

Carbon Markets and Economic Signals : A Bibliometric Review of Global Research Trends and Emerging Themes

¹Loso Judijanto, ²Yana Priyana

¹IPOSS Jakarta, ²Master of Management Universitas Nusa Putra

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ABSTRACT

This study examines the global research landscape of carbon markets in connection with broader economic signals, drawing on 75 Scopus-indexed publications retrieved through a structured bibliometric search. Using VOSviewer as the principal analytical tool, the study constructs keyword co-occurrence networks to identify dominant research themes, thematic clusters, the temporal evolution of scholarly attention, and the relative concentration of research effort across the field. The network visualization reveals four interconnected clusters spanning carbon price dynamics and forecasting, carbon trading and commerce, emissions trading and environmental economics, and the energy-policy nexus surrounding electricity and power markets. The overlay analysis indicates that themes related to machine learning, forecasting, and China-centred carbon trading represent the most recently active research frontier, while emissions trading, environmental economics, and carbon sequestration reflect a comparatively earlier, established stream of inquiry. Density mapping confirms that carbon, carbon markets, and commerce constitute the most intensively researched nodes, functioning as the intellectual core that links price-formation mechanisms with macro-financial and policy signals. Citation analysis further identifies the publications that have most shaped the field's understanding of how energy prices, geopolitical risk, and financial market dynamics transmit into carbon price behaviour. Collectively, these findings depict carbon markets as an economically embedded research domain in which price discovery, risk spillovers, and forecasting innovation are increasingly studied as interconnected economic signals rather than isolated environmental phenomena.

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A. INTRODUCTION

Carbon markets have evolved from a narrowly defined environmental policy instrument into an economically significant arena where price signals interact with energy markets, financial assets, and macroeconomic conditions. Originating from cap-and-trade schemes such as the European Union Emissions Trading System, carbon pricing mechanisms were initially designed to internalize the social cost of greenhouse gas emissions (Redmond & Convery, 2015). Over the past decade, however, the carbon price has increasingly behaved as an economic signal in its own right, responding to and transmitting shocks from oil and gas prices, exchange rates, geopolitical risk, and investor sentiment (Duan et al., 2021), (Ren et al., 2022).

The growing entanglement of carbon markets with broader economic and financial systems has produced a rapidly expanding body of literature. Scholars have examined carbon price volatility and its drivers (X. Wang et al., 2025), (T. Zhang & Zou, 2025) the forecasting of carbon prices using machine learning and deep learning methods (Y. Wang et al., 2023), (Jiang et al., 2026) the connectedness between carbon, energy, and commodity markets (J.-H. Zhang, 2026), (Maneejuk et al., 2025) and the role of carbon markets in shaping corporate financial outcomes (Chen et al., 2024). This expansion spans disciplines including energy economics, financial economics, environmental policy, and data science, making it increasingly difficult to maintain a structured understanding of the field's intellectual trajectory.

Bibliometric analysis offers a systematic and reproducible approach for mapping the intellectual structure of a research domain. By examining keyword co-occurrence patterns, publication trends, and citation structures, bibliometric techniques allow researchers to identify dominant themes, trace the temporal evolution of scholarly attention, and uncover emerging frontiers without the subjectivity inherent in narrative literature reviews (J. Liu et al., 2025). Applied to carbon markets, bibliometric mapping can reveal how the field has moved from a primarily regulatory focus toward a more economically oriented research agenda centred on price discovery, volatility spillovers, and forecasting.

Despite the breadth of existing literature, comprehensive bibliometric studies that explicitly position carbon markets within the framework of economic signals remain limited. Many existing reviews focus narrowly on specific sub-themes such as carbon price forecasting or regional emissions trading schemes without offering an integrated view of how carbon markets intersect with energy prices, financial markets, and macroeconomic uncertainty (J.-H. Zhang, 2026) (Balcilar et al., 2025). This study addresses that gap by conducting a bibliometric review using 75 Scopus-indexed publications.

This study aims to: (1) identify dominant thematic clusters within the carbon markets literature; (2) trace the temporal evolution of research themes through overlay analysis; (3) examine the concentration of scholarly attention through density mapping; and (4) identify the most influential publications shaping the field through citation analysis.

