



Spillovers and cointegration on Financial Markets and Commodities: an Auto Regressive Distributed Lag approach

VERSÃO FINAL APÓS DEFESA

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Dedicatória

Quero dedicar ao meu Pai, à minha Mãe, ao meu Irmão, as pessoas que me acompanham desde sempre. Estiveram comigo nos momentos bons e nos momentos menos bons, em todas as conquistas e em todos os fracassos. Que as conquistas não fiquem por aqui e que vocês continuem a acompanhar. Quero fazer uma dedicatória especial ao Avô Carlos e à Avó Tina. O Avô que todos os dias me apoia e motiva e a Avó, que embora já não esteja cá, deixou uma marca enorme na pessoa que sou hoje.

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Resumo alargado

Este trabalho de investigação, no âmbito da dissertação, aborda a relação entre os preços dos mercados financeiros e o preço das commodities de energia tendo como objetivo principal a resposta à pergunta: qual é o efeito de spillover dos preços das commodities para os preços dos mercados de ações quando se incluem as quebras estruturais, o Índice de Incerteza da Política Económica e o índice de produção industrial?

Para enquadrar esta questão, foi realizada a revisão de literatura, abrangendo estudos que analisam a integração dos mercados de commodities e financeiros, o impacto do Índice de Incerteza da Política Económica e a importância dos índices de produção industrial. Diversos estudos anteriores identificaram a interdependência dos preços do petróleo e dos mercados de ações, bem como a transmissão de risco de preços do petróleo para o mercado de ações.

O estudo centra-se em alguns determinantes chave que influenciam os preços nos mercados de ações. Neste estudo em particular e de acordo com a revisão de literatura realizada, selecionamos os seguintes determinantes: preço do WTI, preço do Brent, preço do Gás e preço do Carvão. De acordo com a técnica econométrica utilizada são identificados efeitos das determinantes sobre o preço dos mercados de ações quer no curto prazo, como no longo prazo; o que nos permitiu averiguar se haveria alteração nos sinais dos coeficientes e nos níveis de significância

Aplicando a metodologia econométrica Auto Regressive Distributed Lag (ARDL), integrada no método da cointegração. O uso desta metodologia permite diferenciar entre os efeitos de curto e longo prazo, oferecendo insights sobre o comportamento que os investidores devem adotar para otimizar as suas carteiras, bem como sobre as decisões que os formuladores de políticas devem tomar para atingir os seus objetivos. Os dados utilizados incluem preços de commodities, índices de produção industrial, e indicadores da incerteza política.

Os resultados do estudo indicam diferenças significativas nos efeitos de curto e longo prazo das commodities sobre os mercados financeiros. No curto prazo, os spillovers do preço do Brent impactam positivamente o índice CAC40, enquanto o Shanghai Composite é afetado positivamente pelos spillovers do WTI. Esses efeitos sugerem que, no curto prazo, os investidores podem encontrar oportunidades de ganhos imediatos ao reagirem às mudanças nos preços das commodities. A rápida reação dos mercados às flutuações dos preços das commodities pode ser explicada pela necessidade imediata dos investidores de ajustar as suas carteiras para mitigar riscos ou aproveitar as oportunidades de lucro rápido, influenciadas também pelo sentimento dos investidores e pela volatilidade do mercado.

Por outro lado, os efeitos de longo prazo demonstram uma relação mais complexa e menos favorável entre os preços das commodities e os mercados financeiros. Os spillovers do WTI afetam negativamente os índices DAX e CAC40 a longo prazo, sugerindo uma pressão contínua sobre esses mercados devido à dependência das economias em relação aos preços do petróleo. Além disso, o Shanghai Composite é negativamente impactado a longo prazo pelos spillovers do WTI, enquanto os spillovers do Brent afetam negativamente o CAC40. Esses resultados destacam a importância de uma abordagem de investimento mais cautelosa e estratégica a longo prazo, considerando a influência duradoura das flutuações dos preços das commodities nos mercados financeiros e a necessidade de políticas robustas para mitigar esses impactos adversos.

A evidência sobre os efeitos de spillover entre o preço das commodities de energia tem implicações significativas para os processos de tomada de decisão dos investidores, tanto no curto quanto no longo prazo, especialmente para aqueles com carteiras que contêm ativos de empresas envolvidas na produção de petróleo, carvão e gás natural. Esse entendimento permite aos investidores desenvolver e avaliar estratégias potenciais de diversificação destinadas a mitigar riscos e flutuações nos retornos dos ativos do mercado de ações e na sua correlação com os mercados de commodities, particularmente durante períodos de instabilidade econômica e financeira, como a crise da pandemia de COVID-19 e o conflito em curso envolvendo as ações militares da Rússia na Ucrânia.

A presença de noise traders, conforme indicado pelo sentimento dos investidores, deve ser considerada um aspecto crucial da estabilidade do mercado de ações, que é positivamente influenciada por esses investidores. Os resultados deste estudo revelam uma relação significativa entre o ruído nas negociações, medido pelo sentimento dos investidores, e preços dos mercados financeiros. Essa significância estatística sugere que os investidores tendem a tomar decisões de investimento mal informadas nos mercados de ações.

As implicações políticas do estudo sugerem que compreender essas interdependências pode facilitar o desenvolvimento de políticas econômicas e financeiras mais robustas. Monitorizar variáveis como os preços das commodities, o Índice de Incerteza da Política Econômica e o índice de produção industrial é crucial para melhorar a tomada de decisões financeiras.

Este estudo avança na literatura ao esclarecer a interação complexa entre commodities e mercados financeiros, fornecendo um quadro abrangente para futuras investigações neste domínio. As descobertas destacam a importância de considerar tanto os efeitos de curto quanto de longo prazo e de incorporar quebras estruturais na análise.

Palavras-chave

Mercados financeiros; Commodities; Sentimento do Investidor; Índice de Produção Industrial; ARDL

Abstract

This research examines the dynamic interactions between financial markets and commodities through the application of the Auto Regressive Distributed Lag (ARDL) methodology. The analysis centers on the influence of the price of commodities, the Economic Policy Uncertainty index, and the industrial production index on commodity prices and stock market performance. Utilizing a suite of econometric tests, the study discerns both short-term and long-term relationships among the examined variables. The findings underscore the substantial impact of the price of commodities, the Economic Policy Uncertainty index, and the industrial production index, in addition to the influence of structural breaks over time within stock markets. These insights are pivotal for devising investment strategies and managing portfolio risks, highlighting the necessity of monitoring these variables to enhance financial decision-making. The policy implications of the study suggest that comprehending these interdependencies can facilitate the development of more robust economic and financial policies. In summary, this research advances the literature by clarifying the intricate interplay between commodities and financial markets, providing a comprehensive framework for future investigations in this domain.

Keywords

Financial Markets; Commodities; Investors Sentiment; Industrial Production Index; ARDL

Index

List of figures	xvii
List of tables	xix
List of Acronyms	xxi
1. Introduction	1
2. Literature Review	3
2.1 The commodities' role in Stock Markets	3
2.2 The Investor's sentiment Index and Returns on the Stock market	5
2.3 The influence that the Economic Policy Uncertainty Index, Industrial Production Index, and Structural Breaks exert on Stock Markets	6
3. Data and Methodology	8
3.1 Data	8
3.2 Methodology	12
4. Results	14
5. Discussion	22
5.1 Spillover between financial markets and commodities	23
6. Conclusion and Policy Implications	25
6.1. Limitations and future research	26
References	28

List of figures

Fig. 1 – Evolution of Industrial Production Seasonally Adjusted Index 2015=100	10
Fig. 2 – Evolution of Closing Price of Commodities	11
Fig. 3 – Evolution of Economic Policy Uncertainty	11
Fig. 4 – Evolution of Closing Price of Financial Markets	12

List of tables

Table 1 – Variables	8
Table 2 – Descriptive statistics	8
Table 3 – Unit Root Test (ADF, PP, and KPSS) with break results	14
Table 4 – Test for Multiple Breaks at Unknown Breakpoints (Ditzen et al., 2021)	16
Table 5 – ARDL bounds test for investigating long-run equilibrium relationships	18
Table 6 – Short-run estimation results for the ARDL with breaks	19
Table 7 – Long-run estimation results for the ARDL with breaks	20
Table 8 – Post-estimation tests	20

List of Acronyms

ADF	Augmented Dickey-Fuller
ARDL	Auto Regressive Distributed Lag
ECT	Error Correction Term
IPI	Industrial Production Index
KPSS	Kwiatkowski–Phillips–Schmidt–Shin
PP	Phillips-Perron
WTI	Western Texas Intermediate

1. Introduction

With the financialization of commodity markets, commodities exert significant influence on financial markets and the global economy. The commodities exert influence by being traded in those referred markets or by being the core business of some companies that are listed in such markets. Oscillations in the commodities can impact the companies that use them as feedstock by augmenting their production costs and reducing their profits. However, for the companies that extract these goods and then sell them, raises in prices can generate high profit rates.

