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Mapping the effects of Spillovers between Energy and Agricultural Futures in context of biofuels: A Bibliometric Approach

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ABSTRACT
Using bibliometric analysis techniques, we examine relevant publications from major academic databases to map the intellectual structure and evolution of this research domain. Our findings reveal four key themes: co-integration and volatility spillover between energy and agricultural commodities, the role of biofuel policies in price transmission, speculation and financialization in commodity markets, and uncertainty and risk in energy-agriculture linkages. The bibliometric results indicate growing research interest in this area, especially since the 2008 financial crisis, but also highlight gaps in the literature. Specifically, we identify needs for further investigation into asymmetric spillover effects, the impact of speculation, and modeling approaches that integrate economic theory with econometric time series analysis. This review provides a comprehensive overview of existing knowledge on energy-agriculture market interactions and suggests promising directions for future research to inform policy and practice in this critical domain.

Keywords: *Energy futures, Agricultural futures, Biofuels, commodity markets, Price transmission, Bibliometric analysis*

1. Introduction
The global futures market started with the agricultural futures. The pricing of different commodities is distinctly based on their production, weather, inventory, consumption and geopolitical regulation. Energy products, especially downstream products of crude oil are inextricably connected to production, processing, mobility and sales of agricultural produce (Malliaris & Malliaris, 2008).

After mid-2006, crude oil, wheat, and corn futures markets showed increased volumes, linked to the rise of bio-ethanol fuel. The global demand for biofuels like methanol, ethanol, and biodiesel has grown due to environmental concerns, prompting government support. Ethanol, the most widely used biofuel, is produced from food commodities such as sugarcane in India and Brazil, maize in the USA, and wheat in the EU. By 2024, China's stockpiling resulted in 57% of the world's residual wheat and corn supply, 66% of rice, and 46% of cotton, compared to pre-2021 levels.(Boussios, 2024).

The question from the above literature is whether movements in crude oil futures catalyze traders to make decisions in agricultural markets. A debate has spurred between food versus fuel due to the expanding nature of agricultural produce (Serra & Zilberman, 2013). Crude oil futures are an ideal starting point for analyzing the commodity futures market under herd

mentality due to their intricate connections with other commodities and the economy. Traders might excessively transfer price movements across markets. Understanding short- and long-term asymmetric inferences between agricultural and energy markets clarifies diversification opportunities. (Awartani et al., 2016; Coffee, 2009)**.** The open interest among the markets can be analyzed using dynamic correlation instead of coefficient correlation. Most of the empirical studies have relied on financial econometrics for testing the futures markets of agriculture and energy. Financial econometrics was developed originally for stock markets. The literature needs to be revisited, and new methods devised that address recent developments in the food-energy nexus (Adhikari & Putnam, 2020)**.**

2. Rationale of Study

Energy significantly influences food costs; thus, understanding volatility transmission is crucial to grasping energy's price effects on agriculture. The rising focus on bio-fuels necessitates examining their impact on food price variability. Anticipating energy price hikes or commodity shortages, firms, consumers, and speculators tend to stockpile inventories. There's limited literature on the implications of spillovers between efficient energy futures markets and weaker agricultural markets. Empirical analysis is needed to assess inventory holding's role in both sectors. Agricultural market bubbles require distinct modeling compared to stock markets due to pricing linked to consumers' marginal willingness to pay. Post-financial crisis and after crude oil prices dropped below zero, literature consolidation is necessary. Agricultural futures often face immediate regulatory impacts amid rising crude oil prices, global inflation, or increased volatility. Investors and traders continuously seek indicators to gauge if investment optimism will yield rewards amidst the dynamic energy and agricultural markets.

3. Research Background

Commodity investment initially involved agricultural futures. Since the early 1800s, Midwest grains were stored in Chicago before being shipped to the East Coast. Chicago's central location made it a key hub between Midwestern farmers and East Coast consumers. During storage, grain prices fluctuated due to quality changes or demand shifts. To stabilize prices, forward contracts were introduced, obligating sellers to deliver a specified quantity of grain at a set price and date, with upfront payment. The Chicago Board of Trade (CBOT) was established in 1848, providing standardized futures contracts. Energy futures became popular in 1978 with the NYMEX oil futures contract, followed by exchanges like APEX, DCE, and INE offering products such as LSFO and RBD Palm Oil futures. Government policies to enhance energy security, promote rural economic growth, address global warming, and reduce fossil fuel prices primarily drove global biofuel production growth in the early 2000s (Hochman et al., 2010). In 2019, world ethanol production reached about 29 billion gallons, with the US, Brazil, and the EU producing 54%, 34%, and 5%, respectively (World Fuel Ethanol, 2015). The EU dominated world biodiesel production, producing 9 million tonnes in 2009, accounting for 65% of global output (EBB, 2010).

