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Market Efficiency and Dynamic Connectedness in Commodities: Emerging Trends, Methodological Advances, and Research Challenges from a Bibliometric Perspective

Eficiência de Mercado e Conectividade Dinâmica em *Commodities*: Tendências Emergentes, Avanços Metodológicos e Desafios de Pesquisa sob uma Perspectiva Bibliométrica

Eficiencia de Mercado y Conectividad Dinámica en Commodities: Tendencias Emergentes, Avances Metodológicos y Desafíos de Investigación desde una Perspectiva Bibliométrica

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***Abstract*:** *Market efficiency is a central concept in economic and financial studies; however, its application to commodity markets remains relatively underexplored, despite their growing relevance in the context of economic crises, climate change, and technological advances. This study analyzes the scientific production on market efficiency and dynamic connectivity in agricultural commodities between 1979 and 2024, using a bibliometric approach to map emerging trends, identify gaps in the literature, and highlight new research opportunities. Commodity markets exhibit specific characteristics that challenge the assumptions of the Efficient Market Hypothesis (EMH), such as seasonality, high logistics costs, and vulnerability to exogenous shocks. By explicitly incorporating the perspective of dynamic connectivity, the results reveal how interdependencies among markets evolve over time and across different economic regimes, highlighting trends such as the impact of fluctuations in maritime transportation, disruptions in agricultural production, the role of cryptocurrencies as safe-haven assets, and the growing integration of ESG criteria. Disruptive technologies, including artificial intelligence and big data, emerge as promising tools for price forecasting and volatility analysis across different segments of commodity markets. The study also evidences the increasing interdependence between local and global markets, particularly during crises such as COVID-19, which expose structural fragilities and reinforce the need for effective risk mitigation strategies. This study contributes to the advancement of the literature by integrating consolidated theoretical foundations with emerging approaches, providing relevant analytical insights for researchers and for the development of corporate strategies aimed at enhancing the resilience and sustainability of global commodity markets.*

Keywords: *Market Efficiency. Dynamic Connectivity. Bibliometric Analysis.*

Resumo: A eficiência de mercado é um conceito central nos estudos econômicos e financeiros, mas sua aplicação aos mercados das *commodities* ainda é menos explorada, apesar de sua crescente relevância diante de crises econômicas, mudanças climáticas e avanços tecnológicos. Este estudo analisa a produção científica sobre eficiência de mercado e conectividade dinâmica em *commodities* agrícolas entre 1979 e 2024, utilizando uma abordagem bibliométrica para mapear tendências emergentes, lacunas na literatura e identificar novas oportunidades de pesquisa. Os mercados das *commodities* possuem particularidades que desafiam os pressupostos da Hipótese de Mercado Eficiente (HME), como sazonalidade, custos logísticos elevados e vulnerabilidade a choques exógenos. Ao incorporar a perspectiva da conectividade dinâmica, os resultados evidenciam a evolução das relações de interdependência entre mercados ao longo do tempo, destacando tendências como o impacto das flutuações no transporte marítimo, desvios na produção agrícola, o papel de criptomoedas como refúgios seguros e a integração de critérios ESG. Tecnologias disruptivas, como inteligência artificial e *big data*, aparecem como ferramentas promissoras para prever preços e analisar a volatilidade em diferentes segmentos dos mercados de *commodities*. A pesquisa também evidencia a interdependência crescente entre mercados locais e globais, especialmente em crises como a Covid-19, que expõem fragilidades estruturais e reforçam a necessidade de estratégias de mitigação de risco. Este estudo contribui para o avanço da literatura ao integrar fundamentos teóricos consolidados com abordagens emergentes, oferecendo subsídios analíticos relevantes para pesquisadores e para o desenvolvimento de estratégias corporativas voltadas à resiliência e à sustentabilidade dos mercados globais de *commodities*.

Palavras-Chave: Eficiência de Mercado. Conectividade Dinâmica.Análise Bibliométrica.

Resumen: *La eficiencia de mercado es un concepto central en los estudios económicos y financieros; sin embargo, su aplicación a los mercados de commodities sigue siendo relativamente poco explorada, a pesar de su creciente relevancia en el contexto de crisis económicas, cambios climáticos y avances tecnológicos. Este estudio analiza la producción científica sobre eficiencia de mercado y conectividad dinámica en commodities agrícolas entre 1979 y 2024, utilizando un enfoque bibliométrico para mapear tendencias emergentes, identificar vacíos en la literatura y señalar nuevas oportunidades de investigación. Los mercados de commodities presentan características específicas que desafían los supuestos de la Hipótesis de los Mercados Eficientes (HME), como la estacionalidad, los elevados costos logísticos y la vulnerabilidad a choques exógenos. Al incorporar explícitamente la perspectiva de la conectividad dinámica, los resultados muestran cómo las interdependencias entre los mercados evolucionan a lo largo del tiempo y bajo distintos regímenes económicos, destacando tendencias como el impacto de las fluctuaciones en el transporte marítimo, las perturbaciones en la producción agrícola, el papel de las criptomonedas como activos refugio y la creciente integración de criterios ESG. Las tecnologías disruptivas, como la inteligencia artificial y el big data, se presentan como herramientas prometedoras para la predicción de precios y el análisis de la volatilidad en diferentes segmentos de los mercados de commodities. El estudio también evidencia la creciente interdependencia entre los mercados locales y globales, especialmente durante crisis como la COVID-19, que revelan fragilidades estructurales y refuerzan la necesidad de estrategias eficaces de mitigación de riesgos. Este estudio contribuye al avance de la literatura al integrar fundamentos teóricos consolidados con enfoques emergentes, ofreciendo aportes analíticos relevantes para los investigadores y para el desarrollo de estrategias corporativas orientadas a la resiliencia y sostenibilidad de los mercados globales de commodities*.

Palabras clave: *Eficiencia de Mercado. Conectividad Dinámica. Análisis Bibliométrico.*

Introduction

Market efficiency is a central concept in economic and financial studies and continues to stimulate academic and practical debates, especially in a context of rapid global transformations. Although widely explored in traditional financial markets, its application to commodity markets still constitutes a relatively underexplored field, yet increasingly relevant. This relevance becomes evident in light of recent events such as economic and health crises, geopolitical conflicts, climate change,

and the accelerated advancement of disruptive technologies. These factors have reshaped the dynamics of commodity markets, exposing particularities that challenge the conventional understanding of market efficiency and demand more in-depth analyses (Moraes, Sobral & Melo, 2021; Li et al., 2024; Samal, 2024).

From a theoretical perspective, the roots of the market efficiency concept date back to Louis Bachelier, whose introduction of stochastic processes in 1900 laid the foundation for the Efficient Market Hypothesis (EMH) (Bachelier, 1900). Later, Eugene Fama formalized the levels of efficiency as weak, semi-strong, and strong, consolidating a theoretical framework that remains a reference in the financial field (Fama, 1965; 1970).

Additionally, authors such as Samuelson, Mandelbrot, and Cowles expanded the understanding of price unpredictability and the central role of information in value formation (Cowles, 1933; Samuelson, 1965; Mandelbrot, 1966). Although originally developed for financial markets, these theories provide relevant analytical tools for understanding commodity markets, especially with regard to volatility, information integration, and arbitrage opportunities (Moraes, Sobral & Melo, 2021; Urak et al., 2024).

In this context, commodity markets present particular characteristics that distinguish them from traditional financial markets. Factors such as seasonality, climatic variables, production cycles, government policies, and high logistical costs shape their dynamics in specific and often unpredictable ways. Moreover, these markets are particularly vulnerable to exogenous shocks, such as natural disasters and geopolitical tensions, which frequently cause significant fluctuations between global supply and demand (Samal, 2024; Panagiotou & Naka, 2024). For example, while agricultural commodities such as corn and soybeans are directly impacted by climatic events, minerals such as iron and copper respond more strongly to fluctuations in global industrial demand (Vasileiou & Tzanakis, 2024; Cakici & Zaremba, 2024). Similarly, energy markets such as oil and natural gas strongly reflect the effects of geopolitical conflicts and economic sanctions (Chiappari, Scotti & Flori, 2024; Asl et al., 2024).

In recent years, the growing role of technologies such as artificial intelligence, big data, and digital assets has significantly expanded the analytical horizon of these markets, bringing unprecedented challenges and opportunities (Moraes et al., 2024; Samal, 2024). At the same time, the advancement of the Environmental, Social, and Governance (ESG) agenda has promoted important structural changes, such as the increased demand for strategic metals linked to the energy transition, such as lithium and cobalt (Wang et al., 2024; Snene & Jeribi, 2024).

