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Causality in quantiles between crude oil prices and Latin American stock market

BY

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Abstract

This study analyzes the influence of international crude oil price (West Texas Intermediate - WTI) over Latin American stock markets namely Argentina, Brazil, Chile, Colombia, Ecuador, Mexico and Peru under two perspectives: the dynamic linear and nonlinear models of Granger causality. The analysis period comprised 68 months of daily WTI and stock markets price returns in Latin American, over the period between May 1st, 2015 and January 15th, 2021. The results for the linear model of Granger causality showed, overall, no causality for Argentina, Chile, and Ecuador with WTI, but it was detected for Brazil, Colombia, Mexico and Peru. On the other hand, using the nonlinear model of Granger causality in quantiles, the results showed causality in all quantile intervals in Latin American stock markets, except for Colombia and Mexico at the extreme upper interval. Thus, the dynamic nonlinear method of Granger causality in quantiles showed a better approach to analyze two different markets in a time series, verifying its contemporary behavior, divided by quantile intervals within the analysis.

Key-words: Oil prices; Latin American stock markets; Granger causality. Causality in quantiles.

1. INTRODUCTION

This study examines the causal dynamic between WTI price shocks and Latin American stock markets through quantile regression (see Bassett and Koenker, 1982). Oil represents a major resource around the world and their prices may impact, negatively and positively, the company's stock prices, observing local differences in each region based on production and refining of this commodity (Jiang et al., 2020).

In some cases, oil refining does not keep up with the demand of growing countries, which is sustained by commodity imports (IEA, 2019). Marczak (2017) says that Latin America represents the most important emerging markets free trade partner to the US exports than any other region in the world; which means, an interesting market to study.

Identifying the intrinsic relationship between oil price shocks and major index stock prices is the essence of this study, not only the impact of rising and falling oil price returns, but using Granger non-causality test, several advantages are obtained, such as different scales and locations of conditional distribution, great scope of dynamic causal relationship - which also decreases the presence of heterogeneity, a common feature in financial time series – and its cause in regards to the significant information loss about the true relationship of variables, unless multiple levels of quantiles are investigated.

Testing the quantile causality approach can better ascertain the effects of asymmetric causality. Studying oil price shocks and stock market indexes, the low activity of the market will be represented by lower quantile intervals; stability by the normal market phase (middle quantiles), and the upper quantile intervals capture the bull-phase of the market.

There are some papers that study the impact of oil price shocks on stock markets around the world (Tchatoka, 2019; Kushwah and Siddiqui, 2020; Muritala et al., 2020; Ni et al., 2020; Wu et al., 2020; Mokni, 2020; Gonzales et al., 2020; Salisu and Gupta, 2020 and Anand and Sunil, 2021), but Latin America shows minority in these studies, such as Adrangi et al. (2020), Naeem et al. (2020) and Ferreira et al. (2020). However, causality in quantiles and

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dynamic relations between oil prices and stock market are found in recent studies such as Kiritsis and Andersson (2019), Albulescu et al. (2020), Bhatia and Basu (2020), Guangping and Xiaoxing (2020), Xiao and Wang (2020), Bal and Dash (2020) and Wang et al. (2020), but to the best of our knowledge, no such study has been found specifically for the Latin American market with these characteristics.

Companies' production costs can be affected by an increase in the costs of inputs for oil production factors, because there is no complete substitution among oil production factors, and it may cause an increase in food prices and perhaps an increase in domestic inflation (Jiang et al., 2020). Because of this, any oscillation in oil prices can have a considerable influence on economic activities such as employment, investment, and stock market return (Bhatia and Basu, 2020); hereby, it is an important issue which needs to be thoroughly studied among researchers, investors, and policymakers for a long time (Guangping and Xiaoxing, 2020).

It is important to study the relationship between crude oil prices and the Latin American stock market because the region contains the second largest oil reserves in the world and some of these countries display the biggest oil reserve in the world, such as Venezuela (303 billion barrels of crude oil reserves). Although Venezuela has a huge oil reserve, is not the one with the highest oil production in Latin American: Brazil ranked the first country in terms of petroleum production, followed by Mexico in second and Venezuela in third (STATISTA, 2019).

The commodity and financial markets have become interconnected unprecedently, requiring more study about the relationships in these markets. In addition, commodity markets and the investors have undergone an increasing flow of investments, producing liquidity for both markets (Tiwari et al., 2020). Due to Venezuela's high inflation rate in recent years, reaching 350.000% in 2019 (TRADING ECONOMICS, 2021), the authors decided to keep it out from the analysis.