B. RESEARCH METHOD

This study adopts a bibliometric methodology to systematically examine the global research landscape connecting carbon markets and economic signals. Bibliometric analysis evaluates the scientific output and intellectual structure of a research field through publication patterns, citation relationships, and keyword co-occurrence networks enabling systematic and reproducible mapping of a diverse and rapidly growing body of literature. The methodological design comprises three stages: data collection, data preparation, and bibliometric visualization and analysis.

Data were sourced from the Scopus database, selected for its broad coverage of peer-reviewed literature across energy economics, finance, environmental science, and engineering. The search was structured around keyword queries centred on carbon markets and related concepts, including carbon price,

carbon trading, emissions trading, and carbon economy, combined with terms reflecting economic and financial signals such as price volatility, forecasting, and market dynamics. The final dataset comprised 75 Scopus-indexed publications covering the period up to 2026, capturing both foundational contributions (Redmond & Convery, 2015) and the most recent developments in the field (Yan & Lin, 2026), (J.-H. Zhang, 2026).

Following data extraction, the dataset underwent cleaning in which duplicate entries and records with insufficient bibliographic information were removed. Bibliometric analyses were conducted using VOSviewer, a software application for constructing and visualizing bibliometric networks. The study employed keyword co-occurrence analysis as the primary analytical technique, with a minimum co-occurrence threshold applied to retain only meaningful associations. The resulting network was examined across three visualization modes: the network map illustrating thematic clustering; the overlay map depicting the temporal evolution of research themes based on average publication year; and the density map representing the relative concentration of research activity around each keyword node.

C. RESULTS AND DISCUSSION

Keyword Co-Occurrence Analysis

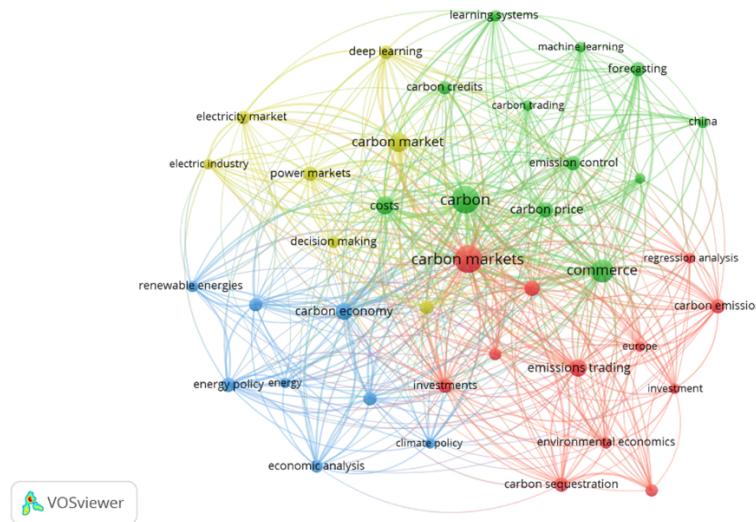


Figure 1. Network Visualization

Source: Data Analysis

Figure 1 presents the keyword co-occurrence network generated from the bibliometric analysis. The network displays a densely interconnected structure organized into four colour-coded thematic clusters, with node size reflecting keyword frequency and edge thickness reflecting co-occurrence strength. At the centre, *carbon markets*, *carbon*, and *commerce* occupy the most prominent positions, confirming their role as the conceptual anchors of the field.

The red cluster encompasses carbon markets, commerce, emissions trading, carbon emission, environmental economics, carbon sequestration, investment, and Europe, capturing the financial and regulatory dimension of the literature. This cluster reflects the substantial body of research examining emissions trading schemes and their connection to investment behaviour and environmental economics (Redmond & Convery, 2015),(Chen et al., 2024). The green cluster, centred on carbon, emission control, carbon price, machine learning, forecasting, and China, reflects the growing methodological stream applying

artificial intelligence to carbon price prediction (Balcilar et al., 2025). The prominence of China signals the volume of research conducted on its regional and national carbon trading pilots.

The yellow cluster, comprising electricity market, electric industry, power markets, carbon market, costs, and decision making, captures the energy-market dimension linking carbon pricing to power-sector decision making. The blue cluster including carbon economy, renewable energies, energy policy, and climate policy reflects the macroeconomic and policy-oriented stream examining how carbon markets interact with renewable energy investment (Ren et al., 2022), (Maneejuk et al., 2025). Collectively, the four clusters illustrate that carbon market research integrates price-formation mechanisms, forecasting methodology, and macro-financial signals within a single interconnected landscape.

