. Because of the negativity of π, the total effect/impact is to revert ΔLBO_t back to its long-run trajectory as determined by $LBAP_t$ in equation (4). Our results collaborate with Lee et al.'s (2010) empirical findings. Their results suggest that stock prices will eventually return to their original equilibrium resulting from major structural changes in the financial market. Evidently, our empirical results reveal that following a drift away from the long-run equilibrium in previous period, convergence to the equilibrium is corrected by 3.8%. In other words, approximately 3.8% of the error is corrected every week in the event of a system shock.

4.3 Granger Causality Test

Table 6: Pairwise Granger Causality Tests

Null Hypothesis:	F-Statistic	Prob.
LBO does not Granger Cause LBAP	7.33299*	9.E-06
LBAP does not Granger Cause LBO	1.82567	0.1220

*Significant at 5% level of significance. ($F_{critical} = 2.37$)

The computed F* test statistic is compared with the critical value of 2.37 at 5% significance level. The H_0 that $\delta_j = 0$ from equation (6) is rejected in favour of δ_j being statistically different from zero. This implies that LBO granger cause LBAP. Conversely, the H_0 that $\alpha_i = 0$ from equation (7) cannot be rejected implying that the coefficient of the lagged LBAP in equation (7) is insignificant and thus not statistically different from zero. Our test results therefore show the existence of unidirectional causality running from LBO to LBAP suggesting a short-run lead-lag relationship. The share price of Petrobras is thus sensitive to changes in Bovespa index. In particular, changes in Bovespa index could be used to predict the past share price of Petrobras at least for the period under review. Our finding is consistent with Bashar (2006) who analysed the effect of changes in oil prices on GCC stock markets. His results show that only Saudi Arabia and Oman markets have predictive power of oil price changes. Our result is unsurprising given the proliferation of other oil producing companies comprising of greater weights in the index. The inability of the Petrobras to predict or cause changes in Bovespa index could also be seen from the weak speed of adjustment as it can only correct about 3.8% convergence to equilibrium following a shock to the stock market.

5.0 Conclusion

While empirical findings have been mixed and inconclusive, many studies that tend to investigate the cointegration and causality of equity markets have concentrated on inter-relationships between or among developed, developing or emerging markets and studies on intra-relationship is almost non-existent. This study analysed the causal relationship between the log share price of Petrobras (LBAP) and the log of Bovespa index (LBO) as well as investigating the cointegration relationship between the series. It is noteworthy that, cointegration test seeks to test for any long-term relationship or equilibrium between the variables while Granger causality tests for the presence of short-term causal relation of LBO and LBAP. Our results suggest that the series are cointegrated and thus have a long-run relationship. In particular, in the event of long-run disequilibrium in previous period following a shock to the index, about 3.8% of such divergence is corrected each week by changes in the share price of Petrobras.

Our findings also show a unidirectional causality from Bovespa index to share price of Petrobras suggesting the predictive power of former. In particular, our results show that investors and financial analysts could use the past values of Bovespa index to predict movements in the share price of Petrobras. Although this dynamic is obvious based on our findings, it is imperative to note that the value of assets or portfolios forming Bovespa is not only contingent on the movements of the index. Individual oil producing companies may not be significant enough to trigger any change in Bovespa index. However, the collective effect of all these individual companies may be gargantuan and thus could granger cause or predict past values of the index. In addition, the feedback or reactions of forward looking investors to new information or news bulletins typically drives movements in assets prices. Such influence also depends on the informational efficiency and the speed with which such news is reflected in the asset prices. This is basically what the weak form efficient market hypothesis (EMH) preaches.[17] The weak form test of EMH has to do with whether or not security prices fully reflect historical price or past information. News by definition is impulsive and the resultant changes in price may be unpredictable. In other words, prices follow a random walk. According to Malkiel (1985:194), “a blindfolded monkey throwing darts at a newspaper’s financial pages could select a portfolio that would do just as well as one carefully selected by experts.” The rationale being that even a naive investor buying a diversified portfolio at the stock market prevailing prices will earn a rate of return as generous as that earned by the experts. It is argued that security prices adjust even before an investor gets time to trade and earn a profit from any new information. Thus, prices are said to be unpredictable when they follow this direction. Results from our causality test however show the predictive power of Bovespa index over the share price of Petrobras. This is in sharp contrast to the EMH. This could be due to the restrictive assumptions underlying the EMH. Among others, it assumes that securities markets are extremely efficient in reflecting information about individual stocks as well as the stock market at large and that a market is said to be efficient if its stock prices fully reflect all available information. Thus when information arises, the news spreads very quickly hence incorporated into the prices of securities without any hesitation. Thus, neither the technical analysis involving the study of prices of past stock in an attempt to predict future prices, nor the fundamental analysis involving the cross examination of financial information such as company earnings or asset values would help an investor achieve returns greater than those that could be earned by holding a randomly selected portfolio of individual stocks. Investors may over-react to news thus making the stock market too noisy thereby increasing market volatility. As a consequence, stock prices in emerging markets drift away from their fundamentals at least for some period of time. As stock prices behave this way, it fails to reflect all the available information in the market.

Brennan and Cao (1997) note that foreign investors’ valuations and reactions to favourable news in the home market typically outweigh that of domestic investors. The logic is that domestic investors naturally have exact information and might have received the available market news earlier than their foreign counterparts. As a

[17] See Fama (1970) and Malkiel (1985) for an in-depth analysis of EMH.

consequence, foreign investors end up buying domestic stocks at higher prices and domestic investors are left with holding fewer domestic shares thus becoming well diversified and may even accept lower expected returns. It then follows that domestic stock prices initially rise and later revert overtime as the increase in investors' base puts a downward pressure on the expected returns. For example, an increase in oil price in the international market may not fully reflect the same proportion or reaction in the local market because of "informational rigidities or inefficiencies" and localization of oil firms coupled with their associated alternative fuels in emerging market economies.

Our result is consistent with Lee et al. (2010). Their empirical evidence shows that stock prices are not characterized by the EMH hence revealing the presence of profitable arbitrage opportunities among stock markets when real stock price indices are rigorously pursued. Simulation from our graphical representation of LBO and LBAP shows that movements of these variables are extremely similar. In addition to further findings, we conclude that Bovespa significantly influence or affect the share price of Petrobras. It is therefore crucial for financial analysts and investors to pay much attention to movements in Bovespa index when investing (or analyzing changes) in Petrobras.

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