For developing markets – such as Latin America – food prices, consumer price indexes, and inflation can be affected by oil price shocks, because the domestic fuel prices, especially the diesel, are immediately linked to oil prices and may lead to an increase in the food supply chain since the delivery logistics is carried out by delivery trucks (Zingbagba et al., 2020). In Brazil, for example, road freight transport represents 60% of the bulk cargo handling matrix, and diesel is the main fuel source for buses, trucks, and agricultural machines (Péra and Caixeta-filho, 2018).

The annual average WTI wavered from US$ 30.26 in 2000 to US$ 99.98 in 2013 and its actual price, based in January 2021 (STATISTA, 2021), is US$ 52.00. Latin American stock market evolution of domestic markets (as share of GDP) is led by Chile, followed by Brazil, Colombia, Mexico, and Peru with similar figures; Argentina showed the lowest ratio (OECD, 2019). This paper is divided into 5 sections: Chapter 1 is the introduction, Chapter 2 brings the literature review, Chapter 3 deals with the econometric methodology and Chapter 4 with data and empirical analysis, and finally, the conclusions will be presented in Chapter 5.

2. LITERATURE REVIEW

The problem with predicting the oil prices is defining the expression of values of the series, whether in nominal or real terms, which periods to evaluate, and which econometric methods for their evaluation. The topic of causality has been studied in the areas of finance, macroeconomics, and other sciences.

Our research is based on the causality and dynamic between crude oil prices and the Latin American stock market using the quantile regression and tests of null hypothesis of Granger non-causality in quantile intervals, that is the conditional quantiles of the employed energy prices.

Turhan, Sensoy & Hacihasanoglu (2014) says that oil is seen as an important indicator of movements in the exchange rate and in the capital market because higher oil prices reduce the wealth of oil-importing nations by transferring their revenue to oil-exporting nations through trade balance. Therefore, researching the relationship between the oil market and the stock market is relevant for asset allocation and portfolio risk management, as investors make their decisions based on information available in both markets. Smyth and Narayan (2018) declare that one of the reasons for favorable association between oil prices and stock market is that investors may associate increasing in oil prices returns with a booming economy.

Inside the relationship between crude oil and stock market, Mokni (2020) shows a dynamic quantile regression study between oil price and stock markets in oil-importing and oil-exporting countries, where the stock market is more affected by negative oil price shocks. Lin and Su (2020) found that oil-importing countries are more sensitive than oil-exporting countries between oil market uncertainty and the Islamic stock market. For BRICS (Brazil, Russia, India, China, and South Africa) stock market, the effect of oil price shocks is stronger under extreme circumstances than under normal ones, that is, it allows for disaggregated data into different cumulative components and analyzes the causal dynamic between positive and negative extreme shock arrangements (Wang, 2020). Gong, Bu, and Chen (2020) investigate the impacts of economic factors in the United States market and found dependence of oil and the stock market, more specific about negative news from the stock market and the impact of aggregate oil demand.

For Asian leading oil-importing and oil-exporting countries, oil prices are interconnected with them; besides, the oil-exporting countries show stronger relationships than oil-importing countries (Ashfaq et al., 2020). However, Turkey´s stock market reveals negative impact when the oil prices go up, but it stabilizes in the long term (Polat, 2020). For Mishra et al. (2019), it is found that fluctuations in oil prices may have a positive effect on the Islamic stock index in the short term, but on reaching stability, oil prices have a negative influence on the Islamic stock market.

Xiao and Wang (2020) investigate two crude oil, WTI and Europe Brent, upon eight stock indexes countries - Dow Jones Industrial

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Average (DJIA) for the U.S., BOVESPA for Brazil, the CAC40 for France, DAX for Germany, FTSE100 for United Kingdom, the S&P/TSX for Canada, Nikkei 225 for Japan and the SSE for China. They found dynamic information flows into these markets in bidirectional terms of significance and magnitude, in some cases, quite asymmetric.

For the China stock market and international oil market, a strong bidirectional linear and non-linear spillover effect was found, and nonlinear bidirectional Granger causality also in short, medium, and long markets (Peng et al., 2020). Also, Troster et al. (2018) found unidirectional causality in Granger-causality quantile analysis from fluctuations in oil prices to economic growth in the U.S. at the extreme quantiles of the distribution series, and nonlinear Granger causality indicates a bidirectional relationship between oil prices and India stock market return (Bal and Dsah, 2020).