Currently commercialized biofuels are predominantly first-generation biofuels based on food crops. Ethanol is primarily produced from coarse grains (representing 51% of global ethanol output by feedstocks in 2008–2010), particularly corn, and sugarcane (accounting for 29% of global ethanol output in the same period) (OECD-FAO, 2011). Biodiesel is mainly produced from vegetable oils (rapeseed oil in Europe and soybean oil in the US). Approximately 20 million hectares (1% of worldwide agricultural land) were allocated to grow biofuel feedstocks in 2008 (Scarlat and Dallemand, 2011). In 2008–2011, around 11% of global coarse grain production, 13% of vegetable oil production and 21% of sugar cane production were utilised for automotive fuel (OECD-FAO, 2011). These average figures, however, obscure significant differences across countries and commodities.

The proportion of US corn production transformed into alcohol for fuel reached 40% in 2010–2011 (USDA, Economic Research Service, 2011). In Brazil, 55% of sugarcane was distilled into ethanol in the same period (Valdes, 2011). More recently, skepticism surrounding the benefits of promoting biofuels has increased as these have been implicated as one of the causes of the 2007/08 and the 2010/11 global food crises, having negative environmental and social impacts, among other concerns. This has led many governments to reconsider support for biofuels. One of the most significant effects of the growing biofuel production has been the alteration in the nature of the link between agricultural commodity and energy markets that has precipitated the food versus fuel debate. While this link was traditionally weak (Taheripour and Tyner, 2008) and primarily supply driven (i.e., through input costs, particularly through energy intensive agricultural inputs), a wide range of analyses have reported a stronger connection since the increase in the biofuel industry demand for food commodities. Although much of the interest among the press and the academic world has been on the implications of biofuels for food prices, some research papers also investigate how biofuels affect fossil fuel prices (Whistance and Thompson, 2010).

The spillover among energy and agriculture is influenced by global stock and green energy links. Strong price increases that may be termed as inefficiencies can be a result of real economic factors (Mensi et. al., 2025). There are apprehensions regarding futures trading leading to price rise. The question of spillover is important primarily as it allows the identification of general causality between oil and agricultural markets. A number of empirical studies have been conducted in the past to explore the co-movement of rising oil and agricultural prices (Mitra et. et. al., 2024; Roache, 2010; Wang et. al., 2024). Speculation significantly predicts energy and agricultural price volatility. Defined as short-term trading driven by other investors' behavior rather than fundamental aspects, speculation is viewed differently by two schools of thought. One dismisses speculators' influence on commodity prices, while the other argues that speculative trading creates artificial demand, leading to inflationary pressures and rising prices in futures and physical markets. Some recent articles have presented non-exhaustive reviews on the biofuel-related price transmission literature. In this article, an extensive review of the time-series literature addressing the impacts of biofuels on food and/or fuel prices is conducted.

4. Research methodology

Literature search that is repeatable, transparent and reviews methods systematically improves the reliability of results and reduces subjective bias (Zupic and Cater, 2015). A review protocol identifies, describes and evaluates published research, throughout the study period assuring a level of accuracy and tranparency. Review protocols such as PRISMA have in the past gained popularity for conducting systematic literature reviews. The current study employs Scientific Procedures and Rationales for Systematic Literature Reviews (SPAR-4-SLR) protocol by (Paul & Barari, 2022).

