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**THE INFLUENCES BETWEEN OIL MARKET AND LATIN
AMERICAN STOCK MARKET**

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*The best ambitions are related to the
development of character and ability, not status and
power.*

*The path wasn't always easy, however, today I
can look back and be proud of the journey I have been
taken, the family I have built, for being in constant
personal, academic and professional evolution,
achieving personal satisfaction for the goals achieved.*

*I thank my wife Anamaria and daughter
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Summary

This Ph.D. Thesis investigates two of the world's most important markets: the oil market and the Latin American market. The oil market is of immense importance, primarily because oil is a vital source, accounting for one-third of the world's total energy supply, and playing a significant role in global economies. Latin American has a notable presence in the global oil market due to its significant oil reserves and production.

Several countries in the region of Latin American are significant oil producers, and the oil industry plays a crucial role in their economies. Some countries experience strong political interference in oil production and investments, particularly through state-owned companies, as Venezuela, for example, holds the world's largest proven oil reserves. However, political challenges and economic interference in the management of its national oil company, *Petróleos de Venezuela, S.A. (PDVSA)*, have led to corruption allegations and declining oil production, resulting in significant economic and social consequences for the country. Unfortunately, we were unable to obtain data from Venezuela for this study, due to its closed nature and lack of available data for analysis.

Other oil producing countries in Latin America were able to contribute their data to this study. The selection of countries in the sample was based on their economic significance and representation within Latin American economies. The largest economies in the Americas are United States, Brazil, Mexico, Argentina, and Chile (Statista, 2020). Brazil has emerged as a significant player in the oil market, especially due to the development of its pre-salt offshore oil reserves, which Petrobras being the leading state-owned company in the market. Mexico, another important oil producer, has its state-owned company (Pemex), historically holding a monopoly over the country's oil sector. In addition to Brazil, and Mexico, this study includes Argentina, Chile, Colombia, Ecuador and Peru. While these countries may not be major

players in terms of global oil production, they possess significant oil reserves that contribute to the Latin American oil market, playing a crucial role in their local economies, export revenue and energy security.

The oil market is giant traded commodity, involving large-scale imports and exports between nations, whether they are oil-producing and oil-consuming nations. These transactions can have significant influences on geopolitical relationships. Furthermore, oil revenues contribute significantly to government budgets, infrastructure development, social welfare programs, and investment in other sectors.

Oil plays a critical role as an input for many industries, including manufacturing, transportation, agriculture and construction. Fluctuations in oil prices can have substantial effects on inflation, employment rates, and overall economic growth. This means that oil prices can impact local markets within countries and consequently affect capital market.

Oil prices can influence stock market performance in several ways. They directly impact industrial sectors enterprises such energy companies, oilfield services, manufacturing and transportation, as well as the consumer goods companies. The volatility of oil prices can create uncertainty in financial markets, leading to increase risk aversion among investors. Additionally, oil prices have relationships with currency markets due to capital flows, exchange rates and international trade. Oil also is a key commodity in investment portfolios, exchange trade funds (ETFs), and bond markets.

To better understanding how the oil market can affect the Latin American capital market, the thesis is structure into three independent papers, each aimed at capturing the influences between oil market and the Latin American capital market: (i) “Asymmetric Influences on Latin American Stock Markets: A Quantile Approach”, (ii) “Causality in quantiles between crude oil prices and Latin American stock market”, and (iii) “Extreme return spillovers

between WTI, VIX and six Latin American stock markets: A quantile connectedness approach”.

The three papers employ a quantile regression model to assess their results from different perspective. Each econometric model was designed to address potential issues of endogeneity and autocorrelation that may arise due to the data structure. The data used in the analysis comprises daily closings values of Latin American stock market indexes, the S&P 500 market index, crude oil market measure by West Texas Intermediate (WTI) and Volatility Uncertainty Index (VIX), which is a popular measure of expected stock market volatility based on S&P 500 index options from the Chicago Board Options Exchange. All data were collected from sources such as Yahoo Finance and Investing websites. The price of crude oil was specifically captured by the Energy Information Administration website using its main international indicator, WTI.

In the first paper, the study compared the quantile regression (QR) and the ordinary least squares (OLS) regression analysis methods to measure the asymmetric effects of capital markets under different states of stock market performance conditions (e.g., low and high stock market performance and stability) during negative and positive price sessions. This aspect has rarely been explored in Latin American markets. Furthermore, our analysis incorporated performance measures such as the Sharpe ratio, Sortino ratio, Rachev ratio, and STARR ratio to assess the performance of the Latin American stock markets.

The first study examined the effects of shocks from changes in trading sessions prices in the previous period of the Latin American stock market (Argentina, Brazil, Chile, and Mexico). The variables considered included the West Texas Intermediate (WTI) oil market index, exchange rate, the S&P 500 index, and the impact of the COVID-19 pandemic period on both positive or negative price changes. The COVID-19 period was divided into two phases using

a dummy variable to differentiate the period before and after the onset of the pandemic. Testing the quantile causality approach allows for a better understanding of asymmetric causality, and enables the analysis of the stock market performances across different quantile ranges (e.g., large, lower and extreme intervals).

The quantile regression (QR) and ordinary least square (OLS) analyses revealed associations between variations in oil prices and the Latin American stock markets. It was evident that changes in oil price positively affected the Latin American capital markets, particularly when the oil market operated in the positive conditions. This effect was especially pronounced for the Argentine and Chilean markets, while Brazil and Mexico exhibited fewer influences in this analysis.

Trading sessions that closed negatively had a negative effect on the Brazilian, Chilean, and Argentine markets (except for the lower quantile in Argentina), but they had a positive effect on the Mexican market when it was operating below average and stably. Conversely, trading sessions with prices above the previous day's closing positively affected all Latin American stock markets, except for the Brazilian market, which showed an association only when the market operated above average.

Exchange rate variations exhibited a negative association with both negative and positive Latin American stock market prices. The Argentine market showed an asymmetric and cross-pattern relationship in this analysis. The American market (S&P 500) consistently demonstrated positive associations across all quantile regression (QR) and ordinary least square (OLS) analyses. The significant influence of the U. S. stock market has on Latin American markets is notable, and changes in exchange rates negatively affect all Latin American countries.

During the COVID-19 pandemic period, the Argentine, Chilean, and Mexican markets showed negative QR associations when the market was operating below average (lower quantile). However, these markets exhibited positive QR associations when the Brazilian market stable and the Chilean and Mexican markets were above average. No significance associations were observed in the OLS analysis.

In the second article, the influence of international crude oil price (WTI) over Latin American stock markets was examined from two perspectives: dynamic Granger causality (linear) and nonlinear models were employed to analyze causal relationships between variables at different quantile intervals. Granger causality is a statistical concept that assesses whether past values of one variable can help predict future values of another variable. The paper showed different results when analyzed using linear Granger causality model, which capture a linear pattern between variables, and nonlinear Granger causality model, which can relax this assumption and allow for more flexible and complex relationships.

The justification for choosing these econometrics models in the second article was to identify the causal relationships between these markets, establishing that X_t may have an effect on Y_t , and simultaneously predicting whether X_{t-1} contributes to and influences the forecast of the present value of Y_t from two perspective of Granger causality. This work considered several statistical tests focused on detecting non-linearity in the data series generation procedures.

To check for normal distribution and stationarity in the series, we employed the ADF (Augmented Dickey-Fuller), DF-GLS (Dickey-Fuller Generalized Least Squares), Union test (union root test) and KPSS (Kwiatkowski-Phillips-Schmidt-Shin) test on all samples. This article analyzed several Latin American countries including Argentina, Brazil, Chile, Colombia, Ecuador, Mexico and Peru, examining the relationship between crude oil prices (WTI) using quantile regression. This statistical method allowed to analyze the different

performances of the stock market across various quantile ranges (large, lower and extreme intervals) in the analysis, assessing not only the impact of oil price returns, but also the effects of asymmetric causality.

Argentina, Brazil, Chile, Ecuador and Peru exhibit significant causality across all quantile intervals, indicating that WTI influences the Latin American stock markets across large, lower and extreme intervals. However, this relationship was not evident in linear analysis for Argentina, Chile and Ecuador. Additionally, Colombia and Mexico do not reject the null hypothesis of Granger non-causality in the extreme quantile interval (0.80-0.95), which represents high-performance stock market conditions.

The causality test conducted using the traditional linear Granger method with a lag of five periods in all models between daily WTI and the returns of Latin American stock markets showed the causality was observed in Brazil, Colombia, Mexico and Peru. However, causality was not found between Argentina, Chile and Ecuador.

Conversely, when the quantile nonlinear Granger causality method was applied between daily WTI and stock market price returns for Latin America, causality was confirmed across all countries in the sample. The significance of the final results of this work lies in the comparative analysis between two distinct markets, based on the divergent behaviors of the stock markets across quantiles, rather than relying on average analysis using a basic linear model. This demonstrates the notable disparity in the analysis between two models.

Hence, the significance of the findings in this article is to encourage future studies to explore market relationship using nonlinear models than basic linear models. As the conclusion of this study, no similar research specifically targeting the Latin American market with these results has been identified.

The third article of this thesis shifted the perspective of econometric analysis by examining extreme return spillovers and connectedness to analyze the crude oil market (WTI), Volatility Uncertainty Index (VIX), S&P 500 and six Latin American stock markets namely Argentina, Brazil, Chile, Colombia, Mexico and Peru. This work utilized the quantile connectedness approach to analyze quantile connectedness at various quantiles as proposed by Ando et al. (2018).

This framework differs from the others due to its treatment of the VAR residuals, assuming that the correlation of the VAR residuals is driven by a finite number of common factors. This means that idiosyncratic shocks to each variable in the system can be isolated. By asserting that errors are not correlated between the equations, the factorial VAR system can be estimated directly on an equation-by-equation basis. Therefore, utilizing a factorial structure substantially simplifies the estimation problem by making the system of equations that comprise the model sectionally independent VAR.

Furthermore, the findings clearly demonstrated the significance role of the U.S. market within the system, as most of the spillover in the matrix originated from it. This highlights the strong dependence that the Latin American market and the oil market experience, especially during periods of low performance and market stability. However, during the bull market conditions, fear dominates the markets, with VIX influencing the entire system as sender of spillovers. Despite Colombia, Peru and Mexico being only Latin American countries that exhibit a net transmitting role within the system during the bear market conditions until the stability of the market. Their values are weaker compared to those of S&P 500 across all system conditions. Additionally, the VIX index transitions from a net receiver to a net transmitter within the system when bullish market conditions emerge.

The fear of the market index and the S&P 500 are the only net transmitter to the system during bull market conditions. In contrast, Argentina and Brazil show net receivers spillover during all market conditions, with higher values compare to the others Latin American countries. The oil market is a net receiver of spillover across the entire sample, and total return connectedness is higher only at the extreme quantiles (lower and upper). Directional connectedness confirms our findings regarding the U.S. market as the main driver of spillover to the system, but this position is lost to the VIX index when the market conditions shift to a bull market.

Each article of the thesis aimed to analyze two major global markets – the oil market and the Latin American capital market – using different econometric models to identify similarities, differences, positive and negative impacts, asymmetries, and significance with various variables and interpretations. The results varied in terms of analytical approach, observation period, and countries included, but each article produced relevant finding. They demonstrated the evolution of market indices in Latin American countries and oil prices, along with a brief explanation of the political turmoil effects on each country's stock markets.

The significance of the final results in each article of this thesis is rooted in the comparative analysis between two distinct markets, highlighting the behavioral differences of the stock markets across various quantiles. In the first study, the smaller quantiles $\tau = 0.05$ and $\tau = 0.25$ signify a scenario where the stock market operates with returns below the conditional average (indicative of low performance); $\tau = 0.50$ indicates a scenario where the stock market operates with returns close to the conditional average (indicative of stability); and $\tau = 0.75$ and $\tau = 0.95$ indicates a scenario where the stock market operates with returns above the conditional average (indicative of high performance).

In the first article, to assess the impact of the COVID-19 period, the quality variable ‘Dummy’ was used (1 = after March 9, 2020, 0 = before March 9, 2020). The second article was segmented into 8 quantiles intervals, representing large intervals, lower intervals, and extreme intervals. Finally, the third article focused on different market conditions; ($\tau = 0.05$) representing a scenario where the stock market operates with returns below the conditional average (indicative of low performance); $\tau = 0.50$ representing a scenario where the stock market operates with returns close to the conditional average (indicative of stability); and $\tau = 0.95$ representing a scenario where the stock market operates with returns above the conditional average (indicative of high performance).

In summary, the presence of asymmetries between the oil market and the stock market indicates that these markets do not always move in tandem or exhibit the same dynamics. Certain unique characteristics or events can cause divergent movements between these markets.

In conclusion, this thesis contributes to the literature by enhancing our understanding of the dynamics relationship between oil market and the Latin American stock market. It provides insights for managing portfolio risk and exposure, considering various quantiles associated with different states of stock market performance (including low and high stock market performance and stability) during negative and positive price sessions. This area of research has been relatively unexplored in Latin American markets. Investors and analysts operating in these markets should be aware of these asymmetries and take them into consideration when making investment decisions or analyzing market dynamics.

Resumen

Esta tesis doctoral investiga dos de los mercados más importantes del mundo: el mercado del petróleo y el mercado latinoamericano. El mercado del petróleo es de inmensa importancia, principalmente porque el petróleo es una fuente vital, representando un tercio del suministro total de energía del mundo y desempeñando un papel significativo en las economías globales. América Latina tiene una presencia notable en el mercado global del petróleo debido a sus significativas reservas y producción de petróleo.

Varios países en la región de América Latina son importantes productores de petróleo, y la industria petrolera juega un papel crucial en sus economías. Algunos países experimentan una fuerte interferencia política en la producción de petróleo y las inversiones, particularmente a través de empresas estatales. Venezuela, por ejemplo, posee las mayores reservas probadas de petróleo del mundo. Sin embargo, los desafíos políticos y la interferencia económica en la gestión de su empresa nacional de petróleo, Petróleos de Venezuela, S.A. (PDVSA), han llevado a acusaciones de corrupción y una disminución en la producción de petróleo, resultando en consecuencias económicas y sociales significativas para el país. Desafortunadamente, no pudimos obtener datos de Venezuela para este estudio, debido a su naturaleza cerrada y la falta de datos disponibles para el análisis.

Otros países productores de petróleo en América Latina pudieron contribuir con sus datos a este estudio. La selección de países en la muestra se basó en su importancia económica y representación dentro de las economías latinoamericanas. Las economías más grandes de América son Estados Unidos, Brasil, México, Argentina y Chile (Statista, 2020). Brasil ha emergido como un jugador significativo en el mercado del petróleo, especialmente debido al desarrollo de sus reservas de petróleo en el presal, con Petrobras siendo la principal empresa estatal en el mercado. México, otro importante productor de petróleo, tiene su empresa estatal

(Pemex), que históricamente ha mantenido un monopolio sobre el sector petrolero del país. Además de Brasil y México, este estudio incluye a Argentina, Chile, Colombia, Ecuador y Perú. Aunque estos países no sean grandes actores en términos de producción mundial de petróleo, poseen reservas significativas de petróleo que contribuyen al mercado petrolero latinoamericano, desempeñando un papel crucial en sus economías locales, ingresos por exportación y seguridad energética.

El mercado del petróleo es un gigante de las mercancías comercializadas, que involucra importaciones y exportaciones a gran escala entre naciones, ya sean productoras o consumidoras de petróleo. Estas transacciones pueden tener influencias significativas en las relaciones geopolíticas. Además, los ingresos del petróleo contribuyen significativamente a los presupuestos gubernamentales, el desarrollo de infraestructuras, los programas de bienestar social y la inversión en otros sectores.

El petróleo juega un papel crítico como insumo para muchas industrias, incluyendo la manufactura, el transporte, la agricultura y la construcción. Las fluctuaciones en los precios del petróleo pueden tener efectos sustanciales en la inflación, las tasas de empleo y el crecimiento económico en general. Esto significa que los precios del petróleo pueden impactar los mercados locales dentro de los países y, consecuentemente, afectar el mercado de capitales.

Los precios del petróleo pueden influir en el rendimiento del mercado de valores de varias maneras. Impactan directamente a los sectores industriales, como las empresas energéticas, los servicios petroleros, la manufactura y el transporte, así como a las empresas de bienes de consumo. La volatilidad de los precios del petróleo puede crear incertidumbre en los mercados financieros, llevando a un aumento de la aversión al riesgo entre los inversores. Además, los precios del petróleo tienen relaciones con los mercados de divisas debido a los

flujos de capital, los tipos de cambio y el comercio internacional. El petróleo también es una mercancía clave en carteras de inversión, fondos cotizados en bolsa (ETFs) y mercados de bonos.

Para comprender mejor cómo el mercado del petróleo puede afectar al mercado de capitales de América Latina, la tesis está estructurada en tres artículos independientes, cada uno dirigido a capturar las influencias entre el mercado del petróleo y el mercado de capitales latinoamericano: (i) "Influencias asimétricas en los mercados de valores latinoamericanos: un enfoque cuantil", (ii) "Causalidad en cuantiles entre los precios del petróleo crudo y el mercado de valores latinoamericano", y (iii) "Transferencias extremas de rendimiento entre WTI, VIX y seis mercados de valores latinoamericanos: un enfoque de conectividad cuantil".

Los tres artículos emplean un modelo de regresión cuantílica para evaluar sus resultados desde diferentes perspectivas. Cada modelo econométrico fue diseñado para abordar posibles problemas de endogeneidad y autocorrelación que pueden surgir debido a la estructura de los datos. Los datos utilizados en el análisis comprenden los valores de cierre diarios de los índices bursátiles latinoamericanos, el índice de mercado S&P 500, el mercado de petróleo crudo medido por el West Texas Intermediate (WTI) y el Índice de Incertidumbre de Volatilidad (VIX), que es una medida popular de la volatilidad esperada del mercado de valores basada en las opciones del índice S&P 500 de la Bolsa de Opciones de Chicago. Todos los datos fueron recopilados de fuentes como Yahoo Finance y sitios web de inversión. El precio del petróleo crudo fue capturado específicamente por el sitio web de la Administración de Información Energética utilizando su principal indicador internacional, el WTI.

En el primer artículo, el estudio comparó los métodos de regresión cuantílica (QR) y de mínimos cuadrados ordinarios (OLS) para medir los efectos asimétricos de los mercados de

capitales en diferentes estados de condiciones de rendimiento del mercado de valores (por ejemplo, rendimiento y estabilidad bajos y altos) durante sesiones de precios negativos y positivos. Este aspecto rara vez ha sido explorado en los mercados latinoamericanos. Además, nuestro análisis incorporó medidas de rendimiento como el índice de Sharpe, índice de Sortino, índice de Rachev y índice de STARR para evaluar el rendimiento de los mercados de valores latinoamericanos.

Ese primer estudio examinó los efectos de los choques derivados de cambios en los precios de las sesiones de negociación en el período anterior en los mercados de valores latinoamericanos (Argentina, Brasil, Chile y México). Las variables consideradas incluyeron el índice del mercado de petróleo West Texas Intermediate (WTI), el tipo de cambio, el índice S&P 500 y el impacto del período de la pandemia de COVID-19 en los cambios de precios, ya sean positivos o negativos. El período de COVID-19 se dividió en dos fases utilizando una variable ficticia para diferenciar el período antes y después del inicio de la pandemia. La prueba del enfoque de causalidad cuantílica permite una mejor comprensión de la causalidad asimétrica y permite el análisis de los rendimientos del mercado de valores en diferentes rangos cuantílicos (por ejemplo, intervalos grandes, bajos y extremos).

Los análisis de regresión cuantílica (QR) y de mínimos cuadrados ordinarios (OLS) revelaron asociaciones entre las variaciones en los precios del petróleo y los mercados de valores latinoamericanos. Fue evidente que los cambios en el precio del petróleo afectaron positivamente a los mercados de capitales latinoamericanos, especialmente cuando el mercado del petróleo operaba en condiciones positivas. Este efecto fue especialmente pronunciado en los mercados argentino y chileno, mientras que Brasil y México mostraron menos influencias en este análisis.

Las sesiones de negociación que cerraron en negativo tuvieron un efecto negativo en los mercados brasileño, chileno y argentino (excepto en el cuantil inferior en Argentina), pero tuvieron un efecto positivo en el mercado mexicano cuando operaba por debajo del promedio y de manera estable. Por el contrario, las sesiones de negociación con precios por encima del cierre del día anterior afectaron positivamente a todos los mercados de valores latinoamericanos, excepto al mercado brasileño, que mostró una asociación solo cuando el mercado operaba por encima del promedio.

Las variaciones en el tipo de cambio mostraron una asociación negativa tanto con precios negativos como positivos en los mercados de valores latinoamericanos. El mercado argentino mostró una relación asimétrica y de patrón cruzado en este análisis. El mercado estadounidense (S&P 500) demostró consistentemente asociaciones positivas en todos los análisis de regresión cuantílica (QR) y mínimos cuadrados ordinarios (OLS). La influencia significativa que tiene el mercado de valores de EE. UU. en los mercados latinoamericanos es notable, y los cambios en los tipos de cambio afectan negativamente a todos los países latinoamericanos.

Durante el período de la pandemia de COVID-19, los mercados argentino, chileno y mexicano mostraron asociaciones negativas en la regresión cuantílica (QR) cuando el mercado estaba operando por debajo del promedio (cuantil inferior). Sin embargo, estos mercados exhibieron asociaciones positivas en la regresión cuantílica (QR) cuando el mercado brasileño estaba estable y los mercados chileno y mexicano estaban por encima del promedio. No se observaron asociaciones significativas en el análisis de mínimos cuadrados ordinarios (OLS).

En el segundo artículo, se examinó la influencia del precio internacional del petróleo crudo (WTI) sobre los mercados de valores latinoamericanos desde dos perspectivas: se emplearon

modelos de causalidad de Granger dinámica (lineal) y modelos no lineales para analizar las relaciones causales entre variables en diferentes intervalos cuantílicos. La causalidad de Granger es un concepto estadístico que evalúa si los valores pasados de una variable pueden ayudar a predecir los valores futuros de otra variable. El documento mostró resultados diferentes cuando se analizó utilizando un modelo lineal de causalidad de Granger, que captura un patrón lineal entre variables, y un modelo no lineal de causalidad de Granger, que puede relajar esta suposición y permitir relaciones más flexibles y complejas.