For the Indian market, Kumar (2019) found strong evidence of a bidirectional nonlinear relation between oil price and stock market, where, in previous months, positive and negative shocks on oil prices have negative significant impact on stock prices.

The effects of oil price on the Chinese investors' sentiment are – in most of the cases – significantly negative, with a non-linear Granger causality relationship (He, 2020). The results for another study of He et al. (2019) with the same characteristics reveal a bidirectional nonlinear Granger causality, rather than a linear Granger causality. Brazilian stock market and oil price were significantly correlated in a shorter time scale but – in the long run – no significant impact was observed (Ferreira et al., 2020).

Another study for the Ghana stock market and oil prices shows that the relationship between those markets depends, especially, whether the oil price is exogenous or endogenous (Zankawah and Stewart, 2020). However, the Islamic stock market is impacted by oil prices just under the long-term and bullish market conditions (Godil et al., 2020). The Qatar market and the oil market are significantly correlated but it was evident that the 2008 global financial crisis showed stronger impact than the oil price shocks (Benlagha, 2020).

For Wu et al. (2020) the price of crude oil is the most relevant information of stock markets interdependence, whether these stock markets belong to oil-importing or oil-exporting countries. Su et al. (2020) investigate the factors driving oil price in the United States and found out that local currency affects oil price more than political conflicts that have an important impact, under negative and positive perspectives. For the Pakistan market, oil prices impact positively on the financial market; it means that the booming oil market is a sign of economic activity and growth, being beneficial to the financial sector (Atil et al., 2020).

Using the standard linear Granger causality test to analyze the oil price shocks in predicting volatility jumps in the S&P500, no evidence was found, but it changed for nonparametric causality-in-quantiles test, upon the whole distribution of the series, where evidence of volatility jumps has been verified (Gkillas et al., 2020). Jiang et al. (2020) applied quantile-on-quantile and causality-in-quantiles to verify the effects of oil shocks on exchange rates for developed and developing countries, and the results show causality relationship for developed currency countries in all the entire quantiles, but for developing currency countries, he only applied it at first and second moment causal flows for the quantile analysis.

Tchatoka (2019) extended the quantile-on-quantile (QQ) regression model to fit the relationship between oil price shocks on the stock market return for the US stock market and 15 oil importing and exporting nations. The results show that large negative oil price shocks increase stock returns when markets are performing well (only supported by major oil importers as China, Japan, and India) and large positive oil price shocks generally demonstrate higher stock returns when markets perform well for oil exporting countries (Canada, Russia, Norway) and moderately oil-dependent countries (such as Malaysia, Philippines, and Thailand).

However, Hamilton (2009) proposes that oil prices have a different impact on the shocks exchange markets, due to the fact that fluctuations in oil supply and demand shocks affect aggregate shocks returns. Lin and Su (2020) find negative linkage between oil market uncertainty and the Islamic stock market, and the relationship between those markets does have heterogeneity as well as asymmetry.

Finally, Anand and Sunil (2021) examined the Indian context; results indicate that expected oil price shocks affect corporate stock returns and volatility. The impact of global oil price shocks on the Lebanese stock market shows that there is evidence of oil prices Granger- causing stock prices but not vice versa, and the behaviour of the shocks happened on the same day and the day after, disappearing thereafter (Dagher and Hairiri, 2013).

3. ECONOMETRIC METHODOLOGY

Quantile regression presents a complete picture that provides information about the relationship between the *y* outcome and the *x* regressors at different points in the conditional distribution of *y*, compared to Ordinary Least Squares (OLS) regression that summarizes the mean relationship between the outcome variable of interest and a set of regressors, based on the conditional average function $E(y|x)$. The quantile regression demonstrates the relationship between *Y* and *X* across all quantiles of the conditional distribution of *Y*. Starting from the classic linear model:

$$Y_t = \theta' X_t + u_t, t = 1,\cdots,n.$$

where X_t are vectors of regressors, containing a constant, and u_t are i.i.d mean zero errors and are independent of X_t. The regression above can be loaded according to the following optimization problem:

$$\hat{\theta} = \underset{\theta}{min} \sum_{t=1}^{n} \rho\,(Y_t - \theta' X_t), \qquad (1)$$

where $\rho\,(\cdot)$ is a criterion (loss) function.

We apply the quantile regression model to explore the dependence between oil price changes and the Latin America stock market returns. The information provided by the quantile regression goes beyond the relationship in terms of mean, and it is a significant

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approach to the statistical analysis of linear and nonlinear response models. The quantile regression estimator is less sensitive to the presence of outliers, asymmetry, and heterogeneity in the variable response. This method assumes that the value of εi conditional on the regressors in $\tau - th$ quantile is zero.