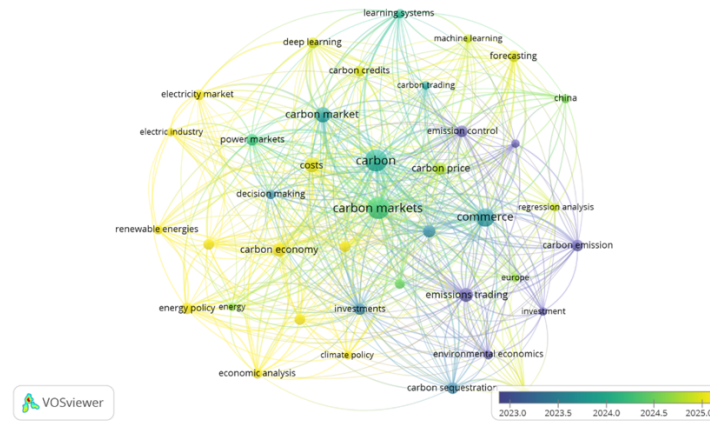


Figure 2. Overlay Visualization

Source: Data Analysis

Figure 2 presents the overlay visualization, in which node colour reflects the average publication year of articles associated with each keyword. Darker purple-blue tones indicate earlier research themes, while green and yellow tones signal more recent scholarly activity. Keywords such as *emissions trading*, *environmental economics*, *carbon sequestration*, and *europe* appear in darker tones, indicating these themes represent an earlier, more established stream of scholarship in the regulatory and environmental-economics domain (Duan et al., 2021), (Lyu et al., 2024).

In contrast, keywords displayed in bright yellow including *forecasting*, *machine learning*, *learning systems*, *electricity market*, and *renewable energies* signal the most recently active research themes. This pattern confirms that scholarly attention has shifted markedly toward artificial intelligence-based carbon price forecasting and the interaction between carbon and electricity market dynamics (Jiang et al., 2026), (Yi, 2025). Carbon, carbon markets, and carbon price occupy an intermediate teal green position, reflecting their status as enduring core themes active throughout the entire study period.

The temporal trajectory revealed by the overlay visualization carries important implications for understanding how carbon market research has responded to real world policy developments and technological innovations. The gradual colour shift from purple-blue toward yellow across the network suggests that the field has undergone a sustained methodological transformation rather than an abrupt paradigm change, with regulatory and economic themes continuing to anchor the literature even as newer computational approaches gain prominence (Tudor et al., 2025). This layered evolution reflects the cumulative nature of carbon market scholarship, in which foundational work on emissions trading mechanisms and environmental economics has not been displaced but rather supplemented by an emerging layer of data-intensive research that treats carbon prices as dynamic financial signals responsive to geopolitical shocks, energy market fluctuations, and macroeconomic uncertainty (Elsayed et al., 2025). The co-existence of older and newer thematic streams within a single, densely connected network further implies

that future advances in carbon price forecasting and market modelling are likely to draw simultaneously on the regulatory insights embedded in earlier scholarship and the predictive precision offered by contemporary machine learning architectures.

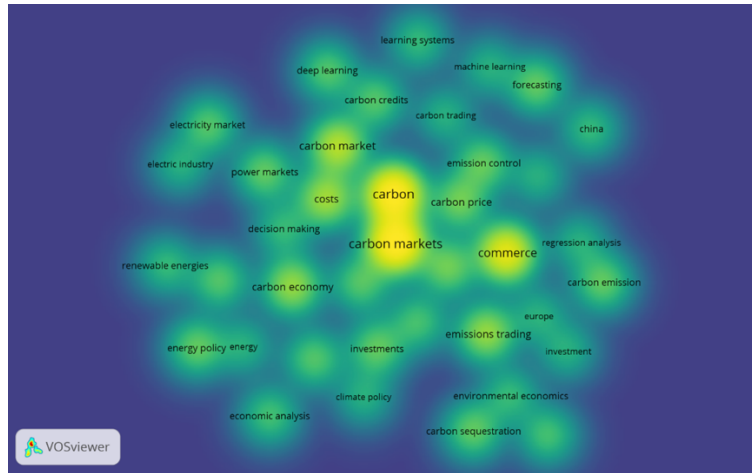


Figure 3. Density Visualization
Source: Data Analysis

Figure 3 presents the density visualization, in which bright yellow regions indicate high occurrence concentration and research intensity, while green and blue areas reflect progressively lower density. The highest density regions are concentrated around *carbon*, *carbon markets*, and *commerce*, confirming their dominance as organizing constructs. These nodes are characterized not only by high individual frequency but also by strong interconnectedness with surrounding conceptual domains including emissions trading, carbon price, and carbon economy (T. Zhang & Zou, 2025).