Despite these advances, there remains a considerable gap in the literature regarding the integrated and systematized analysis of these specificities, particularly with respect to regional and sectoral differences (Pindyck & Rotemberg, 1990; Askari & Hajizadeh, 2024). This gap reveals the absence of comprehensive bibliometric studies that organize the scientific production on market efficiency applied to commodities, especially in terms of thematic, methodological, and temporal evolution, as well as the incorporation of recent approaches such as dynamic connectivity (Pullaykkodi & Acharya, 2024; Liu & Anwar, 2024). The lack of this integrated perspective limits the consolidation of accumulated knowledge, hinders the identification of emerging trends, and restricts the advancement of new research agendas in the field.

Given the increasing interconnection between local and international markets, it becomes essential to understand how global events and structural transformations affect market efficiency.

After all, the way information is priced in these markets plays a central role in mitigating volatility, formulating public policies, and developing more sustainable investment strategies (Fama, 1970; Ahmed et al., 2024).

In this context, this study aims to analyze the scientific production on market efficiency and dynamic connectivity in agricultural commodities from 1979 to 2024 through a bibliometric approach of a quantitative and descriptive-analytical nature. The objective is to map the evolution of the literature, identify thematic and methodological patterns, highlight research gaps, and point out new opportunities for advancing studies in this field. Using databases such as Scopus, Web of Science, and Scielo, the research examines temporal trends, leading authors, predominant methodologies, and regional and thematic gaps in publications between 1979 and 2024. Additionally, the study considers the impacts of economic crises, climate change, and technological advances, as well as differences among agricultural, mineral, and energy markets.

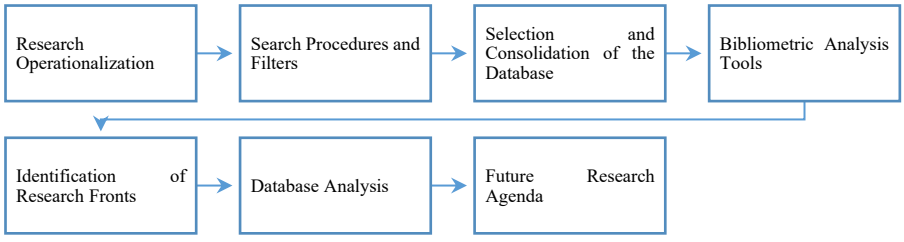
From a theoretical standpoint, the study synthesizes the main contributions of the literature and identifies gaps and opportunities for interdisciplinary integration, addressing essential contemporary issues. From a practical perspective, the research provides insights for public policies and the development of corporate strategies aimed at stability and food and energy security. Thus, the study not only reinforces the academic relevance of the topic but also highlights its importance in building robust responses to current economic and environmental challenges (Aria & Cuccurullo, 2017; Amin, Badruddoza, & Sarasty, 2024).

Methodological Elements of the Research

This study aims to analyze the scientific production on market efficiency and dynamic connectivity in agricultural commodities from 1979 to 2024, using a bibliometric approach of a quantitative and descriptive-analytical nature. The purpose is to map the evolution of the literature, identify thematic and methodological patterns, highlight research gaps, and indicate new opportunities for advancing knowledge in this field (Aria & Cuccurullo, 2017; Moraes et al., 2024).

To achieve this objective, the research adopts a quantitative, descriptive, and analytical approach and structures the bibliometric analysis based on the three dimensions proposed by Aria and Cuccurullo (2017): conceptual structure, social structure, and intellectual structure. Figure 1 summarizes the methodological steps and procedures adopted, which are detailed in the following subsections.

Figure 1 – **Procedures for Bibliometric Analysis**



Source: Prepared by the authors (2024).

Step 1 – Research Operationalization

In the operationalization stage, the Scopus, Web of Science, and SciELO databases were selected, recognized for their academic relevance in the fields of economics, finance, and commodity markets (Moraes et al., 2024). Access to these databases was carried out through the CAPES Journal Portal, enabling the extraction of high-impact national and international publications.

The research employed a structured search strategy, composed of terms such as "market efficiency," "efficient market hypothesis," and "commodities," combined with related keywords. To broaden the search scope without compromising relevance, Boolean operators (AND, OR) and truncation (*) were used, as recommended by Aria and Cuccurullo (2017).

Step 2 – Search Procedures and Filters

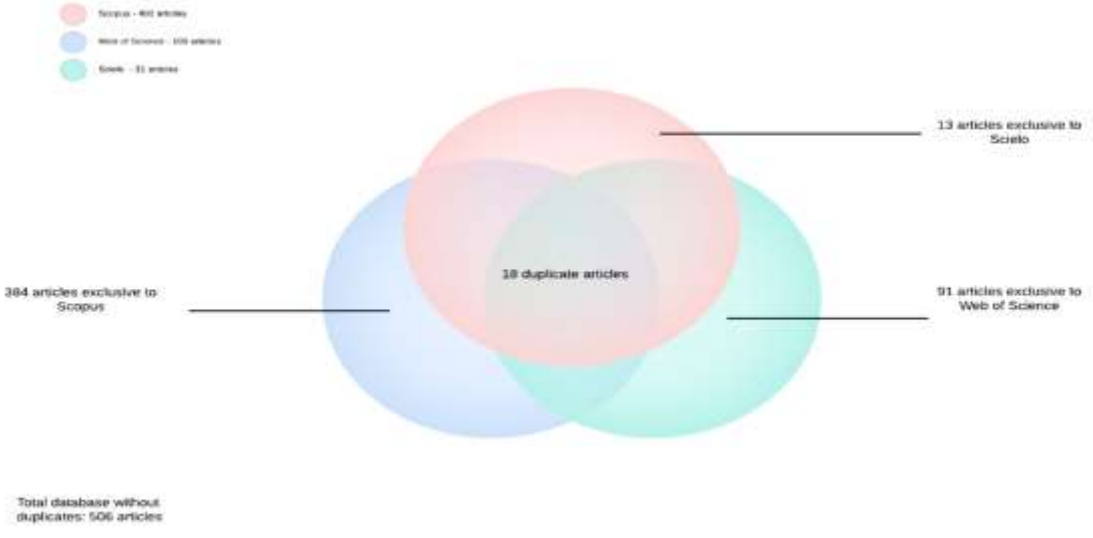
The search terms were defined to balance specificity and scope, allowing for the capture of core concepts and their terminological variations. The search was limited to peer-reviewed academic articles and review papers published between 1979 and 2024, ensuring the inclusion of both well-established studies and recent research.

Step 3 – Selection and Consolidation of the Database

Initially, 542 articles were identified: 402 from Scopus, 109 from Web of Science, and 31 from Scielo. After exporting the metadata in BibTeX format, the data were integrated and analyzed using R and RStudio (Moraes et al., 2024). During the data organization and cleaning process, 18 duplicate articles were identified and removed, resulting in a final corpus of 506 unique publications.

Figure 2 presents the overall database selection, and the analysis showed that Scopus concentrated the majority of publications (78.69%), followed by Web of Science (18.65%) and Scielo (2.67%), confirming Scopus as a comprehensive and robust source for studies related to market efficiency and dynamic connectivity in commodities.

Figure 2 – **Unique documents after removal of duplicates across the three data sources**



Source: Research data (2024).

Step 4 – Bibliometric Analysis Tools

The metadata were analyzed using the Bibliometrix package, implemented in the R environment, along with its graphical interface Biblioshiny, enabling the generation of interactive visualizations of scientific production, citations, and relevant journals (Aria & Cuccurullo, 2017). Additionally, VOSviewer was used for mapping bibliometric networks, highlighting connections among authors, countries, and keywords, which allowed for the identification of scientific collaboration patterns and emerging themes in the literature (Van Eck & Waltman, 2014).

Step 5 – Identification of Research Fronts

Based on the bibliometric analyses, emerging trends and gaps in the literature were identified, highlighting promising topics for future investigation. The specific inclusion of publications from 2024 proved essential for understanding how recent events, such as technological advances, climate change, and institutional transformations, have influenced the debate on market efficiency and dynamic connectivity in commodities.

Step 6 – Database Analysis

As proposed by Aria and Cuccurullo (2017), the database analysis was structured into three complementary analytical dimensions:

(i) Conceptual structure, which involved the identification of term co-occurrences, allowing the mapping of the thematic evolution of the literature over time;

(ii) Social structure, based on co-authorship network mapping, aimed at highlighting interactions and collaborations among researchers;

(iii) Intellectual structure, focused on the analysis of author co-citation networks, enabling the identification of the main theoretical influences and references in the field.

Step 7 – Future Research Agenda

Finally, the analysis revisited the study by Moraes et al. (2024), incorporating a specific review of articles published in 2024, presented in the results section. The objective of this step was to identify emerging themes and perspectives for future research in the field of market efficiency and dynamic connectivity in commodities. This analysis highlighted relevant gaps in the literature and emphasized topics such as the use of artificial intelligence in price forecasting, the impacts of ESG practices, and regional specificities in agricultural, energy, and mineral markets.