In this study, we considered several statistical tests, focused on non-linearity in the procedures of generating the data series. To check normal distribution and stationarity to the series it was used ADF, DF-GLS, Union test (union root test), and KPSS test for all samples.

From the time series, logarithmic differences in prices (log-returns) were calculated in order to correct non-stationarity, common in series of this type, the log-return is obtained by the formula (2):

$$r_t = \ln(P_t) - \ln(P_{t-1}) \qquad (2)$$

where P_t and P_{t-1}, represent the original prices of the closing of the indexes of the stock exchanges under analysis and the closing prices of crude oil, at moments t and $t-1$.

Testing the causal relationship between two stationary time series, Y_t and X_t, is the pioneering interpretation of Granger (1969), where $(Y,X)_{t-1}$ is the information grouping originated by Y_t and X_t, up to time t – 1. According to the author, the random variable x does not Granger-cause the random variable y if the equation (3) below is valid:

$$F_{yt}(\eta|(Y,X)_{t-1}) = F_{yt}(\eta|Y_{t-1}), \quad \forall\eta \in \mathbb{R} \qquad (3)$$

where $F_{Yt}(\cdot|\mathcal{F})$ is the conditional distribution of y_t, denoting $\mathcal{F}$ as the grouping of information available at time $t-1$ and $(Y,X)_{t-1}$ indicates the set of information created by yt up to time $t-1$. Granger Causality requests that the previous information of x not modify the conditional distribution of yt. The variable x is referred to as Granger-causing y when formula (3) breaks down to preserve itself.

In turn, to consider the null hypothesis of non-Granger causality in mean instead of equation (3), the conditional will be applied using the conditional expectation given by equation (4).

$$\mathbb{E}(y_t|(Y,X)_{t-1}) = \mathbb{E}_{Yt}(y_t|Y_{t-1}) \qquad (4)$$

Where $\mathbb{E}(y_t|\mathcal{F})$ is the mean of $F_{Yt}(\cdot|\cdot)$. At this point, it can be said that x_t does not Granger-cause y_t in mean if the condition (4) is maintained, otherwise, Granger-cause y_t in mean.

In this study, we follow the bivariate autoregressive model for the Granger test causality between two stationary time series, with their proper names label, stock exchange returns (r_stock_t) and oil price returns (r_oil_t), as can be seen in the equations (5) and (6).

$$r\_stock_t = \alpha_0 + \sum_{i=1}^{p_1} \emptyset_i r\_stock_{t-1} + \sum_{i=1}^{p_1} \varphi_i r\_oil_{t-1} + \varepsilon_t \quad (5)$$

$$r\_oil_t = \alpha_0 + \sum_{i=1}^{p_2} \alpha_i r\_oil_{t-1} + \sum_{i=1}^{p_2} \beta_i r\_stock_{t-1} + \varepsilon_t \quad (6)$$

where the vector of random errors is $\epsilon_t = (\varepsilon\_oil_t, \varepsilon\_stock_t)$.

The Wald test is used to guide the Granger non-causality test, and the Akaike Information Criterion (AIC) shows the ideal lag of order. Rejecting the null hypothesis of non-Granger causality in mean brings about the lagged values of r_oil_t affect r_stock_t, and therefore, can explain that there is a causal link between oil price returns and the stock exchange prices. In order to locate a more sensitive causal relationship that clarifies the different quantiles of the study, the novel non-causality test in quantiles will be conducted, as shows the equation (6).

$$Q_{Yt}(\tau|(Y,X)_{t-1}) = Q_{Yt}(\tau|Y_{t-1}), \ \forall\tau \in [a,b] \qquad (7)$$

where $Q_{Yt}(\tau|\mathcal{F})$ indicates the τ-th quantile $F_{Yt}(.|\mathcal{F})$. If the equation (7) holds [a, b], x_t does not Grange-cause y_t in the quantile range. The non-causal relationship in quantiles between oil price and stock market returns will be tested, considering the conditional quantile versions of equation (5) and (6) as follows:

$$Qr_{stock_t}(\tau|X_{t-1}) = \gamma(\tau) + \sum_{j=1}^{q} \alpha_j(\tau) r_{stock_{t-j}} + \sum_{j=1}^{q} \beta_j(\tau) r\_oil_{t-j} \qquad (8)$$