Moderate density areas, appearing in green tones, surround terms such as *emissions trading*, *carbon economy*, and *energy policy*, indicating well-developed but secondary research areas. Peripheral regions in blue encompass *forecasting*, *machine learning*, *china*, and *carbon sequestration*, suggesting active frontier zones with considerable potential for further intensification of scholarly attention relative to the established core (Elsayed et al., 2025).

The spatial contrast between the dense core and the diffuse periphery reflects the uneven maturation of knowledge within the carbon markets and economic signals domain. While carbon, carbon markets, and commerce have achieved considerable conceptual depth through decades of sustained scholarly engagement, adjacent themes such as forecasting, machine learning, china, and carbon sequestration remain comparatively underexplored relative to their growing policy and methodological relevance (Paraschiv et al., 2024). The moderate-density zone surrounding energy policy, carbon economy, and renewable energies occupies a strategically significant transitional position between the established regulatory core and the emerging technology-driven periphery, yet the research intensity in this area remains lower than might be expected given the urgency of the energy-carbon nexus in contemporary climate policy discourse (Maneejuk et al., 2025), (Tudor et al., 2025). Collectively, these density patterns suggest that the field's conceptual infrastructure is sufficiently mature to support deeper integration of data driven forecasting methods and region-specific market analyses into its mainstream scholarly agenda, with the peripheral frontier zones representing the most promising terrain for future research investment (H. Wang & Lyu, 2025).

Citation Analysis

Table 1. Most Cited Article

Citations	Author and Year	Title	Publication
88	(Duan et al., 2021)	The marginal impacts of energy prices on carbon price variations: Evidence from a quantile-on-quantile approach	Energy Economics
61	(Ren et al., 2022)	Asymmetric effects of decomposed oil-price shocks on the EU carbon market dynamics	Energy
47	(Redmond & Convery, 2015)	The global carbon market-mechanism landscape: Pre and post 2020 perspectives	Climate Policy
29	(Lyu et al., 2024)	Volatility spillovers and carbon price in the Nordic wholesale electricity markets	Energy Economics
24	(Chen et al., 2024)	Belated stock returns for green innovation under carbon emissions trading market	Journal of Corporate Finance
18	(Maneejuk et al., 2025)	Asymmetric volatility spillover effects from energy, agriculture, green bond, and financial market uncertainty on carbon market	Energy Economics
16	(Y. Wang et al., 2023)	A novel deep learning carbon price short-term prediction model with dual-stage attention mechanism	Applied Energy
14	(Balcilar et al., 2025)	Technological innovations fuel carbon prices and transform environmental management across Europe	Journal of Environmental Management
11	(Elsayed et al., 2025)	AI and carbon pricing in turbulent times: Navigating market dynamics for a sustainable future	International Review of Financial Analysis
9	(S. Liu et al., 2025)	An agent-based approach to modeling power firms' emission reduction strategies and market dynamics	Applied Energy

Source: Scopus, 2026

Discussion

The findings of this bibliometric analysis depict carbon markets as an economically embedded research domain whose intellectual structure increasingly mirrors that of conventional financial and commodity markets. The consistent prominence of carbon, carbon markets, and commerce across all three visualization modes confirms that the field's core architecture remains organized around price formation and trading mechanisms, even as surrounding thematic clusters diversify (Duan et al., 2021).

A significant finding concerns the growing scholarly attention devoted to machine learning, forecasting, and the interaction between carbon and electricity markets, as confirmed by the overlay visualization. This trend suggests that researchers are increasingly moving beyond examining whether macroeconomic variables affect carbon prices, toward developing data-driven tools capable of anticipating price movements under conditions of geopolitical and market uncertainty (Jiang et al., 2026). This evolution

mirrors broader developments in financial economics, where machine learning and time-series foundation models have become dominant methodological themes in price prediction research (Li et al., 2026).