Commodity oscillations can have the mentioned impact on the companies but being traded in the financial markets can also impact the price of such markets. Oil is one of the most influential commodities and recent studies corroborate such influence on other commodities, markets, or indexes (Asadi et al., 2022; Crawford et al., 2021; Egging and Gabriel, 2006; Jingjian et al., 2023; Murry and Zhu, 2008). According to a report by the International Energy Agency (IEA), natural gas constitutes less than 25% of the global energy supply¹. Although, coal is becoming one of the most consumed sources of energy. According to a study from IEA², coal represents more than 25% of the total energy supply leading to high oscillations in the past years reaching the highest price, since 2008, 2022. One of the main players in financial markets is the investors, without them, there would not exist trading. Their feelings regarding market fluctuations, the policies taken by the governments, or the decisions that companies make can influence their willingness to invest in commodities, companies, or markets. The uncertainty has been increasing since the global financial crisis and has reached a maximum value, since 2008, in 2020. As the uncertainty rises, investors tend to get insecure and invest less or disinvest because they are not sure of what the future holds for them.

Another macroeconomic variable that influences the markets is the industrial production index and the market's dependence on industry. This dependence will oscillate depending on the core business of the companies inserted in the financial market.

Market results can also be affected by other external factors. Periods of crisis, recession, or uncertainty can lead to lower results. In 2008 the markets analyzed presented lower prices due to the financial crises felt in that year and extending to the next year. COVID-19 and the armed conflict's impact on markets can be seen in the prices of the financial markets in 2019, 2020, 2021 and 2022, respectively. This means that the markets can also be influenced by endogenous and exogenous crises and felt in some periods that can suggest structural breaks.

¹ <https://www.iea.org/reports/key-world-energy-statistics-2021/supply>

² <https://www.iea.org/reports/key-world-energy-statistics-2021/supply>

The literature available is very vast and full of contributions where conclusions can be taken to constitute portfolios or to know where to invest. Although, a gap was found when analyzing the short- and long-term, the inclusion of periods of structural breaks as exogenous and the different outcomes depending on other factors that are not the commodities, such as the impact that the Economic Policy Uncertainty index and industrialization have on the financial markets.

The question we are looking to answer is: what is the spillover effect from the price of commodities to the stock markets when including the breaks, the Economic Policy Uncertainty, and the industrial production index?

To reach this question there are some to answer earlier, being the integration order of each variable and cointegration of the equations done. To find the answers, integration tests will determine the order of integration of the variables. After those tests, we will employ the Auto Regressive Distributed Lag (ARDL) econometric model. This model enable the differentiation between short- and long-term and gives insights into what should be the behavior that the investor needs to have to optimize their portfolio or the decisions that policymakers should apply to reach their objectives.

The most notable findings from this paper indicate that WTI spillovers significantly impact the DAX and CAC40 indices in the long run, although there is no effect in the short run. The Shanghai Composite experiences negative long-term impacts and positive short-term impacts from WTI spillovers. Additionally, Brent spillovers to the CAC40 are positive in the short run and negative in the long run. Both the German (DAX) and French (CAC40) markets are adversely affected by the Policy Uncertainty Index.

Additionally, evidence suggests volatility transmission between stock prices and commodity prices across international borders. According to contagion theory, investors react to publicly available information and observe price changes in other proxy markets to acquire information not readily accessible in their local markets. This implies that information shocks in one market can influence the prices and volatility of other markets. In the context of international investment, this phenomenon has become an increasing concern for both investors and policymakers, as it underscores the interconnectedness and potential risks inherent in global financial markets.

All in all, this paper is structured in the first part by the literature review where we analyze literature regarding the topic. Then we present the data that will be used, and the methodology employed. After this topic, we present the results and obtain and discuss the findings. In the end, we analyze the spillover effect and after that we present the conclusions and the policy implications, as well as the limitations and lines for future research.

2. Literature Review

Financial markets include any location or system that provides buyers and sellers with the means to trade financial instruments (bonds, stocks, derivatives, currencies). They facilitate interaction between those in need of capital and those with capital to invest. In addition to capital acquisition, financial markets allow participants to transfer risks (usually through derivatives) and promote trade.

Funke et al. (2015) mentioned the relation between the global market and other factors saying that besides domestic factors, external global conditions can also impact the difference between offshore and onshore currency. Exchange rates in emerging markets are typically influenced by global factors such as liquidity and risk sentiment. Considering time is a crucial element in contagion analysis, as proposed by (Liao et al., 2018). They argue that the dependency structure exhibits variations over time, characterized by distinct periods of high and low dependence. The author also underscores the spatial aspect, having identified evidence of positive, negative, and asymmetric spillover effects between the US capital market and the other six G7 countries. It's noteworthy that a significant decline in stock prices in one market can prompt widespread investor sell-offs, potentially triggering a domino effect across other capital markets, as discussed by Chang et al. (2019), Liao et al. (2021), and Zhang et al. (2021).

2.1 The commodities' role in Stock Markets

In the markets, as said, the participant buys and sells different financial instruments, such as bonds, stocks, and commodities. Various authors, such as Silvério and Szklo (2012), Jingjian et al. (2023), and Hu et al. (2023), have addressed the impact of markets on commodities, as well as the spill-over effect and integration among them. Considering these, they have found that commodities have a significant impact on various markets. The spillover effect refers to how an event or decision in a specific market or commodity affects others. Evidence has been found that these effects occur between commodities and financial markets (Aboura and Chevallier, 2015). The spillover effect is not limited to commodity-markets or markets-commodity but also commodity-commodity. West Texas Intermediate (WTI) and Brent transmit shocks and uncertainties to the energy market. WTI is the most relevant variable in the analysis, transmitting risk to many markets and companies. In addition to the mentioned impact, it also affects the prices of other energies, indicating that fluctuations in the WTI market will affect the others in the coming months, and there is generally an extreme risk of spillover in international energy markets (Hu et al., 2023).

Asadi et al. (2023) explore in their article the complex relations between commodities and financial assets in the USA and China. The conclusion obtained in the analysis was that of all the variables used, coal was the one with the fewest connections with other variables. Coal influences directly the exchange rate of USD/CNY³.

The interdependence of oil prices and stock markets, along with the transmission of crude oil price risk to the stock market, is well illustrated in the research conducted by Cui et al. (2021) and S. Li et al. (2022). The findings suggest that, firstly, the recent financial crisis has heightened the connections between the crude oil market and the Chinese stock market. Additionally, the risk spillovers from oil prices to the Chinese stock market exhibit significant asymmetric characteristics, particularly with increased long-term downside risk spillovers.

As the effects can spread from one market to another market, or from one commodity to another commodity, the concept of integration urges with importance in the literature. Zhang (2019) found that many variations in various oil markets result from innovations in the WTI market, and this market experiences few shocks with changes in other oil markets. In general, Egging and Gabriel (2006) concluded the lack of integration in oil markets. Despite this conclusion, there may be measures that affect oil markets across the board, subsequently affecting financial markets as well. Market liberalization may bring positive returns for consumers and investors; however, if the correct measures are not applied, it could lead to price increases and a decrease in well-being (Egging and Gabriel, 2006).

The price of WTI and the markets exhibit bidirectional causality and are increasingly seen as financial assets (Silvério and Szklo, 2012). The market plays a significant role in shaping the WTI price, with the WTI price influencing the market. The price of oil not only has an impact on the prices of other commodities. Gas and oil have a long-term relationship; when there are supply shocks, the market doesn't collapse entirely but undergoes various adjustments in different markets. The long-term equilibrium Asche et al (2012) found may not always be used to predict future developments in relative prices.

According to Xie and Tang (2022), the uncertainty in the oil market tends to exert positive and asymmetric influences on the uncertainty of stock markets in BRICS countries. This observation reinforces the notion that the volatility of oil prices serves as a significant channel influencing financial markets, as also supported by Cui et al. (2021). Notably, high oil prices were found to negatively impact the stock markets of importing countries by increasing production costs, reducing corporate profits, and dimming

³ United States Dollar/ Chinese yuan Renminbi

investment prospects. Conversely, oil-exporting countries may experience positive effects, including higher yields and investment profits, as discussed by Prabheesh et al. (2020), Mensi et al. (2021), and Balcilar et al. (2021).