$$Qr_{oil_t}(\tau|Y_{t-1}) = \omega(\tau) + \sum_{j=1}^{q} \delta_j(\tau) r\_oil_{t-j} + \sum_{j=1}^{q} \xi_j(\tau) r\_stock_{t-j} \qquad (9)$$

where X_{t-1} and Y_{t-1} demonstrate the group of information generated by past values of (r_stock_t) and (r_oil_t) available at time *t*. The formula for the null hypothesis of the non-existence of Granger causality at the quantile level τ ε (0,1) can be verified by:

$$\text{H0: } \beta(\tau) = 0, \forall\tau \in [0,1] \qquad (10)$$

To stabilize τ ∈ (0,1), the Wald statistical of $\beta(\tau)=0$ can be expressed:

$$W_t(\tau) = T\frac{\hat{\beta}_t(\tau)'(\Psi\hat{\Omega}(\tau)\Psi')^{-1}\hat{\beta}_T(\tau)}{[\tau(1-\tau)]} \qquad (11)$$

where $\hat{\Omega}(\tau)$ characterizes a consolidate estimator of $\Omega(\tau)$ which is the variance-covariance matrix of $\hat{\beta}(\tau)$. Although the Wald test considers non-causality at the fixed quantile level, it will also be tested the non-causality in quantiles over some quantile intervals, such as τ ϵ [a, b]. However, the Wald statistical technique follows the weak agreement given by:

$$W_T(\tau) \Longrightarrow \| \frac{B_q(\tau)}{\sqrt{\tau(1-\tau)}} \|^2, \ \tau \in \mathrm{T}, \qquad (12)$$

where $B_q(\tau) = [\tau(1-\tau)]^{1/2}\ N(0,I)$ is a vector of *p*-independent Brownian bridges and its weak limit is the sum of the square of *p*-independent Bessel processes (Koenker and Machado, 1999). The next equation (12) is a sup-Wald test for the above null hypothesis.

$$\sup_{\tau \in \mathrm{T}} W_T(\tau) \rightsquigarrow \sup_{\tau \in \mathrm{T}} \| \frac{B_q(\tau)}{\sqrt{\tau(1-\tau)}} \|^2. \qquad (13)$$

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The results of the Sup-Wald test at various intervals [a; b] can be used to differentiate the range of quantiles from which causality appears. In the sup-Wald test, the number simulations vary according to standard Brownian motion manipulating a random Gaussian walk.

4. THE DATA AND EMPIRICAL ANALYSIS

In this study, it was analyzed the daily closing data indexes of the main stock exchanges in Latin America: Argentina (Merval), Brazil (Ibovespa), Chile (iShares MSCI Chile - ECH), Colombia (COLCAP Index), Ecuador (BVQA), Mexico (Dow Jones Mexico) and Peru (S&P Lima). The data were all collected from the Yahoo Finance and Investing website; the analysis period comprised 68 months, over the period between May 1st, 2015, and January 15th, 2020. In the same period, the price of crude oil was also captured by the Energy Information Administration website by its main international indicator, the West Texas Intermediate (WTI).

The Latin American has been seen as a large market, with a large representation in the size of their stock markets in recent decades; data show that domestic stock capitalization increased 585% between 2000-2012 against a 70% growth in other international markets (OECD, 2013). The classification of countries in this analysis, with the leading crude oil reserves (in billion barrels) in Latin America is the following: Brazil (12.84), Ecuador (8.27), Mexico (6.43), Argentina (2.02), Colombia (1.78), Peru (1.22), and Chile (0.15), but only Brazil ranking amongst the top ten oil-producing countries around the world (OPEC, 2020). On Table 1 we provide a statistical description of the employed dataset and on Table 2 we provide the statistical test for unit roots and stationary for all sample period.

Table 1 – Descriptive Statistic from stock market index and oil prices (daily log differences from May 1st, 2015 to January 15th, 2021)

Country	Minimum (%)	Maximum (%)	Mean (%)	Standard deviation (%)	Skewness	Kurtosis (excess)
Argentina	-63.501	13.913	-0.053	3.296	-6.111	108.612
Brazil	-18.972	12.249	0.022	2.541	-0.874	7.267
Chile	-18.426	14.102	-0.027	2.060	-0.769	11.461
Colombia	-17.174	13.592	-0.014	1.813	-1.365	19.418
Ecuador	-3.884	4.910	0.009	0.481	0.868	19.930
Mexico	-10.316	7.165	-0.016	1.597	-0.872	5.688
Peru	-11.324	10.922	0.026	1.187	-0.591	15.716
WTI	-72.027	42.583	-0.010	4.084	-2.915	88.864

Note: all currency values in the analysis have been converted to local dollar.