Overall, the methodology combined advanced bibliometric analysis with systematic procedures, allowing the proposed future research agendas to be directly derived from the patterns, trends, and gaps identified in the data, thereby contributing consistently to the theoretical and practical advancement of the literature.

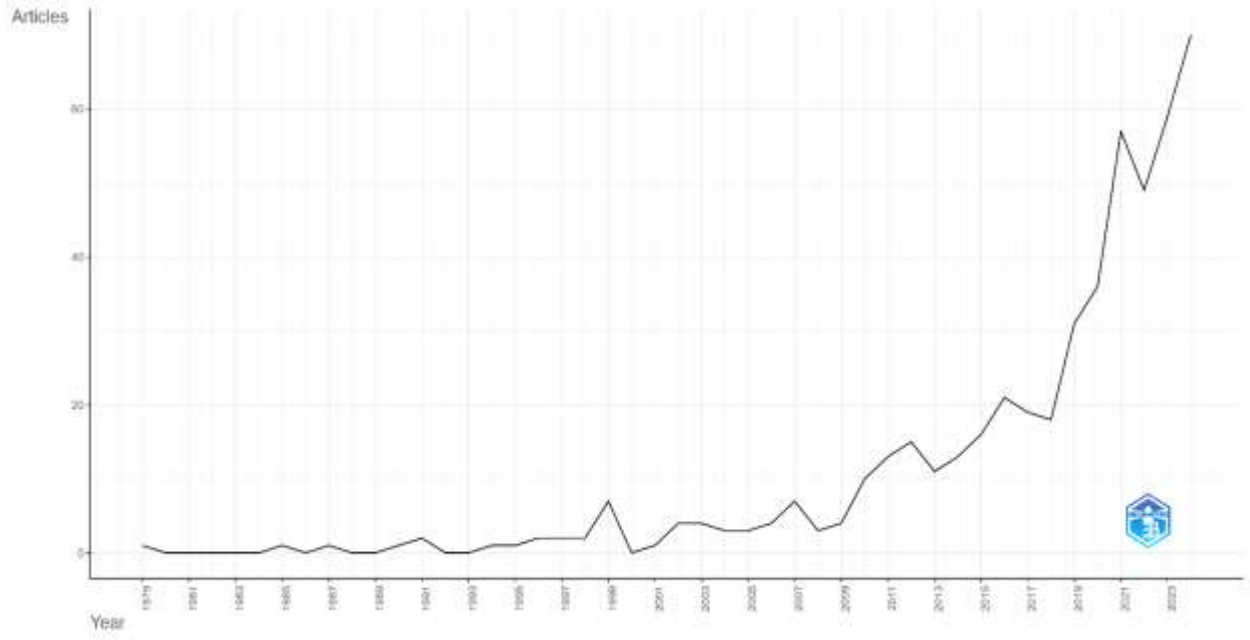
Results and Discussion

Research Fronts on Efficient Markets and Dynamic Connectivity in Commodities: Trends and Perspectives

Figures 3 and 4 present, respectively, the temporal evolution of publications and the citation patterns related to the concepts of market efficiency and dynamic connectivity with a focus on commodities, covering the period from 1979 to 2024. It is observed that, starting in the 1990s, there

is a marked increase in the volume of studies, reflecting a significant expansion of academic interest in this research field.

Figure 3 – **Temporal Evolution of Scientific Production on the Topic**

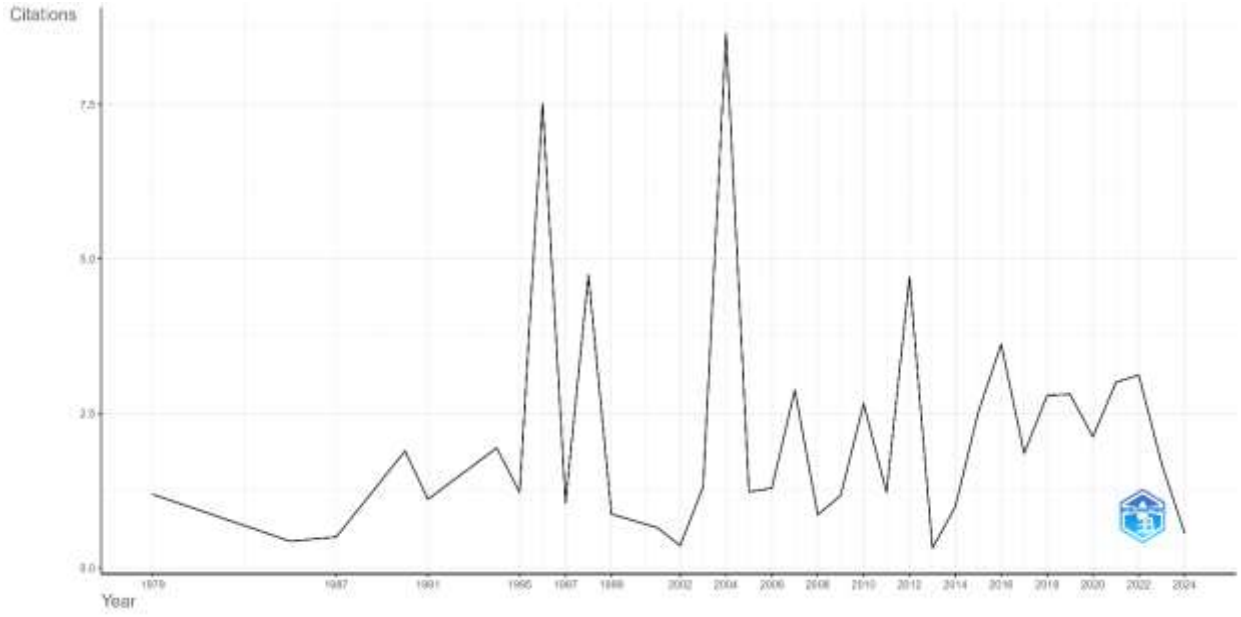


Source: Bibliometrix (2024).

This growth is associated with the expansion of the scope of the efficient market hypothesis, which was previously applied almost exclusively to financial markets and has increasingly come to include commodity markets. This shift has been driven by rising volatility, intensified international integration, and the need to understand the dynamic interactions between different markets – key elements in the analysis of dynamic connectivity. In this context, commodity markets have come to be analyzed not only in isolation but as interconnected systems, subject to shock transmission and temporal dependencies among prices, returns, and volatility.

Globalization has played a fundamental role in this process by promoting increasingly intense integration between financial markets and commodity markets. Frankel and Rose (1998) and Obstfeld and Taylor (2004) emphasize that the rise in capital mobility and trade integration has intensified the interdependence between these markets, creating conditions conducive to the emergence of dynamic connectivity structures, in which shocks in one market are rapidly transmitted to others. This greater systemic complexity has increased academic interest in understanding how market efficiency manifests in environments characterized by high interconnection.

Figure 4 – **Temporal Evolution of Citations of Scientific Publications on the Topic**



Source: Bibliometrix (2024).

Critical events, such as the Asian financial crisis (1997) and the Russian crisis (1998), analyzed by Baur and McDermott (2010), highlighted the direct impact of financial shocks on commodity markets. These episodes underscored the importance of investigating dynamic connectivity as a mechanism for transmitting instabilities between financial markets and natural resource markets, emphasizing that market efficiency can change significantly during periods of crisis. Complementarily, Hamilton (2009) demonstrated how global crises affect strategic commodities, such as oil, revealing the interdependent and dynamic nature of these markets.

Another key factor driving the growth of publications, particularly from the 1990s onward, was advances in computational capabilities. The development of greater processing power, combined with the widespread use of statistical and econometric software, enabled the application of more sophisticated models capable of capturing dynamic, nonlinear, and interdependent relationships between markets, as highlighted by Merton (1997) and Jorion (2007). These advances allowed studies to evolve from static analyses to approaches incorporating dynamic connectivity, expanding the understanding of informational efficiency, volatility, and shock transmission.

From the 2000s onward, the expansion of derivatives and futures markets further intensified the debate on market efficiency and dynamic connectivity. Black and Scholes (1973) established the theoretical foundations for derivative pricing, while Hull (2017) highlighted the role of these instruments in the dissemination of information between spot and futures markets. The continuous interaction between these markets reinforced the need for empirical approaches capable of capturing dynamic connectivity among prices, returns, and volatility, particularly in environments characterized by high uncertainty.

The economic growth of emerging countries, such as China and India, also contributed significantly to the intensification of research. As discussed by Bergsten (2008) and Rodrik (2011),

these economies began to exert a direct influence on global commodity prices, altering patterns of demand, supply, and connectivity between regional and international markets. This new configuration stimulated studies focused on analyzing how structural changes in global trade affect market efficiency and the mechanisms of shock transmission.