2.2. The Investor's sentiment and Returns on Stock markets

Although the importance of the markets and commodities, the investors take an important role in both the pre-mentioned concepts. Investors, being the ones who trade and participate in the market, have an important role in the process of setting the price. One of the variables that usually is used in the literature is the Investor's Sentiment. A study from Jingjian et al. (2005) regarding Brent sought to analyze the impact of crude price fluctuations on the stock market with and without the variable of investor concern. This variable is not always involved in the crude price formulation process. However, when present, in some cases, it causes energy prices to fall even more than expected due to stock selling in this context. On the other hand, the broader the analysis spectrum or the larger the company in question, the less impact investor concern will have. The volatility of information may vary depending on the nature of the change; that is, if it is a negative change, the volatility will be higher than if the change is positive (Jingjian et al., 2023).

The importance of investors in the markets, in some cases including the variable regarding investors sentiment does not affect positively. Lean et al. (2023) sought answers regarding the role of commodity futures markets in portfolio optimization and risk control allowing variations over time and asymmetric volatility in reacting to news. The conclusion found was that in the case of the S&P500, there is a relationship with some commodities, and weekly returns are, on average, positive. The authors also investigated how diversifying investment portfolios and including commodities can influence the trade-off between risk and return. They concluded that including commodities in investment portfolios does not always improve the trade-off between risk and return (Lean et al., 2023).

Xing and Ladley (2019) assert that the presence of noise traders is essential for the growth of the stock market and that their activity positively influences the market's stability. Studies conducted by Zargar and Kumar (2019), Cuong et al. (2019), and Ahmed (2019), among others, have examined the impact of noise traders on stock returns. Recent analyses have explored the presence and behavioral interactions of noise traders in various international stock markets, including the Vietnamese market (Cuong et al., 2019), the US market (Ahmed, 2019), the Indian market (Savita, 2020), and the Nigerian market (Emmanuel and Ahmed, 2020). These investigations consistently

highlight that noise traders, despite being uninformed, constitute a crucial element in the functionality of stock markets.

Conversely, Banerjee and Pradhan (2020) and Savita (2020) found that the behavior of noise traders in Indian stock exchanges does not significantly affect trading activities. In contrast, Chiu-Lan and Fang (2020) and Choi et al. (2020) reported a positive relationship between trading noise and abnormal returns on real estate assets, attributing this to individuals' tendency to make misinformed decisions. Kumar (2020) observed that disclosed information has varying impacts on informed versus uninformed agents. Furthermore, research by He et al. (2020) indicates that investor sentiment has an asymmetric relationship with stock returns and stock volatility.

2.3. The influence that the Economic Policy Uncertainty Index, Industrial Production Index, and Structural Breaks exert on Stock Markets

Other factors that cannot be directly related to the markets or commodities can still influence the price and the returns of the markets or commodities. Sakurai and Kurosaki (2020) investigated how the relationship between the oil market and the US stock market evolved in the aftermath of the COVID-19 pandemic. Utilizing excess correlations and the bivariate normal distribution with H statistics, they observed a heightened asymmetry in correlation after the COVID-19 crisis. Egging and Gabriel (2006) addressed market liberalization and how it should be carried out in line with the goals of the "Lisbon 2010 Agenda." They concluded that if the correct decisions were not made, the consequences for the market might not be as intended. Instead of increasing well-being, it could lead to a decrease in well-being and an increase in prices.

Dua and Tuteja (2023) delved into the repercussions of economic and financial crises, including the 2007-2009 recession, the 2010-2012 eurozone crisis, and the COVID-19 crisis, on the economies of China and India. The authors aimed to discern specific and shared cycles in the economic growth rates of these two nations. Their findings suggested that the impact of the pandemic on the global economy was severe, surpassing that of previous crises. It underscored the significance of commercial and financial interactions in shaping the economic dynamics of emerging market economies.

Hong et al. (2022), Dogan et al. (2022), and Wang et al. (2022) employed the Granger causality test to examine the presence of Granger causality during the pandemic crisis. Their findings indicated the existence of Granger causality, highlighting the substantial impact of the pandemic on commodity indices. This impact extended to influencing both prices and volatilities, resulting in increased uncertainty and altering the relationships among various commodities.

Duprey et al. (2017) studied the industrial production impact on financial markets and concluded that financial stress has worse results when the industrial production index is also contracting. Although the impact during crisis, after the shock the effect does not necessarily remain for an extended period.

Despite all the studies carried out over the years, none were found that related the markets with the different commodities adding Economic Policy Uncertainty index and considering the short-term and long-term effects using Auto Regressive Distributed Lag (ARDL).

Considering the literature analyzed, some questions are still to be answered. A modeling that includes the markets, the commodities, the Economic Policy Uncertainty index, and the industrial production index of the country in which the market inserts. Considering the data that will be used and the period in analysis, the study of the possible structural breaks is necessary and, if existing, the insertion in the modeling as exogenous variables. When comparing the literature available with all the events that occurred throughout the years, there is still some information to analyze, some models to test and so many other works available. In this paper, it is introduced a new approach using points that other authors used but taking it further. There is information available about the spillover effect of commodities, markets, and other indexes, but not much information about this spillover effect when introducing the structural breaks present in the data used.

With this said the purpose of this paper is to give new insight to investors and policymakers about the relationship between commodities and markets, introducing the industrial production index and the Economic Policy Uncertainty index, while also introducing the breaks in the modeling. The model used will be able to separate the long-run and short-run relationships, making it possible for the investors to decide the composition of their portfolio in the short and long run, and enabling policymakers to choose between structural and conjunctural policies to achieve their goals.

By introducing the Economic Policy Uncertainty index, policymakers can verify the impact that some policies had on the investors and the industrial production index makes it possible to verify the dependence of the industry that the market of that country has.

3. Data and Methodology

3.1. Data

For the study, monthly data will be used, starting from January 2008 and ending in October 2023.

Table 1. Variables

Variable	Diminutive	Source
WTI	wti	Federal Reserve
Brent	brent	Markets Insider
Coal	coal	Markets Insider
Gas	gas	Markets Insider
Economic Policy Uncertainty Index	e pu	Policy Uncertainty
Industrial Production Index USA	ipi_usa	OECD Data
Industrial Production Index China	ipi_ch	OECD Data
Industrial Production Index Germany	ipi_ger	OECD Data
Industrial Production Index France	ipi_fr	OECD Data
Industrial Production Index UK	ipi_uk	OECD Data
Industrial Production Index Japan	ipi_jpn	OECD Data
Dow Jones	dj	Markets Insider
S&P 500	sp	Markets Insider
NIKKEY 225	nk	Markets Insider
Shanghai Composite	sc	Markets Insider
DAX	dax	Markets Insider
CAC40	cac	Markets Insider

The analysis of descriptive statistics for time series reveals important characteristics of commodity prices (WTI, Brent, coal, natural gas) and economic and market indices (IPI, Dow Jones, S&P 500, Nikkei, etc.). Among the commodities, coal stands out for its high volatility, evidenced by the highest standard deviation (59.79) and elevated kurtosis (11.11). The average price of Brent (78.68) is higher than that of WTI (72.79), with both showing moderate volatility. Natural gas also shows high volatility with a low average (3.82) and high skewness (2.174).

Table 2. Descriptive statistics

	Mean	Median	Maximum	Minimum	Std. Dev.	Skewness	Kurtosis	Jarque-Bera	Prob.	Obs.
Wti	72.79	72.1	133.880	16.548	23.29	0.131	2.263	4.847	0.089	190
Brent	78.68	75.20	139.8300	22.740	25.447	0.135	1.996	8.596	0.014	191

Coal	100.03	84.53	383.2476	39.331	59.79	2.708	11.11	760.81	0.000	192
Gas	3.82	3.308	12.78938	1.703	1.850	2.174	8.623	404.27	0.000	192
ipi_usa	98.40	99.51	104.1181	84.598	4.768	-1.192	3.699	49.147	0.000	191
ipi_ch	105.35	109.1	142.2809	58.88	19.38	-0.570	2.809	10.58	0.005	190
ipi_jpn	99.50	100.22	119.448	79.632	6.342	-0.02	5.462	48.015	0.000	190
ipi_ger	97.06	98.36	107.709	71.306	6.441	-1.461	5.441	114.73	0.000	190
ipi_fr	100.16	99.72	115.259	68.059	4.631	-1.574	16.7	1564.44	0.000	190
ipi_uk	99.520	99.53	113.323	88.573	5.401	0.299	2.819	3.096	0.213	190
epu	182.60	160.22	435.308	79.934	74.859	0.817	2.867	21.369	0.000	191
dj	20257.37	17819.69	36817.79	7235.466	8483.49	0.404	1.864	15.529	0.000	192
sp	2353.51	2081.41	4674.773	757.1327	1114.5	0.584	2.159	16.579	0.000	192
nk	18049.6	17816.88	33077.59	7694.783	7096.7	0.279	1.973	10.93	0.004	192
sc	2926.6	2990.8	5045.942	1876.015	547.43	0.386	4.025	13.166	0.001	192
dax	10235.8	10449.26	16672.35	3969.151	3367.67	0.009	1.852	10.553	0.005	192
cac	4813.14	4665.1	7507.689	2725.319	1173.16	0.496	2.469	10.115	0.006	192

The industrial production indices vary considerably, with China having the highest average (105.35). Most stock market indices, such as the Dow Jones (average of 20257.37) and the S&P 500, demonstrate significant volatility and positive skewness, indicating asymmetric distributions. The Jarque-Bera test suggests that most series do not follow a normal distribution, except for the EPU, which shows a possibly normal distribution (p-value of 0.2127). These results underline the importance of considering volatility and non-normality when modeling these time series.