La justificación para elegir estos modelos econométricos en el segundo artículo fue identificar las relaciones causales entre estos mercados, estableciendo que X_t puede tener un efecto en Y_t , y al mismo tiempo predecir si $X_{(t-1)}$ contribuye e influye en el pronóstico del valor presente de Y_t desde dos perspectivas de causalidad de Granger. Este trabajo consideró varias pruebas estadísticas centradas en detectar la no linealidad en los procedimientos de generación de series de datos.

Para verificar la distribución normal y estacionariedad en las series, empleamos las pruebas ADF (Dickey-Fuller Aumentada), DF-GLS (Dickey-Fuller Generalizada de Mínimos Cuadrados), la prueba de raíz unitaria (Union test) y la prueba KPSS (Kwiatkowski-Phillips-Schmidt-Shin) en todas las muestras. Este artículo analizó varios países latinoamericanos, incluyendo Argentina, Brasil, Chile, Colombia, Ecuador, México y Perú, examinando la relación entre los precios del petróleo crudo (WTI) utilizando la regresión cuantílica. Este método estadístico permitió analizar los diferentes desempeños del mercado de valores en varios rangos cuantílicos (intervalos grandes, bajos y extremos) en el análisis, evaluando no solo el impacto de los rendimientos del precio del petróleo, sino también los efectos de la causalidad asimétrica.

Argentina, Brasil, Chile, Ecuador y Perú exhiben una causalidad significativa en todos los intervalos cuantílicos, lo que indica que el WTI influye en los mercados de valores latinoamericanos en intervalos grandes, bajos y extremos. Sin embargo, esta relación no fue evidente en el análisis lineal para Argentina, Chile y Ecuador. Además, Colombia y México no rechazan la hipótesis nula de no causalidad de Granger en el intervalo cuantílico extremo (0.80-0.95), que representa condiciones de mercado de valores de alto rendimiento.

La prueba de causalidad realizada utilizando el método tradicional de Granger lineal con un rezago de cinco períodos en todos los modelos entre el WTI diario y los rendimientos de los mercados de valores latinoamericanos mostró que se observó causalidad en Brasil, Colombia, México y Perú. Sin embargo, no se encontró causalidad entre Argentina, Chile y Ecuador.

Por el contrario, cuando se aplicó el método de causalidad de Granger no lineal cuantílica entre el WTI diario y los rendimientos de precios del mercado de valores para América Latina, se confirmó la causalidad en todos los países de la muestra. La importancia de los resultados finales de este trabajo radica en el análisis comparativo entre dos mercados distintos, basado en los comportamientos divergentes de los mercados de valores en diferentes cuantiles, en lugar de depender de un análisis promedio utilizando un modelo lineal básico. Esto demuestra la notable disparidad en el análisis entre los dos modelos.

Por lo tanto, la importancia de los hallazgos en este artículo es alentar futuros estudios a explorar las relaciones de mercado utilizando modelos no lineales en lugar de modelos lineales básicos. Como conclusión de este estudio, no se ha identificado investigación similar que se centre específicamente en el mercado latinoamericano con estos resultados.

El tercer artículo de esta tesis cambió la perspectiva del análisis econométrico al examinar los derrames extremos de rendimiento y la conectividad para analizar el mercado de petróleo crudo (WTI), el Índice de Incertidumbre de Volatilidad (VIX), el S&P 500 y seis mercados

de valores latinoamericanos, a saber, Argentina, Brasil, Chile, Colombia, México y Perú. Este trabajo utilizó el enfoque de conectividad cuantílica para analizar la conectividad cuantílica en varios cuantiles, según lo propuesto por Ando et al. (2018).

Este estudio difiere de los demás debido a su tratamiento de los residuos de VAR, asumiendo que la correlación de los residuos de VAR está impulsada por un número finito de factores comunes. Esto significa que los choques idiosincráticos a cada variable en el sistema pueden ser aislados. Al afirmar que los errores no están correlacionados entre las ecuaciones, el sistema VAR factorial puede ser estimado directamente en una base de ecuación por ecuación. Por lo tanto, utilizar una estructura factorial simplifica sustancialmente el problema de estimación al hacer que el sistema de ecuaciones que componen el modelo VAR sea seccionalmente independiente.

Además, los hallazgos demostraron claramente el papel significativo del mercado estadounidense dentro del sistema, ya que la mayor parte de los derrames en la matriz se originaron en él. Esto resalta la fuerte dependencia que experimentan el mercado latinoamericano y el mercado petrolero, especialmente durante períodos de bajo rendimiento y estabilidad del mercado. Sin embargo, durante condiciones de mercado alcista, el miedo domina los mercados, con el VIX influenciando todo el sistema como emisor de derrames. A pesar de que Colombia, Perú y México son los únicos países latinoamericanos que exhiben un papel de transmisión neta dentro del sistema durante las condiciones de mercado bajista hasta la estabilidad del mercado, sus valores son más débiles en comparación con los del S&P 500 en todas las condiciones del sistema. Además, el índice VIX pasa de ser un receptor neto a un transmisor neto dentro del sistema cuando emergen condiciones de mercado alcista.

El índice de miedo del mercado (VIX) y el S&P 500 son los únicos transmisores netos al sistema durante las condiciones de mercado alcista. En contraste, Argentina y Brasil muestran

transmisores netos de derrames durante todas las condiciones del mercado, con valores más altos en comparación con otros países latinoamericanos. El mercado del petróleo es un receptor neto de derrames en toda la muestra, y la conectividad total de retorno es mayor solo en los cuantiles extremos (inferiores y superiores). La conectividad direccional confirma nuestros hallazgos con respecto al mercado estadounidense como el principal impulsor de derrames hacia el sistema, pero esta posición se pierde frente al índice VIX cuando las condiciones del mercado cambian a un mercado alcista.

Cada artículo de la tesis tuvo como objetivo analizar dos mercados globales importantes: el mercado del petróleo y el mercado de capitales latinoamericano, utilizando diferentes modelos econométricos para identificar similitudes, diferencias, impactos positivos y negativos, asimetrías y significados con diversas variables e interpretaciones. Los resultados variaron en términos de enfoque analítico, período de observación y países incluidos, pero cada artículo produjo hallazgos relevantes. Demostraron la evolución de los índices de mercado en los países latinoamericanos y los precios del petróleo, junto con una breve explicación de los efectos de las turbulencias políticas en los mercados de valores de cada país.

La importancia de los resultados finales en cada artículo de esta tesis se basa en el análisis comparativo entre dos mercados distintos, resaltando las diferencias de comportamiento de los mercados de valores en varios cuantiles. En el primer estudio, los cuantiles más pequeños $\tau = 0.05$ y $\tau = 0.25$ indican un escenario donde el mercado de valores opera con rendimientos por debajo del promedio condicional (indicativo de bajo rendimiento); $\tau = 0.50$ indica un escenario donde el mercado de valores opera con rendimientos cercanos al promedio condicional (indicativo de estabilidad); y $\tau = 0.75$ y $\tau = 0.95$ indican un escenario donde el mercado de valores opera con rendimientos por encima del promedio condicional (indicativo de alto rendimiento).

En el primer artículo, para evaluar el impacto del período de COVID-19, se utilizó la variable de calidad 'Dummy' (1 = después del 9 de marzo de 2020, 0 = antes del 9 de marzo de 2020). El segundo artículo se dividió en 8 intervalos cuantílicos, que representan intervalos grandes, intervalos bajos e intervalos extremos. Finalmente, el tercer artículo se centró en diferentes condiciones de mercado; ($\tau = 0.05$) que representa un escenario donde el mercado de valores opera con rendimientos por debajo del promedio condicional (indicativo de bajo rendimiento); $\tau = 0.50$ que representa un escenario donde el mercado de valores opera con rendimientos cercanos al promedio condicional (indicativo de estabilidad); y $\tau = 0.95$ que representa un escenario donde el mercado de valores opera con rendimientos por encima del promedio condicional (indicativo de alto rendimiento).

En resumen, la presencia de asimetrías entre el mercado del petróleo y el mercado de valores indica que estos mercados no siempre se mueven en tándem o exhiben las mismas dinámicas. Ciertas características únicas o eventos pueden causar movimientos divergentes entre estos mercados.

En conclusión, esta tesis contribuye a la literatura al mejorar nuestra comprensión de la dinámica relación entre el mercado del petróleo y el mercado de valores latinoamericano. Ofrece perspectivas para gestionar el riesgo y la exposición de la cartera, considerando varios cuantiles asociados con diferentes estados de rendimiento del mercado de valores (incluyendo bajo y alto rendimiento del mercado de valores y estabilidad) durante sesiones de precios negativos y positivos. Esta área de investigación ha sido relativamente poco explorada en los mercados latinoamericanos. Los inversores y analistas que operan en estos mercados deben ser conscientes de estas asimetrías y tenerlas en cuenta al tomar decisiones de inversión o al analizar la dinámica del mercado.

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Introduction

The oil market refers to be the global marketplace where crude oil and oil products are traded. It is a complex and highly influential market that plays a critical role in the world economy, serving as a key input for various sectors including transportation, manufacturing and power generation. Therefore, price fluctuations in this commodity can have significant impacts on economies of countries worldwide. Oil prices can affect consumer costs, production expenses, and overall economic stability, making it a vital area of study and analysis in the global finance landscape.

Oil, being a commodity, it is traded through a combination of physical trading involving barrels of crude oil through spot market transactions or long-term contracts, as well as financial instruments such as futures options contracts. This allows participants in the market to speculate on the future price of oil without the need to take physical possession of the commodity. The oil market operates with both physical and financial components, providing flexibility for market participants to manage risk, hedge positions, and make investment decisions based on anticipated price movements.

The global dynamics between oil supply and demand can be significantly influenced by geopolitical events, which create uncertainties in oil producing countries and impact commodity production. For instance, during the COVID-19 pandemic period, there was an economic slowdown worldwide, affecting people's lives and leading to a historic drop in oil prices. In April 2020, the price of West Texas Intermediate (WTI) crude oil, in the US benchmark, plummeted to below minus US\$ 40 per barrel (OECD, 2020). As of May 2024, the price of crude oil – WTI has recovered to around US\$ 78,38 per barrel (Investing, 2024).

Fluctuations in oil prices have significant implications for oil-producing countries, oil companies, stakeholders, consumers and investors (Ilyas et al., 2021). An increase in oil prices can result higher costs for industries reliant on petroleum products, including transportation and manufacturing, which may lead to increase consumer prices. Conversely, a decrease in oil prices can benefit oil-important countries by lowering their important bills and potentially stimulating economic growth through increase consumer spending and investment opportunities. The impact of oil prices fluctuations underscores the interconnectedness of the global economy and the importance of monitoring and understanding trends in the oil market.

Crude oil is a significant component of production costs for oil companies, and such as, the uncertainty surrounding its price can complicate corporate investment decisions. The uncertainty can have direct or indirect impacts on the financial performance and value of the company, thereby, affecting the wealth of shareholders (Maghyereh and Abdoh, 2020). Fluctuations on oil prices can influence profitability, operational efficiency, and strategic planning within oil companies, highlighting the critical importance of managing and mitigating risks associated with oil price volatility in the energy sector.

The main companies in the energy sector, including oil and gas companies, have their capital structure publicly traded on the stock exchange, and often hold significant weight in stock market indices due to their size, market capitalization, and global reach. Therefore they are directly impacted by fluctuations in oil prices and which can result in changes to their revenues and profitability, ultimately influencing the stock prices of this sector in the capital market. Additionally, these companies have a historical track record of paying dividends to shareholders, make them an attractive choice for investors seeking income and diversification in their investment portfolios. This sectors

performance can contribute to the overall stock market performance, given its prominence and influence in the global economy. Investors often view energy companies as stable, dividend-paying investment, enhancing the appeal of including them as investment portfolios.

The main companies in the energy sector, including oil and gas companies, have their capital structure publicity traded on the stock market and often hold significant weight in stock exchange indices due to their size, market capitalization, and global reach. Therefore, they are directly impacted by fluctuations in oil prices, which can result in changes to their revenues and profitability, ultimately influencing the stock prices of this sector in the capital market. Additionally, these companies this sector's performance can contribute for overall stock market performance, given its prominence and influence in the global economy.

In the 2023 financial year, the Brazilian state-owned company Petrobras distributed a total of \$14 billion in dividends, while the company's market value reached a new record of \$114 billion (Gradilone, 2024). These figures highlight the significance of these companies to investors, as they wield considerable influence in daily stock market trading due to their substantial market capitalization. Therefore, studying the relationship between the oil market and the Latin American stock market is of great importance, given the impact and prominence of these energy companies on regional and global financial markets. Understanding how fluctuations in oil prices affect these companies can provide valuable insights for investors and analysts assessing market dynamics and investment opportunities.

Indeed, the oil market is closely intertwined with the behaviour of the stock market. Fluctuations in oil prices can profoundly impact investor sentiment and risk appetite,

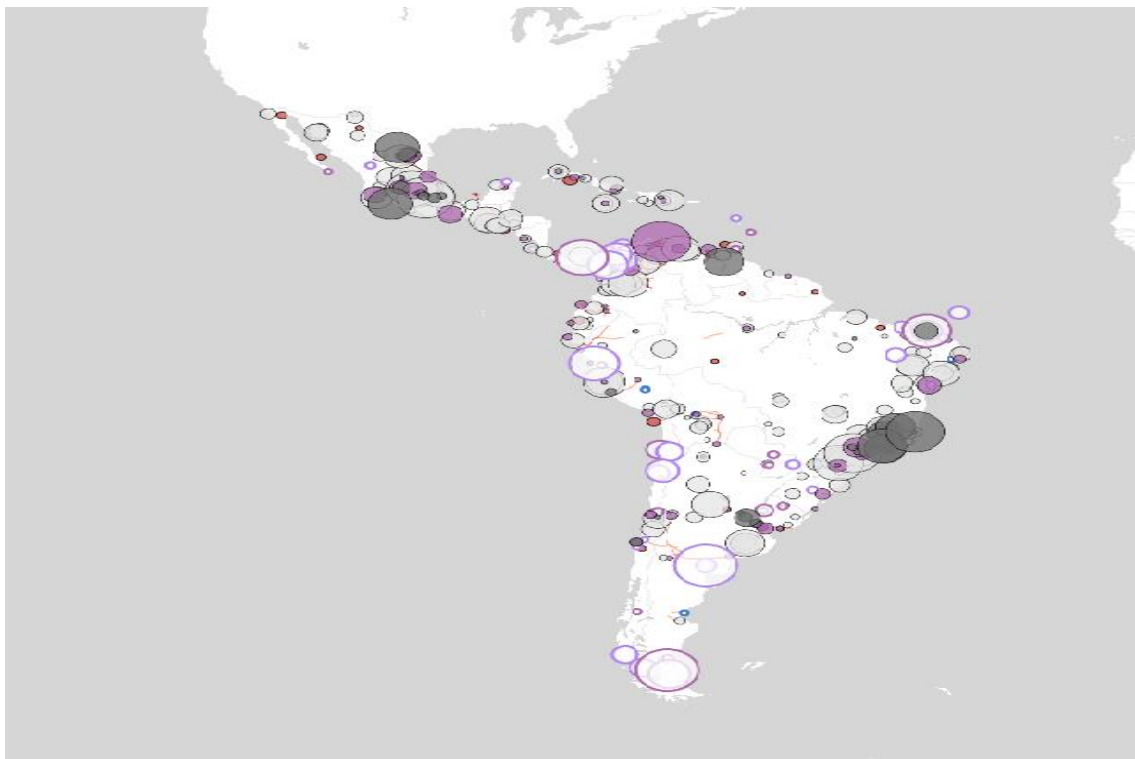
leading to movements in stock prices and, consequently, influencing overall market performance. This linkage is especially significant because the oil and gas sector is interconnected with major industries such as transportation, manufacturing, and petrochemicals. Changes in oil prices can affect production costs, consumer prices, and economic activities across various sectors, making them key factors driving market movements and investor decisions. Understanding these relationships is essential for comprehending market dynamics and assessing investment opportunities in related industries.

Latin America is an important oil-producing region with substantial reserves and increasing interest from international investors. The primary strength of oil production in Latin America is offshore Brazil (Smith, 2023), where significant offshore oil fields contribute to the region's oil output. Additionally, other countries in Latin America produce substantial amounts of oil, including Venezuela, Mexico, Colombia, Argentina, Ecuador, and Peru (Statista, 2022). This diverse oil production landscape in Latin America contributes significantly to global oil supply and plays a crucial role in the region's economic development and international trade relationships.

Currently, the Latin American region boasts 671 oil and gas extraction sites and 212 oil and gas pipelines, as depicted in Figure 1. Notably, Latin America saw the highest percentage of new oil discoveries globally between 2022 and 2023 (Global Energy Monitor, 2024). Among the leading oil and gas companies in Latin America based on sales revenue in 2022 are Petrobras (Brazil) with \$134 billion, followed by Pemex (Mexico) with \$122 billion, Copec (Chile) with \$31 billion, and YPF (Argentina) with \$11 billion in revenue. Unfortunately, Venezuela is not included in this study due to missing data. These figures underscore the significance of the oil and gas sector in Latin America and its role in the regional economy and global energy landscape.

One interesting aspect that distinguishes the Latin American market, particularly in the oil sector, is the predominance of state-owned oil companies. The largest oil companies in Latin America, including those in Venezuela, Brazil, Ecuador, Mexico, Argentina, Colombia, and Peru, are all state-owned enterprises. These countries also boast significant proven oil reserves in the region, as of 2021, and collectively contribute to the total oil production in Latin America, positioning them among the largest oil producers globally (Statista, 2024). This unique characteristic highlights the central role of government ownership and management in the oil industry across Latin America, shaping policies and strategies that impact the region's energy sector and broader economy.

Figure 1 - Oil and gas extraction area in Latin America



Source: Global Energy Monitor, 2024

Latin American national oil companies often face government interference in their decision-making processes, which may not always align with business interests. This interference can present challenges in achieving optimal efficiency, transparency, and accountability in their operations. Political pressures to change regulations and policies can also complicate operations for these companies, impacting their ability to adapt to market conditions and pursue competitive strategies.

Furthermore, national oil companies may encounter an absence of market-oriented incentives and competition, as governments prioritize social welfare considerations over strategic resource management. This can limit innovation, investment, and the overall competitiveness of these companies in the global energy market (World Bank, 2020). Balancing national interests with business imperatives remains a critical challenge for state-owned enterprises in the oil sector across Latin America and other regions.

Many Latin American countries have a history marked by high levels of corruption, bribery, socio-political instability, and government mismanagement. For instance, Argentina and Venezuela currently experience the highest inflation rates globally, with rates of 102% and 300%, respectively (Yapur, 2024). Additionally, countries like Colombia and Mexico are known for hosting some of the largest drug cartels globally, while corruption and graft remain endemic across much of Latin America (Ammann and Kushner, 2020).

These factors significantly impact economic and political landscapes, as well as investor perceptions and market dynamics. This thesis effectively represents these challenges by examining election periods, changes in governments, and the influence of such events on stock market movements. Understanding these socio-political factors is crucial for

assessing investment risks and opportunities in Latin American markets, particularly within the context of the oil and energy sectors.

The central aim of this doctoral thesis is to analyse causality and dynamic associations between the oil market and the Latin American stock market using various econometric techniques. To achieve this objective, a comprehensive literature review was conducted on the relationship between the oil market and Latin American stock exchanges. This investigation is particularly important given that these dynamics and interactions have been relatively understudied compared to other global markets.

Quantitative methods were applied to existing data to identify asymmetric patterns or correlations between oil market movements and stock market behavior in Latin America. By examining causality and dynamic associations, this thesis seeks to contribute to a deeper understanding of the interconnectedness between these markets and provide insights for investors, policymakers, and researchers interested in the region's economic and financial landscape.

Studying the dynamics between the oil market and Latin American stock markets contributes valuable insights to the fields of finance, economics, and international relations. It enhances our understanding of market interactions and their relationship to geopolitical factors, shedding light on complex economic and political dynamics in the region.

The findings from this research can benefit various stakeholders, including investors, policymakers, and businesses, by providing a deeper interpretation of market dynamics and enabling more informed decision-making. Understanding these interactions helps to mitigate risks associated with market volatility and informs the development of effective strategies to navigate this globally influential market.

By bridging the gap between finance, economics, and international relations through empirical analysis and quantitative methods, this research aims to contribute to academic knowledge and practical applications, ultimately supporting more informed and strategic decision-making in the context of Latin American markets and their connections to the global oil economy.

The research content of this thesis has been divided into three independent articles, each employing a different econometric approach. However, a consistent statistical technique used across all three papers was quantile regression (QR). This technique allows for the analysis of the relationship between variables at different percentiles of the conditional distribution, capturing variations across different segments of the data distribution.

By using quantile regression, the analysis in each paper delves into specific details of stock market movements across different performance levels, including stability, bullish and bearish market conditions. This approach enriches the analysis by providing a nuanced understanding of how various factors impact different segments of the market, offering valuable insights beyond traditional linear regression models that focus solely on average effects.

Overall, the use of quantile regression in all three papers enhances the richness and depth of the analysis, allowing for a comprehensive exploration of the relationships between variables and their implications across different market conditions and performance levels.

Quantile regression proves particularly useful when analyzing datasets where the focus is on the tails of the distribution or when the conditional distribution is non-normally distributed, as is often the case with time series data. It is also effective when dealing with distributions that are not symmetric or when outliers are present in the data.

In both studies within this doctoral thesis, a leptokurtic distribution was observed, characterized by a sharp peak around the mean and thicker tails on both sides. This distribution implies that extreme values, both positive and negative, are more likely compared to a normal distribution. The presence of such distribution characteristics underscores the importance of using quantile regression, which allows for a more robust analysis that captures the behaviour and impact of extreme values on the relationships being studied.

Furthermore, skewness, a statistic describing the asymmetry of the series distribution, played a prominent role in the analysis of this doctoral thesis. Skewness provides additional insights into the shape and behaviour of the data, further enhancing the understanding of market dynamics and the relationship between variables in non-normally distributed datasets. By considering these statistical properties, the thesis offers a comprehensive examination of market phenomena that go beyond traditional linear modelling approaches, highlighting the importance of exploring data characteristics and outliers in financial and econometric analyses.