Source: prepared by the authors, 2021.

We investigate the impact of oil price shocks on stock markets around the daily closings of the seven Latin American stock market indexes and the price of crude oil in the international market. 1372 data were collected from Argentina, 1401 from Brazil, 1460 from Chile, 1368 from Colombia, 1388 from Ecuador, 1469 from Mexico, 1414 from Peru, and 1411 from WTI. The averages were all close to zero, positive for Brazil, Ecuador, and Peru, although negative means were verified for Argentina Chile, Colombia, Mexico, and for the oil price. The widest gap between the minimum price and the maximum price is verified in Argentina and in the oil price, resulting in a high variance and standard deviation. Asymmetry is negative for all stock markets, except for Ecuador, and kurtosis has high values (with the exception of Brazil and Mexico), indicating that the variables under analysis represent a leptokurtic distribution, higher peaks around the average and thicker tails on both sides.

Table 2 – Unit root and stationarity of daily log differences from countries WTI

Country	Unit root test (lag max =5)		Stationarity (lag = 7)	
	DF-GLS	P-value	KPSS	P-value
Argentina	-18,173	0,000	0,078	>0,10
Brazil	-6,529	0,000	0,090	>0,10
Chile	-14,453	0,000	0,123	>0,10
Colombia	-7,191	0,000	0,074	>0,10
Ecuador	-36,340	0,000	0,287	>0,10
Mexico	-28,239	0,000	0,072	>0,10

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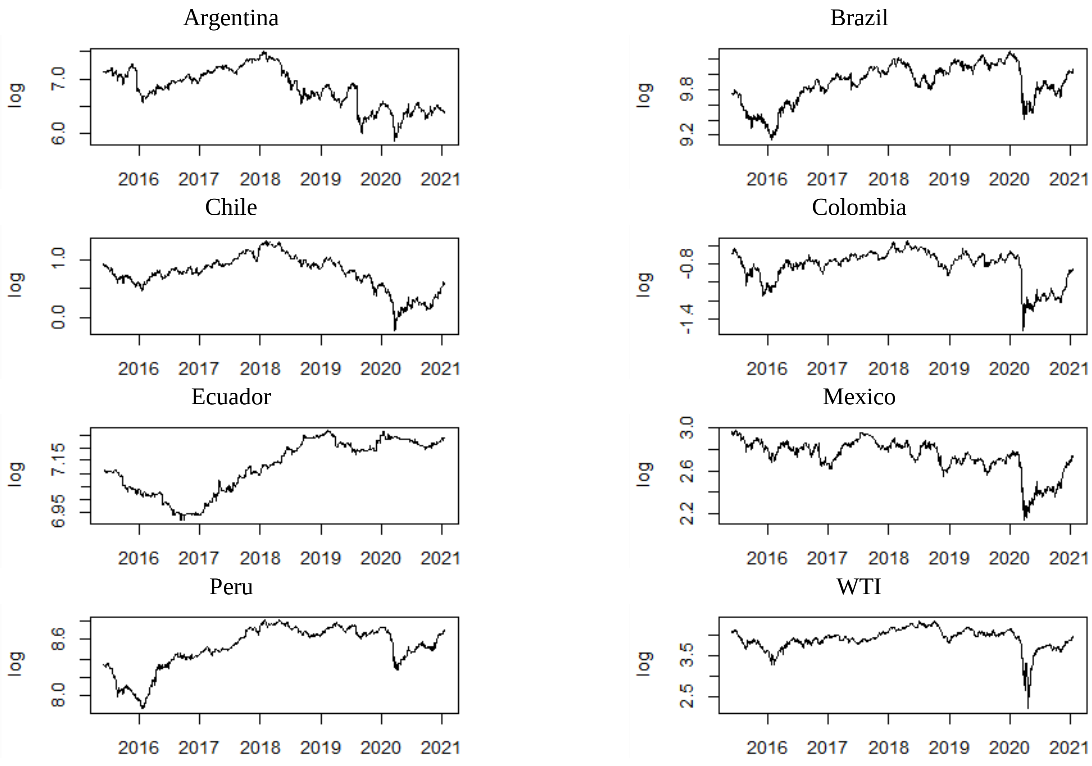
Peru	-6,099	0,000	0,139	>0,10
WTI	-6,043	0,000	0,071	>0,10

Note: all currency values in the analysis have been converted to local dollar.
Source: prepared by the authors, 2021.