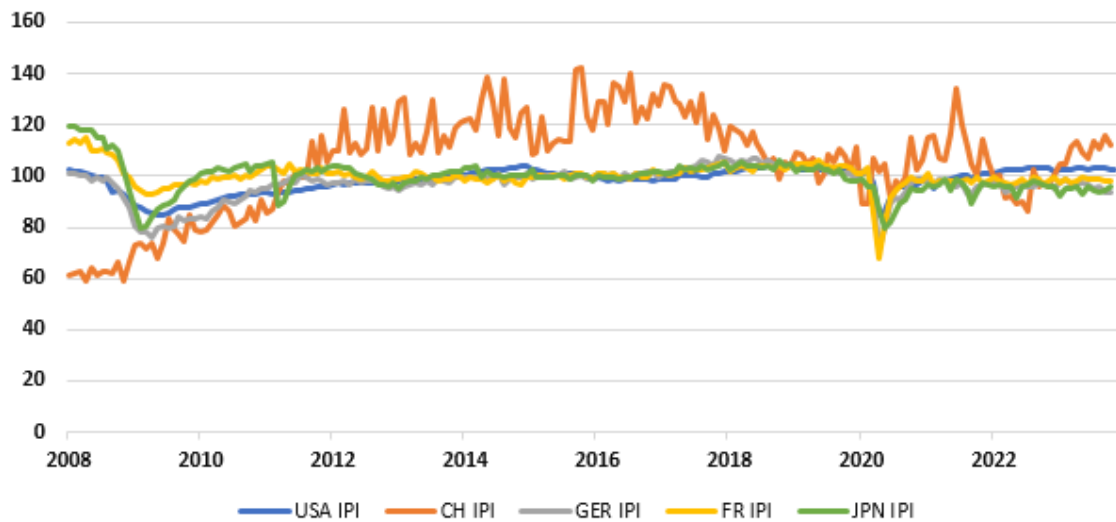


Fig. 1. Evolution of Industrial Production Seasonally Adjusted Index 2015=100

In the Fig 1., it is possible to observe the evolution of the Industrial Production Index for the different countries under analysis. China (CH IPI), graphically, showed an upward trend, although the trajectory exhibits high levels of volatility. It is noteworthy that China experienced a significant expansion period between 2010 and 2018, in 2021, and from 2022 onwards.

The remaining countries exhibit very similar Industrial Production Indices. For these countries, the impact of the Global Financial Crisis between 2008 and 2010 is visible, and the effects of the COVID-19 pandemic that occurred in early 2020 are also evident. The different behavior displayed in China can be explained by the policies that the Chinese government applied. In terms of the Industrial Production Index, graphically, China does not seem to affect or be affected by the others. Although, three of the six countries are European and conduct similar policies, which can explain the similar evolution.

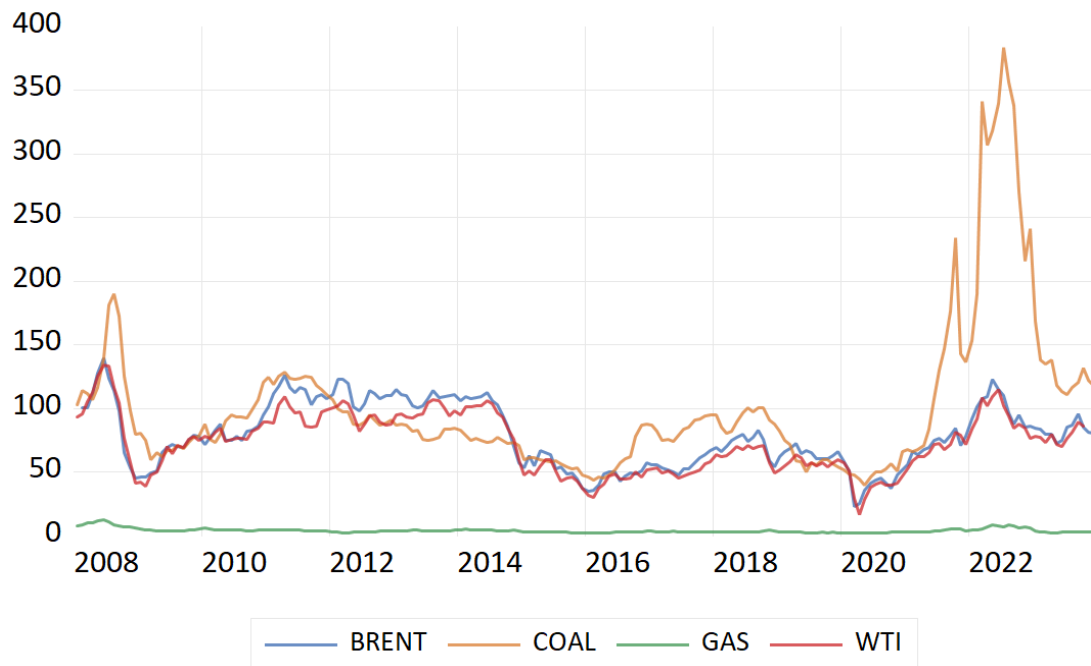


Fig. 2. Evolution of daily closing Price of Commodities.

Among the commodities addressed in this study (Fig. 2), Coal, Brent, and WTI show similar variations over the years under analysis. All three variables experienced declines between 2008 and 2009, between 2014 and 2016, in 2020, and a peak in 2022. This peak is notably more pronounced in the case of coal.

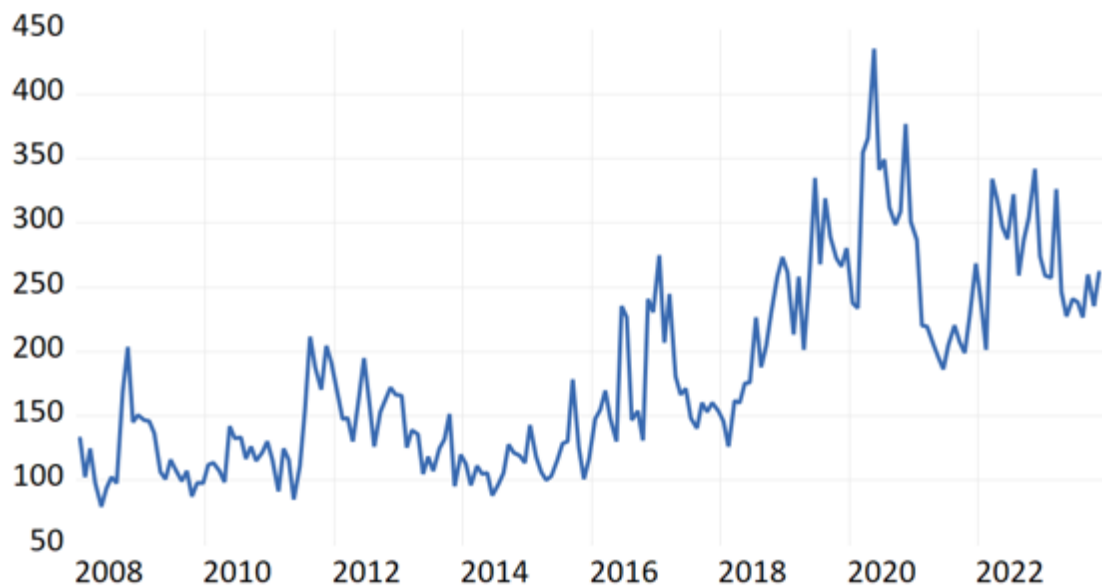


Fig. 3. Evolution of Economic Policy Uncertainty Index.

This index (Fig. 3) has shown an upward trend, and the peaks in 2020 due to the pandemic crisis and the extended period of instability in 2022 due to armed conflict are noteworthy.