In the first article, both quantile regression (QR) and ordinary least squares (OLS) regression were employed to assess the asymmetric effects of capital markets under different states of stock market performance conditions (including low and high performance and stability) during negative and positive price sessions. This approach represents a relatively unexplored area within Latin American markets.

The regression analysis methods were compared while controlling for various factors, including autocorrelation, exchange rates, the S&P 500 index, and the impact of the COVID-19 pandemic period. Additionally, the analysis incorporated performance

measures such as the Sharpe ratio, Sortino ratio, Rachev ratio, and STARR ratio to evaluate the performance of Latin American stock markets under different conditions

By using both QR and OLS regression techniques and integrating a comprehensive set of control variables and performance measures, the study aims to provide a nuanced understanding of market dynamics, particularly focusing on asymmetries in stock market behavior across different performance states and market conditions. This holistic approach enhances the robustness and depth of the analysis, contributing valuable insights to the field of financial econometrics within the Latin American context.

In the second article, dynamic linear and nonlinear models of Granger causality were utilized to provide a more effective approach for analyzing the relationship between the oil market and the Latin American stock market. The analysis was further refined by dividing the data into eight quantile intervals, which represented different segments of the conditional distribution: big intervals (0.05-0.95, 0.05-0.50, 0.50-0.95), lower intervals (0.20-0.40, 0.40-0.60, 0.60-0.80), and the last (0.05-0.20, 0.80-0.95) the extreme intervals.

This study demonstrated that employing a dynamic nonlinear method of Granger causality within quantile intervals offered a superior approach to analyzing two distinct markets in a time series context. By examining contemporary behaviour across quantile intervals, the analysis provided insights into how the relationship between the oil market and Latin American stock market varies under different market conditions and performance levels. This approach allowed for a more nuanced understanding of causal relationships and interactions within specific segments of the market distribution, enhancing the depth and accuracy of the analysis.

In the third article, extreme return spillovers and connectedness among crude oil (West Texas Intermediate), the Volatility Uncertainty Index (VIX), S&P 500, and Latin American stock markets were examined. The study utilized a quantile vector autoregression (QVAR) model to estimate the time series data. The analysis focused on three specific quantiles: extreme lower quantile ($\tau = 0.05$), medium quantile ($\tau = 0.5$), and for an extreme upper quantile ($\tau = 0.95$).

By employing this approach, the study conducted a nuanced investigation of connectedness and integration between these markets across different levels of market performance and conditions. This methodology allowed for a detailed examination of how extreme market movements and shocks in crude oil prices, volatility, and broader market indices like the S&P 500 impact Latin American stock markets. The analysis provided insights into the dynamics of market interconnectedness and the transmission of shocks across different quantile intervals, enhancing our understanding of systemic risk and market integration within the studied regions.

The research motivation is rooted in the understanding that crude oil prices fluctuate daily based on market demand expectations, leading to periods of both high and low performance over time. These fluctuations elicit varied reactions from investors in different market conditions, resulting in cycles of positive and negative responses within the Latin American stock market.

This phenomenon reflects the broader impact of oil price shocks on economic activities and investor behavior, as demonstrated in Hamilton's seminal study in 1983. Hamilton (1983) showed that increases in oil prices contributed to economic downturns in the U.S. economy, highlighting the interconnectedness between oil markets and broader economic trends.

By investigating these dynamics within the context of Latin American markets, the research aims to uncover how oil price fluctuations influence market performance and investor sentiment in the Latin American market.

The challenge of predicting oil prices stems from several factors, including the need to define the expression of price values (whether in nominal or real terms), determining the relevant time periods for analysis, and selecting appropriate econometric methods for evaluation. These considerations are critical due to the complex and dynamic nature of oil markets, which are influenced by various economic, geopolitical, and supply-demand factors. The issue of causality, particularly in relation to oil price movements and their impacts on financial and macroeconomic variables, has been a subject of study across multiple disciplines, including finance, macroeconomics, and related scientific fields.

Econometric methods such as vector autoregression (VAR), Granger causality tests, and structural VAR (SVAR) models are commonly used to analyze causality and dynamics in time series data. These methods help researchers identify directional relationships, lead-lag effects, and transmission mechanisms between oil prices and various economic variables.

Overall, addressing the complexities of predicting oil prices requires a multidimensional approach that integrates economic theory, empirical analysis, and advanced econometric techniques. By advancing our understanding of causality and predictive modeling in oil markets, researchers aim to enhance forecasting accuracy and inform strategic decision-making in energy markets and beyond.

This doctoral thesis research focuses on studying the causality and dynamics between crude oil prices and the Latin American stock market using quantile regression and tests

of the null hypothesis of Granger non-causality within quantile intervals. This approach involves analyzing conditional quantiles of energy prices to understand how different levels of oil price fluctuations influence stock market performance across various segments of the distribution

By employing quantile regression, the research aims to capture heterogeneous effects of oil price shocks on the stock market, particularly focusing on how these effects vary across different quantile intervals of the conditional distribution. Additionally, the study utilizes Granger causality tests to assess the direction and strength of causal relationships between oil prices and stock market movements within specific quantile segments

The doctoral thesis consists of three independent articles published in international journals, presenting a compendium of research articles on the relationship between crude oil prices and the Latin American stock market.

The first article titled "Asymmetric influences on Latin American stock markets: a quantile approach" was published in "The Journal of Economic Asymmetries." This article focuses on exploring asymmetrical effects between the oil market and Latin American stock markets using a quantile regression approach.

The second article titled "Causality in quantiles between crude oil prices and Latin American stock market" was published in the "Global Journal of Arts Humanity and Social Sciences." This paper investigates different econometric approaches for analyzing the relationship between oil prices and Latin American stock markets and emphasizes how methodological choices can lead to varying conclusions.

The third article titled "Extreme return spillover between WTI, VIX, and six Latin American stock markets: a quantile connectedness approach" was published in "Studies

in Nonlinear Dynamics & Econometrics." This article explores the integration and connectedness between the oil market and Latin American capital markets using a quantile connectedness approach

The conclusions and main findings of the thesis are presented in the concluding section, synthesizing the key insights and contributions from each of the three articles. This compendium of research articles contributes to the existing literature by providing comprehensive insights into the dynamics and interactions between oil markets and Latin American stock markets across different quantile intervals and market conditions



Asymmetric influences on Latin American stock markets: A quantile approach

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ABSTRACT

This study examines the impact of international crude oil prices on quantiles of the distribution of stock market returns in Argentina, Brazil, Chile, and Mexico, from May 1, 2015 to January 15, 2021. For this purpose, quantile and ordinary least squares regression analysis methods were compared, controlling for the effects of autocorrelation, exchange rates, the S&P 500, and the COVID-19 pandemic period. We performed the analyses considering five quantiles associated with different states of stock market performance. The results showed that oil price fluctuations exhibited positive influences on Latin American stock markets, more prominent when oil prices were positive, as well as across all quantiles for the S&P 500 index. However, the exchange rate had a negative impact, except in Argentina. Asymmetric responses were found under negative and positive influences in previous trading sessions, as well for the pandemic period.

1. Introduction

The prices of crude oil interfere with capital markets because any change in oil prices directly impacts the inflow (or outflow) of oil dollars, which directly affects a country's exchange rate as well as speculator behavior (Volkov & Yuhn, 2016). This has also been demonstrated by Hamilton's seminal study (1983), where it was shown that increases in oil prices had an effect on the depression that had occurred in the U.S. economy.

On the basis of this framework, the main objective of this study was to analyze the impact of West Texas Intermediate (WTI) – international crude oil prices on various quantiles of the return distributions of stock markets for a group of salient Latin American economies (Argentina, Brazil, Chile, and Mexico). In addition, we also analyzed the influence of other control variables, such as autocorrelation effect, the exchange rate, the Standard and Poor's 500 index (S&P 500) return, and the COVID-19 pandemic period.

For this purpose, we compared the quantile regression (QR) and the ordinary least squares (OLS) regression analysis methods for measuring the asymmetric effects of capital markets in different states of stock market performance conditions (low and high stock market performance and stability) under negative and positive price sessions, which has rarely been explored in Latin American markets. In addition, our analysis included the Sharpe, Sortino, Rachev, and STARR ratio performance measures to rate the performance of the Latin American stock markets.

On the one hand, this analysis is critical, since different studies have shown that there were important nonlinear, asymmetric dependence and causal relationships among crude oil prices. Ramos and Veiga (2013) found a negative effect on the stock markets of

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oil-importing countries, while the impact was positive for oil-exporting countries. A study by [Sim and Zhou \(2015\)](#) discovered asymmetry between the oil market and the U.S. stock market, i.e., large negative oil price shocks positively affected equity prices when the stock market was performing well and, conversely, when negative oil price shocks affected the U.S. stock market, the influence of positive oil price shocks was weak. A stronger and more asymmetric response to oil prices across the stock markets in the Brazil, Russia, India, China, and South Africa (BRICS) countries was demonstrated in a study by [Wang et al. \(2020\)](#).

On the other hand, studies of G7 countries by [Lee et al. \(2012\)](#) and [Hatemi-J et al. \(2016\)](#) detected no causal effect of oil prices on stock market prices. It is even more interesting that there are no studies that have compared oil price shocks on the Latin American stock markets using a quantile regression analysis to find asymmetry linked to these markets.

As crude oil is a commodity, its price varies daily according to the demand expectations of the players in this market, thus, increasing the prospects of high and low performances for a certain time and causing investors to react positively and negatively in different market conditions, i.e., up or down cycles in response to these shocks. This same analysis has led to a movement of dollars entering and leaving the Latin American markets, in view of the fact that investors are always looking for the best return options when markets are down. It also corroborates the assumptions of [Markowitz \(1952\)](#) that investors, when having to choose between two investments with equal expected returns, will choose the investment that imposes less risk, and between two investments with the same risk, they will choose the investment with the highest expected return.

Our evidence has implications for investors, since according to the results, it is possible to demonstrate which Latin American markets are closely linked in an asymmetric way (negatively or positively). The evidence also provides important information on the risks of hedging management decisions, as we analyzed the behavior of stock markets in relation to different price fluctuations (analyzing the entire distribution of QR returns), which vary according to market circumstances.

The remainder of this article is divided into four sections. In Sections 2 and 3, we describe the theoretical framework and methodology used; in Section 4, we present the results; and finally, in Section 5 we summarize the conclusions.

2. Literature review

There is vast literature showing the impacts of oil prices on stock markets in several countries ([Zhu et al., 2016](#); [Smyth & Narayan, 2018](#); [Mensi et al., 2018](#); [Kushwah & Siddiqui, 2020](#); [Muritala et al., 2020](#); [Ni et al., 2020](#); [Wu et al., 2020](#); [Mokni, 2020](#); [Gonzales et al., 2020](#); [Salisu & Gupta, 2020](#)). However, Latin American markets represent a minority in these studies between oil prices on stock markets ([Adrangi et al., 2020](#); [Delgado et al., 2018](#); [Ferreira et al., 2020](#); [Naeem et al., 2020](#); [Salgado et al., 2017](#)) despite the fact that the characteristics of these Latin American studies differ from our analysis.

On the one hand, Latin American countries produce oil and own the reserves of this commodity; therefore, they hold strategic power in the negotiations. However, at the same time, they suffer from geopolitical risks, macroeconomic trends, and imbalances in consumer demand and corporate profitability ([Becard et al., 2020](#), pp. 55–81). Thus, fluctuations in the prices of world oil directly impact these economies, and a major channel to measure it is through the impact of stock prices on the stock exchanges.

At the time of writing this paper, Goldman Sachs predicted that world demand for oil would fall by at least 8% in 2020 and would only return to pre-COVID-19 levels after 2022 ([Goede, 2020](#)). Therefore, these expectations should have an effect on stock markets since the oil market is vulnerable to scales, market trends, and outbreaks ([Mensi et al., 2020](#)).

[Chang \(2020\)](#) found asymmetric evidence between the oil price shock and the stock market in the short term in Russia, Indonesia, and India; however, this asymmetry was not verified in Brazil, China, Mexico, or Turkey. For oil-exporting countries (Saudi Arabia, Canada, Norway, and Russia), a positive dependence was found (also verified for the oil-importing countries of emerging economies, such as Brazil, China, South Korea, and India). However, for importing countries from developed economies (Germany, USA, France, and Japan), a negative dependence was found ([Jesus et al., 2020](#)). Conversely, [Ahmad and Anwer \(2020\)](#) found a positive asymmetric relationship between oil prices and the trade balance for Brazil, India, China, and South Africa.

Similar to our study, the distinguished work of [Wang et al. \(2020\)](#) used the Granger causality model to demonstrate the causality between unequal combinations in the face of extreme (positive and negative) and normal shocks between the International Oil Price (WTI) and the Brazil, Russia, Indian, China, and South Africa (BRICS) stock markets. In this current study, it was found that large variations in oil prices (positive and negative) had a significant and asymmetrical impact on the extreme variations in stock prices (positive and negative) among all the stock markets under analysis.

3. Methodology

For the analysis of this study, the daily closing data of the main stock exchanges indexes in Latin American were collected on the Yahoo Finance website: Argentina (Merval), Brazil (Ibovespa), Chile (iShares MSCI Chile—ECH), Mexico (IPC), S&P 500; the North American market and the data for Latin American exchange rate were collected from the Investing website. The analysis period comprised 1334 observations from Argentina, 1360 from Brazil, and 1409 from Chile, Mexico, WTI, and S&P 500; daily data from 1 May 2015 to 15 January 2021.

The selection of this sample is checked by its turnover and its representativeness within the Latin American economies, being the American stock exchange the largest of them, followed by Brazil, Mexico, Argentina, and Chile ([Statista, 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).

Latin American represents the world's second-largest crude oil reserves (first is the Middle East), and the classification by country is Brazil, Mexico, Argentina, and Chile; Brazil and Mexico are exporter countries of crude oil and petroleum products and Brazil and Chile

are importers of crude oil (Opec, 2020).

Initially, QR will be used in this study, as the work aims to detect a contemporary relationship, in other words, we are interested in association in the sense of relationship. QR detects and quantifies the nonlinear causality of effects between random variables, as the measures are based on nonparametric QR and as logarithmic functions of constrained and unconstrained expectations of quantile verification loss functions. From the time series, logarithmic differences in prices (log-returns) were calculated in order to correct the non-stationarity of the price series, the log-return is obtained as in equation (1):

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

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

In order to explore the impact of WTI prices, dynamic returns, the exchange rate, the S&P 500 index and the COVID-19 pandemic period on the various quantiles of the distribution of the stock market returns, we proceeded with the estimation of quantile and OLS regression, where the logarithmic market differences for the main indices of the Latin American market are regressed with the variations of WTI oil market, the previous trading sessions, exchange rates, S&P 500 index, and for the effect of COVID-19 (for both positive or negative price changes, respectively). The COVID-19 period was divided into two periods, using a dummy to differentiate the analysis period prior to the onset of the pandemic from the post-pandemic period.

The QR model was used, which allows exploration of the relation between the variables and the stock market index along the different quantiles of the distribution, because, in this study, we are analyzing various parts (quantile) of the data distribution, that is, the analysis is being verified in a broader way, mainly at the extremes (tails) of the data distribution. Furthermore, QR estimator is robust in the presence of conditional heteroskedasticity, asymmetries, or extreme values (fat tails), features exhibited by daily frequency financial data (Duarte et al., 2017); this method is also robust especially when the conditional distribution is skewed or has heterogeneous variance.

The quantile regression, introduced by Koenker and Bassett (1978), is based on the estimation of quantile functions that specify a quantile τ of the variable y_i conditioned on a group of variables x_i as a linear function specified in equation (2):

$$Q_\tau(y_i|x_{i1}, x_{i2}, \dots, x_{ik}) = \beta_0(\tau) + \beta_1(\tau)x_{i1} + \beta_2(\tau)x_{i2} + \dots + \beta_{ik}(\tau)x_{ik} + \varepsilon_i(\tau) \quad (2)$$

where $i = 1, 2, \dots, n$

Equation (2) can be written in a simplified form by $y = \alpha(\tau) + x_i\beta(\tau)$, where y is the response variable vector; X is the explanatory variable matrix; $\beta(\tau)$ is the marginal effect of the explanatory variables X in the τ th quantile of y , an effect that may be a variant that depends on the chosen quantile and $\varepsilon(\tau)$ is the residual error vector in the quantile $\tau \in (0, 1)$.

In this study, in order to analyze the asymmetric effect of the variations of the explanatory variables on Latin American stock markets, a QR equation will be applied (3). The effects of autocorrelation are considered in the equation (dependence of the series with its values in the immediately preceding period) and the influence of the exchange rate and S&P 500 index covariates will be considered.

$$r_t = \beta_0(\tau) + \beta_1(\tau)r_{t-1} + \beta_2(\tau)r_{t-1}^+ + \beta_3(\tau)wti_t^- + \beta_4(\tau)wti_t^+ + \beta_5(\tau)ex_t^- + \beta_6(\tau)ex_t^+ + \beta_7(\tau)sp_t^- + \beta_8(\tau)sp_t^+ + \beta_9d_{Covid-19} + \varepsilon_i(\tau). \quad (3)$$

where r_t is the logarithmic difference in prices (log-returns), wti_t , ex_t and sp_t are the changes in the oil price, the exchange rate and the S&P 500 index for the period (t); r_{t-1}^- is the stock market price when $r_{t-1} \leq 0$, r_{t-1}^+ is the stock market price when $r_{t-1} > 0$; wti_t^- is the oil price variation when $wti_t \leq 0$, wti_t^+ is the oil price variation when $wti_t > 0$; ex_t^- is the exchange rate variation when $ex_t \leq 0$, ex_t^+ is the exchange rate variation when $ex_t > 0$; sp_t^- is the S&P 500 variation when $sp_t \leq 0$, and sp_t^+ is the S&P 500 variation when $sp_t > 0$.

Table 1

Descriptive statistics and performance measure for Latin American stock index, WTI, and S&P 500 log-returns.

Statistics	Log-return of Countries, WTI, and S&P 500 (%)					
	Argentina	Brazil	Chile	Mexico	WTI	S&P 500
Observations	1334	1360	1409	1409	1409	1409
Minimum	-47.692	-16.246	-16.736	-6.526	-72.027	-12.765
Maximum	9.773	13.656	10.452	4.796	42.583	8.968
1_Quantile	-1.050	-0.807	-0.750	-0.470	-1.330	-0.304
3_Quantile	1.419	1.019	0.741	0.534	1.325	0.535
Mean	0.116	0.060	-0.015	0.002	-0.010	0.041
Median	0.189	0.096	-0.030	0.004	0.083	0.064
Standard deviation	2.802	1.827	1.608	1.000	4.086	1.201
Skewness	-3.923	-1.215	-1.154	-0.605	-2.914	-1.139
Kurtosis	64.601	15.898	17.321	5.391	88.763	20.815
Sharpe	0.040	0.032	-0.009	0.002	-0.003	0.034
Sortino	0.052	0.043	-0.013	0.002	-0.004	0.046
Rachev	0.956	0.946	0.952	0.938	0.954	0.856
STARR	0.035	0.007	-0.002	0.001	-0.005	0.011

Data: May 1, 2015–January 15, 2021.

These variables was measured by quantile analysis under different market states (high/low and stability market), where five quantiles were specified. The smaller quantiles $\tau = 0.05$ and $\tau = 0.25$ represent a situation in which the stock market is operating with returns below the conditional average (low performance); $\tau = 0.50$ represents a situation in which the stock market is operating with returns close to the conditional average (stability); $\tau = 0.75$ and $\tau = 0.95$ represent a situation in which the stock market is operating with returns above the conditional average (high performance). When the result of the coefficient β is significantly positive, it can be inferred that the stock market returns would increase (decrease) when the variables go up (down).

4. Results

Firstly, a descriptive analysis of the four Latin American stock exchange indexes, WTI and S&P 500, in log-return (calculated by formula (1)), is presented in Table 1. In particular, statistics for the Latin American index: IBOVESPA for Brazil, Merval for Argentina, iShares MSCI Chile ETF–ECH for Chile, and the S&P/BMC IPC for Mexico. To rate the performance of Latin American markets, the last four lines in Table 1 include Sharpe, Sortino, Rachev and STARR ratios performance measure. The Latin American exchange rate descriptive analysis, in log-returns calculated by formula (1), is presented in Table 2. In both Tables 1 and 2, the results are presented in percentage for better numerical visualization.

The data were collected from the daily closings of the four Latin American stock market indexes: WTI, exchange rates, and S&P 500. For Argentina there are 1334 observations, for Brazil 1360, for Chile, Mexico, WTI, and S&P 500 there are 1409 observations. For all variables, mean returns are close to zero, positive for Argentina, Brazil, Mexico, and S&P 500, while for the Chilean and WTI markets, negative averages were verified.

The widest gap between the minimum and the maximum return is observed in Argentina and WTI, resulting in a higher variance and standard deviation. Some interesting data in Table 1 is that the lows (minimum values) of the Latin American stock markets, WTI, and S&P 500 are greater than the highs (maximum values). Performance appraisal is a better term than risk measure and these measures can be described as the return (or reward) per unit of variability (or risk).

The greater performance ratio in Table 1 measure by Sharpe, Sortino, Rachev and STARR, means better performance, and Argentina, Brazil and S&P 500 markets show the greatest performance for Sharpe, Sortino and STARR ratios, in the other hand, Rachev ratio elected Argentina, WTI and Chile. Negative returns will generate negative performance ratios, as it can be seen for Chile and WTI markets.

On the other hand, the Latin American exchange rate for Latin American countries in Table 2 shows the opposite, the high values are greater than the lows. A negative skewness is exhibited in all stock markets, except for the Latin American exchange rate, and kurtosis presents high values, indicating a leptokurtic distribution, i.e., with a sharp peak around the mean and thick tails on both sides.

The Argentine stock market and WTI have the highest values for lows, and the Brazil stock market and WTI show the highest values for highs in the market (as can be seen for their standard deviations). For exchange rate, in Table 2, the Argentine currency has the largest exchange variation, followed by Brazil in the minimum values and Mexico in the maximum values. Because there was no data in some days in the observations due to the different holiday periods in Latin American countries, the Kalman filter method was applied for missing data imputations (Grewal, 2011; Manke, 2018).

Evolution in logarithm of the values of the Latin American stock market index, WTI, and S&P 500 are displayed in Fig. 1.