According to Table 2, it can be verified that the time series distributions of stock market indexes log differences and the oil price are stationary since the null hypothesis of unit root was rejected for the first tests (Dickey-Fuller (DF) statistic using a generalized least square (GLS) rationale test), considering the p-values of these (Smeekes, 2013-2015). The stationary stochastic process of the series was confirmed by the KPSS test, in which there was no rejection of the null hypothesis of stationarity for any of the seven countries and WTI series under analysis. Figure 1 shows Latin American stock market behavior of daily log values.

Figure 1 – Latin American Stock Market index behaviour of daily log values (all currency values in the analysis have been converted to local dollar)



Source: prepared by the authors, 2021.

Figure 1 shows the behavior of dynamic movements of daily log values from Argentina, Brazil, Chile, Colombia Ecuador, Mexico, and Peru stock markets and WTI. It can be seen in the stock market behavior for Argentina that it shows a little growth between 2016 and 2018, but after that, it dropped continuously. In 2019 President Mauricio Macri lost his re-election, the S&P Merval Argentine index plummeted 48%, the second-largest single-day drop for any stock market in the world since 1950. Argentina was suffering a period of economic crisis over the year 2018, treasure bonds default, local currency losing value and stock market sharply falling precipitously (Reinicke, 2019).

The Brazil stock market behavior shows sustainable growth after 2016 when President Dilma Rousseff was impeached. Chile downward movement of the stock exchange can be observed after 2018, with the beginning of the current presidency Sebástian Piñera. The Colombia and Mexico stock markets and WTI behaviour shows a lateral movement during the period of analysis.

The Ecuador and Peru stock markets demonstrate sustainable growth, after 2016 from Peru (it was the second best-performing stock market in the world, showing a dollar-denominated profit of 58,91% (Mejía, 2016), and after 2017 from Ecuador, when President Lenin Moreno took office in 2017, implementing a slew of market-friendly policies.

There was substantial fall in the whole sample in Figure 1 of the Latin American stock market, and the WTI at the year 2020 showed the effect of COVID-19 on these markets, except in the Ecuador stock market index. According to Cuéllar et al. (2020), it may be possible because it was discovered in the Amazonian Condor, a copper mine that began production almost at the same time as the COVID-19 outbreak in China.

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In order to meet the objective of this study, we opted for the application of Granger causality (linear) analyzing between quantile intervals (nonlinear). The justification for choosing this econometric model is to identify the causal meaning between two variables: oil prices and the Latin American stock market, establishing that X_t may have an effect on Y_t, and at the same time, predict whether X_{t-1} collaborates and influences the forecast in the present value of Y_t. In this sample we use 5 lags for all models, it means, history until $t - 5$ can be viewed on Table 3.

Table 3 – Granger causality tests in mean between daily WTI and Stock Markets price returns in Latin American

Wti => Stock Market	Statistics	P-value	Decision
Argentina	0.997	0.418	No causality
Brazil	3.237	0.007	Causality
Chile	1.160	0.330	No causality
Colombia	4.240	0.001	Causality
Ecuador	0.430	0.830	No causality
Mexico	3.840	0.002	Causality
Peru	5.670	0.000	Causality

Note: 5 lags was used for all models, and all currency values in the analysis have been converted to local dollar.

Based on Table 3, WTI does not affect Argentina, Chile, and Ecuador stock markets, but at the same time, it affects Brazil, Colombia, Mexico, and Peru, according to the Granger causality test process with 5 lags. Table 3 is based on linear Granger causality test in mean between WTI and Latin American Stock markets price returns; on the other hand, Table 4 shows the diagnostic test results for quantile causality between those markets. It is noteworthy that this work contrasts the causality in the sense that WTI affects the Latin American stock market only and not the other way around.

As can be seen on Table 3, Argentina, Chile, and Ecuador, based on linear Granger causality, are not affected by the oil price market; however, based on non-linear Granger quantile causality, the whole series shows a causal relationship in the entire data distribution on Table 4. The analysis relationship is non-linear, at different times throughout the series, there are large intervals, less wide intervals, and extreme intervals.