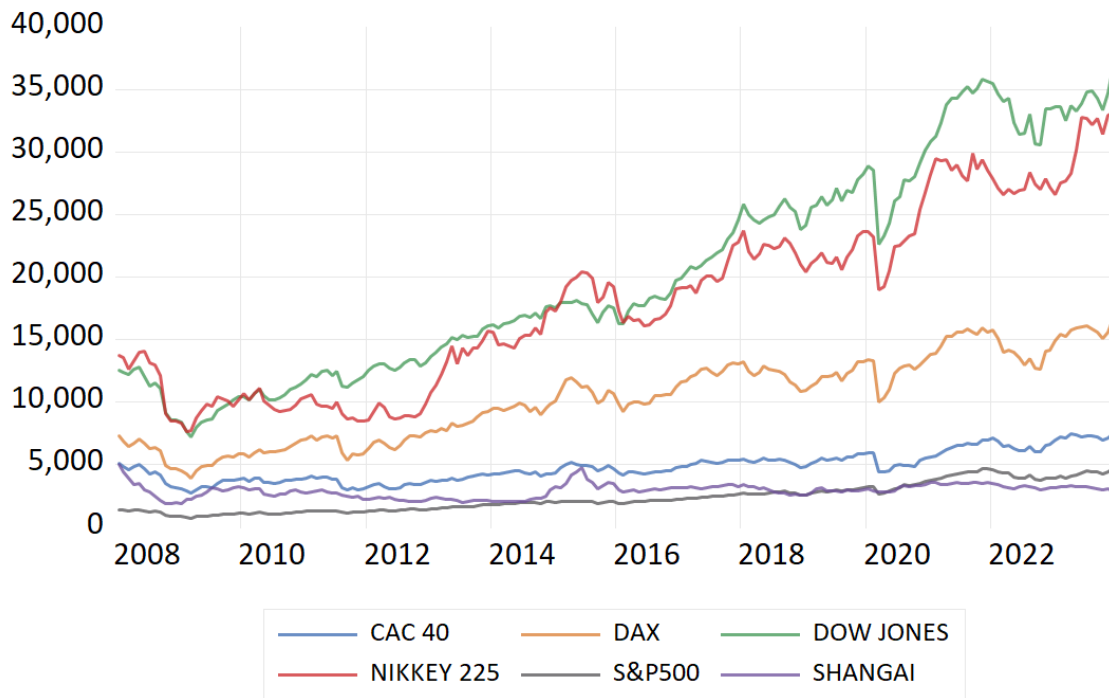


Fig. 4. Evolution of Closing Price of Financial Markets.

The behavior of the markets over the years under analysis is very similar among them (Fig. 5). However, despite this similarity, certain markets are more influenced than others, such as Dow Jones, NIKKEI 225, and DAX. The graphical impact of the global financial crisis on the markets in 2008/2009, the impact of the pandemic crisis in 2019/2020, and the crisis of the armed conflict in 2022/2023 are visibly apparent.

This evolution that the price of financial markets presents can suggest the existence of periods where happened structural breaks. After this analysis, we are alarmed to test stationarity on variables. This test needs to be done not only on markets but also on other variables.

3.2. Methodology

Due to the nature of the series and the period in analysis, it is essential to analyze the cointegration. To analyze cointegration, the first step taken is to determine the integration order of each variable. Ditzen et al. (2021) developed a test capable of identifying structural changes, being an important point in the analysis of time series and considers the significance of examining different scenarios without trending regressors introducing multiple structural changes. In this test the H_0 : no breaks against the alternative hypothesis H_1 : n breaks, where n is the number of the breaks.

If there is a combination of $I(0)$ and $I(1)$ integrated variables, the ARDL (Autoregressive Distributed Lag) methodology can be applied, as it accommodates different orders of integration and allows for the inclusion of dummy variables to control for structural

breaks. The integration order is important to avoid spurious regression results (Moutinho, Madaleno, and Bento, 2020).

To realize the study, the econometric model selected is the one introduced by Engle and Granger (1987), Autoregressive Distributed Lag (ARDL). Considering the robustness of the results to any stationarity level, this econometric model can be applied to the data used in this study. The null hypothesis for integration after the modeling is:

$$H_0 : \delta_1 = \delta_2 = \delta_n = 0$$

$$H_1 : \delta_1 \neq \delta_2 \neq \delta_n \neq 0$$

The F-test will be used to determine cointegration, as the rejection of the null hypothesis indicating cointegration.

The ARDL model, as expressed by Pesaran et al. (2001), is detailed as follows:

$$(1) \quad \partial(L, p)y_t = \sum_{i=1}^k \beta_i(L, p)X'_{it} + \delta'w_t + \mu_t$$

where, $\partial(L, p) = 1 - \partial_1 L - \partial_2 L^2 - \dots - \partial_p L^p$, and $\beta_i(L, p) = \beta_{i1} + \beta_i L + \beta_{i2} + \dots + \beta_{iqi} L^{qi}$ $i = 1, 2, \dots, k$ and where L is a lag operator such that $LY_t = y_{t-1}$ and w_t is an $s \times 1$ vector of explanatory variables. X'_{it} is a vector containing explanatory variables, as mentioned by Moutinho et al. (2023).

In this equation, the speed of adjustment coefficient is given by: $\alpha = 1 - \sum_{j=1}^p \phi_k$, and the long-term coefficient is given by $\theta = \frac{\sum_{j=0}^q \beta_k}{\alpha}$.

There are advantages in including information about short and long-term. θ represents the long-run coefficients, being these coefficients result from the impact that the independent variables have on the dependent variable. In case there is cointegration, it corresponds to the negative cointegration coefficients after normalizing the coefficient of the dependent variable to unity.

On the other hand, α represents the rate at which a long-term equilibrium distortion is corrected, given that the equilibrium between the dependent and explanatory variables is influenced by a deviation from this equilibrium in a previous period. This coefficient must be non-zero and significantly negative if, over the long term, the variables will revert to their equilibrium relationship. The optimal lag for the ARDL model was determined using the Akaike information criterion (AIC). Additionally, a joint significant F-test statistic of the lagged level variables was used to examine the presence of long-term behavior among the variables.

4. Results

Due to the nature of the series and the period in analysis, the unit root tests that will be used are the ones that include breaks. In the first step, we will run tests that can detect up to 2 breakpoints and, then a test for multiple unknown breakpoints.

Table 3. Unit Root Test with break results

	Variable	T-statistic	Specification	Break	Coefficient Break
Commodities	wti	-4.922**	(3)	2014M09	7.154
	Dwti	-11.249***	(1)	2008M12	-12.533**
	brent	-4.627*	(3)	2014M08	7.655
	Dbrent	-12.034***	(1)	2008M10	-30.062***
	coal	-6.543***	(4)	2021M12	-37.455**
	Dcoal	-13.121***	(4)	2022M07	56.888***
	gas	-6.363***	(4)	2008M06	2.52***
	Dgas	-11.255***	(1)	2008M10	-0.535
EPU	epu	-6.191***	(4)	2018M06	-30.273
	Depu	-18.42***	(4)	2020M03	121.85***
IPI	ipi_usa	-4.543	(1)	2020M02	1.644
	Dipi_usa	-13.979***	(4)	2020M04	-13.146***
	ipi_ch	-4.371*	(4)	2009M04	-4.393
	Dipi_ch	-20.71***	(4)	2009M01	9.19
	ipi_jpn	-4.957*	(1)	2009M05	-0.531
	Dipi_jpn	-14.427***	(1)	2009M02	-8.084***
	ipi_ger	-4.498	(3)	2020M02	2.596
	Dipi_ger	-16.111***	(4)	2020M04	-21.725***
	ipi_fr	-7.627***	(4)	2020M04	21.356***
	Dipi_fr	-14.145***	(4)	2020M03	-18.327***
	ipi_uk	-5.1*	(1)	2020M04	-17.818***
	Dipi_uk	-15.991***	(1)	2020M04	-16.787***
Markets	dj	-4.375	(3)	2020M04	-499.567
	Ddj	-15.316***	(4)	2020M03	-6169.262***
	sp	-4.701*	(3)	2020M04	-63.337
	Dsp	-14.139***	(4)	2020M03	-666.945***
	nk	-3.865	(3)	2008M06	993.851
	Dnk	-13.339***	(4)	2020M03	-4450.626***
	sc	-5.679***	(4)	2014M10	-134.572
	Dsc	-11.767***	(1)	2009M07	353.29**
	dax	-4.803*	(3)	2020M03	-3354.317***
	Ddax	-13.89***	(4)	2020M03	-3431.717***
	cac	-4.639	(1)	2020M01	240.546
	Dcac	-13.972***	(4)	2020M03	1496.221***

Notes: Trend specification/break specification: (1) trend and intercept/trend and intercept; (2) trend and intercept/trend only; (3) trend and intercept/intercept only; (4) intercept only/intercept only. The ***, **, and * represent the number of breaks detected according to the critical values 1%, 5%, and 10% respectively. D connotes first differences.