4.1.1. Assembling

This phase encompasses two sub-phases, identification and acquisition. The identification sub-phase involves locating articles pertaining to energy and agricultural futures (domain) using three databases, Scopus, Web of Science (WoS) and EBSCO Business Source Ultimate (source quality) ((Aria & Cuccurullo, 2017; Bretas & Alon, 2021), and selecting journal articles (source type) to comprehend the association. (Echchakoui, 2020) proposed that conducting bibliometric analysis using multiple databases would be superior to utilising a single database, as they complement each other. Scopus offers broader coverage of articles from developing nations, including conference proceedings, WoS provides high-quality ISI-indexed journals and articles (primarily from Western countries) with the most precise search database, whilst EBSCO Business Source Ultimate is the highest quality business research database providing scholarly

papers for business, accounting, commerce, finance, banking, marketing and management, with access to peer-reviewed, full-text journals and other resources that provide historical information and current trends in business (Fahimnia et al., 2015). These selections align with the SPAR-4-SLR principles (Paul et al., 2021). Hence, the identification sub-phase is crucial as it establishes the foundation for the review. In the acquisition sub-phase, this study searches and collects data using these databases (search technique and material acquisition). The search was conducted on May 14, 2024. Search keywords were selected based on an initial multi-iteration review of previous literature, employing macro keywords such as "agricultural futures," "energy," and "spillover," and the publications in the search results were examined for frequently used keywords. 'Method' and 'Field' were created to create an adequate search string. Ultimately, the following query was finalised:

(TITLE-ABS-KEY (agricultural AND futures) AND TITLE-ABS-KEY (energy) AND TITLE-ABS-KEY (spillover)).

The assembly phase yielded 115 publications with 91 results from Web of Science**,** 26 results from Scopus and 8 results from EBSCO Business Source Ultimate.

4.1.2. Arranging

The arranging phase comprises two sub-phases: organisation and refinement. The study intends to consolidate data from three databases and employ EBSCO Business Source Ultimate, Scopus and WoS filters for initial publication organisation from search outcomes (e.g., subject area, document type, and source type). A manual assessment to eliminate irrelevant articles constitutes the secondary organisation (organising codes). The refinement process mirrors the organisation's two-stage approach. Specifically, it involves merging data from Scopus and WoS and applying filters. The study restricts its focus to "articles" (document type) composed in "English" (language) and published in "journals" (source type) within the realm of "business, management, social science and psychology" (subject area), aligning with suggestions by (Chakma et al., 2024; Paul et al., 2021). Lastly, a manual screening of articles for relevance was conducted, excluding those unrelated to women's leadership and emotions. This process yielded 30 articles at the arranging stage.

Inclusion and exclusion criteria - Selection Strategy Summary

Inclusion criteria	**IC 1**	**Phrases matching the search string**
	IC 2	Academic articles and working papers
	IC 3	Literature written in English
	IC 4	Publication date: Available until 14th of May, 2024
Exclusion criteria	EC1	Conference and workshop proceedings, papers presenting a summary of the workshop
	EC2	Opinion blogs or web pages
	EC3	Non-professional/ Non-academic online publications
	EC4	Papers available as PowerPoint presentations
	EC5	Papers available with abstracts only

4.1.3. Assessing

The assessment stage is divided into two parts: evaluation and reporting. This review examines 30 publications based on their performance and maps the body of knowledge (i.e., intellectual, and conceptual structure) that they collectively contribute to and represent for women leadership and emotions research. To outline the trend a performance analysis was performed

using Microsoft Excel and Bibliometrix-R, whereas a network analysis of articles was conducted using bibliographic coupling analysis and a co-occurrence analysis of keywords.

The scientific mapping utilizing bibliographic coupling analysis of documents shows the intellectual structure as well as the evolution of the literature, which is then depicted using a thematic map using co-occurance analysis. Finally, we undertake this analysis to better comprehend the intellectual and conceptual structures expressed in the preceding approaches. Gaur & Kumar (2018) highlight important trends in the literature and recommend future research directions. This review, like previous bibliometric reviews, acknowledges that its conclusions may depend on the accuracy and completeness of the bibliometric data derived from EBSCO Business Source Ultimate, Scopus and WoS (Chakma et al., 2024; Singh & Dhir, 2019)

4.2. Results

Before shedding light on the crucial research questions, an understanding of the current academic literature can help to understand the characteristics of the relationship between agricultural commodity markets and the energy markets. Identification of the distinct approaches that link the two markets can help in advancing theory and guide real-world application. Bibliometric analysis techniques play the role of integrating the body of knowledge that is known currently on the subject.