The density visualization reinforces these observations by confirming that while the conceptual core remains tightly organized around carbon, carbon markets, and commerce, emerging thematic zones including renewable energy investment, geopolitical risk transmission, and AI-based forecasting are gaining scholarly momentum (Elsayed et al., 2025), (Maneejuk et al., 2025). The continued centrality of emissions trading and environmental economics also reflects substantial regulatory and policy interest in understanding how cap-and-trade mechanisms translate into measurable economic and environmental outcomes (Tudor et al., 2025).

The citation analysis identifies the specific contributions that have most significantly shaped the field's treatment of carbon prices as economic signals. The prominence of (Duan et al., 2021) and (Ren et al., 2022) reflects the field's continued reliance on quantile-based and shock-decomposition methods for understanding the asymmetric transmission of energy and oil-price shocks into carbon markets. The appearance of recent contributions on geopolitical risk, agent-based modelling, and AI-driven forecasting within the most influential works underscores the field's expansion from static regulatory analysis toward dynamic, economically integrated modelling of carbon price behaviour (Balcilar et al., 2025).

Theoretically, the findings suggest that carbon market research stands at an important juncture. The convergence of traditional emissions-trading frameworks with energy-price transmission mechanisms, geopolitical risk analysis, and machine-learning forecasting creates significant opportunities for theoretical and methodological integration. At the same time, this convergence raises questions about the conceptual boundaries of carbon markets, particularly as financial instruments such as carbon ETFs and decentralized finance tokens increasingly intersect with traditional emissions allowances (Katoch & Khan, 2026), these questions represents a timely agenda for future research.

D. CONCLUSION

This study concludes that carbon markets have developed into an economically embedded and methodologically diverse research field within global energy and environmental economics. Based on the bibliometric analysis of 75 Scopus-indexed publications, the findings show that the literature is strongly centred on the relationship between carbon, carbon markets, commerce, carbon price, and emissions trading. The keyword co-occurrence analysis confirms that carbon markets function as the main intellectual anchor of the field, while related concepts such as carbon price, carbon trading, and carbon economy form the core thematic foundation that connects regulatory frameworks with broader economic and financial systems.

The results indicate that the field has expanded well beyond its original regulatory focus on emissions trading. Recent studies increasingly connect carbon markets with machine learning-based forecasting, electricity market dynamics, geopolitical risk, and cross-market volatility spillovers. This shift demonstrates that current scholarship no longer treats carbon prices solely as policy outcomes, but increasingly examines them as economic signals embedded within broader energy, financial, and commodity market systems, reflecting the growing interdisciplinary character of the field.

The citation analysis confirms the enduring influence of foundational methodological contributions on energy-price transmission and quantile-based modelling, alongside early regulatory overviews, as the works that have most significantly shaped the field's intellectual development. At the same time, the rapid rise of AI-driven forecasting and cross-market spillover research as highly cited streams signals a meaningful reorientation of scholarly priorities. Future research should give greater attention to the integration of real-time geopolitical risk indicators, cross-asset connectedness analysis, and regional carbon trading scheme heterogeneity to provide a more nuanced and comprehensive understanding of how carbon pricing mechanisms contribute to long-term economic resilience and environmental stability.