When analyzing stationarity with break results, it is possible to conclude that COAL, GAS, EPU, IPI_FR, and SC display stationarity to any significance level at level. WTI shows stationarity at level to 10% and 5% confidence levels. BRENT, IPI_CH, IPI_UK, IPI_JPN, S&P, and DAX are stationary at a level to 10% confidence level. The rest of the variables are stationary to any significance level at first differences.

Table 3. shows the results of the MDF test, providing information regarding the presence of structural breaks. This test confirms the previous results and reveals the financial crisis in 2008/2009 and the pandemic crisis in 2020.

The breaks introduced in the Auto Regressive Distributed Lag were the ones found in Table 3. The breaks are in 2009, September 2014, April 2020, and 2022. All the possible breaks were tested and the ones that did not display significance were taken out of the analysis.

Table 4. Test for Multiple Breaks at Unknown Breakpoints (Ditzen et al., 2021)

	WTI	BRENT	COAL	GAS	EPU	IPI_USA	IPI_CH	IPI_GER	IPI_FR	IPI_UK
F(1 0)	116.84***	114.47***	199.62***	81.16***	376.88***	171.12***	319.94***	100.70***	42.13***	99.05***
F(2 1)	98.61***	73.60***	53.15***	99.54***	31.27***	63.44***	83.62***	77.62***	55.16***	106.04***
F(3 2)	25.54***	79.00***	61.54***	123.25***	15.71***	81.20***	45.87***	90.53***	60.33***	39.46***
F(4 3)	109.34***	87.95***	62.84***	148.05***	32.34***	85.03***	39.68***	136.97***	104.32***	46.72***
F(5 4)	113.90***	92.65***	64.85***	149.90***	33.44***	90.77***	39.94***	147.76***	104.81***	61.74***
Detected number of breaks:	5***, 5**, 5*	5***, 5**, 5*	5***, 5**, 5*	5***, 5**, 5*	5***, 5**, 5*	5***, 5**, 5*	5***, 5**, 5*	5***, 5**, 5*	5***, 5**, 5*	5***, 5**, 5*

	IPI_JPN	DJ	S&P	NK	SC	DAX	CAC
F(1 0)	51.56***	693.74***	523.83***	477.79***	100.21***	541.17***	325.49***
F(2 1)	10.58**	127.57***	179.62***	311.33***	56.54***	133.47***	142.89***
F(3 2)	13.66**	255.51***	145.57***	74.55***	64.43***	100.70***	32.51***
F(4 3)	151.32***	32.80***	34.15***	57.12***	67.29***	27.93***	66.95***
F(5 4)	152.30***	37.73***	28.10***	55.43***	77.80***	18.87***	67.51***
Detected number of breaks:	5***, 5**, 5*	5***, 5**, 5*	5***, 5**, 5*	5***, 5**, 5*	5***, 5**, 5*	5***, 5**, 5*	5***, 5**, 5*

Note: The ***, **, and * represent the number of breaks detected according to the critical values 1%, 5%, and 10% respectively. The critical values for F(1|0): 12.29***, 8.58**, 7.04*. F(2|1): 13.89***, 10.13**, 8.51*. F(3|2): 14.8***, 11.14**, 9.41*. F(4|3): 15.28***, 11.83**, 10.04*. F(5|4): 15.76***, 12.25**, 10.58*

As it's possible to see in Table 4., All test statistics exceed their respective critical values at all levels of significance, implying rejection of the null hypothesis of fewer breaks in favor of the alternative hypothesis of more breaks.

The identified number of breaks signifies the minimum and maximum number of breaks for which the null hypothesis is rejected. In this instance, both the minimum and maximum detected number of breaks are 5.

To perform ARDL modeling, the data will be separated into 6 different equations:

$$Y_1 = \beta_0 + \beta_1 X1 + \beta_2 X2 + \beta_3 X3 + \beta_4 X4 + \beta_5 X5 + \beta_6 W_1 + \beta_7 \text{ShiftDummies} \quad (1)$$

$$Y_2 = \beta_0 + \beta_1 X1 + \beta_2 X2 + \beta_3 X3 + \beta_4 X4 + \beta_5 X5 + \beta_6 W_1 + \beta_7 \text{ShiftDummies} \quad (2)$$

$$Y_3 = \beta_0 + \beta_1 X1 + \beta_2 X2 + \beta_3 X3 + \beta_4 X4 + \beta_5 X5 + \beta_6 W_6 + \beta_7 \text{ShiftDummies} \quad (3)$$

$$Y_4 = \beta_0 + \beta_1 X1 + \beta_2 X2 + \beta_3 X3 + \beta_4 X4 + \beta_5 X5 + \beta_6 W_2 + \beta_7 \text{ShiftDummies} \quad (4)$$

$$Y_5 = \beta_0 + \beta_1 X1 + \beta_2 X2 + \beta_3 X3 + \beta_4 X4 + \beta_5 X5 + \beta_6 W_3 + \beta_7 \text{ShiftDummies} \quad (5)$$

$$Y_6 = \beta_0 + \beta_1 X1 + \beta_2 X2 + \beta_3 X3 + \beta_4 X4 + \beta_5 X5 + \beta_6 W_4 + \beta_7 \text{ShiftDummies} \quad (6)$$

As shown, the variables used will have information about the markets (Close prices of Dow Jones (Y1), S&P500 (Y2), NIKKEY 225 (Y3), Shanghai Composite (Y4), DAX (Y5), and CAC 40 (Y6)), the price of some commodities (WTI (X1), Brent (X2), Coal (X3), and Gas (X4)), Economic Policy Uncertainty Index (X4), and the Industrial Production Index of the country where the stock market inserts (USA (W1), Japan (W6), China (W2), Germany (W3), and France (W4)) . Keeping in mind the period in analysis, there may be some periods that had policies, and crises, that influenced the values registered by the variables. With this information, the introduction of the structural breaks will be done as exogenous variables.

The variable WTI is expected that have a positive impact on the markets according to the studies from Silvério and Szklo (2012) and Zhang (2019). This effect will not only be in the American markets but also markets from other regions as Hu et al. (2023) demonstrated in their article. In the Brent case, the results expected are similar to the ones found for WTI as the results found in the studies developed by Cui et al. (2021) and S. Li et al. (2022).

It is expected that coal will have a positive impact because coal influences positively other variables that have a positive relation with the markets as shown by Asadi et al. (2023) which did not find a direct relationship between coal and the markets. Gas is expected to have a positive impact on the markets by having an impact on other variables as shown by Silvério and Szklo (2012). Summarizing, it is expected that all the commodities have a positive impact on the markets studied.

The Economic Policy Uncertainty index is expected to have a negative impact on the financial market, as shown by various authors (Kurosaki (2020), Dua and Tuteja (2023), Hong et al. (2022), Dogan et al. (2022), and Wang et al. (2022)). The higher the value of the index, the greater the negative impact on the markets. The Industrial Production Index is expected to have a positive result as studied by Duprey et al. (2017). This impact may be significant in the period of the crisis and after the crisis as the impact gets more significant in fragile periods of the markets.

To do the ARDL modeling with breaks, the breaks were inserted in the original model, suggesting that the breaks do affect the variables, but the variables do not affect the break.

The breaks considered in the next analysis were found in the Unit root tests with breaks. Meaning that the breaks are: 2009, September 2014, 2020, April 2020, and 2022.

After running the models, Equation (1), (2), and (3) it was used 2014, April 2020, and 2022 dummies, and Equation (4), (5), and (6) were used September 2014 and April 2020.

Table 5. ARDL bounds test for investigating long-run equilibrium relationships.

Equation	ARDL Specification	F-Statistic	T-Statistic	Cointegration Decision
(1)	ARDL(4,0,4,4,4,1,0)	4.434**	-3.877	INCONCLUSIVE
(2)	ARDL(4,0,4,4,4,3,0)	4.681***	-2.704	NO
(3)	ARDL(2,0,1,0,4,1,0)	3.463*	-4.170*	YES*
(4)	ARDL(2,4,0,0,0,0,1)	5.605***	-6.004***	YES***
(5)	ARDL(1,0,1,1,2,1,1)	3.606*	-4.188*	YES*
(6)	ARDL(1,0,1,4,4,1,1)	3.803**	-4.260*	YES*

For the bounds test, the asymptotic critical value bounds are taken from Pesaran et al. (2001) and presented by Kripfganz and Schneider (2018), with unrestricted intercept and no trend with max lags k in the dependent variable and regressors equal to 4. ***, **, * statistically significant at 1%, 5%, and 10%, respectively.

In the short-run estimates, Equation (3) to Equation (6) have a negative and significant Error Correction Term (ECT-1). A negative and statistically significant coefficient on the error-correction term implies that roughly 10.884%, 23.837%, 11.893%, and 11.659% of the disequilibrium in the previous months is corrected within one month, respectively, consisting in the existence of cointegration.