Fig. 1 display the evolution in logarithm of the values in each of the Latin American markets, WTI and S&P 500 along the years in analysis, and it can be seen that COVID-19 period caused a substantial drop in the markets. Argentina highlights two substantial lows in the Argentine stock market—in 2019 and 2020. The first refers to the presidential election on August 12th, where Mauricio Macri was defeated causing a 30% plunge of the Merval index, while the second drop was caused by the COVID-19 pandemic.

Brazilian stock market dynamics (IBOVESPA index) shows upward movement after 2016 (year of the impeachment of President Dilma Rousseff), suffering a sharp drop only with the COVID-19 effect in 2020, in which the stock exchange plummeted from 120,000 points to below 70,000.

According to the plots, the Chilean stock market displays a downward movement, especially after 2018, with the beginning of the current president Sebastián Piñera. There is also a sharp drop in 2020 due to COVID-19 period. The Mexican stock market shows two

Table 2

Descriptive statistics for Latin American exchange rate log-returns.

Statistics	Log-return of Exchange Rate (%)			
	Argentina/USD	Brazil/USD	Chile/USD	Mexico/USD
Observations	1334	1360	1409	1409
Minimum	−6.170	−5.946	−3.651	−4.273
Maximum	30.435	7.162	4.242	8.074
1_Quartile	−0.118	−0.611	−0.398	−0.503
3_Quartile	0.328	0.716	0.443	0.497
Mean	0.169	0.038	0.012	0.017
Median	0.090	0.021	0.000	−0.020
Standard deviation	1.397	1.111	0.696	0.888
Skewness	9.701	0.065	0.142	0.834
Kurtosis	184.052	2.722	2.055	6.603

Data: May 1, 2015–January 15, 2021.

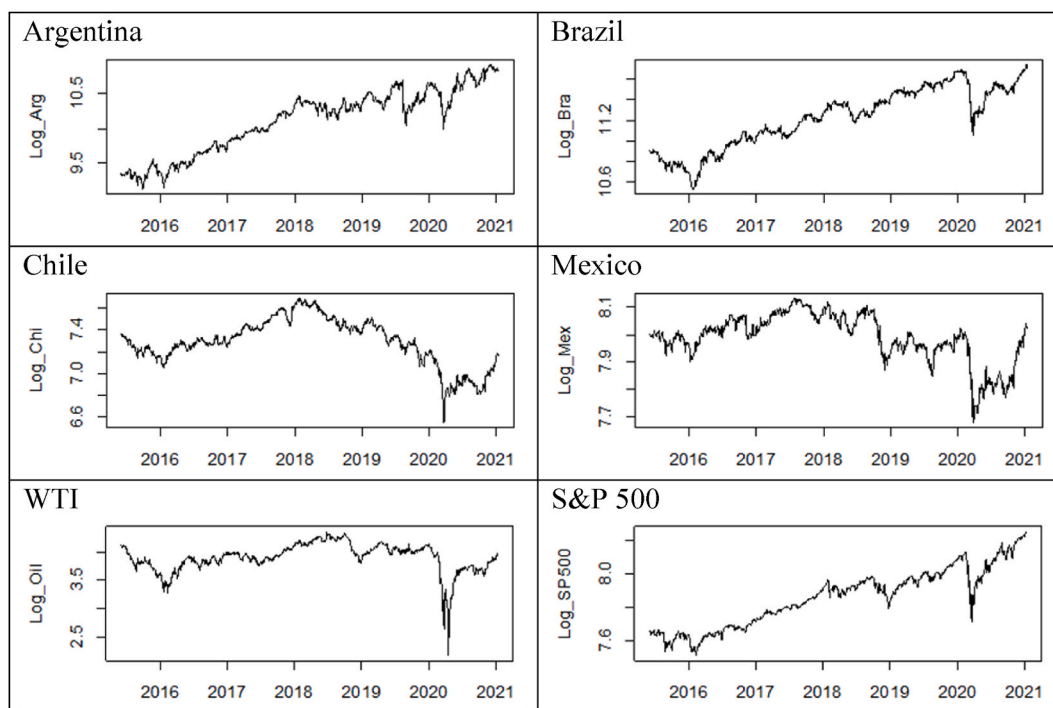


Fig. 1. Evolution in logarithm of the Latin American stock market index values.
Data: May 1, 2015–January 15, 2021.

salient remarks that are worth mentioning: the drop in 2018, caused by a change in the government, and the COVID-19 crash in 2020.

Fig. 2 shows the evolution in the logarithm of the Latin American exchange rate values, and the distribution of the oil price series follows a lateral line for the years under analysis, suffering a sharp drop in 2020, in which, for the first time in history, negative prices are observed for the main index of the reference price of oil in the American market (WTI), with a drop from USD 18 to USD -38 (Ambrose, 2020). The lockdown effect imposed by world governments during the COVID-19 pandemic meant that there was a sharp and immediate decrease in oil consumption worldwide, with an average decline of 30% in the consumption of this commodity worldwide (Krauss, 2020).

S&P 500 displays sustainable market growth, especially after 2016, although, also dropping during 2020 due to the COVID-19 effect. From the figures, it can be seen that all markets suffered substantial declines due to the COVID-19 effect; however, all markets have already reached, or passed, the prices they had obtained before the pandemic.

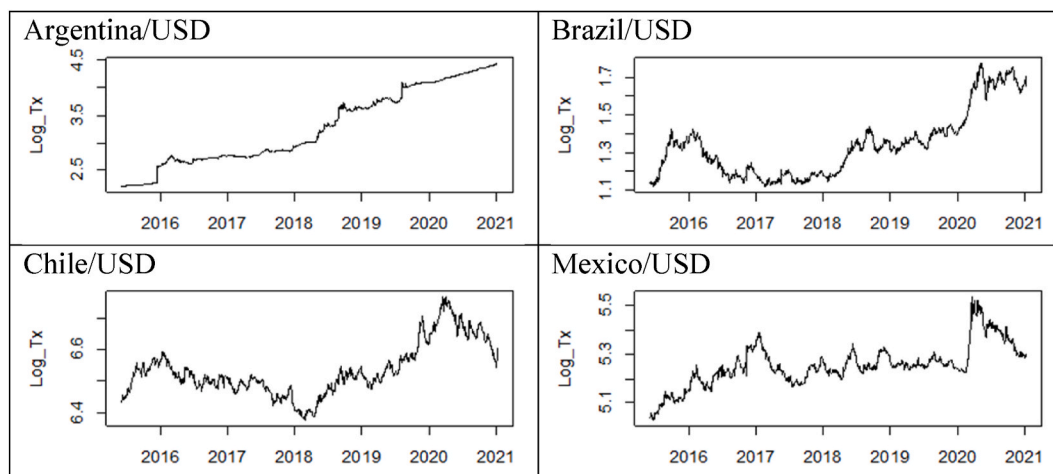


Fig. 2. Evolution in logarithm of the Latin American exchange rate values.
Data: May 1, 2015–January 15, 2021.

Several Latin American countries are facing economic and political turmoil, which may significantly impact their currencies (Guas, February 2019). Brazil's currency was one of the worst-performing in the world in 2020 (Oyamada, 2021). The Mexican peso lost 21% of its value against the American dollar in 2020, while Chile was down 10.4% on a year-to-date basis (Focuseconomics, 2021). Argentina is facing the worst currency volatility in its history—the official peso rate fell 22% against the dollar in 2020 (Mander, 2020).

All these series exhibit a non-stationary pattern in levels; however, they seem to be stationary in log returns. This issue was tested in Table 3, where Dickey–Fuller (DF) and KPSS test results are displayed. It is noteworthy that, as conventional unit root tests are not reliable in the presence of permanent changes in volatility (see Cavaliere & Taylor, 2009), the bootstrap approach is used for the unit root test, which is valid in the presence of a wide class of permanent variance changes that includes simple and multiple volatility change processes.

According to Table 3, it can be verified that the time series distributions of stock market indexes log-returns, WTI, S&P 500, and Latin American exchange rate are stationary since the null hypothesis of the unit root was rejected for the test, considering their *p*-values (Smeekes, 2013 and 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 series under analysis; both tests confirm that variables are stationary at the 1% level.

To verify the influence of the COVID-19 period, the quality variable Dummy was used (1 = after March 9, 2020, 0 = before March 9, 2020). The smaller quantiles $\tau = 0.05$ and $\tau = 0.25$ represent a situation in which the stock market is operating with returns below the conditional average (low performance); $\tau = 0.50$ represents a situation in which the stock market is operating with returns close to the conditional average (stability); $\tau = 0.75$ and $\tau = 0.95$ represent a situation in which the stock market is operating with returns above the conditional average (high performance). Tables 4–8 report QR and OLS regression estimates for Latin American stock market returns. Following the QR literature, we show numerical results for five quantiles from 0.05 to 0.95 considering different financial market states. The analyses of the variables in Tables 4–8 are based on their statistical significance (* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$) marked with the asterisks beside the values.

In analyzing the QR relationship between oil prices and the Argentine market variations shown in Table 4, it was observed that in the lower quantiles ($\tau = 0.05$ and $\tau = 0.25$), the negative oil price variations (wti_t^-) show an asymmetric cross-correlation pattern. When the oil price changes were positive (wti_t^+), a positive QR association follows the same direction of the stock market, starting in the middle quantile ($\tau = 0.5$) to the upper quantiles ($\tau = 0.75$ and $\tau = 0.95$). In the OLS regression analysis, only a positive association for wti_t^+ was identified.

For the dynamics of the returns, lower quantiles ($\tau = 0.05$ and $\tau = 0.25$) show a positive dependence when the price variations were negative (r_{t-1}^-). This dependence becomes negative in the upper quantiles ($\tau = 0.75$ and $\tau = 0.95$). However, if in the previous period, the price changes were positive (r_{t-1}^+), there was only a positive dependence on the stability and upper quantiles ($\tau = 0.5$, $\tau = 0.75$, and $\tau = 0.95$). This behavior clearly defines an asymmetric cross-pattern between positive and negative price changes. Comparatively, in the OLS regression analysis, there was only a negative autocorrelation for r_{t-1}^- .

A QR positive relationship between the exchange rate changes and variations in the Argentine stock market exists; it was observed that, when exchange rate changes were negative (ex_t^- , only positive association within the exchange rate market for the entire Latin American sample of this study), following changes occurred in the stock market in the lower quantiles ($\tau = 0.05$ and $\tau = 0.25$) and for $\tau = 0.5$ and $\tau = 0.95$. However, when changes in the exchange rate were positive (ex_t^+) the association shows only a negative association in the first quantile ($\tau = 0.05$), demonstrating an asymmetric cross-correlation pattern. In the OLS regression analysis, a negative association for ex_t^+ was identified.

There was a positive association between variations in the S&P 500 index and variations in the price of the Argentine stock market. It is noteworthy that this association does not depend on the analyzed quantile; it also does not depend on whether the index variations were negative (sp_t^-) or were positive (sp_t^+), as the betas represent high and significant values across the entire sample, representing a greater impact. In a way, this pattern of behavior shows that the relationship between the variables was not unique but dependent on the analysis of the quantile.

The inclusion of a dummy variable in the period after the beginning of the pandemic ($d_{\text{covid-19}}$) was able to capture a drop in the

Table 3

Unit root and stationarity of daily log differences from Latin American stock market index, S&P 500, WTI, and Latin American exchange rate.

Country	Unit Root Test (Lag Max = 5)		Stationarity (Lag = 7)	
	DF-GLS	Significance	KPSS	Significance
Argentina	−2.677	0.008	0.024	>0.10
Brazil	−5.017	0.000	0.046	>0.10
Chile	−13.071	0.000	0.096	>0.10
Mexico	−32.795	0.000	0.066	>0.10
S&P 500	−19.678	0.000	0.065	>0.10
WTI	−9.007	0.000	0.044	>0.10
Arg/USD	−33.563	0.000	0.089	>0.10
Bra/USD	−7.977	0.000	0.137	>0.10
Chi/USD	−9.895	0.000	0.068	>0.10
Mex/USD	−21.862	0.000	0.101	>0.10

Note: values were calculated based on the indices in local currency.

Table 4Quantile and OLS regression for Argentine stock market (dependent variable $\Delta\log(\text{Argentina})$).

$\Delta\log(\text{Argentina})$	Quantile Regression ^a					OLS
	$\tau = 0.05$	$\tau = 0.25$	$\tau = 0.50$	$\tau = 0.75$	$\tau = 0.95$	
Constant	−0.021*** (0.003)	−0.005*** (0.001)	0.001 (0.001)	0.007*** (0.001)	0.020*** (0.003)	0.001 (0.001)
wti_t^-	0.216** (0.102)	0.184** (0.079)	0.085 (0.060)	0.019* (0.011)	−0.074 (0.173)	0.022 (0.026)
wti_t^+	0.058* (0.033)	0.058 (0.057)	0.138** (0.063)	0.205*** (0.016)	0.259*** (0.061)	0.122*** (0.029)
r_{t-1}^-	0.253*** (0.072)	0.208** (0.091)	−0.028 (0.084)	−0.142*** (0.053)	−0.390*** (0.133)	−0.094** (0.037)
r_{t-1}^+	0.104 (0.071)	0.031 (0.046)	0.103** (0.048)	0.213*** (0.044)	0.513*** (0.139)	0.087* (0.049)
ex_t^-	0.621*** (0.163)	0.561*** (0.108)	0.388* (0.198)	0.066 (0.221)	−0.808* (0.483)	0.201 (0.131)
ex_t^+	−2.789* (1.572)	0.017 (0.243)	0.013 (0.080)	0.148 (0.099)	0.207 (0.151)	−0.322*** (0.058)
sp_t^-	0.689*** (0.130)	0.875*** (0.076)	0.769*** (0.126)	0.839*** (0.083)	1.002*** (0.217)	0.936*** (0.092)
sp_t^+	0.909*** (0.144)	0.603*** (0.152)	0.686*** (0.138)	0.845*** (0.120)	0.972*** (0.291)	0.606*** (0.108)
$d_{Covid19}^b$	−0.021*** (0.004)	−0.006* (0.003)	−0.003 (0.002)	0.005* (0.003)	0.010 (0.007)	−0.002 (0.002)
Observations	1334	1334	1334	1334	1334	1334
Adjusted R ²						0.180

Note: * $p < 0.10$ ** $p < 0.05$ *** $p < 0.01$.^a $r_t = \beta_0(\tau) + \beta_1(\tau)r_{t-1}^- + \beta_2(\tau)r_{t-1}^+ + \beta_3(\tau)wti_t^- + \beta_4(\tau)wti_t^+ + \beta_5(\tau)ex_t^- + \beta_6(\tau)ex_t^+ + \beta_7(\tau)sp_t^- + \beta_8(\tau)sp_t^+ + \beta_9d_{Covid19} + \varepsilon_i(\tau)$.^b Dummy variable takes value of 1 after March 9, 2020 and 0 in the previous period.**Table 5**Quantile and OLS regression for Brazilian stock market (dependent variable $\Delta\log(\text{Brazil})$).

$\Delta\log(\text{Brazil})$	Quantile Regression ^a					OLS
	$\tau = 0.05$	$\tau = 0.25$	$\tau = 0.50$	$\tau = 0.75$	$\tau = 0.95$	
Constant	−0.013*** (0.002)	−0.003*** (0.001)	0.001** (0.001)	0.007*** (0.001)	0.012*** (0.002)	0.002*** (0.001)
wti_t^-	0.097** (0.038)	0.111** (0.050)	0.041 (0.026)	0.006 (0.035)	−0.007 (0.080)	0.029* (0.017)
wti_t^+	0.019 (0.044)	0.005 (0.027)	−0.008 (0.027)	0.020* (0.012)	0.082 (0.080)	−0.006 (0.016)
r_{t-1}^-	−0.024 (0.197)	−0.090 (0.060)	−0.120*** (0.033)	−0.084*** (0.031)	−0.244** (0.100)	−0.112*** (0.033)
r_{t-1}^+	0.111 (0.083)	−0.021 (0.045)	−0.047 (0.039)	−0.030 (0.055)	0.181*** (0.045)	−0.008 (0.037)
ex_t^-	0.025 (0.126)	−0.148 (0.092)	−0.263*** (0.067)	−0.484*** (0.092)	−0.815*** (0.228)	−0.337*** (0.060)
ex_t^+	−0.966*** (0.162)	−0.753*** (0.056)	−0.688*** (0.069)	−0.565*** (0.094)	−0.267 (0.223)	−0.615*** (0.058)
sp_t^-	1.195*** (0.218)	0.742*** (0.133)	0.596*** (0.082)	0.541*** (0.061)	0.628*** (0.236)	0.871*** (0.050)
sp_t^+	0.518*** (0.101)	0.682*** (0.119)	0.704*** (0.067)	0.745*** (0.082)	0.997*** (0.104)	0.731*** (0.057)
$d_{Covid19}^b$	0.0001 (0.004)	0.0003 (0.001)	0.002** (0.001)	0.001 (0.001)	−0.001 (0.003)	0.001 (0.001)
Observations	1360	1360	1360	1360	1360	1360
Adjusted R ²						0.510

Note: * $p < 0.10$ ** $p < 0.05$ *** $p < 0.01$.^a $r_t = \beta_0(\tau) + \beta_1(\tau)r_{t-1}^- + \beta_2(\tau)r_{t-1}^+ + \beta_3(\tau)wti_t^- + \beta_4(\tau)wti_t^+ + \beta_5(\tau)ex_t^- + \beta_6(\tau)ex_t^+ + \beta_7(\tau)sp_t^- + \beta_8(\tau)sp_t^+ + \beta_9d_{Covid19} + \varepsilon_i(\tau)$.^b Dummy variable takes value of 1 after March 9, 2020 and 0 in the previous period.

price variation only in the lower quantiles ($\tau = 0.05$). In the OLS regression analysis, the dummy did not identify a significant change.

According to Table 5, there was a positive QR association between the changes in the oil prices and changes in the Brazilian market when the stock market was operating with returns below the conditional average (low performance, $\tau = 0.05$ and $\tau = 0.25$) at the negative oil price variations (wti_t^-). When the oil price markets became positive (wti_t^+), there was only a positive association with the stock market in the $\tau = 0.75$ quantile.

The dynamics of the stock market returns had a negative dependence when the price changes were negative in the previous period (r_{t-1}^-), for the medium to upper quantiles ($\tau = 0.5$, $\tau = 0.75$, and $\tau = 0.95$). When the price changes were positive in the previous period (r_{t-1}^+), only the highest quantile ($\tau = 0.95$) shows positive and significant dependence. This characteristic behavior of the Brazilian market shows an asymmetrical cross-pattern between negative and positive price variations. With OLS regression analysis, negative price variations in the previous period (r_{t-1}^-) show a negative association. In the analysis of the association of exchange rate variations, there was a negative QR and OLS association with the Brazilian stock market in both price variations (negative and positive), showing cross-pattern asymmetry.

In analyzing the association of variations in the S&P 500 index, the betas had the highest values and there was a positive association with all the quantiles of the QR and OLS regression analyses. When the price variations of the index were negative (sp_t^-), the highest value of the quantiles was verified in the first quantile $\tau = 0.05$ (when the stock market was operating with returns below the conditional average (low performance)), which decreased as the quantiles increased.

On the other hand, the opposite was true when the price variations of the S&P 500 index were positive (sp_t^+), with the highest value of the quantiles observed in the quantile $\tau = 0.95$ (when the stock market represented a situation in which it was operating with returns above the conditional average (high performance)) and decreased as the quantiles decreased. This movement clearly defines an association of cross-asymmetry.

Table 6Quantile and OLS regression for Chilean stock market (dependent variable $\Delta \log(\text{Chile})$).

$\Delta \log(\text{Chile})$	Quantile Regression ^a					OLS
	$\tau = 0.05$	$\tau = 0.25$	$\tau = 0.50$	$\tau = 0.75$	$\tau = 0.95$	
Constant	−0.009*** (0.002)	−0.004*** (0.001)	−0.001 (0.001)	0.003*** (0.001)	0.009*** (0.001)	−0.00004 (0.001)
wti_t^-	0.162 (0.103)	0.031 (0.020)	0.054*** (0.020)	0.068* (0.035)	−0.025 (0.033)	0.034*** (0.013)
wti_t^+	−0.003 (0.043)	0.047*** (0.018)	0.065** (0.032)	0.084*** (0.018)	0.050** (0.023)	0.058*** (0.014)
r_{t-1}^-	0.119 (0.078)	0.071 (0.045)	−0.019 (0.045)	−0.040 (0.051)	−0.287*** (0.077)	−0.049 (0.034)
r_{t-1}^+	−0.045 (0.121)	0.078 (0.049)	0.203*** (0.051)	0.265*** (0.057)	0.390*** (0.116)	0.200*** (0.037)
ex_t^-	−0.385 (0.242)	−0.627*** (0.099)	−0.712*** (0.091)	−1.065*** (0.121)	−1.478*** (0.425)	−0.815*** (0.092)
ex_t^+	−1.572*** (0.341)	−1.008*** (0.130)	−0.833*** (0.093)	−0.631*** (0.103)	−0.809*** (0.121)	−0.967*** (0.086)
sp_t^-	0.795*** (0.235)	0.536*** (0.080)	0.362*** (0.063)	0.347*** (0.071)	0.252*** (0.033)	0.613*** (0.046)
sp_t^+	0.246 (0.242)	0.200*** (0.060)	0.258*** (0.048)	0.322*** (0.106)	0.646*** (0.215)	0.238*** (0.054)
$d_{Covid19}^b$	−0.014*** (0.005)	−0.003* (0.001)	−0.0001 (0.001)	0.004*** (0.001)	0.008*** (0.001)	0.0002 (0.001)
Observations	1409	1409	1409	1409	1409	1409
Adjusted R ²						0.425

Note: * $p < 0.10$ ** $p < 0.05$ *** $p < 0.01$.^a $r_t = \beta_0(\tau) + \beta_1(\tau)r_{t-1}^- + \beta_2(\tau)r_{t-1}^+ + \beta_3(\tau)wti_t^- + \beta_4(\tau)wti_t^+ + \beta_5(\tau)ex_t^- + \beta_6(\tau)ex_t^+ + \beta_7(\tau)sp_t^- + \beta_8(\tau)sp_t^+ + \beta_9 d_{Covid19} + \varepsilon_i(\tau)$.^b Dummy variable takes value of 1 after March 9, 2020 and 0 in the previous period.**Table 7**Quantile and OLS regression for Mexican stock market (dependent variable: $\Delta \log(\text{Mexico})$).