Table 4 – Diagnostic test results for quantile causality between daily WTI and Stock Markets price returns in Latin America

Wti => Stock Market	Quantile interval							
	[0.05 0.95]	[0.05 0.50]	[0.50 0.95]	[0.20 0.40]	[0.40 0.60]	[0.60 0.80]	[0.05 0.20]	[0.80 0.95]
Argentina	152.54***	152.54***	50.91***	57.30***	35.97***	50.91***	152.54***	28.88***
Brazil	87.41***	87.41***	58.99***	86.96***	87.41***	57.86***	25.62***	58.99***
Chile	138.71***	138.71***	122.15***	138.71***	122.15***	69.50***	10.15***	69.50***
Colombia	242.17***	242.17***	115.90***	242.17***	132.29***	115.90***	229.60***	13.79
Ecuador	203.20***	134.73***	203.20***	134.73***	203.20***	203.20***	78.30***	112.20***
Mexico	159.39***	159.39***	62.40***	159.39***	134.72***	32.65***	49.28***	10.78
Peru	1352.59***	881.79***	1352.59***	211.28***	1352.59***	75.50***	351.99***	73.93***

Note: The asterisks indicate the rejection of the null hypothesis of Granger non-causality in the quantile interval. Significance (* = 10%; ** = 5%; *** = 1%). The critical values for the Sup-Wald test can be obtained through Monte Carlo simulations based on Andrews (1993) and Andrews (2003). Non-symmetrical values were interpolated. For facilitating the comparative process, it was 5 lags for all models.

Donald W. K. Andrews. (1993). Tests for Parameter Instability and Structural Change with Unknown Change Point. Econometrica, 61(4), 821-856. doi:10.2307/2951764

Donald W. K. Andrews. (2003), Tests for Parameter Instability and Structural Change with Unknown Change Point: A Corrigendum. Econometrica, 71(1): 395-397. doi:10.1111/1468-0262.00405

Note: all currency values in the analysis have been converted to local dollar.

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Source: prepared by the authors, 2021.

On Table 4 it was used the Wald test to conduct the Granger non-causality test in mean, where the ideal truncation order was selected by the Akaike information criterion (AIC). For now, the WTI market affects the whole Latin American stock market indexes, with robust significance, demonstrating that there is a causal relationship between WTI and Latin American stock market indexes.

Table 4 is divided into 8 intervals, the first three columns represent the big intervals (0.05-0.95, 0.05-0.50, 0.50-0.95), the columns in the middle the lower intervals (0.20-0.40, 0.40-0.60, 0.60-0.80), and the last two columns (0.05-0.20, 0.80-0.95) the extreme intervals. Argentina, Brazil, Chile, Ecuador, and Peru have significant causality in the whole quantile intervals on Table 4, it means that the WTI affect causes influences on the Latin American stock markets between big, lower, and extreme intervals, despite not having presented this relationship upon linear analysis (Table 3) in Argentina, Chile and Ecuador. Colombia and Mexico do not reject the null hypothesis of Granger non-causality in the extreme quantile interval (0.80-0.95) that represents high activity of stock market.

Latin America represents the second world-proven crude oil reserve and production (first is Middle East), and the results on Table 4 demonstrate, based on the non-linear method of Granger causality analysis, that Latin American capital markets are affected by WTI prices in the different quantile ranges (big, lower and extreme intervals) of the analysis.

5. CONCLUSIONS

The purpose of this study was to analyse whether the oil price shocks affect the Latin American stock markets, using the nonlinear method of Granger causality. In this case, the analysis is a contemporary association; oil prices today affecting stock markets today, unlike traditional Granger analysis, in which oil prices today can have an effect on stock markets tomorrow.

Knowing the predictability of oil price fluctuations triggering a similar effect on the stock market, it can bring important information to investors and public policy makers. For all series of the Latin American stock markets and the oil price, the problems of unit root were disseminated and stationary. It showed rejection for the tests of unit root and confirmed by the KPSS test for stationarity, and all currency values from the analysis were converted to local dollar.

The causality test made by the traditional linear method of Granger, in mean for five lags in all models between the daily WTI and the returns of Latin American stock markets, showed that causalities were verified in Brazil, Colombia, Mexico, and Peru. However, causality between Argentina, Chile, and Ecuador was not found. On the other hand, when the quantile nonlinear Granger causality method was used between the daily WTI and stock market price returns for Latin America, causality was verified among all countries in the sample. The results of the quantile regression were divided into eight intervals: three large quantile intervals, three medium quantiles, and two extreme intervals. Across the sample, the results demonstrated robust results for quantile causality between daily WTI and stock market price returns in Latin America, only Colombia and Mexico did not show significance in the range (0.80-0.95).

The greater importance in the final results of this article is based on the development analysis between two different markets, based on the differences in behavior of the stock markets, divided by quantiles, and not on the analysis based on the average by the basic linear model. Thus, it is worth for future studies to develop relations between markets based more on nonlinear models than basic linear models.

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