In Equation (3), the dummies relative to the breaks that occurred in September 2014 and April 2020 have a positive and significant impact on any confidence level. LD NK, D1 Brent, D1 Gas, and LD Gas are statistically significant. The first 3 variables display a positive impact in the dependent variable whereas the last one shows a negative impact. Regarding Equation (4), the dummies are also statistically significant to any confidence level. The impact that they had in the market is positive, although smaller than the impact in the previous stock analyzed. When analyzing the other variables, LD SC, D1 WTI, LD WTI, and L2D WTI are statistically significant, and all the variables have a positive impact on the Shanghai Composite market.

Table 6. Short-run estimation results for the ARDL with breaks

Short Run	(1)	(2)	(3)	(4)	(5)	(6)
LD DJ	-0.096					
L2D DJ	-.215***					
L3D DJ	-.097					
LD S&P		-.0738				
L2D S&P		-.321***				
L3D S&P		-.133*				
LD NK			.145**			
LD SC				.185***		
D1 WTI				4.27**		
LD WTI				3.37*		
L2D WTI				3.666*		
L3D WTI				-3.106		
D1 BRENT	40.331***	4.253***	17.912*		19.583***	11.955***
LD BRENT	16.013**	.758				
L2D BRENT	10.641	1.3				
L3D BRENT	16.161**	1.899**				
D1 COAL	-11.840***	-1.077***			-4.641***	-3.139***
LD COAL	-3.809	.0264				.105
L2D COAL	-10.993***	-.934***				-1.294*
L3D COAL	-9.330***	-.998***				-1.478**
D1 GAS	218.491**	21.854*	233.338**		63.593	26.38
LD GAS	-131.957	-18.227	-194.233*		-99.815*	-37.797
L2D GAS	74.763	12.333	183.172			14.478
L3D GAS	280.356***	26.693**	165.908			76.349***
D1 EPU	-7.181***	-.739***	-6.198		-4.154***	-1.585***
LD EPU		-.0754				
L2D EPU		-.37**				
D1 IPI_CH				2.261		
D1 IPI_GER					26.013**	
D1 IPI_FR						12.241**
SD_2014_9	442.107	39.585	1348.945***	210.7***	662.968***	228***
SD_2020_4	1226.912***	187.811***	858.977***	115.609***	495.119***	167.198**
SD_2022	-	-152.108***	387.777			
Constant	-4253.584**	-414.849*	1163.592	1059.035***	-273.948	-146.347
ECT-1	-.0789***	-.0569***	-.109***	-.238***	-.119***	-.117***
R ²	0.5358	0.5707	0.3418	0.3163	0.4575	0.5465
Adjust R ²	0.4594	0.4937	0.2748	0.2556	0.4093	0.4912

Note: The ***, **, and * represent the number of breaks detected according to the critical values 1%, 5%, and 10% respectively. L connotes lags and D connotes differences.

Equation (5) and Equation (6) are relative to German (DAX) and French markets (CAC 40), respectively, and show similar results when analyzing the impact of the independent variables. D1 Brent, D1 Coal, and D1 EPU are statistically significant to any confidence level. The first variable has a positive impact and the last two have a negative impact in both models. In addition, to DAX, LD Gas is statistically significant, having a negative impact, and D1 IPI_GER is also statistically significant but has a positive impact. On the CAC40 analysis, L2D Coal and L3D Coal are statistically significant and have a negative impact while L3D Gas and IPI_FR have a positive and significant impact.

In both Equations (5) and (6), the dummies September 2014 and April 2020, are statistically significant and have a positive impact. Although they have a positive impact in both markets, the impact is bigger in DAX.

Table 7. Long-run estimation results for the ARDL with breaks

Long Run	(1)	(2)	(3)	(4)	(5)	(6)
WTI	564.623***	92.37**	158.402	-20.324*	116.96*	91.775***
BRENT	-472.366***	-71.591**	-34.125	11.936	-49.285	-62.718**
COAL	70.89**	1.324	-44.524**	.224	-16.791*	.9994
GAS	-2735.773***	-420.785**	-44.162	-5.013	-253.718	-1.638
EPU	12.276	.0478	2.091	-4.098***	-.130	5.634
IPI_USA	701.852**	97.9**				
IPI_CH				-8.438**		
IPI_GER					69.623	
IPI_FR						41.472
IPI_JPN			-59.667			
Shift	YES	YES	YES	YES	YES	YES
Dummies						
R ²	0.5358	0.5707	0.3418	0.3163	0.4575	0.5465
Adjust R ²	0.4594	0.4937	0.2748	0.2556	0.4093	0.4912

By analyzing Table 7., Coal is the only variable that is statistically significant in Nikkey 225 (Equation (3)), being this impact negative. In Equation (4), WTI, EPU, and IPI have a negative and significant impact on the Shanghai Composite. The DAX 40 (Equation (5)) is affected by WTI positively and negatively by Coal. In the French markets (CAC40), WTI and Brent are statistically significant and have a positive and negative impact, respectively.

Table 8. Post-estimation tests

Equation	Durbin-Watson	Breusch-Godfrey	White test	Reset test
(1)	1.789	8.014***	185.00	13.17***
(2)	1.9	2.905*	185.00	9.23***
(3)	1.944	0.768	169.41	5.43***
(4)	1.972	0.010	164.16**	4.89***
(5)	1.906	0.559	170.41**	9.81***
(6)	1.924	0.321	185.00	8.08

Durbin-Watson tests for autocorrelation and in none of the equations we can conclude that there is no evidence for autocorrelation in the residuals of the regression. Breusch-Godfrey also tests for autocorrelation of the residuals, and it is possible to say that exist autocorrelation for equations (1) and (2). This can suggest that there was a problem in the specification of the model and that could be missing variables, so this can lead to inefficient coefficients. White test is used to test heteroskedasticity and by rejecting the null hypothesis in equations (4) and (5) it is possible to say that the errors do not have constant variation and the coefficients estimated can be incorrect. The Reset test can detect errors in the model specification and if the null hypothesis gets rejected that

means that there are omitted variables and so that the specification is incorrect. With this, Equations (1), (2), (3), (4), and (5) present omitted variables.

Equation (6) is the one that represents better reality as it has not omitted variables. Although the other equations present some issues, they will be analyzed, except Equations (1) and (2) but we keep in mind the existence of omitted variables and heteroskedasticity in residuals.

5. Discussion

This study presents an approach using a recent data set and dummies as exogenous variables.

The data set used comprehends different types of crises, such as financial and exogenous, so the existence of stationarity with breaks needed to be tested. From the stationarity tests with breaks, were identified various breaks. The ones that were significant and introduced to the model were September 2014, April 2020, and January 2022.

The breaks introduced suggest that the markets perform better after the shocks as the values are positive. These results suggest that the introduction of the breaks in the modeling had a positive impact getting better and more consistent results to all the equations. However, as said, some equations have omitted values and some of them can be related to other breaks that were not introduced to the equations.

Although the expected results and the literature analyzed demonstrate the relation between the American Markets and the independent variables, in this study these markets do not display cointegration opposing to the results found by other authors (Aboura and Chevallier, 2015, and Silvério and Szklo, 2012). In the rest of the markets analyzed it is possible to see the impact of the commodities in each market. The analysis carried out will need to have some reservations as Equations (3), (4), and (5) because they have omitted variables.

In the long run, WTI has a positive and significant impact on the European Markets, (German and French markets) as suggested by various authors (Silvério and Szklo, 2012, Zhang, 2019, Hu et al., 2023). This result can suggest the dependence of the European markets on WTI. In the French market, Brent has a negative and significant impact, raising some questions regarding its dependence of France on European oil. These results corroborate with the studies from Cui et al. (2021) and S. Li et al. (2022) that the Brent results may be similar to the ones found for WTI. Based on the analysis, it can be concluded that the impact of WTI on the market, whether positive or negative, will correspondingly influence the impact of Brent crude oil in the opposite direction. As happened in the analysis of Brent and CAC 40, the dependence of Japan and Germany on Coal is also suggested by the negative and significant relation between these variables. In the Coal analysis, the conclusion found in this paper is that coal influences directly the German and Japanese markets and has a negative impact on both of them. Asadi et al. (2023) did not find a direct relation between the markets and coal but this commodity has an impact on other variables (Iron and exchange rates) that influence directly the markets.

China is the only country that seems to be affected by the Economic Policy Uncertainty Index and by its Industrial Production Index. As the population of China may be insecure

about the policies conducted by their leaders the market gets affected negatively, by the growing uncertainty, the doubts in the investors rise and they tend to get insecure, transmitting these insecurities to the market and, therefore, getting lower results. The result obtained in the Industrial Production Index is surprising as a rise in this index has a negative impact on the market and it is opposed to the expected results. Duprey et al. (2017) found significance in the short-run and the negative impact was only in fragile periods of the economy.