4.2.a. Word cloud & Search Grid

The word cloud represents the most recurring words in the abstracts and titles of the articles included in the database search (n= 68). The graph represents terms that appear most frequently in the abstracts and titles based on the prominence it holds. A word that appears frequently is displayed in greater font size. At a short glance, the results indicate that "energy" and "futures" are the most recurrent terms. As these terms were part of the search query instructions, the following words that have a high frequency of occurrence are "transmission" and "co-integration." From the agricultural perspective the words that occupy space are – food and corn. It should be noted here that corn is one of the primary inputs for "ethanol" which appears in the graph.

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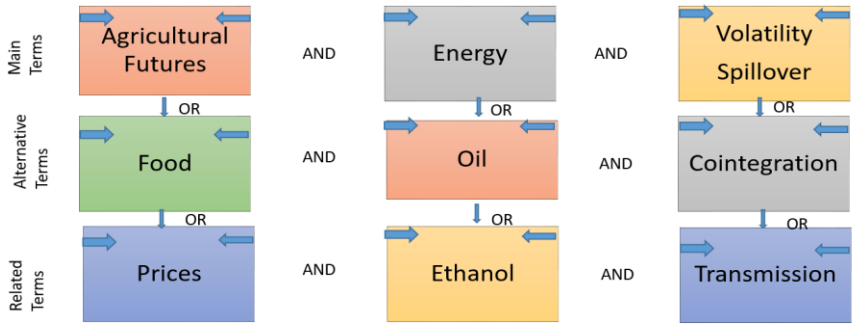

Figure 1: Search Grid from the Bibliometric Search

For the first set in the search criterion, the terms representing the agricultural market were utilized. The second set consisted of terms that captured the energy markets. The third set was used to provide contextual basis to the search through the specification of 'interconnectedness' related search only. Figure 1 captures this in the form of a search grid (first recommended in (Lim, 2024)). The framework emphasizes on the interactions between the main terms, alternative terms and related terms. The terms identified provide a robust foundation of knowledge that underpins the ongoing discourse on the linkage between agricultural and energy markets, drawing from the existing body of academic works.

4.2.b. Theme-based – Co-word Analysis

Co-word analysis as a method of Bibliometric Analysis was popularized by (Cobo et al., 2011). It involves mapping words on a strategic map, to analyze the research results, detect and visualize the conceptual subdomains – namely topics and general thematic areas.

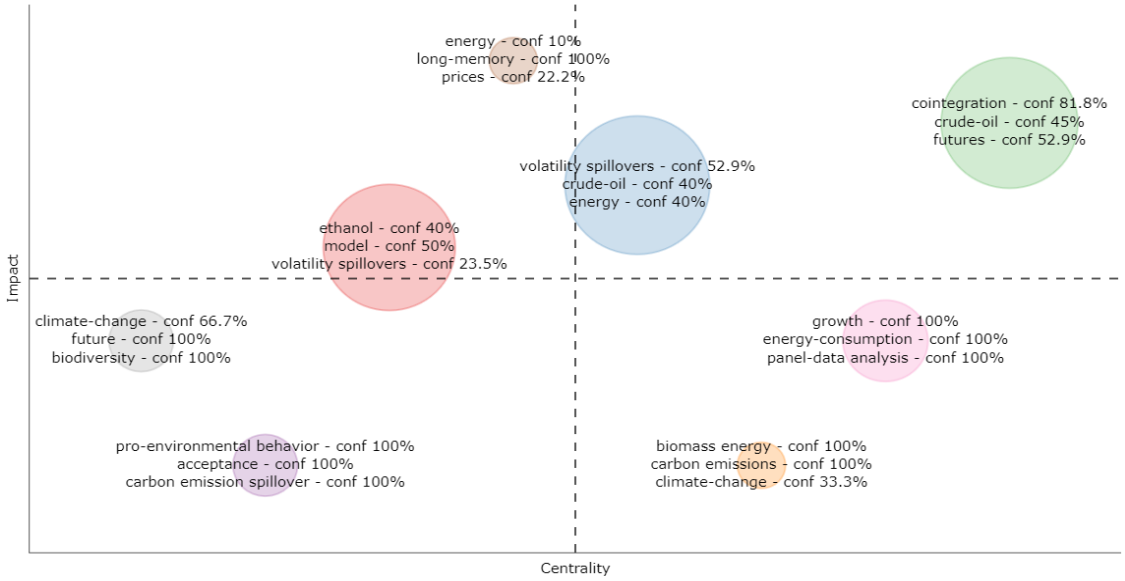

Figure 1: Strategic Diagram of the themes identified by bibliometric search

Cluster 1

Isolated Themes: The themes which appear in the upper left quadrant of the thematic map are called isolated and highly developed themes. These have strong internal ties but weak external ties indicating that while they are highly developed, they have little impact on the development of the themes around them ((Cobo et al., 2018))