In addition, processes of economic liberalization in countries such as Brazil, Russia, India, and China introduced new institutional dynamics into commodity markets, particularly in the agricultural and energy sectors. According to Rodrik (2011), these transformations require analyses that take into account regional specificities, as well as the effects of dynamic connectivity between domestic and international markets, thereby expanding the scope of empirical investigations.

At the same time, growing concerns about environmental and sustainability issues have expanded the scope of analysis in the commodities literature. The volatility of food and energy prices, associated with climatic and environmental factors, has become a central topic in recent studies. Baumol (1986) and Hirshleifer (1989) argue that environmental and socioeconomic variables influence price formation, introducing new sources of shocks that affect dynamic connectivity and challenge the traditional assumptions of informational efficiency.

From a methodological perspective, the consolidation of advanced quantitative techniques has strengthened the analysis of market efficiency and dynamic connectivity in commodities. Models such as cointegration (Engle & Granger, 1987), GARCH (Bollerslev, 1986), fractional integration, and, more recently, dynamic connectivity models and financial networks have enabled the capture of volatility transmission and temporal dependencies across markets, providing robust tools to address the complexity of these markets. These approaches have expanded the analytical capacity of studies, allowing for a better understanding of how shocks propagate over time and across different segments of the commodity market.

As a result, there has been not only a quantitative but also a qualitative growth in the literature, which has increasingly incorporated contemporary themes such as technological disruptions, sustainability, and the systemic integration of global markets. The joint analysis of market efficiency and dynamic connectivity has thus become essential for understanding the functioning and evolution of commodity markets in an increasingly interconnected global environment.

Table 1 – **Essential Literature on the Topic**

Title	Author (s)	Year	Total Citations
Time series momentum	Moskowitz et al.	2012	741
Momentum crashes	Daniel & Moskowitz	2016	525
An econometric model of serial correlation and illiquidity in hedge fund returns	Getmansky et al.	2004	495
The econometrics of financial markets	Pagan	1996	447
Momentum strategies in commodity futures markets	Miffre & Rallis	2007	272

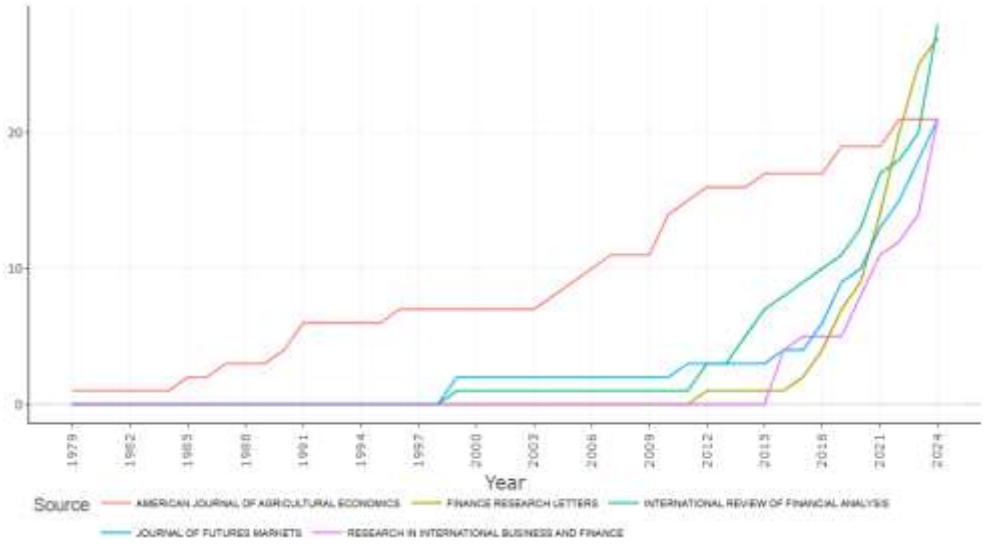
Source: Bibliometrix (2024).

To complement the analysis of publication trends, Table 1 presents the main references on market efficiency applied to commodities, classified according to their academic relevance, measured by the total number of citations. These studies have provided the theoretical and methodological

foundation for the field, particularly regarding the incorporation of dynamic approaches.

Notable works include Time Series Momentum (Moskowitz, Ooi & Pedersen, 2012), with 741 citations, which introduced the concept of momentum in time series and challenged the efficient market hypothesis; Momentum Crashes (Daniel & Moskowitz, 2016), with 525 citations, which analyzed the risks associated with momentum strategies in volatile scenarios; and An Econometric Model of Serial Correlation and Illiquidity in Hedge Fund Returns (Getmansky, Lo & Makarov, 2004), with 495 citations, which highlighted the effects of illiquidity on returns and volatility. These studies have significantly contributed to the incorporation of dynamic and interdependent approaches in market analysis.

Figure 5 – **Leading Journals in Scientific Production on the Topic**

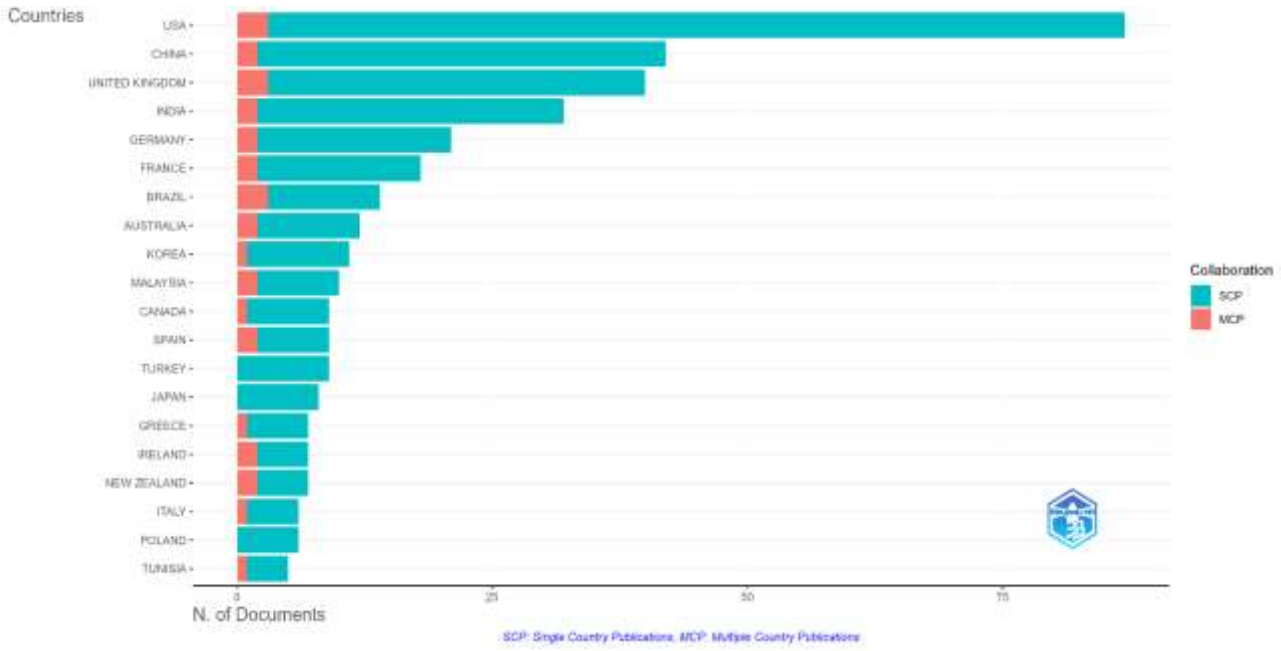


Source: Bibliometrix (2024).

Figure 5 also highlights the most relevant journals in the literature on market efficiency with a focus on commodities, which have been essential for consolidating knowledge in the field since 1979. The American Journal of Agricultural Economics leads with 434 articles (37.19%), emphasizing analyses of price formation, volatility, and integration between spot and futures markets. Additionally, the International Review of Financial Analysis, with 165 articles (14.14%), stands out for the application of advanced quantitative methodologies, while Finance Research Letters, with 113 articles (9.69%), is notable for addressing emerging topics and macroeconomic events. These journals have played a central role in disseminating studies that incorporate dynamic connectivity as a key element in the analysis of commodity markets.

Additionally, Figure 6 presents the leading countries in scientific production on market efficiency. The United States occupies a prominent position, with 121 publications and 4,616 citations, reflecting its academic centrality.

Figure 5 – **Most Cited Countries on the Topic**



Source: Bibliometrix (2024).

China ranks second, with 86 publications and 1,276 citations, highlighting its growing influence driven by investments in science and technology. The United Kingdom completes the top three, with 55 publications and 702 citations, standing out for the quality and impact of its research. These results suggest that scientific production on market efficiency and dynamic connectivity is concentrated in economies with strong participation in global commodity markets, as also observed by Moraes et al. (2024).