$\Delta \log(\text{Mexico})$	Quantile Regression ^a					OLS
	$\tau = 0.05$	$\tau = 0.25$	$\tau = 0.50$	$\tau = 0.75$	$\tau = 0.95$	
Constant	−0.008*** (0.001)	−0.003*** (0.0005)	−0.0002 (0.0004)	0.003*** (0.0004)	0.009*** (0.001)	0.00003 (0.0004)
wti_t^-	0.021 (0.081)	0.002 (0.027)	0.004 (0.008)	0.021 (0.017)	0.046 (0.045)	0.025*** (0.008)
wti_t^+	0.066*** (0.015)	0.028 (0.020)	0.012 (0.012)	0.020 (0.012)	0.007 (0.020)	0.015* (0.009)
r_{t-1}^-	0.241*** (0.049)	0.089 (0.068)	0.096** (0.041)	−0.009 (0.047)	−0.041 (0.149)	0.057 (0.038)
r_{t-1}^+	−0.036 (0.056)	0.041 (0.066)	0.094** (0.044)	0.245*** (0.058)	0.206 (0.137)	0.139*** (0.041)
ex_t^-	0.064 (0.086)	−0.049 (0.077)	−0.159*** (0.054)	−0.224*** (0.064)	−0.247 (0.163)	−0.142*** (0.051)
ex_t^+	−0.687*** (0.197)	−0.288*** (0.048)	−0.202*** (0.048)	−0.146*** (0.041)	−0.189 (0.160)	−0.331*** (0.045)
sp_t^-	0.408*** (0.091)	0.420*** (0.045)	0.441*** (0.047)	0.342*** (0.032)	0.165 (0.188)	0.313*** (0.032)
sp_t^+	0.150 (0.158)	0.316*** (0.055)	0.438*** (0.051)	0.447*** (0.033)	0.585*** (0.076)	0.392*** (0.035)
$d_{Covid19}^b$	−0.005* (0.003)	−0.003** (0.001)	0.0005 (0.001)	0.003** (0.001)	0.007*** (0.002)	0.0001 (0.001)
Observations	1409	1409	1409	1409	1409	1409
Adjusted R ²						0.348

Note: * $p < 0.10$ ** $p < 0.05$ *** $p < 0.01$.^a $r_t = \beta_0(\tau) + \beta_1(\tau)r_{t-1}^- + \beta_2(\tau)r_{t-1}^+ + \beta_3(\tau)wti_t^- + \beta_4(\tau)wti_t^+ + \beta_5(\tau)ex_t^- + \beta_6(\tau)ex_t^+ + \beta_7(\tau)sp_t^- + \beta_8(\tau)sp_t^+ + \beta_9 d_{Covid19} + \varepsilon_i(\tau)$.^b Dummy variable takes value of 1 after March 9, 2020 and 0 in the previous period.

In the analysis of the COVID-19 period ($d_{covid-19}$), the Brazilian stock market did not capture a significant association in the quantile sample; only when the market was stable, the quantile $\tau = 0.5$ appears to have had a positive significance, but with a small beta value.

Table 6 shows the positive QR association of the Chilean capital market with variations in the oil price in the quantiles $\tau = 0.5$ and $\tau = 0.75$ when changes were negative (wti_t^-). However, when the oil market was positive (wti_t^+), a positive association was observed in all the quantiles of the sample, except for the first quantile ($\tau = 0.05$). In the OLS regression analysis, both markets for oil price changes (negative and positive) showed significance.

In the analysis of the dynamics of the stock market returns, a negative dependence was observed only in the extremely high performance of the stock market ($\tau = 0.95$) when in the previous period, the price variations were negative (r_{t-1}^-). However, when the price changes were positive in the previous period (r_{t-1}^+), there was a positive dependence on a larger number of quantiles in the sample, from stability to high performance of the market, and the values increased as the market warmed up. The OLS regression analysis showed significance only when the price changes were positive in the previous period (r_{t-1}^+).

In evaluating the analysis of the association of the stock market with changes in the exchange rate, a significant and negative association was observed for the entire sample of the contemporary series and OLS regression, for both negative (ex_t^-) and positive (ex_t^+) analyses, except in the first quantile ($\tau = 0.05$), when changes in the exchange rate were negative. The highest values of this association were found in extreme quantiles; when changes in the exchange rate were negative (ex_t^-), the values of the betas increased as the market heated up. In contrast, when changes in the exchange rate were positive (ex_t^+), the highest beta value was found in the

Table 8

Summary empirical results for QR and OLS regression for the Latin American stock markets.

		Argentina				Brazil				Chile				Mexico			
		QR		OLS		QR		OLS		QR		OLS		QR		OLS	
		L	E	H		L	E	H		L	E	H		L	E	H	
Oil	-	+	Θ	Θ	Θ	+	Θ	Θ	Θ	Θ	+	Θ	+	Θ	Θ	Θ	+
	+	Θ	+	+	+	Θ	Θ	Θ	Θ	+	+	+	+	+	Θ	Θ	Θ
Dynamics returns	-	+	Θ	-	-	Θ	-	-	-	Θ	Θ	-	Θ	+	+	Θ	Θ
	+	Θ	+	+	+	Θ	Θ	+	Θ	Θ	+	+	+	Θ	+	+	+
Exchange rates	-	+	+	Θ	Θ	Θ	-	-	-	-	-	-	-	Θ	-	-	-
	+	-	Θ	Θ	-	-	-	-	-	-	-	-	-	-	-	-	-
S&P 500	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
COVID-19	-	-	Θ	Θ	Θ	Θ	+	Θ	Θ	-	Θ	+	Θ	-	Θ	+	Θ

Notes: L, E, and H represent low performance, stability, and high performance of the stock market, based on the lower, middle, and higher quantiles from the QR analysis, respectively. OLS represents the ordinary least squares regression analysis. Θ means no significant dependence, while + (-) indicates positive (negative) and statistically significant co-movement.

low performance ($\tau = 0.05$) of the stock market and decreased as the market warmed up. This market shows the standard association of cross-pattern asymmetry.

S&P 500 and the Chilean stock market had a positive association in all the quantiles, as well as in the OLS regression analysis, both in the negative (sp_t^-) and positive (sp_t^+) index variations, except for the first quantile ($\tau = 0.05$) of the positive index variations. When the index was negative (sp_t^-), the highest beta value was found in the first quantile and the value decreased as the quantiles increased. In contrast, when the index was positive, the values of the betas increased as the capital market moved from low performance to high performance (lowest quantiles for the highest quantiles), showing cross-pattern asymmetry.

The COVID-19 period ($d_{\text{covid-19}}$) negatively affected the Chilean stock market when it was at low performance (lower quantiles); however, as the market started to heat up, there was a positive association. For the OLS regression, there was no significance.

In analyzing the QR relationship between oil price variations and the Mexican capital market (Table 7), there was no significance when the oil prices were negative (wti_t^-); however, there was a positive significance when the analysis was performed by OLS regression. When the oil market showed positive prices (wti_t^+), the first quantile ($\tau = 0.05$) showed a positive association for the QR and OLS analyses.

In the analysis of the dynamics of the stock market returns, there was a positive dependence on the variation of prices for the previous day ($\tau = 0.05$ and $\tau = 0.5$) when the price variations were negative (r_{t-1}^-), and when the price variations were positive (r_{t-1}^+), quantiles $\tau = 0.5$ and $\tau = 0.75$ showed significance. In the OLS regression analysis, significance appeared only when the prices were positive.

There was a negative association for exchange rate variations with the Mexican stock market when the exchange rate changes were negative (ex_t^-). This affected the market from stability ($\tau = 0.5$) to high performance ($\tau = 0.75$, $\tau = 0.95$), and the values of the betas increased as the quantiles increased. In contrast, when the exchange rate changes were positive (ex_t^+), the association continued to be negative and the values decreased as the quantiles increased, showing cross-pattern asymmetry. Both the QR and OLS regression analyses showed significance.

The American S&P 500 index had a positive association with the Mexican market, both in the QR as well the OLS regression analysis. In extreme quantiles, this dependence did not occur when the market was negative (sp_t^-), and in the first quantile ($\tau = 0.05$) when the market was positive (sp_t^+).

During the pandemic period ($d_{\text{covid-19}}$), there was a negative association when the market was in low performance ($\tau = 0.05$, $\tau = 0.25$) and this association became positive when the market heated up ($\tau = 0.75$, $\tau = 0.95$). There was no significance in the analysis by OLS regression. Table 8 shows summary empirical results for the Latin American regression analysis viewed in the last Table 4–7

According to Table 8, the QR and OLS analyses show associations with variations in oil prices and the Latin American stock markets; it is clear that changes in the oil price positively affected the Latin American capital markets, in particular, when the oil market operated in the positive market, and especially for the Argentine and Chilean markets. Brazil and Mexico showed fewer influences in this analysis. However, the work of Adrangi et al. (2020), who studied the same sample as our study, found that Argentina was the only country not affected by oil price shocks.

Trading sessions that closed in the negative had a negative effect the Brazilian, Chilean, and Argentine markets (except for the lower quantile for Argentina), but had a positive effect on the Mexican market when it was operating below average and stably. However, trading sessions with prices above the previous day's closing positively affected all Latin American stock markets, with the exception of the Brazilian market, which only showed an association when the market operated above average.

On the one hand, the exchange rate variations had a negative association with both negative and positive Latin American stock market prices; the Argentine market showed an asymmetric and cross-pattern relationship in this analysis. The American market (S&P 500) had positive associations across all QR and OLS analyses. The influence that the U. S. stock market has on the Latin American markets is remarkable and the changes in the exchange rates negatively affect all Latin American countries.

In the analysis for the COVID-19 pandemic period, the Argentine, Chilean, and Mexican markets showed negative QR associations

when the market was operating below average (lower quantile); however, the markets showed positive QR associations when the Brazilian market was operating stably and the Chilean and Mexican markets were operating above average. In the OLS analysis, there was no significance associations.

In order to verify if the quantile models were really different and to give a little more robustness to the results, an F-test was applied between the extreme models ($\tau = 0.05$ and $\tau = 0.95$) for all of the Latin American markets, as show in [Table 9](#).

The F-test verified the hypothesis H_0 that the estimated coefficients in the models are equal, confirming that the estimates for the lower and upper quantiles were different, and the null of equality was rejected for all of the Latin American markets.

4.1. Discussion

Investors are continuously watching the market for asymmetric bets—higher chances of winning than losing. Positive asymmetric series allow for greater gains, just as negative asymmetric series allow for greater losses. The finance literature highlights that a series of financial returns does not show enough autocorrelation for the future predictability of prices ([Fama, 1970](#)).

This thesis is supported together with the efficient market hypothesis (EMH), which reports that in an efficient market, it is impossible to predict a future price increase based on past historical data or according to the measure of associations between variables. Based on this, investors are not able to obtain abnormal returns with the information at their disposal since all information is already absorbed by market prices; that is, the more efficient the market is the more unpredictable and random the continuation of prices charged by it.

The classic OLS method in a regression model presents only one measure of central tendency. However, the QR method advances the analysis, allowing for the verification of all the conditional distributions in different quantiles of the distribution of a series of returns, thus, providing richness in the analysis of stock markets with different scenarios and asymmetries in price variations. This helps investors to analyze how markets are linked and to more accurately define in which market performance state the significances occur.

In this study, variations among the Latin American markets were clearly demonstrated in the different stock market scenarios. As can be seen, the oil price market presented positive associations for all the Latin American stock markets when the oil price was negative or positive, demonstrating asymmetric cross-pattern behavior for negative oil prices. In Argentina and Brazil, the associations were verified by the low performance of the negative stock market, which was in contrast to Chile (stable market) and Mexico (no association in the QR analysis, but significance for OLS regression analysis). This positive association between the oil price market and the stock market has been reported in the works of [Salgado \(2017\)](#), [Ferreira et al. \(2020\)](#), and [Naeem et al. \(2020\)](#).

However, when the oil price market was positive, there were positive associations for Argentine and Chilean stock markets, Mexico showed significance just in the lower performance of the stock market, and Brazil did not show significance. It is remarkable that Brazil and Mexico are the largest markets in terms of oil reserves, oil exports, and stock markets and, from this sample, the statistical regression between positive oil prices and a positive stock market showed no significance for Brazil and, for Mexico, significance appeared when the market started to heat up.

Regarding dynamic returns, Argentina and Mexico showed asymmetric cross-pattern behavior associated with negative price changes, although when the previous trading session was positive, it positively affected all of the Latin American markets. This result showed evidence for investors, since the results demonstrated that a negative previous price session negatively affected the Brazilian market with more significance than the other countries. On the other hand, a positive previous price session demonstrated the same pattern analysis for Argentina, Chile, and Mexico, because the markets were positively influenced from the stock market rally.

The exchange rates (both positive and negative) negatively affected the markets in Brazil, Chile, and Mexico (Brazil and Mexico showed the same pattern analysis). Argentina demonstrated a positive association with a negative exchange rate in low performance and stable markets, and for the OLS regression analysis, Argentina demonstrated a negative association with a positive exchange rate in a low performance market.

It is worth mentioning that the Latin American stock markets are influenced by foreign direct investment (FDI); Argentina, Brazil, Chile, and Mexico are the four best destinations for FDI ([Oecd, 2018](#)). On the one hand, when more foreign currency enters the local market, consequently, more local currency is purchased, which results in a positive foreign exchange market and capital market heating. On the other hand, when there is a greater exit of investors from the market, local currency is sold to buy dollars for financial capital leaving the country, which negatively affects the foreign exchange market (this finding is also supported by the study of [Delgado \(2018\)](#)).

The American S&P 500 market positively affected all Latin American stock markets, both for negative and positive prices. The QR and OLS regression results both showed higher value of the betas in the sample, with significance, showing a strong link between the U. S. stock market and the Latin American stock markets.

The COVID-19 pandemic period had positive and negative associations in different quantiles for Argentina, Chile, and Mexico; however, for Brazil, the association was only positive in terms of market stability. In this article, the applied model absorbed the possible impact that the COVID-19 period may have had on the magnitude of the oscillations in the returns. There were no comparisons before or after the results of the betas because they were unique for the periods. It is important to note that the COVID-19 pandemic period may have had an influence on the returns, as we did not investigate whether the COVID-19 period changed the relationship between returns.

There were significant betas (positive and negative) and most followed a pattern of increasing and/or decreasing. However, a significant finding of this study is that the QR analysis provided more accurate and detailed information within the distribution of all stock market returns than that of the OLS regression analysis. The associations all had differences when the QR analysis was verified by

Table 9

Summary F-test for the Latin American stock markets.

	Argentina $\tau = 0.05$ and $\tau = 0.95$	Brazil $\tau = 0.05$ and $\tau = 0.95$	Chile $\tau = 0.05$ and $\tau = 0.95$	Mexico $\tau = 0.05$ and $\tau = 0.95$
F-test	92.599	65.289	77.577	47.381
P-value	5.995e-14 ***	2.966e-09***	2.336e-11***	2.807e-06 ***

Note: * $p < 0.10$ ** $p < 0.05$ *** $p < 0.01$.

the OLS regression analysis of the Latin American markets, demonstrating that the QR analysis was richer in details in different scenarios of the stock market due to the different association signs and significances across the quantiles.

5. Conclusions

The procedures applied in this research differed from other works. First, we analyzed the impact of the WTI (negative and positive) crude oil prices on different scenarios of the Latin American stock markets (low and high stock market performance and stability), which has rarely been explored in Latin American studies. Second, we used an econometric technique capable of overriding the behavioral aspects of the market, where the variables were measured analyzing five quantiles, under different market states (high/low and stable markets). Third, we detected (even if superficially) the interference of local political events and the effect of the COVID-19 pandemic period on the analysis of the stock market behavior indexes under analysis.

The results indicate that there was asymmetry in the behavior pattern of the Latin American stock exchanges and a shock due to fluctuations in the market with negative oil prices. The asymmetric cross-pattern behavior was also found in the dynamic returns for the Argentine and Mexican markets, and for exchange rate variations for Argentina.

There was a positive association between positive oil price changes and the Latin American stock markets, with less association for Brazil and Mexico (these two countries are the largest Latin American stock markets, have the largest crude oil reserves and production, and are the largest exporter countries of crude oil and petroleum products).

The dynamic returns showed that negative previous trade sessions negatively affected the Latin American markets and positive previous trade sessions positively affected these markets, since returns that were dependent over time provided a measure of risk exposure and possible predictability of future series.

The exchange rate demonstrated negative associations with Brazil, Chile, and Mexico under the QR and OLS regression analyses; however, for Argentina, an asymmetric cross-pattern behavior appeared. The S&P 500 showed positive associations under all QR and OLS analyses, and the inclusion of the dummy variable in the period after the start of the COVID-19 pandemic managed to capture a negative and positive association within the Latin American market with the QR analysis. However, given the OLS regression analysis, there was no significance for any market.

It is clear from this study that the analysis of the asymmetric influence of Latin American markets by the QR method proved to be superior to that using the OLS regression method, providing a richness of details among the different quantiles in those markets. The asymmetry verification in the analysis of this study can be considered to be important information for the Latin American stock markets and investors, demonstrating the behavior of the market under negative and positive scenarios, regarding the influence of these variables on the stock exchanges (high/low performance and stable market).

In our future work, we will build upon this study to include more emerging countries in the analysis in order to investigate the robustness of the results using a larger sample that includes oil importing/exporting countries and confirm the asymmetric response of emerging markets to positive and negative oil price shocks in different bull/bear market scenarios.

CRedit authorship contribution statement

Maximiliano Kruei: Conceptualization, Methodology, Software, Stata, Formal analysis, Writing – original draft, preparation.
Paulo Sergio Ceretta: Visualization, Investigation, Torregrosa Montaner Ramón Jose: Supervision.

Declaration of competing interest

None.

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

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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

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 unprecedentedly, 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 & Hacıhasanoglu (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

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:

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

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:

$$\hat{\theta} = \min_{\theta} \sum_{t=1}^n \rho(\tau)(y_t - \theta'X_t), \quad (1)$$

where $\rho(\cdot)$ is the pinball 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 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 ε_i 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):

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

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:

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

where $F_{y_t}(\cdot | \mathcal{F})$ 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 y_t up to time $t - 1$. Granger Causality requests that the previous information of x not modify the conditional distribution of y_t . 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).

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

Where $\mathbb{E}(y_t|\mathcal{F})$ is the mean of $F_{y_t}(\cdot | \cdot)$. 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).

$$r_stock_t = \alpha_0 + \sum_{i=1}^{p_1} \phi_i r_stock_{t-i} + \sum_{i=1}^{p_1} \phi_i r_oil_{t-i} + \varepsilon_t \quad (5)$$

$$r_oil_t = \alpha_0 + \sum_{i=1}^{p_2} \alpha_i r_oil_{t-i} + \sum_{i=1}^{p_2} \beta_i r_stock_{t-i} + \varepsilon_t \quad (6)$$

where the vector of random errors is $\varepsilon_t = (\varepsilon_{oil_t}, \varepsilon_{stock_t})$.

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).

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

where $Q_{Y_t}(\tau|\mathcal{F})$ indicates the τ -th quantile $F_{Y_t}(\cdot|\mathcal{F})$. 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:

$$Qr_stock_t(\tau|X_{t-1}) = \gamma(\tau) + \sum_{j=1}^q \alpha_j(\tau) r_stock_{t-j} +$$

$$\sum_{j=1}^q \beta_j(\tau) r_oil_{t-j} \quad (8)$$

$$Qr_oil_t(\tau|Y_{t-1}) =$$

$$\omega(\tau) + \sum_{j=1}^q \delta_j(\tau) r_oil_{t-j} + \sum_{j=1}^q \xi_j(\tau) r_stock_{t-j} \quad (9)$$

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 $\tau \in (0, 1)$ can be verified by:

$$H_0: \beta(\tau) = 0, \quad \forall \tau \in [0, 1] \quad (10)$$

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

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

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 $\tau \in [a, b]$. However, the Wald statistical technique follows the weak agreement given by:

$$W_T(\tau) \Rightarrow \left\| \frac{B_q(\tau)}{\sqrt{\tau(1-\tau)}} \right\|^2, \quad \tau \in T, \quad (12)$$

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.

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

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.

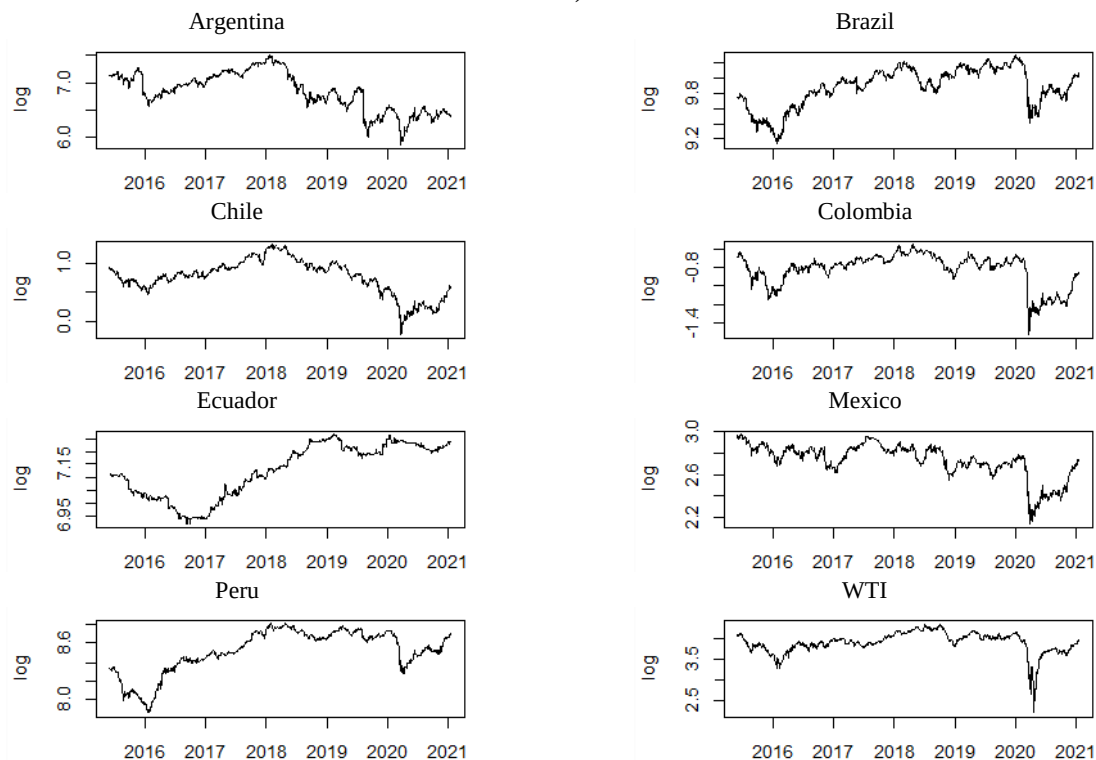
Table 2 – Unit root and stationarity of daily log differences from countries WTI

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
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 (Smeeke, 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 Sebastián 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.