The ethanol cluster is positioned at the crossroads of emerging and developed areas of study. Bibliometric research should (i) argue why now is the opportune time for study (e.g., maturity of event/field or proliferation of research in the field) and (ii) explain what will happen if the

findings and implications are not communicated (e.g., limitation of the field's progress or redundancy of other research). Energy as a theme has gained academic intention due to its utility across industries and households. There is scope for the theme in light of developments across the world for sustainable procurement of fuel. With global food security in light and depleting energy resources, inadequate study on the theme shall lead to imprudent policy framework.

Cluster 2

Motor Themes: The themes present in the upper right quadrant are called motor themes. These themes have strong internal as well as external ties making them central to the development of the topic, idea, concept or journal. Co-integration and volatility spillover among energy sources such as crude oil, natural gas and ethanol and agricultural futures contracts of corn, wheat, sugar, coffee, cotton, soybean, mustard oil and rice have intra and inter segment linkages. The study of the linkages provides a multiple horizon approach. Agricultural production and food supply rely on consumption of energy. Energy insecurity will have a negative impact on security of food.

Cluster 3

Basic Themes: The themes present in the lower right quadrant are called basic or traversal themes. These themes showcase weak internal development but strong external ties. Growth and biomass capture possible linkages in the agriculture-energy nexus. Response of the bio-energy market in the event of asymmetric price movements and market adjustments can help in understanding the association among the demand and supply factors.

Cluster 4

Emerging or Declining Themes: The themes present in the lower left quadrant are categorized as either emerging or declining themes. These themes have weak internal ties as well as weak external ties. Climate-change and pro-environment behavior are themes in their infancy. It attempts to connect the larger picture of attaining sustainability in terms of production and sourcing in energy and agricultural sectors. They are indirectly related to the futures markets.

Calculation associated to Research themes visualization

Identified networks can be represented in two forms namely Callon's centrality and Callon's density. Research themes for the entire sample is measured qualitatively and quantitatively. Each theme aims to establish prominence of the area with respect to the searched keywords on the basis of two measures - Callon's Centrality and density. Callon's centrality measures the strength of relationship among different clusters (Callon et al., 1991). Callon's centrality for a cluster can be measured and expressed as

$$c = 10\,X \sum (e_{kh})$$

Where

k refers to keyword for the selected cluster

h refers to keyword of the other cluster

e_{kh} refers to the link strength between the selected and the other related set of cluster

$$d = 100 \sum_{k=0}^{n} (e_{ij}/)$$

The summation of strength of such ties determines a cluster's centrality in the overall keyword network. Every cluster provides rich insights into the development of diverse components related to the themes. The academic and practical backdrops provide a multi-pronged lens on the subject, enriching the discourse with wide ranging perspectives.

4.3. Findings, Policy Recommendations and Implications of the Study

Research shows that biofuel price transmission connects agricultural and energy futures markets. Speculators gather price-sensitive information for profit, enhancing trade efficiency and market price discovery. This helps forecast the relationship between the two markets and informs risk-taking strategies. Speculators' investments add liquidity, affecting market price fluctuations. However, excessive speculation by institutional investors can lead to price rigging and market manipulation. Stakeholders and policymakers can use these findings to address issues in agricultural and energy futures. The literature review highlights the interdependence of these markets, especially with crops like corn and sugarcane for biofuel production. Based on the results obtained from the bibliometric analysis, the following areas have remained unexplored in the current literature.

a. Co-integration/Volatility spillover exists in agricultural and oil commodity markets

Agricultural markets have an inherent tendency towards price instability. For plantation and energy commodities, futures and spot markets are efficient in price discovery and information transmission. The futures market is more efficient in price discovery of agricultural commodities in India. Futures market provides price signals to farmers to make decisions on what to produce and when to sell. Global warming has exacerbated extreme weather events such as droughts and floods that lead to short-term fluctuations in global food supply. Oil price shocks induced volatility is yet to be classified as a short-term volatility inducing phenomenon or a long-term phenomenon. In such situations it is difficult for market players to differentiate between fundamental causes for price increase and the herd behavior related causes that then hampers price formation role of speculation. Market uncertainty acts as a driver for volatility.