Finally, Figure 7 presents the keyword co-occurrence network, revealing five major thematic clusters that structure the literature on market efficiency and commodities: Market Efficiency and Financial Markets; Futures Markets and Commodities; Innovations and Disruptions; Behavioral Finance; and Quantitative Techniques. These groupings highlight the thematic diversity of the field and reflect the theoretical and methodological evolution of research over time.

From an analytical perspective, the first cluster explores core concepts such as market efficiency and technical analysis, reflecting the ongoing debate on the efficient market hypothesis. The second cluster focuses on futures markets and commodities, addressing aspects related to pricing, volatility, and risk management. The third cluster highlights innovations and disruptive events, such as cryptocurrencies and the Covid-19 pandemic, which have significantly influenced global market dynamics. Additionally, the fourth cluster incorporates a behavioral perspective, analyzing how psychological factors and cognitive biases affect economic decision-making. Finally, the fifth cluster brings together advanced quantitative techniques, such as GARCH models and machine learning methods, widely used in volatility modeling and time series analysis.

Figure 7 – **Keyword Co-Occurrence Network**

Source: Bibliometrix (2024).

In a transversal and integrated manner, it can be observed that these clusters do not exist in isolation but are interconnected through approaches that emphasize dynamic connectivity between markets. This interconnection highlights a recent trend in the literature toward analyzing temporal interdependencies, shock transmission, and the non-static evolution of relationships among prices, volatility, and information in commodity markets, surpassing traditional approaches based on static structures (Patil & Rastogi, 2019; Moraes & Castro Junior, 2025).

In this sense, the keyword co-occurrence network suggests that dynamic connectivity has consolidated as an integrating axis across different strands of the literature, linking classical foundations of market efficiency to contemporary methodologies capable of capturing dynamic and nonlinear relationships. Consequently, this analysis reveals a combination of established foundations and emerging trends, such as blockchain, artificial intelligence, and dynamic modeling, reflecting the maturation of the field and highlighting relevant gaps for future research.

Theoretical and Structural Foundations on the Topic in the Context of Commodities

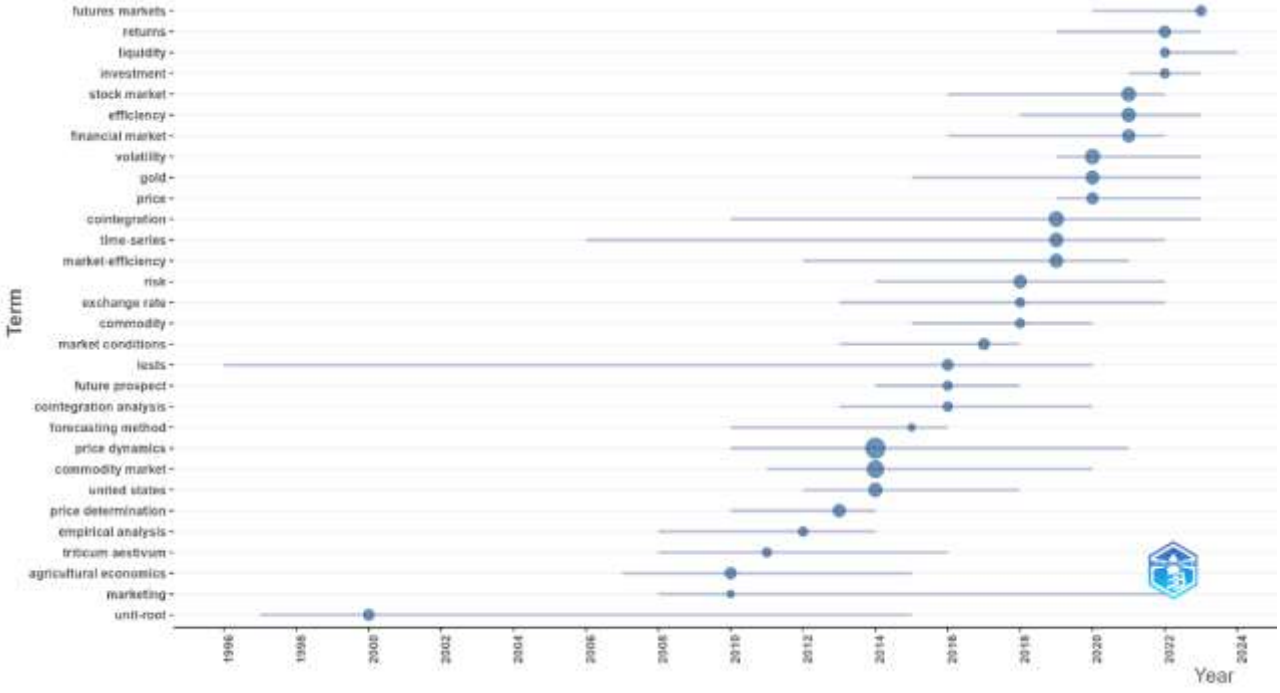
The database analysis serves as a fundamental tool for mapping the conceptual, social, and intellectual structure underpinning studies on market efficiency and dynamic connectivity. In this sense, this approach allows for the identification of the main theories, collaboration networks, and emerging trends that shape the field, providing a comprehensive view of its academic evolution.

Furthermore, by explicitly incorporating the perspective of dynamic connectivity, the analysis moves beyond static approaches to market efficiency, enabling an understanding of how the degree of informational efficiency and interdependencies between markets evolve over time, particularly under different economic regimes and periods of instability. In this context, Figure 8 presents a map highlighting the most relevant research themes, considering both their frequency in publications and

their temporal significance.

Regarding the most prominent topics, price dynamics stands out with 42 occurrences up to 2021, reflecting its centrality in studies on price fluctuations across diverse markets. This finding is directly linked to the interest in understanding how shocks are transmitted between interconnected markets, a core aspect of dynamic connectivity. Complementarily, the commodity market, with 26 occurrences up to 2020, remains a key theme, highlighting its ongoing relevance in the literature.

Figure 8 – **Map of Trending Topics in the Research Field**



Source: Bibliometrix (2024).

Additionally, cointegration, with 18 occurrences up to 2023, demonstrates its applicability in analyzing long-term relationships and structural interdependencies between time series, frequently serving as a basis for studies on market connectivity. Similarly, volatility, with 17 occurrences, has shown recent growth, indicating academic interest in understanding the propagation of instabilities and systemic risks in financial and commodity markets.

Similarly, fundamental topics such as stock market (15 occurrences), time series (14 occurrences), and market efficiency (13 occurrences) remain central in the literature, exploring essential aspects of price behavior and the efficient market hypothesis up to recent periods (2022–2023). Together, these topics provide the theoretical framework necessary for the development of more dynamic approaches aimed at capturing temporal variations in market relationships. Regarding emerging topics, investment (6 occurrences, 2021–2023) and liquidity (6 occurrences, 2022–2024) gain prominence, indicating an expanded analytical focus on microstructural aspects and their effects on dynamic connectivity. Additionally, futures markets (7 occurrences, 2020–2023) underscore the growing relevance of strategies related to hedging and speculation, as well as the role of these markets

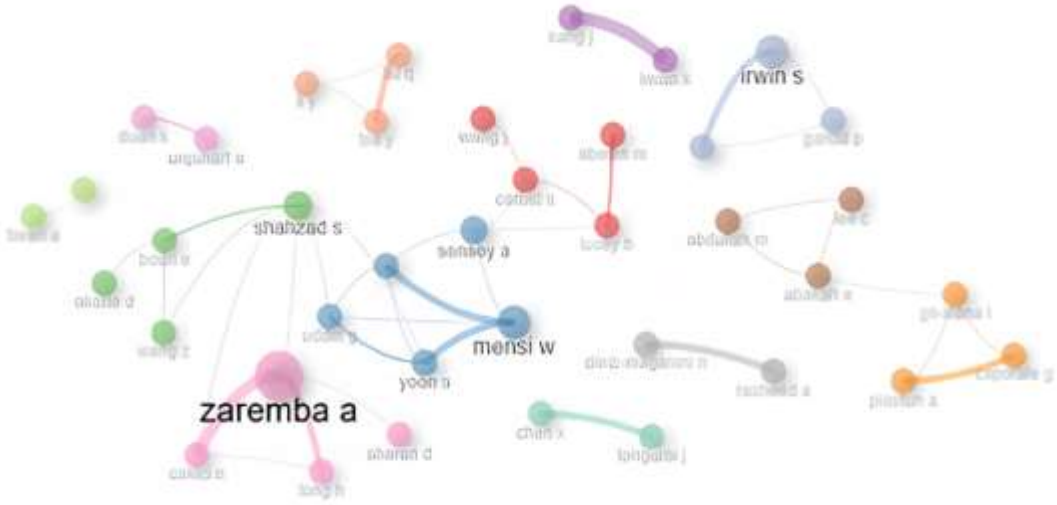
in transmitting information between spot and futures markets.