In the short run, Nikkey 225, DAX, and CAC 40 are affected positively by the price of Brent in the previous month. In the existing literature, the Brent result is similar to the WTI and in this case, only Brent significance can be considered as a finding. In the German and French cases, the dependence on coal is verified in the long run, as the price of coal in the previous month has a negative impact on the current market price. In the French case, the dependence verified in the long run is also verified in the short run, corroborating the dependence that France has on coal.

The dependence that Japan and Germany have on gas is also possible to verify as it presents negative values. However, in the CAC 40 case, the value obtained is positive suggesting that France has gains when the gas price rises. These results go in the same direction as the existing literature in a way that has a positive impact, although the other literature did not find a direct relation between markets and gas and in this study is what happens.

In the European markets analyzed, policies carried out by the government and common policies (due to the European Union), that generate uncertainty in the investors have a negative impact in the short run, as a policy applied in one month will have an impact in the next month. This is the expected result as it was demonstrated by Egging and Gabriel (2006). In these markets, the Industrial Production Index also has a positive impact, showing the dependence of the markets in the industry of the respecting country. This is the expected result as Duprey et al. (2017) found, the impact may be stronger in the short run.

5.1. Spillover between financial markets and commodities

The result found in this paper is that WTI is a net giver of spillovers, going in the same direction as the results found by Asadi et al. (2023). The spillover analyzed by Asadi et al. (2023) searched for pairwise net spillover between some markets and commodities. Although the results are the same, this paper presents this spillover to new markets such as DAX and CAC40 and the differentiation between short and long-run effects. In the DAX and CAC40 cases, the spillover effect is only felt in the long run analysis, as in the Shanghai composite case it affects in the short and long run.

The result found by the pre-mentioned author is that the spillover from WTI to Shanghai Stock has a negative impact, and in this paper was found that in the long run, it has a negative impact but in the short run it has a positive impact.

In the Brent case, the spillover effect in the long run and short run also differs from the French case as short run it has a negative impact and in the long run, it has a positive impact on the markets.

Coal spillovers, according to Asadi et al. (2023), do not have an impact in the markets they have analyzed, although, in the present paper, they have an impact in the short and long run in DAX and the short run in CAC40. The result from the spillovers from gas is the same as the one obtained by the other authors as the mentioned spillovers do not have any impact on the markets studied.

The evidence regarding the spillover effects between financial markets and energy commodities holds significant implications for investors' decision-making processes, both in the short and long term, especially for those with portfolios containing assets from companies involved in oil, coal, and natural gas production. This understanding enables investors to develop and evaluate potential diversification strategies aimed at mitigating risks and fluctuations in stock market prices assets and their correlation with commodity markets, particularly during periods of economic and financial instability, such as the COVID-19 pandemic crisis and the ongoing conflict involving Russia's military actions in Ukraine.

This evidence further underscores the importance of investigating diversification strategies associated with various asset hedging techniques, including the hedge ratio and asset portfolios of energy sector companies listed on stock markets. For investors, the hedge ratio is a critical metric, allowing them to comprehend the relationship between the size of their asset portfolio positions and the extent of their risk exposure in both the commodities market (encompassing oil, coal, and natural gas) and the stock market where energy companies are traded.

6. Conclusion and Policy Implications

This study aimed to analyze the cointegration between markets and commodities, and the spillover effect from the commodities to the markets. To achieve the purpose of the study, it was used an econometric approach through the Autoregressive Distributed Lag (ARDL) model. The analysis covered from January 2008 to September 2023, capturing periods such as the global financial crisis, the pandemic crisis (COVID-19), and the war conflict. The selection of this period was to try to understand how risk transmission and spillovers develop under different circumstances and different types of crises (financial, health, and war).

The most remarkable results from this paper are that WTI spillovers significantly affect the DAX in the long run as it does not affect the short run, Shanghai Composite suffers from spillovers from WTI having a negative impact in the long run and a positive impact in the short run and the spillover from Brent to CAC40 is positive in the short run and negative in the long run. Both German and French markets (DAX and CAC40, respectively) are affected negatively by the Economic Policy Uncertainty index.

In general, DAX and CAC40 display similar results to all the dependent variables, and a possible cause of this fact can be the geographic proximity and similar politics, being both members of the European Union and having the Euro as currency.

Regarding the policy implications, Coal has a surprising effect on some of the markets analyzed, evidencing the importance that this commodity still has nowadays. In the CAC40 case, to increase the market value, policies that foment industrial production can bring some good results and the stability in the government can be considered as another key to reach the objective of increasing the stock market price.

When analyzing the implications of the results that this paper presents to the investors, attention to the possible structural breaks in the markets is very important as they perform bigger and better results in periods after periods of recession. To the investors that seek investments in the Shanghai Composite market, the WTI is a good asset to invest in but not for a long time as in the long run can negatively affect the results obtained. The investors of DAX and CAC40 need to pay close attention to the evolution of coal prices as they negatively influence the results from these markets in the short run. In periods of uncertainty, the results can be lower, as the Economic Policy Uncertainty index negatively influences the results from the markets. However, as said, these periods of uncertainty are usually followed by periods of high expansion. So, this work aims to contribute to providing information to international investors interested in expanding geographically efficient diversification strategies.

In terms of implications for financial theory, the relationship between stock market returns and their endogenous and exogenous drivers should not be confined to linear

methods as posited by efficient market theory. Specifically, examining the impact of commodity prices, such as oil, coal, and natural gas, on stock market returns (e.g., the S&P 500) reveals that both markets can exhibit efficiency and financial stability during periods of both high and low price volatility. However, our analysis suggests that while these markets demonstrate high efficiency in the long term, they only exhibit moderate efficiency in the short term. Furthermore, these markets have shown decreasing efficiency since the onset of various endogenous financial crises and the exogenous crises examined in this study period.

Consequently, we propose that the evolving patterns and interconnections between energy commodity prices and stock market prices can be more accurately described using mathematical equations. The econometric method of cointegration provides a robust analytical framework, supporting the integration of Chaos Theory into financial analysis to elucidate the complex relationship between commodity prices and stock market prices. This approach allows for a more nuanced understanding that accommodates the dynamic and often non-linear interactions observed in these markets.

Lorenz's Chaos theory (2012) is based on the assumption that prices do not evolve according to a stable pattern (confirmed in our study by analyzing the stationarity of the price and return series) and that investors are not exactly rational, nor are their expectations homogeneous (this inference can be validated by the significance of the effect of the investor index on stock market returns). Conversely, utilizing the Investor Sentiment Index to measure and evaluate its impact on stock market returns underscores the influence of noise traders in market trading. The presence of noise traders, as indicated by investor sentiment, should be considered a crucial aspect of stock market stability, which is positively influenced by such traders. Our findings reveal a significant relationship between trading noise, as measured by investor sentiment, and asset prices. This statistical significance suggests that investors are inclined to make poorly informed investment decisions in the stock markets.

Additionally, there is evidence of volatility transmission between stock prices and commodity prices across national borders. According to contagion theory, investors respond to publicly available information and monitor price changes in other proxy markets to obtain information not readily accessible in their local markets. This implies that information shocks in one market can impact the prices and volatility of other markets. In the context of international investment, this phenomenon has become a growing concern for both investors and policymakers, as it highlights the interconnectedness and potential risks associated with global financial markets.

6.1. Limitations and future research

In terms of limitations the volatility co-movement and spillover effect between changes in the prices of oil, natural gas, and coal commodities and changes in the stock prices of the largest companies as well as other utilities, such as natural gas, coal, and oil companies, so these limitations can be considered as opportunities for future research. To improve future research, we could also incorporate other macroeconomic and financial variables, to explain whether the events taking place in the financial markets cause shocks to the domestic economic variables of each country. For this purpose, we suggest in future research considering various stock markets in developed and emerging countries, using the Multifractal detrending moving average (MF-DMA), which allows the latter to study the multifractal properties of non-stationary time series, and to associate the degree of multifractal relationship of these series of prices of stock markets and prices of commodities markets. We also believe that it should use daily data, extending the sample used in this current study to include Latin American stock markets to compare efficiency in its weak form, financial integration, and risk transmission, in the different geographies. Thus, the first empirical objective is to propose and test the hypothesis of contagion in the current periods of the two great exogenous crises, such as the pandemic crisis and the military war. As an econometric approach, we propose the use of multivariate volatility models from the DCC-GARCH family, among others. In the second econometric approach, we will employ techniques such as Markov-Switching models, and, as additional analysis, we will test for time-varying causality between stock returns and the factors influencing them. Besides the explanatory variables already included in this study, we plan to incorporate annual dividends and exchange rates to achieve more robust results and to test the validity of the Efficient Market Hypothesis.

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