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.

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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Extreme Return Spillover Between the WTI, the VIX, and Six Latin American Stock Markets: A Quantile Connectedness Approach

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Abstract: This study examined extreme return spillovers and connectedness between crude oil (West Texas Intermediate), the Volatility Uncertainty Index (VIX), S&P 500, and six Latin American stock markets, namely, Argentina, Brazil, Chile, Colombia, Mexico, and Peru, using quantile connectedness. This approach allowed for a nuanced investigation of connectedness and added to the understanding the integration between these markets. The results indicated that the S&P 500 market was a full sender of spillover in the whole sample of the quantiles, when, to the contrary, the oil market was the highest receiver. The total spillovers were more intense during extreme quantiles, with swings between transmission and reception for VIX, Colombia, Mexico, and Peru. In addition, when the market turned to operate during bullish conditions, the VIX became a strong sender of spillover. Furthermore, an intense spillover was observed only in the lower and upper quantiles, and the spillover was sharper for the extreme upper quantile.

Keywords: spillovers; Latin American stock markets; quantile vector autoregression

JEL Classification: C01; C21

1 Introduction

The global economy is increasingly integrated, leaving different financial markets closer, and its external shocks can be explained through various channels. The latest financial crises, such as the United States subprime crisis in 2008, the European crisis in 2011, the oil price crash of 2015–2016, and the COVID-19 pandemic crisis, showed the characteristics of the risk contagion among these markets, which is also called risk spillover (Akdag, Iskenderoglu, and Alola 2020). Indeed, oil shocks are a major factor that drive fluctuations in international trade (Backus and Crucini 2000), largely because these shocks appear to have a global impact.

Spillover effects and linkages between capital markets and the oil market are important for hedging, fund allocation, and risk assessment, and they have deepened over time with futures contracts, in part due to their increasing demand and the fact that they are quoted in United States currency (USD). The asymmetric reaction shocks are also critical for financial and commodity markets as traders, speculators, and institutional investors react differently during strong uptrends or downtrends. Ali et al. (2021) argued that markets are often influenced by bad news from other markets, and thus, they establish asymmetric information spillovers, also Reboredo, Ugolini, and Hernandez (2021) stated that assets face the greatest risks when an investment portfolio's downside receives heavy overflow from spillovers.

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A major problem that investors face in diversifying their portfolios is creating policies to prevent the transmission of shocks that are transmitted to financial markets, causing volatility (Bensaida, Litimi, and Abdallah 2018). The studies by Diebold and Yilmaz (2009, 2012) were the first works to introduce a volatility spillover measure based on forecast error variance decompositions from vector autoregressions (VARs) to measure spillovers in returns or return volatilities, and they argued that return and volatility are usually associated with risk. The study by Ando, Greenwood Nimmo, and Shin (2022) addressed a new framework that used regression quantiles to investigate whether the changes with the sizes of the shocks could affect a system's shock network.

This paper innovated to study extreme return spillovers and connectedness between the crude oil market, the Volatility Index, and the Latin American stock market, which can scarcely be found in the literature. Firstly, the motivation of this work was based on an analysis of the risk and knowing which markets are more interrelated or connected than expected, which was influenced by the different performance states of the capital market of one of the most important markets of export/imports goods and services in the world. Secondly, the oil market it is an important global market, especially for Latin America, where Argentina, Brazil, Colombia, Mexico, and Venezuela rank as some of the world's top oil producers, and it has already been well-established that oil price instabilities significantly influence countries' domestic prices and stock market conditions (Wang, Wu, and Yang 2013). Thirdly, the seminal study by Hamilton (1983) showed that increases in oil prices had an effect on the depression that had occurred in the United States' economy, and another study by Hamilton (2011) demonstrated that large variations in the price of oil are expected to occur in the high parts of the distribution of returns.

This study aimed to examine the asymmetry and time-variant connectivity of realized volatility, as well as the higher momentums (i.e. the distributive connectivity of asymmetry and kurtosis) and risks, related to crude oil (West Texas International (the WTI), the Volatility Index (VIX, a popular measure of expected stock market volatility based on the S&P 500 index options from the Chicago Board Options Exchange), the United States market, as represented by the S&P 500, and six Latin American equity markets (Argentina, Brazil, Chile, Colombia, Mexico, and Peru).

On the one hand, this analysis was critical because many past studies have shown similar results for the sharp impacts of COVID-19 throughout the market (Cui et al. 2021; Sui et al. 2021), the oil shocks that significantly affected the stock market's returns and volatility (Anand and Paul 2021), the higher and intense movement observed in the lower and upper levels of the stock market suggests that network connectedness and spillover transmission mechanism between markets are highly connected at extreme market events (Bouri et al. 2021; Feng, Wang, and Yin 2017; Jang and Chen 2022; Khalfaoui, Hammoudeh, and Rehman 2023; Mensi et al. 2021a; Umar et al. 2022), and finally, the indications of the low extent of cross-asset volatility spillovers within each country (Liow 2015).

On the other hand, other studies have demonstrated different findings, such as Olson, Vivian, and Wohar (2014), who found a weaker response of the S&P 500's volatility to the energy price shocks, Zhu, Li, and Li (2014), who showed strong bidirectional Granger causality between crude oil shocks and the stock market, and Diebold and Yilmaz (2012), who considered that the samples were weaker from the total volatility spillover.

The price of oil varies daily according to the demand expectations of the players in the market, and thus, this increases the prospects of high and low performances for a certain time and causes investors to react in anticipation of the future market conditions, i.e. the up or down cycles in response to these shocks. This same analysis has led to a movement of dollars entering and leaving the Latin American markets in view of the fact that investors are always looking for the best return options when markets are down. It also corroborates the assumption of Markowitz (1952) that investors, when having to choose between two investments with equal expected returns, will choose the investment that poses a lower level of risk, and when they must choose between two investments with the same level of risk, they will choose the investment with the highest expected return.

The remainder of this paper is structured as follows: Section 2 presents the literature review. Section 3 discusses our data and descriptive statistics. In Section 4, the methodology is presented, followed by the results, which are discussed in Section 5. Finally, the concluding remarks are presented in Section 6.

2 Literature Review

There is a vast amount of literature discussing the volatility spillover dynamics and relationships between financial markets (Bensaida et al. 2018; Liow 2015; Rejeb and Arfaoui 2016; Tiwari et al. 2018; Tsai 2014; Wen et al. 2019), China's stock market (Chen, Li, and Qu 2019), foreign exchange markets (Huynh, Nasir, and Nguyen 2023), and the prediction of spillover directional measurements (Diebold and Yilmaz 2012), as well as the relationships between green finance and renewable energy sources (Dogan et al. 2022); the COVID-19 pandemic and global foreign exchange markets (Fasanya et al. 2020); crude oil and financial markets (Mensi et al. 2018, 2021b; Wang and Wu 2018); oil and gas markets (Ji, Geng, and Tiwari 2018; Yoon et al. 2019); crude oil and currency markets (Mensi et al. 2021a); crude oil, gold, copper, wheat, and currency markets (Nekhili, Mensi, and Vo 2021); financial globalization and, finally, high tech industries and environmental footprints (Shahzad et al. 2022).

At the same time, Latin American markets have also been the subject of several studies focusing on financial markets (Gonzales, Uribe, and Valencia 2022; Harrathi et al. 2016; Hernandez et al. 2020; Panda, Vasudevan, and Panda 2020), American business cycles (Campos and Andújar 2020), the ESG market (Shaik and Rehman 2022), and the exchange market (Vacaflores and Lesage 2020), as well as studies on gold and Latin American markets (Yousaf et al. 2021) and the COVID-19 pandemic and the Latin American stock markets (Marschner, Dutra, and Ceretta 2022).

The VIX index market is included in studies about spillovers effects that focus on the Latin American market, and there have also been were minority studies, such as those by Sarwar and Khan (2017), Cheuathonghua et al. (2019), and Ghirelli, Pérez, and Urtasun (2021). Alfaro, Medel, and Moreno (2017) analyzed the impact of external financial risk on the sovereign risk in Latin American economies. Iskenderoglu and Akdag (2020) compared the effect of the VIX on the stock exchange indices of developed and developing countries, and Nieto and Mollik (2021) studied the impact of the United States' financial crisis on market volatility, credit risk, and stock returns in Latin America. Despite these related subjects, we were unable to find studies linking crude oil (the WTI), the VIX, the S&P 500, and the Latin American markets, as is shown in our analysis.

On the one hand, Latin American countries produce oil and own the reserves of this commodity; therefore, they hold strategic power in negotiations. However, at the same time, they suffer from geopolitical risks, macroeconomic trends, and imbalances between consumer demand and corporate profitability (Becard, Lessa, and Silveira 2020). Thus, fluctuations in the prices of world oil directly impact these economies, and a major channel to measure this is through the impact of stock prices on stock exchanges.

Goldman Sachs predicted that world demand for oil would fall by at least 8 % in 2020 and would only return to pre-COVID-19 levels after 2022 (Goede 2020). Therefore, these expectations should have an effect on stock markets since the oil market is vulnerable to scales, market trends, and outbreaks (Mensi et al. 2020), and at the time of writing this paper, WTI crude futures had declined by three percent, reaching nearly its lowest price since end of the year 2021, largely because of global banking turmoil that stoked fears of broader weakness in the world economy (McCormick and Brower 2023).

Similar to our study's results, Mensi et al. (2018) found the United States' market net transmitter of spillover to other markets, and Mensi et al. (2021b) showed small magnitudes of upper quantiles during the COVID-19 pandemic. Rejeb and Arfaoui (2016) demonstrated that co-movement between Latin American markets intensified from lower to higher quantiles, indicating that interdependence increased during extreme quantiles, representing bullish and bearish markets. Similar findings could be seen in the study by Bensaida et al. (2018) that showed that total spillovers have been more intense in extreme periods, with frequent oscillations between net risk transmission and net risk reception. Tsai (2014) demonstrated that the fear index has spillover connectedness with the United States stock market and other markets, and the study by Wen et al. (2019) indicated that there was a strong persistence in the spillovers of the S&P 500 index and oil prices. Finally, Dogan et al. (2022) showed that dynamic connectedness is heterogeneous over time and influenced by economic events.

On the other hand, there are some studies with different results than ours, such as the study by Wang and Li (2021), which showed spillovers from the crude oil market to other larger markets. Diebold and Yilmaz (2012)

found that only 12.6 % of the volatility forecast error variance came from spillovers in the analysis of the United States stock market, bonds, foreign exchange, and commodities markets, which was similar to the results of the study by Ji, Geng, and Tiwari (2018).

Ando, Greenwood Nimmo, and Shin (2022) showed a new study technique for estimating vector autoregressions by quantile regression, and it was assumed that this innovation could remove cross-section correlations in the residuals such that the system could be estimated on an equation-by-equation basis using existing quantile regression toolboxes.

3 Data and Descriptive Statistics

In this study, we used daily prices for six Latin American MSCI market indices, namely, Argentina, Brazil, Chile, Colombia, Mexico, Peru, and the S&P 500 for the United States market. The MSCI index was designed to measure the performance of the large and mid-cap segments of various stock markets, and it is a proxy for a market. This device facilitates the pairing of series as observations associated with days when there are no negotiations in the country of origin (holidays, etc.) are not lost. Another advantage concerns the values that are in the American currency, which avoids the need to convert funds using the exchange rate of each country. Therefore, making a conversion is subject to the bias of the exchange rate policy of the country of origin (currency manipulation).

We also considered two important commodity futures markets: the WTI (crude oil) and the Volatility Index (VIX), which is a measure of real-time risk in the United States stock market as measured by the CBOE (Chicago Board Options Exchange). Considered as a market fear index, its daily movements indicate long-term perceptions, and it is an important tool for risk management. The data were obtained from 16 January 2015 to 28 February 2023. The calculation procedure was a 2042 log daily, leading to the differences in the log values for two consecutive daily prices for each series.

Figure 1 display the evolution of the values in the logarithm for each of the Latin American markets, the WTI, the VIX, and the S&P 500 for the period of the analysis. Important anomalies in the price series can be verified in Figure 1, which shows that all series received more relevant sharp declines during the COVID-19 period, with fewer for the S&P 500 market, where minor impact was observed. As the VIX index is a measure of fear of the market, it showed an upward jump during the same period of analysis, and it could be noticed that the most nervous figure within the whole sample was as shown in Figure 1.

Besides the fact that the COVID-19 period caused a substantial drop in the markets, as shown in Figure 1, the oil price series followed a lateral line for the years under analysis, suffering a sharp drop in 2020, in which, for the first time in history, negative prices were observed for the main index of the reference price of oil in the American market (the WTI), with a drop from USD 18 to USD −38 (Ambrose 2020). The lockdown effect imposed by world governments during the COVID-19 pandemic meant that there was a sharp and immediate decrease in oil consumption worldwide, with an average decline of 30 % in the consumption of this commodity worldwide (Krauss 2020).

The S&P 500 has displayed sustainable market growth, especially after 2016, although it dropped during 2020 due to COVID-19. As expected, the VIX index market has been shown to be the most nervous figure of the whole sample because it measures the feeling of fear in the American market. From the figures, it can be seen that all the markets suffered substantial declines due to COVID-19; however, all the markets had already reached, or passed, the prices they had obtained before the pandemic.

There were two substantial lows in the Argentine stock market in 2019 and 2020. The first refers to the presidential election on 12 August 2019, where Mauricio Macri was defeated, causing a 30 % plunge in the MERVAL index, while the second refers to the drop caused by the COVID-19 pandemic.

Brazilian stock market dynamics (the IBOVESPA index) showed upward movement after 2016 (the year of the impeachment of President Dilma Rousseff), suffering a sharp drop only during the COVID-19 pandemic in 2020, when the stock exchange plummeted from 120,000 points to below 70,000.

According to the plots, the Chilean stock market displayed a downward movement, especially after 2018, with the beginning of the reign of the current president, Sebastián Piñera. There was also a sharp drop in 2020

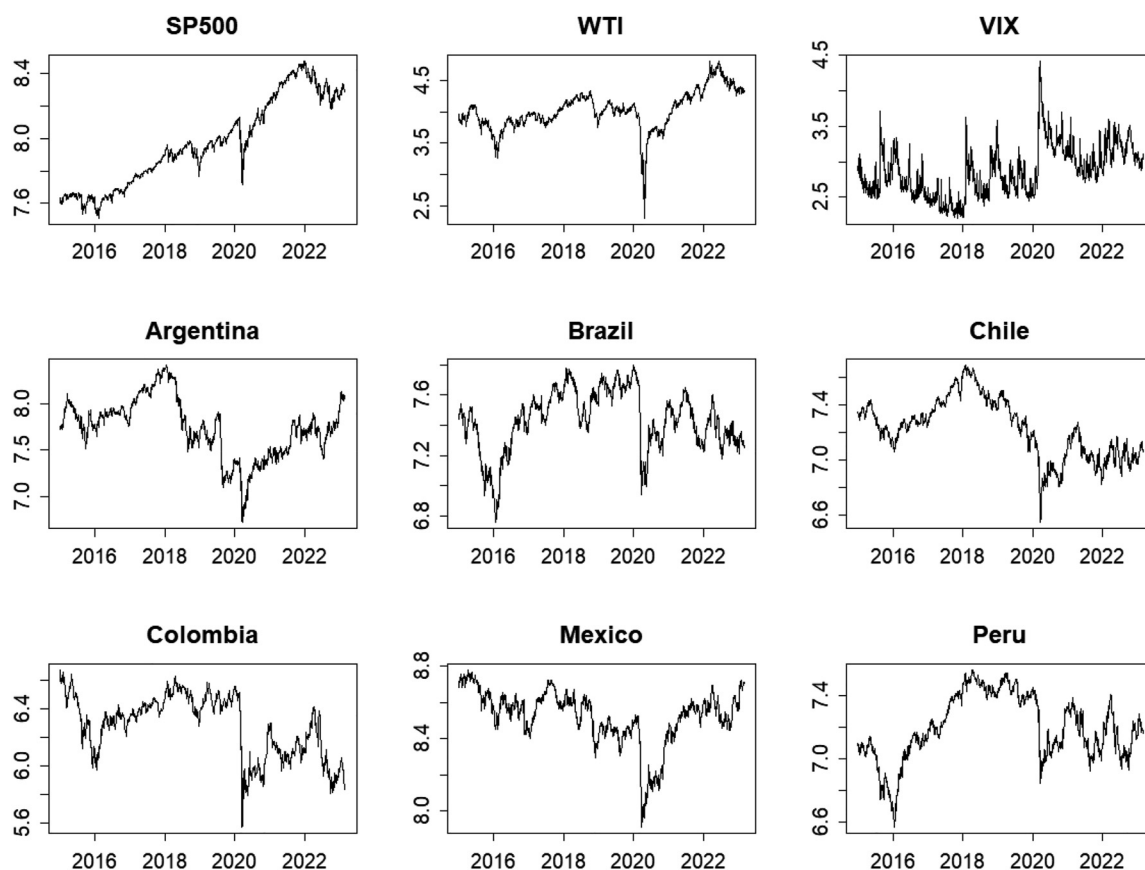


Figure 1: Plots of SP500, WTI, VIX and MSCI stock indices for Latin American countries.

due to the COVID-19 pandemic. The Colombian market illustrated sustainable growth after the year 2016, when the Colombian government and the FARC rebels signed a historic ceasefire agreement, putting an end to more than five decades of armed conflict in the country, ennobling the president of the Colombia, Juan Manuel Santos, to receive the Nobel Peace Prize for his efforts. The COVID-19 pandemic broke down its growth substantially.

The Mexican stock market showed two salient changes that are worth mentioning: the drop in 2018, caused by a change in the government, and the crash due to the COVID-19 pandemic in 2020. The Peru market illustrated an increase in growth after 2016, when the elections took place, despite the fact that the country was continuously living with political instability.

Several Latin American countries were facing economic and political turmoil, which may have significantly impacted the value of their currencies (Guas 2019). Argentina was facing the worst currency volatility in its history – the official peso rate fell 22 % against the United States dollar in 2020 (Mander 2020), and the country showed inflation above one hundred percent in 2022. Brazil's currency was one of the worst-performing in the world in 2020 (Oyamada 2021).

The Mexican peso lost 21 % of its value against the American dollar in 2020, while Chile's currency was down 10.4 % on a year-to-date basis (Focus Economics 2021). The political turmoil in Peru and Colombia was not a new occurrence as there were six different presidents over the preceding five years in Peru (Aquino 2022) and Colombia had held the title of the most troubled country in Latin America (Stunkel 2022). Each market had different intensities due to the crises; however, they clearly showed similarities in volatility patterns, suggesting the presence of a spillover effect between them.

Table 1 presents the summary of descriptive statistics, unit root tests, autocorrelation and correlation of log-returns of the series.

Table 1: Summary of descriptive statistics, unit root tests, correlation of log-returns, and autocorrelation.

	SP500	WTI	VIX	Argentina	Brazil	Chile	Colombia	Mexico	Peru
N ^o observation	2042	2042	2042	2042	2042	2042	2042	2042	2042
Descriptive statistics									
Mean	0.03	0.02	0.01	0.02	−0.01	−0.01	−0.04	0.00	0.00
Variance	1.43***	11.39***	67.08***	7.12***	5.01***	2.98***	3.92***	2.32***	3.09***
Skewness	−0.82***	−2.68***	1.32***	−3.61***	−0.84***	−0.76***	−1.24***	−0.70***	−0.52***
Ex.Kurtosis	15.08***	63.79***	7.16***	67.63***	9.82***	11.52***	20.65***	5.36***	6.69***
Unit root and estacionarity tests									
ERS	−4.81***	−4.57***	−5.72***	−6.16***	−5.82***	−6.56***	−2.67***	−4.53***	−5.63***
KPSS	0.04	0.05	0.01	0.11	0.05	0.05	0.04	0.11	0.07
Autocorrelation									
Q(20)	213.85***	89.41***	24.94***	18.10**	35.80***	23.39***	102.38***	54.95***	35.99***
Q2(20)	2310.99***	426.46***	108.32***	8.51	1242.58***	504.93***	906.67***	1206.17***	913.26***
Pearson correlation									
SP500	1.00***	0.28***	−0.72***	0.50***	0.49***	0.44***	0.50***	0.51***	0.59***
WTI	0.28***	1.00***	−0.22***	0.21***	0.26***	0.28***	0.39***	0.26***	0.29***
VIX	−0.72***	−0.22***	1.00***	−0.42***	−0.36***	−0.32***	−0.35***	−0.40***	−0.45***
Argentina	0.50***	0.21***	−0.42***	1.00***	0.44***	0.34***	0.36***	0.40***	0.41***
Brazil	0.49***	0.26***	−0.36***	0.44***	1.00***	0.50***	0.55***	0.58***	0.54***
Chile	0.44***	0.28***	−0.32***	0.34***	0.50***	1.00***	0.54***	0.51***	0.47***
Colombia	0.50***	0.39***	−0.35***	0.36***	0.55***	0.54***	1.00***	0.55***	0.51***
Mexico	0.51***	0.26***	−0.40***	0.40***	0.58***	0.51***	0.55***	1.00***	0.52***
Peru	0.59***	0.29***	−0.45***	0.41***	0.54***	0.47***	0.51***	0.52***	1.00***

Notes: This table shows the descriptive statistics of returns, the Ljung–Box test (Q(20) and Q2(20)) for the autocorrelation of returns and returns squared, ERS unit root test of Elliott, Rothenberg, and Stock (1996) and KPSS stationary test of the Kwiatkowski et al. (1992).