When considered in an integrated manner, these topics reveal not only the evolution of academic interests but also significant gaps in understanding the dynamic interactions between financial and commodity markets. Thus, the map of trending topics provides a comprehensive view of the dynamics shaping the field, while also identifying promising areas for future research and highlighting the need for studies that explicitly incorporate dynamic connectivity as a central analytical axis.

Next, following the analysis of trending topics, it is equally important to explore the dynamics of academic collaboration that underpin and drive research in the domain of market efficiency and dynamic connectivity, with an emphasis on commodities. In this regard, mapping the co-authorship network allows for the identification of key partnerships, active research groups, and influential figures contributing to knowledge advancement, while also highlighting how scientific collaboration promotes the dissemination of advanced methodologies and interdisciplinary approaches.

Figure 9 illustrates the co-authorship network in the field of market efficiency, highlighting, in an integrated manner, the dynamics of academic collaboration and the key actors shaping research in this area.

Figure 9 – **Academic Contributions on the Topic in Commodities: A Co-Authorship Network**



Source: Bibliometrix (2024).

In this context, among the most influential authors, Shahzad, Sensoy, and Mensi stand out due to their significant number of citations, reflecting the importance of their scientific contributions. Overall, these researchers play a central role in consolidating studies that integrate market efficiency, volatility, and dynamic connectivity, particularly in contexts of economic instability.

In particular, Shahzad, with approximately 75,000 citations, holds a central position in the development of the field, serving as a key figure in studies on volatility, price dynamics, and cointegration between financial and commodity markets. In this regard, his contributions are especially relevant for understanding how shocks propagate across interconnected markets,

underscoring the importance of dynamic connectivity in empirical analysis.

Complementarily, Sensoy, with around 48,000 citations, stands out for his research on market efficiency and interactions between financial and commodity markets, with an emphasis on market responses to crises and the analysis of dynamic dependency structures over time. Similarly, Mensi, with approximately 32,917 citations, is widely recognized for his investigations into volatility and cointegration, as well as for studies examining the impacts of economic and financial shocks on futures markets, often from the perspective of connectivity.

In addition to these central authors, other researchers also exert significant influence in the field. For example, Zaremba (24,750 citations) and Gil-Alana (6,000 citations) have contributed in-depth analyses on price dynamics, volatility, and long-term memory, employing advanced econometric models that capture temporal and nonlinear dependencies. Meanwhile, Tiwari (1,000 citations), although having a lower citation count, has produced relevant work focused on cointegration and volatility, particularly in the context of relationships between futures and commodity markets.

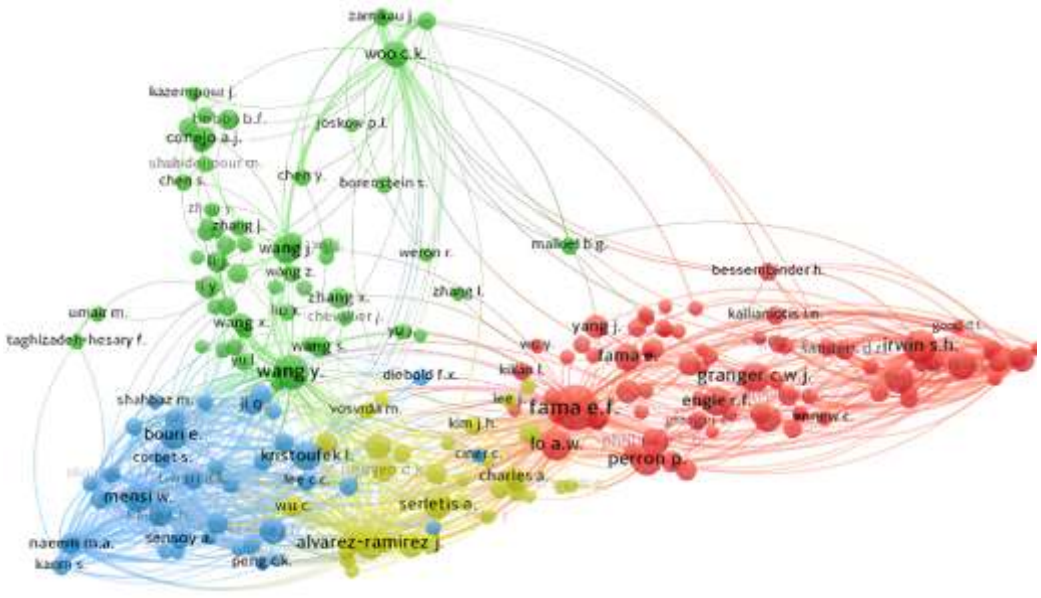
Overall, these researchers play essential roles in structuring and advancing academic knowledge on market efficiency. Their contributions enhance the understanding of the complex and interdependent dynamics of financial and commodity markets, while also indicating future research directions focused on the analysis of dynamic connectivity in high-uncertainty environments.

Complementing this discussion, Figure 10 presents the author co-citation network, highlighting the intellectual connections that underpin studies on financial markets, market efficiency, and dynamic modeling of market relationships. This approach makes it possible to identify the key authors who have shaped the field, widely cited for their foundational contributions. In this context, four author clusters can be observed, each representing distinct theoretical and methodological cores within the finance literature.

At the center of this network, Eugene F. Fama stands out, with 5,130 co-citations and the highest total link strength (192). Recognized as the originator of the Efficient Market Hypothesis (EMH), Fama laid the foundations of modern finance theory by demonstrating that prices efficiently reflect available information. Additionally, the analysis identifies a separate instance of Fama in the database, referred to as Fama (Capital Markets), with 1,632 co-citations and a link strength of 165, further emphasizing the centrality and thematic diversity of his contributions to the field. Although originally based on static structures, the EMH remains the theoretical starting point for contemporary studies investigating how efficiency behaves in dynamic and interconnected contexts.

Another prominent author, Kristoufek, with 3,059 co-citations and a link strength of 177, has made significant contributions to the field. In particular, his research in complex finance employs advanced statistical methods and network analysis to investigate financial correlations, proving especially relevant for understanding dynamic connectivity between commodity markets. Furthermore, his application of approaches such as fractal analysis and nonlinear methods has attracted increasing academic attention.

Figure 10 – **Co-Citation Network of the Most Relevant Authors in the Field of Finance**



Source: Bibliometrix (2024).

Equally important, Engle holds a prominent position in the network, with 1,446 co-citations and a link strength of 173. As the creator of the Generalized Autoregressive Conditional Heteroskedasticity (GARCH) model, Engle revolutionized time series analysis by introducing an essential tool for modeling and forecasting volatility. This advancement, in turn, was fundamental for the subsequent development of dynamic connectivity models, widely used to study shock transmission.

Along the same lines, Bollerslev expanded Engle's contributions by developing the generalized GARCH model. With 1,259 co-citations and a link strength of 164, his research deepened the understanding of volatility patterns and market interdependencies, thereby making a significant contribution to empirical studies on price dynamics, cointegration, and connectivity.

In summary, the analysis of the co-citation network highlights the strong interconnection among these authors, whose contributions have laid the foundations for the main research lines in market efficiency, volatility, and price dynamics. Consequently, their work supports the recent advancement of the literature toward dynamic, systemic, and interdependent approaches, consolidating the field as an academic space in continuous evolution and interdisciplinary expansion.

Research Agenda: Trends and Future Challenges

Considering the breadth of studies reviewed throughout this article, which encompasses both general investigations in the field of finance and analyses directly focused on commodity markets, the

Figure 11 – **Mapping of Major Gaps in the Literature: Perspectives for the Commodity Sector**