Recommended Hypothesis (H01): There is significant impact of Volatility spillover between oil and agricultural futures returns in the commodity market during the normal/tranquil market conditions

b. Asymmetric herding exists in commodity futures markets in times of market volatility

Over the last two decades, interest of researchers and policy makers has increased in understanding large spikes in commodity prices. Excessive price movement among commodities can be attributed to herding. Herding can be defined as the phenomenon of investors imitating one another and basing their decisions on the larger market view. In contrast, anti-herding can be defined as a phenomenon when overemphasis is paid by investors on their self-perception or the perception of a subset of other market participants, that leads to a rise in cross-sectional dispersion. There are disputes among studies regarding the presence of herding, though anti herding behavior has been observed among oil and metal markets.

Despite herding having important implications in energy and agricultural commodities, the domain remains under-studied. Majority of previous studies ignore herding in agricultural markets. In agricultural commodity futures markets the engagement in terms of volumes has been found varying in different market conditions. Prior studies on herding report strong herding in times of volatile markets and there are asymmetric trends in times of different volatility states. In contrast, some studies state herding is not affected by the prevailing market conditions. The above empirical results present a strong case to study energy and agricultural futures markets in light of the market conditions.

Recommended Hypothesis (H02): There is a significant impact of herd behavior in the energy and agricultural futures markets during the extreme market conditions (rising and declining market).

c. Speculation leads to connectedness in agricultural and oil futures market

Scholastic studies on herding and speculation were seen mainly in developed countries focusing on securities, commodities and currency derivatives. Evidence on herding and speculation for agricultural commodity markets in emerging economies is limited. However, few of them emphasized evaluating the lead-lag association between spot and futures prices of commodity derivative contracts. A comprehensive outlook on speculation, spillover, herding and connectedness is a missing puzzle piece in the larger picture of the global agricultural and oil futures market.

Recommended Hypothesis (H03): Speculation has a significant impact on connectedness in the commodity returns in the agricultural and oil futures market.

Separation theorem according to which "when a futures market exists, the optimum production of the firm does not depend upon the (subjective) distribution of the random price nor the firm's attitude toward risk". Thus, whenever a futures market is available, the price and production of the commodity may grow independently. Hence, advancing beyond the empirical analysis of the fundamentals, future studies could concentrate on two external drivers of agricultural commodity prices: the energy sector represented by crude oil prices and natural gas and the financial sector reflected by futures prices.

The various roles and interdependencies among the identified themes. Firstly, future research could expand the scope of the literature by providing a broader perspective. As there is limited literature exploring the relationship between energy and agricultural futures, there is insufficient work in this specific domain. Future research could incorporate progress made over the years. In addition to EBSCO Business Source Complete, Scopus and Web of Science, other databases could be explored for inclusion. The paper focuses on energy and agricultural futures commodities.

5. Conclusion

The commodity futures market is essential for mitigating price risk in primary commodities (energy and agricultural products), enhancing welfare. Bibliometric analysis offers a structured scientific approach to examining conceptual theories, statistical measures, and extensive data. This review precedes a critical assessment of published literature in reputable journals. Literature failing to meet mathematical and statistical standards was excluded. A key aspect of risk management involves understanding market volatility timing, risk integration, and volatility magnitude. The differing movements of gas and oil reveal mixed evidence regarding their linkages to agricultural markets, indicating that natural gas and crude oil are not perfect substitutes.

During the 2008 global financial crisis, information spillovers from energy markets increased agricultural market volatility. Rising traditional energy prices during the crisis led to a shift towards new-age energy products. The research impacts portfolio strategies for agricultural processors, fund managers, speculative traders, and governmental policy formulation, aiding in understanding price patterns in agricultural and energy futures markets and improving efficiency. Future research should compare the reasons behind result differences across various approaches, as differences in methodology, data types, and markets hinder cross-paper comparisons. Comparative analyses are necessary to clarify the effects of policy instruments or market characteristics on research outcomes.

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