***P-value <0.01; ** <0.05.

The average returns shown in Table 1 were clearly the highest for the S&P 500 and the WTI. Negative returns were demonstrated for Brazil, Chile, and Colombia, and a return to zero was shown for both Mexico and Peru. The largest variance could be verified for the WTI, followed by the VIX. Moreover, with the exception of the VIX, the returns for all series were left-skewed, indicating that the distributions of the series were negative and asymmetric around the mean.

Kurtosis in a sample results in leptokurtic series, which means that the distribution of returns will show large tails. From the ERS unit root test by Elliott, Rothenberg, and Stock (1996) and the KPSS stationary test by Kwiatkowski et al. (1992), we could confirm that neither of the market returns were stationary. Finally, the Ljung–Box test (Q(20) and Q²(20)) for the autocorrelations of the returns and the returns squared also indicated that our dataset did not have autocorrelations in the residuals. Lastly, Table 1 demonstrates the adequacy of this study because there were rejections of non-normality for all markets (the extreme spillover test), where high or low returns can be dominating under some market conditions.

The Pearson correlation is shown in Table 1. It can be seen that the S&P 500 was strong and positively correlated with all the Latin American stock markets, though more prominently so with Peru and Mexico, and it was weakly but positively correlated with the oil market. The WTI showed moderate and positive correlations with all samples of the series, and the reverse was true for the VIX, as expected, as it is a measure of fear in the market, and so it had a negative and moderate correlation, despite the fact that it showed a strong correlation with the United States market.

Brazil, Chile, Colombia, Mexico, and Peru presented strong positive correlations between them – more than when analyzing them against the United States market. Argentina had the lowest correlation with the other Latin American countries, and it appeared to have more benefits due to its shared border with Brazil. The strongest values correlations between the Latin American markets were Brazil's strong correlations with Mexico, Colombia, and Peru, and those between Chile and Colombia.

4 Methodology

In this study, we pursued a quantile connectedness approach for analyzing quantile connectedness at various quantiles, as proposed by Ando, Greenwood Nimmo, and Shin (2022). This framework differed from others because of our treatment of the VAR residuals, where we assumed that the cross-sectional correlations of the VAR residuals were driven by a finite number of common factors, which meant that the idiosyncratic shocks to each variable in the system could be isolated. Further, we could state that the errors were not correlated between the equations and the factorial VAR system could be estimated directly on an equation-by-equation basis, thus allowing us to use a factorial structure that substantially simplified the estimation problem because it made the system of equations that made up the model sectionally independent on the VAR system.

Connectivity metrics were calculated by estimating a quantile vector autoregression, QVAR(p), which can be schematized as follows:

$$y_t = \mu(q) + \sum_j^p \Phi_j(q) y_{t-j} + \epsilon_t(q), \quad (1)$$

the formula (1) can be explain by y_t , that means the endogenous variables, the vector of $N \times 1$, q supports for quantiles $[0,1]$, p is the lag length, $\mu(q)$ is the means vector, $\Phi_j(q)$ stands for $N \times N$ QVAR coefficient matrix, and $\epsilon_t(q)$ show the error term with the $N \times N$ variance-covariance matrix $\Sigma(q)$. The quantile connectivity of the various quantiles needs to be constructed by the connectivity matrices, therefore, the definition of the average representation infinite order moving vector (MA) of QVAR(∞), as follows:

$$y_t = \mu(q) + \sum_j^p \Phi_j(q) y_{t-j} + \epsilon_t(q) = \mu(q) + \sum_{i=0}^{\infty} \Psi_i(q) \epsilon_{t-i}, \quad (2)$$

The generalized forecast error variance decomposition (GFEVD) calculated with generalized impulse response function (GIRF) it is a part of the structural analysis that “decomposes” the forecast error variance into the contributions of specific exogenous shocks:

$$C_{ij}^g(H) = \frac{\sum_{jj} (q) \sum_{h=0}^{H-1} \left(e_i' \Psi_h(q) \Sigma(q) e_j \right)^2}{\sum_{h=0}^{H-1} \left(e_i' \Psi_h(q) \Sigma(q) \Psi_h(q)' e_i \right)} \quad (3)$$

The contribution of j th variance of forecast error of the variable i th at horizon H_t is expressed by $C_{ij}^g(H)$ and e_i is a zero vector with unity on the i th position. The normalization of each element in the decomposition matrix is expressed as follows:

$$\tilde{C}_{ij}^g(H) = \frac{\Theta_{ij}^g(H)}{\sum_{j=1}^k \Theta_{ij}^g(H)}, \text{ with } \sum_i \tilde{C}_{ij}^g = 1 \text{ and } \sum_{i,j=1}^k \tilde{C}_{ij}^g(H) = k \quad (4)$$

Total connectedness index at quantile (q), following Diebold and Yilmaz (2009, 2012), based on generalized forecast error variance decomposition (GFEVD) is demonstrate:

$$TCI_t(q) = \frac{\sum_{i,j=1, i \neq j}^k \tilde{C}_{ij}^g(H)}{k-1} \quad (5)$$

The total directional connectedness index (TCI) from variable j th to all other variables i th at quantile (q), where the assets transmit spillover to the system is expressed by:

$$TO_{j,t}(q) = \sum_{i=1, i \neq j}^k \tilde{C}_{ij,t}^g(H) \quad (6)$$

where the assets receive spillover from the system from all variables i th to variable j th at quantile (q) is the formula:

$$FROM_{j,t}(q) = \sum_{i=1, i \neq j}^k \tilde{C}_{ij,t}^g(H) \quad (7)$$

and net directional connectedness (NET) index at quantile (q) is expressed as follow:

$$\text{NET}_{j,t}(q) = \text{TO}_{j,t}(q) - \text{FROM}_{j,t}(q) \quad (8)$$

When the assets are senders of spillover to the system, then the variable TO will be higher than the variable FROM (a receiver of spillover from the system), resulting in $\text{NET}_{j,t}(q)$ positive values, indicating a net transmitter; otherwise, a negative $\text{NET}_{j,t}(q)$ shows that the assets had higher FROM variables, indicating a net recipient.

The time-varying total connectedness index (TCI) was based on a 200 days' rolling window QVAR model with a lag length of order four (BIC) and 10 step-ahead forecast horizons. This model is robust and was consistent with that of Diebold and Yilmaz (2012), which confirmed that the result was not sensitive to the choice of the order of the VAR model or the forecast horizon.

Furthermore, it was possible to calculate the statistical significance of the connectivity spillovers, even if a methodology decomposed them. While the specific approach can vary depending on the methodology used, there are general statistical techniques available to assess the significance of the spillovers.

5 Results

Tables 2–4 summarize the connectedness among the S&P 500, WTI, VIX, and six Latin American stock markets, which were estimated by a quantile vector autoregression (QVAR) model. Table 2 shows the return connectedness at an extreme lower quantile ($\tau = 0.05$), Table 3 shows the return connectedness for a medium quantile ($\tau = 0.5$), and Table 4 shows the return connectedness for an extreme upper quantile ($\tau = 0.95$).

These Tables demonstrate the quantile returns' spillovers using the method that Ando, Greenwood Nimmo, and Shin (2022) described in their methodology. As can be observed in the Tables, the values in the i th row and in the j th column show the strength of the spillover effect from the j th to the i th market. When there is a volatility shock to the return of an individual stock or to the returns of several stocks, this volatility shock is expected to be transmitted for other stocks or other markets. As the stocks of individual institutions are subjected to idiosyncratic shocks, some may be very small while others can be quite large.

Our study considered the direction of the spillovers 'FROM' and 'TO' others among the currency pair returns. The abbreviations in Tables 2–4 which are described as 'TO' mean that the assets transmitted spillover to the system, and those described as 'FROM' mean that the assets received spillover from the system. The abbreviation 'TCI' indicates that total connectedness is displayed in the lower right corner of the Table. Finally, the net directional spillover 'NET' refers to the difference between the total contributions received 'FROM' an asset from other markets and the total contributions – 'TO' – coming from it.

In Table 2, for extreme lower quantile return spillovers ($\tau = 0.05$), the S&P 500 market appeared to be the highest sender of spillover to other markets, showing a TO of 108.59 and a NET 24.87 transmitter of return spillover. It could be argued that the United States market (the S&P 500) is the most exogenous market globally, corroborating the studies by Diebold and Yilmaz (2009) and Masih and Masih (1999).

Table 2: Return connectedness based the quantile VAR (extreme lower quantile tau = 0.05).

	SP500	WTI	VIX	Argentina	Brazil	Chile	Colombia	Mexico	Peru	FROM
SP500	16.29	10.06	9.31	10.47	10.34	10.30	11.01	10.90	11.34	83.71
WTI	13.27	13.22	10.09	10.17	10.48	10.29	11.16	10.57	10.75	86.78
VIX	13.09	10.23	15.10	10.03	10.06	10.05	10.73	10.06	10.64	84.90
Argentina	13.99	10.12	9.82	12.59	10.46	10.41	10.88	10.70	11.03	87.41
Brazil	13.78	10.26	9.68	10.34	12.61	10.25	11.32	10.66	11.10	87.39
Chile	13.44	10.04	9.50	10.43	10.58	12.73	11.10	11.03	11.16	87.27
Colombia	13.59	10.04	9.48	10.38	10.78	10.46	13.15	11.02	11.11	86.85
Mexico	13.64	10.26	9.70	10.37	10.74	10.34	11.08	12.83	11.04	87.17
Peru	13.78	10.29	9.37	10.43	10.50	10.38	11.15	10.72	13.39	86.61
TO	108.59	81.28	76.95	82.61	83.92	82.48	88.43	85.65	88.18	778.10
Inc.Own	124.87	94.50	92.05	95.21	96.53	95.21	101.58	98.48	101.57	TCI
NET	24.87	−5.50	−7.95	−4.79	−3.47	−4.79	1.58	−1.52	1.57	86.46

Notes: Total connectedness table is estimated by a quantile QVAR model with 200-day window and lag length of order 4 (BIC) and a 10-step-ahead forecast.

Table 3: Return connectedness based the quantile VAR (median quantile $\tau = 0.50$).

	SP500	WTI	VIX	Argentina	Brazil	Chile	Colombia	Mexico	Peru	FROM
SP500	35.25	3.30	20.79	7.31	6.13	4.94	6.15	7.29	8.84	64.75
WTI	5.95	56.12	4.88	3.81	5.30	4.74	8.45	4.88	5.87	43.88
VIX	23.27	2.93	37.73	6.76	5.51	4.29	5.60	6.76	7.15	62.27
Argentina	9.57	3.39	8.06	46.00	7.44	6.50	5.12	6.71	7.23	54.00
Brazil	7.56	3.81	6.13	6.73	38.77	8.11	8.76	10.35	9.80	61.23
Chile	7.22	3.65	5.90	5.77	9.00	41.13	8.98	10.04	8.31	58.87
Colombia	7.57	6.39	5.95	4.81	8.77	8.70	39.55	9.68	8.58	60.45
Mexico	8.86	3.77	7.36	6.02	9.65	8.86	9.08	38.24	8.16	61.76
Peru	10.42	4.04	7.62	6.12	9.15	7.09	7.76	8.24	39.56	60.44
TO	80.42	31.28	66.70	47.33	60.94	53.22	59.90	63.93	63.94	527.65
Inc.Own	115.67	87.40	104.43	93.32	99.71	94.35	99.45	102.17	103.50	TCI
NET	15.67	-12.60	4.43	-6.68	-0.29	-5.65	-0.55	2.17	3.50	58.63

Notes: Total connectedness table is estimated by a quantile QVAR model with 200-day window and lag length of order 4 (BIC) and a 10-step-ahead forecast.

Table 4: Return connectedness based the quantile VAR (extreme upper quantile $\tau = 0.95$).

	SP500	WTI	VIX	Argentina	Brazil	Chile	Colombia	Mexico	Peru	FROM
SP500	14.81	9.94	12.13	10.64	10.11	10.24	10.55	10.66	10.92	85.19
WTI	11.54	13.17	13.55	9.98	10.30	10.18	10.61	10.19	10.49	86.83
VIX	10.86	9.70	19.08	10.17	9.48	9.91	10.19	10.18	10.42	80.92
Argentina	11.51	9.74	13.33	13.43	9.90	10.31	10.51	10.55	10.71	86.57
Brazil	11.20	9.84	13.30	10.38	13.02	10.35	10.64	10.64	10.64	86.98
Chile	11.15	9.88	13.44	10.12	10.09	13.11	10.85	10.74	10.62	86.89
Colombia	11.20	9.90	13.51	10.18	10.19	10.49	13.12	10.78	10.63	86.88
Mexico	11.50	9.94	12.79	9.97	10.23	10.49	11.00	13.41	10.67	86.59
Peru	11.53	9.70	13.12	10.17	10.10	10.42	10.75	10.83	13.37	86.63
TO	90.49	78.64	105.19	81.59	80.41	82.40	85.11	84.56	85.10	773.48
Inc.Own	105.30	91.81	124.28	95.03	93.42	95.51	98.22	97.97	98.46	TCI
NET	5.30	-8.19	24.28	-4.97	-6.58	-4.49	-1.78	-2.03	-1.54	85.94

Notes: Total connectedness table is estimated by a quantile QVAR model with 200-day window and lag length of order 4 (BIC) and a 10-step-ahead forecast.

In analyzing the Latin American stock market, for the largest sender of spillover from bearish market conditions, in the extreme lower quantile return for spillovers ($\tau = 0.05$), Colombia had 1.58 and Peru had 1.57, and they emerged as being unique among the other Latin American countries with positive NET transmitters, besides the fact that the average value was close to 1. However, the WTI, the VIX, and the Argentina, Brazil, Chile, and Mexico markets were shown to be negative NET transmitters of return spillover, which classified them as receivers of spillovers from the system. Argentina, Chile (NET = -4.79), the VIX (NET = -7.95), and the WTI (NET = -5.50) represented the most vulnerable markets exposed to external shocks when the market was operating in a bearish performance. Overall, Table 2 shows that approximately 86.46 % of the forecast error variations could be attributed to return spillovers between the markets, and for the biggest values for the total connectedness index from Tables 2–4, Argentina, Brazil, Chile, and Mexico appeared to be the main receivers of shocks from the others.

In analyzing Table 3, which demonstrates the median quantile return spillover ($\tau = 0.5$) characterized by market stability, the S&P 500 was continuously the major sender of spillovers (TO = 80.42 and NET = 15.67), besides the fact that its values shown were lower compared to the extreme lower quantile ($\tau = 0.05$), but it was still the main sender within the whole sample. Among the Latin American countries, Peru still ranked among

the countries that were senders of spillover, but it was competing with Mexico because Colombia had become a receiver of spillover, along with the other countries of the sample. The VIX index had also become a sender of spillover and was the second highest contributor to the system, with a TO of 66.70 and a NET of 4.43, despite being the second highest value receiver in Table 2. Argentina (NET = -6.68), Chile (NET = -5.65), and the WTI (NET = -12.60) remained the largest receivers of the sample and were higher than those observed in the extreme lower quantile ($\tau = 0.05$) in Table 2. It is worth mentioning that, considering market stability, this represented the lowest value of total connectedness, with 58.63 % of the forecast error variations returning spillovers between the markets, and the WTI showed a minor receiver spillover from the others.

In looking at Table 4, which illustrates the extreme upper quantile ($\tau = 0.95$) return spillover, under bull market conditions, the S&P 500 ceased to be the highest sender of spillover to the system, as can be observed in the samples in Table 1 (extreme lower quantile) and Table 2 (medium quantile), and it was ranked second in the sample in Table 3, with a TO of 90.49 and a NET of 5.30. The highest sender of spillover appeared to be the VIX, with a TO of 105.19 and a NET of 24.28, showing the fear and panic of the players during the bull performance of the market. All the Latin American countries in the extreme upper quantile ($\tau = 0.95$) return were receivers of spillover from the system, and Brazil and Argentina ranked the highest scores for receivers of spillover, with NET values of -6.58 and -4.97, respectively.

It is worth mentioning that the total connectedness index began from the TCI of 58.63 in the medium quantile ($\tau = 0.5$) to the TCI of 85.94 and the TCI of 86.46 in the lower ($\tau = 0.05$) and upper ($\tau = 0.95$) quantiles, respectively. This information suggested that spillover return connectedness increased notably during the extreme market conditions. The WTI market had a lower value of sender spillover compared to the others when the market conditions began as stable and progressed to those of a bull market.

Figure 2 shows the time-varying total connectedness index (TCI) based on a rolling window of 200 days and 10 step-ahead forecast horizons.

Figure 2 shows the total connectedness between the markets in the analysis. The extreme quantiles (lower and upper) demonstrated high values for the whole sample, with values between 92 % and 98 %, exposing high spillover between the bearish and bull market conditions, with less for the medium quantile (stability market) (approximately 50 %–70 %). However, the values were still quite high, indicating the presence of return spillovers between the main markets considered.

It can be seen in this Figure 2 that during the stress period of COVID-19, it was possible to notice a vertiginous divergence in the values throughout the sample in medium quantile ($\tau = 0.5$), and at the same time, this verification did not appear in the extreme market conditions (lower quantile [$\tau = 0.05$] and upper quantile [$\tau = 0.95$]).

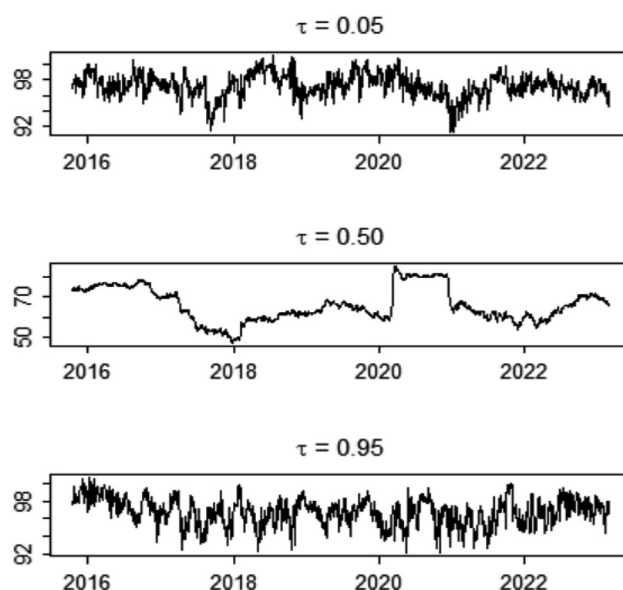


Figure 2: Time-varying total connectedness index (TCI) computed based on a rolling window 200 days and 10 step-ahead forecast horizon. Data: October 16, 2015 – February 28, 2023.

In addition, the extreme spillover increased in intensity as the markets operated in extreme conditions (for the lower [$\tau = 0.05$] and upper quantiles [$\tau = 0.95$]), which can be seen from the higher values in the extreme lower and upper quantiles. The minimum values were found in the medium quantile ($\tau = 0.5$), demonstrating the most moderate connectedness of whole sample. This result was also found in the studies by Wen et al. (2019) and Mensi et al. (2021b).

The maximum values in Figure 2 can be found for the upper quantile ($\tau = 0.95$), and the plot of the difference between the upper and lower quantiles can be observed in Figure 3.

Figure 3 demonstrates the tail dependency, which refers to the clustering of extreme events, and it can be noticed that the extreme upper quantile ($\tau = 0.95$) showed higher values than the extreme lower quantile ($\tau = 0.05$), primarily for the years 2018–2020. The negative (positive) values indicated a strong level of dependence in the lower (upper) quantiles, demonstrating consistency in the link between the analyzed markets.

Figure 4 illustrates the results for the full dynamic connectivity. It can be seen in this figure that the highest levels of connection between the markets are marked by the warmest tones.

It can be seen in Figure 4 that the connections were very strong in the extreme quantiles (lower and upper) throughout the whole sample, confirming the values of total connectedness shown in Tables 2–4, and the impacts of the spillovers in Figure 4 appeared to be symmetric. However, before 2017 and after the year 2020 (the COVID-19 period), a high intensity of connections can be seen in all quantiles (lower, medium, and upper). In analyzing the medium quantile ($\tau = 0.5$), Figure 4 shows the weaker sample.

Figure 5 presents the net pairwise directional connectedness network during low market conditions ($\tau = 0.05$), representing the situation in which the stock market was operating with returns below the conditional average (low performance). A τ value of 0.50 represents a situation in which the stock market is operating with returns close to the conditional average (stability), and a τ of 0.95 represents a situation in which the stock market is operating with returns above the conditional average (high performance).

The size of each circle representing each market assesses its magnitude through net spillovers. The yellow color represents a net receiver spillover from a market, and the blue color is a net contributor of spillover. In this way, the direction and intensity of linkages between markets can be represented by the arrows.

The net pairwise directional connectedness network at different quantiles in Figure 5 partially confirmed the results in Tables 2–4 for observing most of the shock transmission. The S&P 500 was proven to influence the entire market under analysis, losing its position to the euphoria measured by the VIX when the bull market appeared. The WTI shifted to being a sender of spillover when the stability market began in the extreme upper quantile, and Argentina, Brazil, and Chile were the main receivers of spillover from the Latin American countries.

Figure 5 presents the net pairwise directional connectedness network during the market conditions where the S&P 500, Colombia, and Peru were net contributors to spillover under bearish market conditions ($\tau = 0.05$), and the rest of the Latin American countries, the VIX, and the WTI were net receivers. The S&P 500 was the highest net contributor throughout the system, Colombia was a net contributor to the VIX and WTI markets, and Peru was shown to be a net contributor to the VIX market. The values of information transmission from the S&P 500 to the Latin American countries, the WTI, and the VIX were nearly the same.

When a market is operating with returns close to the conditional average (stability, $\tau = 0.5$), the scenario changes. The S&P 500 and Peru were continuous net spillover contributors to the system, but then, Mexico and the VIX also appeared as net spillover contributors. All the Latin American countries, the S&P 500, and the VIX

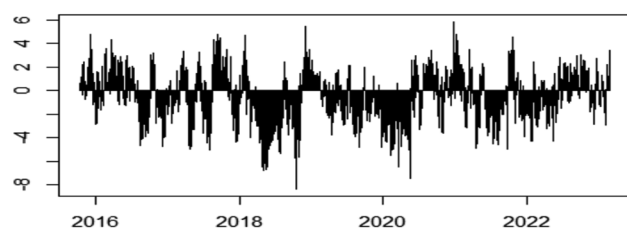


Figure 3: Plot of the difference between upper quantile and the lower quantile. Data: October 16, 2015 – February 28, 2023.