Trends	Research Agenda	Focus	Author (s)
Commodity Markets and Price Dynamics	Impact of Maritime Freight Markets on Commodity Markets. Impact of Deviations in Soybean Crushing Estimates on Returns and Risks. Impact of Bitcoin, Gold, and Gold-Backed Cryptocurrencies as Safe Havens for Commodities. Market Investor Sentiment and Price Dynamics in Weak Markets: Soybean Meal Options' Market. Impact of Media and Fake News on Commodity Futures Prices.	Shock transmission and interdependence; Uncertainty and risks in the agricultural market; Safe-haven assets for commodities in times of crisis; Volatility factors and investor behavior; Impact of media and fake news on commodity futures prices.	(Jena et al., 2024) (Banerjee et al., 2024) (Abakah et al., 2024) (Abdoh & Chitavi, 2024) (Snene & Jeribi, 2024) (Yan, Liang & Zhao, 2024)
Volatility Analysis and Sectoral Connectivity	Impact of COVID-19 on the Volatility Connectivity of Chinese Tourism. Interconnectedness in the Foreign Exchange Market During High Inflation. Impact of Economic and Political Uncertainty on the Volatility of Green Bonds. Interdependencies in Base Metals Futures Markets During the COVID-19 Pandemic. Price Dynamics and Investor Behavior in G7 Markets During COVID-19.	Sectoral volatility and economic interactions; Exchange rate linkages in inflationary regimes; Advanced volatility models in green bonds; Financial stability and the impacts of global crises.	(Hu et al., 2024) (Ahmed et al., 2024) (Wang et al., 2024) (Chen & Tongurai, 2024) (Talbi et al., 2024)
Artificial Intelligence and Technologies in Finance	Machine Learning and Global Factors in Stock Returns. Artificial Intelligence and Big Data Tokens in Herding Patterns. Market Data Analysis Using Wavelet Coherence. Artificial Intelligence in Market Strategies. Cryptocurrency Returns and Machine Learning.	Global patterns with machine learning; Human cognition and collective behavior; Temporal interactions and investor behavior; Forecasting in financial and digital markets; Momentum strategies.	(Cakici & Zaremba, 2024) (Xiaoyang, Ali & Naveed., 2024) (Vasilelou & Tzanakis, 2024) (Cakici et al., 2024) (Li et al., 2024)
Financial Markets and Crises	Impact of Macroeconomic Events on Global Markets. How Stock Markets React to Dividend Announcements During COVID-19. Relationship Between Cryptocurrencies and Conventional Financial Markets. Human Characteristics and Disruptions in Stock Data.	Crises such as COVID-19 and geopolitical conflicts; Impacts of financial announcements during pandemics; Causality and long-term effects; Human reactions and big data in markets.	(Al-Khasawneh et al., 2024) (Huang, 2024) (Luo et al., 2024)
Deep Learning in Commodity Price Forecasting	Application of deep neural networks to forecast commodity prices based on large volumes of historical data and external sources such as weather and macroeconomic factors.	Big Data, Forecasting, and the Commodity Market.	(Snene & Jeribi, 2024) (Kim et al., 2024)
Commodity Market Reactions to Armed Conflicts	Impact of Wars and Armed Conflicts on Commodity Markets; Analysis of Supply Chain Disruptions and Changes in Global Trade Patterns.	Resilience of Commodity Markets in the Face of Geopolitical Shocks.	(Lin & Anwar, 2024) (Bhutto et al., 2024)
Sustainability and Green Finance	Heterogeneous Impact of Economic and Political Uncertainty on Green Bond Volatility; Relationship Between Cryptocurrencies, Gold, and Sustainability.	Sustainability and Financial Risks; Role of Sustainable Assets in the Market.	(Wang et al., 2024) (Snene & Jeribi, 2024)
Development of Sustainable Investment Strategies in Commodities	Analysis of the Implications of Sustainable Investments in Commodities and the Role of ESG (Environmental, Social, and Governance) Criteria in Investor Decisions.	Sustainability in the Commodity Sector and How ESG Criteria Are Shaping Investment Practices and Global Financial Markets.	(Martinez & Araujo, 2024) (Zhang & Sun, 2024)
Cryptocurrencies, Blockchain, and Financial Markets	Does the Carbon Market Signal Market Efficiency of Clean and Dirty Cryptocurrencies? Interconnectedness and Volatility Transmission. Efficient Market Hypothesis in Blockchain. Cointegration of Bitcoin Shocks with Financial and Commodity Markets Hedging or Financialization? Behavioral Analysis of Time Series. Calendar Effects in Digital Markets During Crises.	Carbon Market, Cryptocurrencies; Interconnectedness, Volatility Transmission, GARCH; Efficient Market Hypothesis, Calendar Anomalies, Blockchain, Financial Shocks, Cointegration, Behavioral Analysis.	(Wei et al., 2024) (Kushwah et al., 2024) (Polyzos, Rubbaniy & Mazur, 2024) (Ozer et al., 2024) (Chaild & Handika, 2024) (Sahu et al., 2024)
Market Efficiency, Speculation, Price Transmission, and Market Integration	Informational Efficiency and Speculation in Agricultural Commodity Markets; Horizontal Integration and Market Efficiency in Platform Companies; Transmission of Agricultural Commodity Prices from International to Local Markets; Competence and Effectiveness of Energy Futures in Emerging Economies.	Speculation, Informational Efficiency, Agricultural Markets, Emerging Markets; Horizontal Integration, Market Efficiency, Price Transmission; Emerging Economies.	(Pullaykkodi & Acharya, 2024) (Emediegwu & Rogna, 2024) (Lin & Anwar, 2024) (Samal, 2024)
Investment Strategies and Return Dynamics	Return Seasonality in Commodity Futures; Portfolio Management Under Capital Market Frictions; Market Dynamics in Emerging Countries During Commodity Financial Shocks.	Seasonality, Futures Markets, Commodities, Investment Strategies; Portfolio Management, Market Frictions, Grey Clustering, Financial Markets	(Li et al., 2024) (Tilica et al., 2024) (Lawrence, Obalade & Doorasamy, 2024)
Energy and Commodity Markets	Relationship Between Futures and Spot Prices for Economic Policies; Crisis Effects on Energy Commodity Markets; Advanced Price Forecasting Methods in Specialized Markets.	Futures Prices, Spot Prices, Energy Commodities, Risk Diversification; Spillover, Energy Markets, Crisis Phases; Price Forecasting, Oil and Gas.	(Panagiotou & Naka, 2024) (Chhapparia et al., 2024) (Aslet al., 2024)
Comparative Analysis of Agricultural Commodity Market Dynamics: International, National, and Physical Aspects	Comparative Analysis of Agricultural Commodity Market Efficiency; Identification of Similarities and Clustering in Market Dynamics; Exploration of Convergences and Divergences Between Markets: Impacts of Crises on Commodity Market Behavior.	Comparative Analysis of Agricultural Commodity Markets; Market Efficiency; Cluster Analysis; Price Convergence, Arbitrage Analysis; COVID-19; Market Dynamics; Market Resilience; Structural Change Tests.	(Askari & Hajizadeh 2024) (Amin, Badruddoza & Sarasty 2024) (Urak et al., 2024)

Source: Prepared by the authors (2024).

future research agenda reflects this thematic diversity in an integrated manner. Although some emerging topics originate from broader debates in contemporary finance, their implications for commodity markets become evident when examining the developments related to market efficiency, dynamic connectivity, and the mechanisms of shock transmission between assets and markets.

To identify research opportunities, 70 relevant articles published in 2024 were analyzed. Of these, 13 were inaccessible, and 17 did not present proposals related to research studies. A detailed analysis of the remaining 40 articles enabled the systematic mapping of research agendas, revealing 12 emerging trends of significant relevance for the study of efficient markets, with an emphasis on their direct and indirect interfaces with the commodity sector.

Commodity markets continue to be a cornerstone of the global economy, exhibiting increasing complexity due to global dynamics, recurring economic crises, and technological innovations. In this context, investigating market efficiency, market integration, and responses to economic shocks assumes a central role, offering a broad range of opportunities for new research.

Thus, the following 12 emerging trends stand out, offering potential new insights into the interactions between market efficiency and commodity market dynamics, even though some originate from broader debates in the financial field, particularly in light of the challenges posed by global crises and technological innovations.

1. Commodity Markets and Price Dynamics

Understanding how economic shocks propagate and how commodity price volatility evolves is fundamental to deciphering global interdependencies. The growing impact of assets such as Bitcoin, gold, and other cryptocurrencies, especially during economic crises, reveals new forms of investor behavior in search of safe-haven assets (Jena et al., 2024; Banerjee et al., 2024).

The influence of fake news and investor sentiment, particularly in agricultural commodities like soybean meal, also warrants greater attention (Abdoh & Chitavi, 2024). Additionally, analyzing the relationship between maritime transport and agricultural supply can shed light on how disruptions in trade flows affect risk and returns in commodity markets (Snene & Jeribi, 2024; Yan, Liang & Zhao, 2024).

2. Volatility Analysis and Sectoral Connectivity

Volatility, intensified by crises such as the Covid-19 pandemic, provides a fertile ground for investigation. The interdependence between currency markets and sectors such as metals and tourism can offer important insights into market resilience in the face of external shocks (Hu et al., 2024; Ahmed et al., 2024). Studying how these markets respond to global crises is essential for developing risk mitigation strategies, with particular emphasis on emerging markets (Wang et al., 2024; Chen & Tongurai, 2024; Talbi et al., 2024).

3. Artificial Intelligence and Technologies in Finance

The technological revolution in finance, particularly through artificial intelligence (AI) and machine learning, has the potential to transform price forecasting and the behavior of commodity markets. The integration of big data, climate data, and macroeconomic factors can significantly improve price predictions, especially for agricultural and energy commodities (Vasileiou & Tzanakis, 2024; Cakici & Zaremba, 2024; Li et al., 2024). Additionally, investigating how cryptocurrencies interact with economic variables in portfolio models represents a promising research agenda (Xiaoyang, Ali & Naveed, 2024).