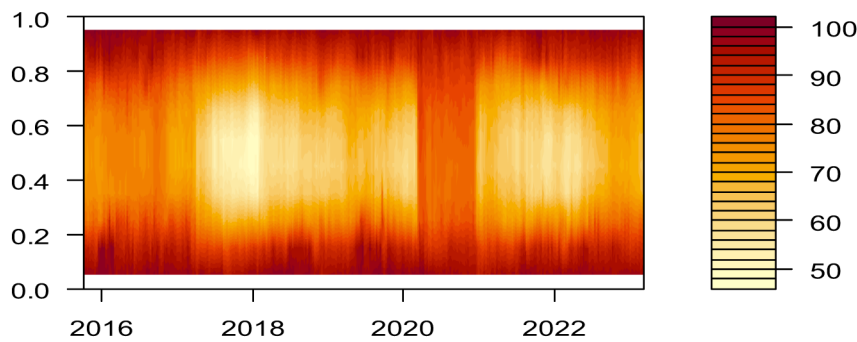


Figure 4: Dynamic total connectedness index. ^aNotes: Results are based on a 200-days rolling-window QVAR model with lag length of order 4 (BIC) and a 10-step-ahead forecast.

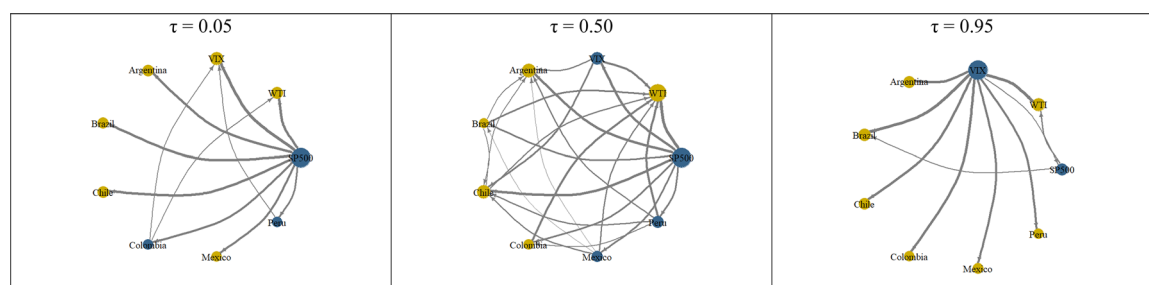


Figure 5: Net pairwise directional connectedness network at different quantiles ($\tau = 0.05$, $\tau = 0.50$ and $\tau = 0.95$).

were linked to the oil market (the WTI). Brazil showed linkage with Argentina and Chile, demonstrating similarity in terms of the distances of its borders, and the same results were found in the analysis of the Mexico and Peru stock markets compared to that of Chile. Argentina and the WTI were net receivers throughout the system, and on the contrary, the S&P 500 continued to be a net contributor to the system.

Analyzing the bull market conditions at the quantile $\tau = 0.95$, when the market was operating with returns above the conditional average (high performance); the VIX market was a net contributor throughout the whole system, along with the S&P 500 market. All the Latin American countries' markets were net receivers of spillover with the WTI market. The markets' expected volatility, as measured by the VIX, showed the fear of the Latin American countries, and the S&P 500 and the oil market (the WTI) were the net receivers of spillover from the VIX's highest values, as shown in Table 4 and Figure 5.

6 Conclusion and Implications

6.1 Key Findings

In this study we examined extreme return spillover and connectedness between crude oil (the WTI), the Volatility Index (VIX), the S&P 500, and six Latin American stock markets (Argentina, Brazil, Chile, Colombia, Mexico, and Peru) from 16 January 2015 to 28 February 2023. We used the quantile connectedness approach to analyze the various quantiles proposed by Ando, Greenwood Nimmo, and Shin (2022), which allowed us to examine the spillover patterns under different market conditions. In particular, we have shown the results from analyzing the periods of turmoil and stress in the financial system and the markets, represented by the extreme quantiles, from the perspective of the markets being net receivers and/or transmitters of spillover over time.

It was clear that United States market has an important role throughout the system because most of the spillover in the matrix began with the S&P 500, showing the strong dependence of the Latin American markets and the oil market, especially during periods of low performance (until market stability was achieved). However, when the markets were operating under bull market conditions, fear overtook the markets, and the VIX influenced the entire system as a sender of spillover.

Despite the fact that Colombia, Peru, and Mexico were the only Latin American countries that were shown to be net transmitters in the system, during bear conditions and until market stability occurred, their values were weaker than the values of the S&P 500 during the whole conditions within the system, and the VIX changed its category – from net receiver to net transmitter – within the system when bullish market conditions appeared. The fear of the market index and the S&P 500 were the only net transmitters in the system when the bull market was operating. Otherwise, Argentina and Brazil were shown to be net receivers of spillover during the whole market conditions, with higher values compared to the other Latin American countries.

The oil market was a net receiver of spillover in the entire sample, and the total return connectedness was higher only in the extreme quantiles (lower and upper). The directional connectedness confirmed our findings, where the United States market was the main driver of spillover in the system, though it lost this position to the VIX when the market conditions shifted to bull market conditions.

6.2 Implications

This study adds to the financial literature, exposing an appreciation for quantile research that can be analyzed as a new modality for academic researchers, investors and policy makers to deeply assimilate the risk transmission pathway between Latin American markets, S&P 500, the oil market and shocks of uncertainty. This work allowed for a nuanced investigation of connectivity and contributed to the understanding of integration between these markets. Acquiring a primary knowledge of the dynamics of spillovers and the connection between the Latin American market, S&P 500, oil market and uncertainties is fundamental to finance-based research, and this empirical work can therefore be useful as a basis for future research on the dynamics of dependence between these markets. Furthermore, our research contributes to the existing dimension of literature on quantile regression by analyzing when the market operates during bullish and bearish conditions. It is also worth noting that the research on the role of net transfers in each Latin American market, this work corroborated in demonstrating the sensitivity to the quantile tool was able to deeply describe the dynamics of net repercussions in the main economies of these countries.

This study also highlighted the network connection between the Latin American market, S&P 500, the oil market and uncertainties, as well as the direction and power of risk transfer between them. Therefore, this research benefits investors and operators in Latin American markets who are looking for an optimal allocation of their portfolios, as well as adequate hedging strategies. For future research, another method from wavelet quantile regression by Mao et al. (2023) could be carried out, or another path such as partial wavelet coherence analysis by Cai and Sakemoto (2022) and Kirikkaleli and Güngör (2021).

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Final conclusions

1. Summary of main findings

The oil market is an important market, especially for Latin America, historically representing an engine of economic development for this region. Many countries in Latin American are important oil producers and exporters. The oil companies studied here are often large, state-owned companies in these countries, and a substantial portion of their revenues typically contribute significantly to a country's imports and exports, thereby influencing exchange rates, stock markets, and the primary balance.

Article 1 mainly focuses on the impact of WTI oil prices (both negative and positive) on various scenarios (low and high stock market performance and stability) of Latin American stock markets, exchange rates, the S&P 500, and the COVID-19 period, exploring their asymmetric influences. An econometric technique was employed to address market behavioural aspects, measuring variables across five quantiles under different market conditions (high/low and stable market conditions). The results indicate asymmetry in the behaviour patterns of Latin American stock exchanges, particularly in response to market fluctuations with negative oil prices. The results were analysed using regression criteria with the quantile method (QR) and ordinary least squares (OLS) method. This methodology highlighted the advantages of the QR method over the OLS method. Additionally, the analysis captured the impact of political turmoil events and the COVID-19 pandemic on stock market behaviour indexes. Furthermore, dynamic returns revealed that negative previous trading sessions had a detrimental effect on Latin American markets, whereas positive previous trading sessions had a positive impact,

indicating that time-dependent returns provide insights into risk exposure and potential predictability of future series.

Article 2 examined the impact of crude oil prices on different quantiles of stock market return distributions in various Latin American emerging markets using dynamic linear and nonlinear Granger causality models. The results from the linear Granger causality model indicated no overall causality between WTI and stock markets in Argentina, Chile, and Ecuador, but causality was detected for Brazil, Colombia, Mexico, and Peru. Conversely, when using the nonlinear Granger causality model across quantiles, causality was observed in all quantile intervals for Latin American stock markets, except for Colombia and Mexico at the extreme upper interval. Therefore, the significance of this article lies in demonstrating that the dynamic nonlinear Granger causality method in quantiles offers a superior approach to analysing two distinct markets in time series, verifying their contemporaneous behaviour segmented by quantile intervals within the analysis. Essentially, this study illustrates that the choice of data and research analysis can reveal intricate relationships, as dynamic nonlinear methods are more adaptable and capable of detecting complex nonlinear causal relationships, unlike linear Granger causality which assumes linearity and may overlook such relationships.

Article 3 innovated by studying extreme return spillovers and connectedness between the crude oil market, the Volatility Index, and the Latin American stock market (Argentina, Brazil, Chile, Colombia, Mexico, and Peru), topics scarcely found in the literature. The aim was to examine asymmetry and time-variant connectivity of realized volatility, as well as higher moments (such as distributive connectivity of asymmetry and kurtosis) and risks. The motivation for this study stemmed from analysing risk and identifying which markets are more interrelated or connected than expected, influenced

by the varied performance states of the capital markets of one of the most important markets for export/import of goods and services in the world. Brazil, Chile, Colombia, Mexico, and Peru exhibited strong positive correlations among them, even more so than when compared against the United States market. Argentina showed the lowest correlation with the other Latin American countries and seemed to benefit more due to its shared border with Brazil. The strongest correlation values between the Latin American markets were observed between Brazil and Mexico, Colombia, and Peru, as well as between Chile and Colombia.

It was evident that the United States market played a significant role throughout the system, as most spillovers in the matrix originated from the S&P 500, highlighting the strong dependence of Latin American markets and the oil market, especially during periods of low performance until market stability was achieved. However, during bull market conditions, fear dominated the markets, with the VIX influencing the entire system as a source of spillovers. The oil market acted as a net receiver of spillovers in the entire sample, with total return connectedness being higher only in the extreme quantiles (lower and upper). Directional connectedness confirmed our findings, showing that the United States market was the primary driver of spillovers in the system, although this position was overtaken by the VIX when market conditions shifted to bull market conditions.

Therefore, the results of the thesis provide new evidence regarding the oil market and Latin American market, which is an area that has been relatively underexplored in the literature. A summary of the main findings is as follows: i) the presence of asymmetry between the oil market and the Latin American market, observed for both negative and positive oil price movements; ii) dynamic nonlinear Granger causality methods are more flexible and capable of detecting complex, nonlinear causal relationships, whereas

linear Granger causality assumes linearity and may not capture such relationships effectively; iii) the oil market acted as a net receiver of spillovers from the market, and total return connectedness was higher only in the extreme quantiles (lower and upper).

2. Contributions to the literature

While the oil market is widely discussed in the literature from various perspectives, the Latin American market has received relatively less attention, despite being one of the largest oil producers and exporters globally. Therefore, the three articles of this thesis aimed to provide evidence on important issues related to the oil market and the Latin American capital market. This study could have made a more substantial contribution if data from key countries in Latin America, such as Venezuela, for example, were available for analysis.

Most Latin American countries have high interest rates, which attract foreign capital investment in fixed income. Additionally, these countries are all exporters of commodities, including oil. This dynamic creates a market where there is a flow of money coming in for investments and money going out in the form of commodity exports.

In the first article, asymmetry was observed between the Latin American stock markets and the oil market, illustrating behaviour under negative and positive scenarios concerning the influence of high/low performance and market stability. Portfolio diversification is a common approach for investors to mitigate risks associated with market asymmetries. Understanding these asymmetries is crucial as they can impact asset allocation, risk management, and the selection of investment strategies. Additionally, the first article examined the COVID-19 pandemic period, demonstrating

positive and negative associations in different quantiles for the markets of Latin American countries. However, it was not investigated whether there were changes in the relationship between returns during this period.

The second article demonstrated causality between the Latin American stock market and the oil market using Granger causality. The importance of these results lies in analysing development based on behaviour differences segmented by quantiles, rather than relying on average analysis using a basic linear model. This highlights the distinction in analysis between different econometric models.

Finally, the third article examined extreme return spillover and connectedness between the oil market and Latin America. While there are numerous studies in this area with similar results, there are relatively few studies in the literature exploring Latin America specifically. The quantile connectivity approach, proposed by the work of Ando et al. (2018), was used to analyse several quantiles. This approach allowed us to examine different patterns of analysis under extreme market conditions, representing periods of turbulence and stress in the financial system and markets. The results focused on whether markets acted as net receivers and/or transmitters of repercussions over time.

It is worth mentioning that in all articles, political issues were prominently highlighted in this thesis, demonstrating the disruptive impact of political disturbances on the stock markets in Latin America. Each country included in the sample experienced its share of political upheavals, which directly affected the local capital markets.

Conclusiones finales

1. Resumen de los principales hallazgos

El mercado del petróleo es un mercado importante, especialmente para América Latina, representando históricamente un motor de desarrollo económico para esta región. Muchos países en América Latina son importantes productores y exportadores de petróleo. Las compañías petroleras estudiadas aquí son frecuentemente grandes empresas estatales en estos países, y una parte sustancial de sus ingresos suele contribuir significativamente a las importaciones y exportaciones del país, influyendo así en los tipos de cambio, los mercados de valores y el balance primario.

El Artículo 1 se centra principalmente en el impacto de los precios del petróleo WTI (tanto negativos como positivos) en varios escenarios (bajo y alto desempeño del mercado de valores y estabilidad) de los mercados de valores latinoamericanos, los tipos de cambio, el S&P 500 y el período de COVID-19, explorando sus influencias asimétricas. Se utilizó una técnica econométrica para abordar aspectos del comportamiento del mercado, midiendo variables a lo largo de cinco cuantiles bajo diferentes condiciones de mercado (altas/bajas y condiciones estables del mercado). Los resultados indican asimetría en los patrones de comportamiento de las bolsas de valores latinoamericanas, especialmente en respuesta a fluctuaciones del mercado con precios negativos del petróleo. Los resultados se analizaron utilizando criterios de regresión con el método de cuantiles (QR) y el método de mínimos cuadrados ordinarios (OLS). Esta metodología destacó las ventajas del método QR sobre el método OLS. Además, el análisis capturó el impacto de eventos de disturbios políticos y la pandemia de COVID-19 en los índices de comportamiento del mercado de valores. Además, los rendimientos

dinámicos revelaron que las sesiones de negociación previas negativas tuvieron un efecto perjudicial en los mercados latinoamericanos, mientras que las sesiones de negociación previas positivas tuvieron un impacto positivo, lo que indica que los rendimientos dependientes del tiempo proporcionan información sobre la exposición al riesgo y la predictibilidad potencial de las series futuras.

El Artículo 2 examinó el impacto de los precios del petróleo crudo en diferentes cuantiles de las distribuciones de retornos del mercado de valores en varios mercados emergentes latinoamericanos utilizando modelos dinámicos lineales y no lineales de causalidad de Granger. Los resultados del modelo de causalidad de Granger lineal indicaron que no hay una causalidad general entre el WTI y los mercados de valores en Argentina, Chile y Ecuador, pero se detectó causalidad para Brasil, Colombia, México y Perú. Por otro lado, al utilizar el modelo de causalidad de Granger no lineal a través de los cuantiles, se observó causalidad en todos los intervalos de cuantiles para los mercados de valores latinoamericanos, excepto para Colombia y México en el intervalo superior extremo. Por lo tanto, la importancia de este artículo radica en demostrar que el método dinámico no lineal de causalidad de Granger en cuantiles ofrece un enfoque superior para analizar dos mercados distintos en series temporales, verificando su comportamiento contemporáneo segmentado por intervalos de cuantiles dentro del análisis. Esencialmente, este estudio ilustra que la elección de datos y análisis de investigación puede revelar relaciones intrincadas, ya que los métodos dinámicos no lineales son más adaptables y capaces de detectar relaciones causales no lineales complejas, a diferencia de la causalidad de Granger lineal que asume linealidad y puede pasar por alto tales relaciones.

El Artículo 3 innovó al estudiar los derrames extremos de retorno y la conectividad entre el mercado de petróleo crudo, el Índice de Volatilidad y el mercado de valores

latinoamericano (Argentina, Brasil, Chile, Colombia, México y Perú), temas escasos en la literatura. El objetivo fue examinar la asimetría y la conectividad variable en el tiempo de la volatilidad realizada, así como los momentos superiores (como la conectividad distributiva de asimetría y curtosis) y los riesgos. La motivación de este estudio surgió al analizar el riesgo e identificar qué mercados están más interrelacionados o conectados de lo esperado, influenciados por los diversos estados de rendimiento de los mercados de capitales de uno de los mercados más importantes para la exportación/importación de bienes y servicios en el mundo. Brasil, Chile, Colombia, México y Perú mostraron fuertes correlaciones positivas entre ellos, incluso más que cuando se comparaban con el mercado de Estados Unidos. Argentina mostró la correlación más baja con los demás países latinoamericanos y pareció beneficiarse más debido a su frontera compartida con Brasil. Las correlaciones más fuertes entre los mercados latinoamericanos se observaron entre Brasil y México, Colombia y Perú, así como entre Chile y Colombia.

Quedó evidente que el mercado de Estados Unidos desempeñó un papel significativo en todo el sistema, ya que la mayoría de los derrames en la matriz se originaron del S&P 500, destacando la fuerte dependencia de los mercados latinoamericanos y el mercado del petróleo, especialmente durante períodos de bajo rendimiento hasta lograr la estabilidad del mercado. Sin embargo, durante condiciones alcistas del mercado, el miedo dominó los mercados, con el VIX influenciando todo el sistema como fuente de derrames. El mercado del petróleo actuó como receptor neto de derrames en toda la muestra, con una conectividad total de retornos más alta solo en los cuantiles extremos (inferior y superior). La conectividad direccional confirmó nuestros hallazgos, mostrando que el mercado de Estados Unidos fue el principal impulsor de los derrames

en el sistema, aunque esta posición fue superada por el VIX cuando las condiciones del mercado pasaron a ser alcistas.

Por lo tanto, los resultados de la tesis proporcionan nuevas evidencias sobre el mercado del petróleo y el mercado latinoamericano, que es un área que ha sido relativamente poco explorada en la literatura. Un resumen de los principales hallazgos es el siguiente: i) la presencia de asimetría entre el mercado del petróleo y el mercado latinoamericano, observada tanto para movimientos de precios negativos como positivos del petróleo; ii) los métodos de causalidad de Granger dinámicos y no lineales son más flexibles y capaces de detectar relaciones causales complejas y no lineales, mientras que la causalidad de Granger lineal asume linealidad y puede no capturar dichas relaciones de manera efectiva; iii) el mercado del petróleo actuó como receptor neto de derrames del mercado, y la conectividad total de los retornos fue más alta solo en los cuantiles extremos (inferior y superior).

2. Contribuciones a la literatura

Sobre el mercado del petróleo se discute ampliamente en la literatura desde diversas perspectivas, el mercado latinoamericano ha recibido relativamente menos atención, a pesar de ser uno de los mayores productores y exportadores de petróleo a nivel mundial. Por lo tanto, los tres artículos de esta tesis tuvieron como objetivo proporcionar evidencia sobre temas importantes relacionados con el mercado del petróleo y el mercado de capitales latinoamericano. Este estudio podría haber hecho una contribución más sustancial si se hubieran tenido datos de países clave en América Latina, como Venezuela, por ejemplo, para su análisis.

La mayoría de los países latinoamericanos tienen tasas de interés altas, lo que atrae inversiones de capital extranjero en instrumentos de renta fija. Además, todos estos países son exportadores de materias primas, incluido el petróleo. Esta dinámica crea un mercado donde hay un flujo de dinero entrante para inversiones y dinero saliente en forma de exportaciones de materias primas.

En el primer artículo, se observó asimetría entre los mercados bursátiles latinoamericanos y el mercado del petróleo, ilustrando comportamientos en escenarios negativos y positivos en relación con la influencia de un rendimiento alto/bajo y la estabilidad del mercado. La diversificación de la cartera es un enfoque común para los inversionistas para mitigar riesgos asociados con las asimetrías del mercado. Comprender estas asimetrías es crucial, ya que pueden afectar la asignación de activos, la gestión del riesgo y la selección de estrategias de inversión. Además, el primer artículo examinó el período de la pandemia de COVID-19, demostrando asociaciones positivas y negativas en diferentes cuantiles para los mercados de países latinoamericanos. Sin embargo, no se investigó si hubo cambios en la relación entre los rendimientos durante este período.

El segundo artículo demostró causalidad entre el mercado bursátil latinoamericano y el mercado del petróleo utilizando la causalidad de Granger. La importancia de estos resultados radica en analizar el desarrollo basado en diferencias de comportamiento segmentadas por cuantiles, en lugar de depender del análisis promedio utilizando un modelo lineal básico. Esto resalta la distinción en el análisis entre diferentes modelos econométricos.

Finalmente, el tercer artículo examinó el desbordamiento extremo de rendimientos y la conectividad entre el mercado del petróleo y América Latina. Aunque hay numerosos

estudios en esta área con resultados similares, hay relativamente pocos estudios en la literatura que exploren específicamente América Latina. Se utilizó el enfoque de conectividad por cuantiles, propuesto por el trabajo de Ando et al. (2018), para analizar varios cuantiles. Este enfoque nos permitió examinar diferentes patrones de análisis bajo condiciones extremas de mercado, representando períodos de turbulencia y estrés en el sistema financiero y los mercados. Los resultados se centraron en si los mercados actuaron como receptores y/o emisores netos de repercusiones con el tiempo.

Vale la pena mencionar que en todos los artículos, se destacaron prominentemente los problemas políticos en esta tesis, demostrando el impacto disruptivo de las perturbaciones políticas en los mercados de valores en América Latina. Cada país incluido en la muestra experimentó su parte de convulsiones políticas, las cuales afectaron directamente a los mercados de capital locales.

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