4. **Financial Markets and Crises**

The interaction between commodity markets and macroeconomic events, such as financial crises and geopolitical tensions, remains central in the literature. Analyzing how commodity markets respond to financial shocks and how digital assets influence traditional markets can deepen the understanding of market efficiency and price dynamics during periods of high uncertainty (Al-Khasawneh et al., 2024; Huang, 2024; Luo et al., 2024; Snene & Jeribi, 2024).

5. ***Deep Learning in Commodity Price Forecasting***

The use of deep learning and neural networks for forecasting commodity prices, combined with big data, offers an innovative perspective. Integrating climate data and economic indicators into forecasting models can provide a more accurate understanding of price dynamics, which is essential for highly volatile markets such as agricultural and energy commodities (Snene & Jeribi, 2024; Sahu, Ramírez & Kim, 2024).

6. **Commodity Market Reactions to Armed Conflicts**

Geopolitical conflicts can profoundly disrupt global supply chains and commodity prices. Investigating how commodity markets, particularly energy commodities such as oil and gas, respond to these disturbances provides essential insights for risk mitigation and diversification strategies (Liu & Anwar, 2024; Bhutto et al., 2024).

7. **Sustainability and Green Finance**

The growing integration of sustainable assets, such as green bonds, into commodity markets reveals a new dimension of financial sustainability. Investigating how these assets behave during economic crises can provide valuable insights into diversification strategies and the benefits of green finance for investors (Wang et al., 2024). Additionally, exploring the relationship between sustainability and cryptocurrencies may open new avenues for more responsible investment policies (Snene & Jeribi, 2024).

8. **Comparative Analysis of Agricultural Commodity Markets**

Studying the dynamics among international, national, and physical agricultural markets is essential to understand the forces shaping prices and supply. Applying clustering analyses and dynamic connectivity methods can reveal structural and behavioral patterns in these markets, highlighting common characteristics, regional differences, and interactions between local and global markets. During crises, such as the Covid-19 pandemic, these techniques are particularly useful for assessing market resilience, identifying groups of markets with similar responses to exogenous shocks, and providing insights into factors that promote stability and recovery.

These analyses can also be used to examine market efficiency in agricultural commodities, assessing levels of efficiency and inefficiency. More efficient markets tend to reflect available information accurately in prices, while inefficient markets may show significant deviations due to structural barriers such as infrastructure gaps or economic policies (Askari & Hajizadeh, 2024; Moraes et al., 2024).

Evaluating market efficiency, combined with econometric models, allows a better understanding of market adaptation to shocks, which in turn supports price forecasting and the development of more effective agricultural policies (Iuga, Mudakkar & Dragolea, 2024). By providing a detailed view of how different markets respond to climate changes, economic crises, and geopolitical tensions, this type of analysis also helps identify markets that operate more efficiently or inefficiently, aiding in optimizing risk mitigation strategies (Amin, Badruddoza & Sarasty, 2024;

Urak et al., 2024).

9. Cryptocurrencies, Blockchain, and Financial Markets

The impact of cryptocurrencies and blockchain technology has been transforming financial markets, including commodity markets. Research on the cointegration between Bitcoin shocks and commodities during financial crises can provide a unique perspective on how digital assets and traditional markets interact in times of economic turbulence (Wei et al., 2024; Kushwah et al., 2024). These studies may contribute to the development of new investment strategies and risk management approaches (Polyzos, Rubbaniy & Mazur, 2024; Sahu, Ramírez & Kim, 2024).

10. Market Efficiency, Speculation, and Market Integration

Market efficiency and speculation remain central topics in commodity research. Investigating price transmission and the horizontal integration of emerging markets, particularly in agricultural commodities, can deepen the understanding of how speculative behavior affects prices and investment strategies in these markets (Pullaykkodi & Acharya, 2024; Liu & Anwar, 2024; Samal, 2024).

11. Investment Strategies and Return Dynamics

Studying seasonality in futures markets and portfolio management strategies is essential for developing effective investment approaches. Examining the impact of financial shocks on emerging markets and how investors adapt their strategies to market fluctuations can provide valuable insights for building more robust risk models (Li et al., 2024; Lawrence, Obalade & Doorasamy, 2024).

12. Energy Markets and Commodities

The relationship between spot and futures prices in energy markets and the impact of economic crises on energy commodities, such as oil and gas, remains highly relevant. Analyzing energy price forecasts during periods of crisis can help develop effective risk diversification strategies, particularly in energy and commodity markets. Additionally, investigating how crises influence energy supply and demand provides valuable insights for investors and policymakers (Panagiotou & Naka, 2024; Chiappari, Scotti & Flori, 2024; Asl et al., 2024).

In conclusion, these research trends should be interpreted as part of an ongoing effort to understand the new market dynamics in a globalized and technologically advanced world. Although some topics originate from broader debates in finance, their developments reveal direct and growing implications for commodity markets, particularly regarding informational efficiency, dynamic connectivity, and shock transmission.

Furthermore, the research agenda highlights the need for markets to adapt to a rapidly changing environment, whether through new technologies, sustainable investments, or global risk mitigation strategies. In this way, these trends not only broaden the theoretical debate but also provide practical support for managing constantly evolving commodity markets, contributing to the advancement of knowledge and the development of more effective economic policies.

Final Considerations

This study mapped and analyzed the scientific literature on market efficiency and dynamic connectivity in the specific context of commodities, integrating classical theoretical foundations,

established divergences in the literature, empirical gaps, and emerging trends. Conducting a bibliometric review proved particularly relevant for this field, given the exponential growth of research and the lack of theoretical consensus regarding the degree of efficiency in commodity markets, especially in the face of recurring shocks and informational asymmetries.

The research underscores the importance of the theoretical foundations of the Efficient Market Hypothesis (EMH), while also highlighting its explanatory limitations when applied to markets characterized by high volatility, seasonality, climate dependence, and exposure to exogenous shocks, as is the case with agricultural, energy, and metal commodities. The results indicate that the theoretical debate is far from exhausted; rather, the limitations of traditional models have driven the emergence of alternative and frontier approaches, such as nonlinear models, multifractal analyses, dynamic connectivity, and machine learning–based methods.

The findings show that commodity markets exhibit heterogeneous behaviors over time and across different types of products, challenging central assumptions of the EMH, such as full predictability and the instantaneous incorporation of information into prices. The literature reveals significant divergences both across studies and over time, particularly during periods of crisis, suggesting that efficiency is a conditional phenomenon dependent on the economic regime. Factors such as production seasonality, logistical costs, market structure, and external events — including geopolitical, health, and climatic crises — reshape the price and return dynamics of commodities.

Furthermore, the review highlights significant gaps in studies applied to emerging markets and specific commodities, which remain underrepresented in both international and national literature. This asymmetry limits the generalization of empirical results and underscores the need for research that considers distinct institutional, regional, and structural contexts, particularly in countries with a strong dependence on the primary sector.

The rise of disruptive technologies, such as artificial intelligence, big data, and advanced modeling methods, emerges as a promising frontier for advancing the field, enabling more refined analyses of volatility, shock transmission, and informational efficiency. However, these approaches also challenge the classical assumptions of the Efficient Market Hypothesis (EMH) by revealing dynamic and non-linear patterns in price formation. Complementarily, the integration of the ESG agenda and sustainability issues emerges as a recent and still underexplored dimension in studies of efficiency in commodity markets.

The analysis also highlights the growing interdependence between spot, futures, and financial markets, demonstrating how global shocks, such as the Covid-19 pandemic, extreme weather events, and geopolitical conflicts, affect the efficiency and resilience of commodity markets. These findings reinforce that market efficiency should be analyzed in a contextualized manner, taking into account regional, sectoral, and temporal specificities, thereby opening avenues for future research focused on comparative evaluations across commodities, countries, and economic regimes.

From a methodological perspective, this study advances beyond previous research by integrating bibliometric analysis with a critical review of empirical findings, enabling the identification not only of thematic trends but also of recurring weaknesses, opportunities for theoretical deepening, and avenues for methodological innovation. The gaps identified provide clear guidance for future research, particularly in the development of models that are more sensitive to the dynamics of commodity markets and the specificities of emerging economies.

As a limitation, it should be noted that the study depends on the selected databases and the

bibliometric criteria adopted, which may restrict the coverage of some relevant studies that are not indexed. Nevertheless, these limitations do not compromise the central findings but rather indicate opportunities for expansion in future research.

Finally, by combining a structured theoretical analysis with empirical and methodological implications, this work contributes to advancing the state of the art on market efficiency and dynamic connectivity in commodities. The results provide valuable insights for researchers and market participants, supporting strategies aimed at food and energy stability, risk mitigation, and the development of more efficient, sustainable, and resilient commodity markets in an increasingly complex global environment.

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