REFERENCES

- Balcilar, M., Elsayed, A. H., Khalfaoui, R., & Hammoudeh, S. (2025). Technological innovations fuel carbon prices and transform environmental management across Europe. *Journal of Environmental Management*, 373. <https://doi.org/10.1016/j.jenvman.2024.123663>
- Chen, F., Chen, Z., & Zhang, X. (2024). Belated stock returns for green innovation under carbon emissions trading market. *Journal of Corporate Finance*, 85. <https://doi.org/10.1016/j.jcorpfin.2024.102558>
- Duan, K., Ren, X., Shi, Y., Mishra, T., & Yan, C. (2021). The marginal impacts of energy prices on carbon price variations: Evidence from a quantile-on-quantile approach. *Energy Economics*, 95. <https://doi.org/10.1016/j.eneco.2021.105131>
- Elsayed, A. H., Khalfaoui, R., Zhang, D., & Urquhart, A. (2025). AI and carbon pricing in turbulent times: Navigating market dynamics for a sustainable future. *International Review of Financial Analysis*, 107. <https://doi.org/10.1016/j.irfa.2025.104632>
- Jiang, L. L., Cheong, W. S., & Ng, J. S. L. (2026). Multi-step ahead carbon credit price forecasting using time series foundation models. *Applied Soft Computing*, 198. <https://doi.org/10.1016/j.asoc.2026.115290>
- Katoch, R., & Khan, S. (2026). Co-movements of NFTs, DeFi tokens and carbon ETFs: nonlinear dynamics and sustainable portfolio implications. *Managerial Finance*, 1–24. <https://doi.org/10.1108/MF-09-2025-0740>
- Li, W., Kang, J., & Wei, Y. (2026). Unstructured news data and carbon price forecasting: a topic-sentiment approach for China's emission allowance market. *Applied Economics Letters*. <https://doi.org/10.1080/13504851.2026.2654786>
- Liu, J., Lee, Y.-H., Li, B.-A., & Yang, J. J. (2025). Home bias and herding in carbon market trading. *Finance Research Letters*, 78. <https://doi.org/10.1016/j.frl.2025.107099>
- Liu, S., Zhou, P., Wang, M., & Xu, A. (2025). An agent-based approach to modeling power firms' emission reduction strategies and market dynamics. *Applied Energy*, 400. <https://doi.org/10.1016/j.apenergy.2025.126590>
- Lyu, C., Do, H. X., Nepal, R., & Jamasb, T. (2024). Volatility spillovers and carbon price in the Nordic wholesale electricity markets. *Energy Economics*, 134. <https://doi.org/10.1016/j.eneco.2024.107559>
- Maneejuk, P., Huang, W., & Yamaka, W. (2025). Asymmetric volatility spillover effects from energy, agriculture, green bond, and financial market uncertainty on carbon market during major market crisis. *Energy Economics*, 145. <https://doi.org/10.1016/j.eneco.2025.108430>
- Paraschiv, F., Schmid, H., Schmitz, M., Dünwald, V., & Groos, E. (2024). The Interplay Between China's Regulated and Voluntary Carbon Markets and Its Influence on Renewable Energy Development—A Literature Review. *Energies*, 17(22). <https://doi.org/10.3390/en17225587>
- Redmond, L., & Convery, F. (2015). The global carbon market-mechanism landscape: pre and post 2020 perspectives. *Climate Policy*, 15(5), 647–669. <https://doi.org/10.1080/14693062.2014.965126>
- Ren, X., Li, Y., Qi, Y., & Duan, K. (2022). Asymmetric effects of decomposed oil-price shocks on the EU carbon market dynamics. *Energy*, 254. <https://doi.org/10.1016/j.energy.2022.124172>
- Tudor, C., Girlovan, A., Sova, R., Sierra, J., & Stancu, G. R. (2025). From Policy to Prices: How Carbon Markets Transmit Shocks Across Energy and Labor Systems. *Energies*, 18(15). <https://doi.org/10.3390/en18154125>
- Wang, H., & Lyu, K. (2025). Environmental tone and carbon market behavior: Understanding market

- dynamics through corporate environmental attitudes in China. *Structural Change and Economic Dynamics*, 74, 792–813. <https://doi.org/10.1016/j.strueco.2025.06.007>
- Wang, X., Lu, F., Safi, A., & Li, X. (2025). Unraveling the dynamics of carbon price volatility: A comprehensive analysis of impacts from climate policy, fossil fuel and renewable energy shocks. *Energy Strategy Reviews*, 62. <https://doi.org/10.1016/j.esr.2025.101966>
- Wang, Y., Qin, L., Wang, Q., Chen, Y., Yang, Q., Xing, L., & Ba, S. (2023). A novel deep learning carbon price short-term prediction model with dual-stage attention mechanism. *Applied Energy*, 347. <https://doi.org/10.1016/j.apenergy.2023.121380>
- Yan, K., & Lin, B. (2026). Carbon–agriculture market connectedness under the EU ETS: Evidence on sectoral heterogeneity and market states. *Energy Economics*, 154. <https://doi.org/10.1016/j.eneco.2026.109160>
- Yi, Y. (2025). Forecasting regional carbon prices in china with a hybrid model based on quadratic decomposition and comprehensive feature screening. *PLOS ONE*, 20(6 June). <https://doi.org/10.1371/journal.pone.0326926>
- Zhang, J.-H. (2026). Dynamic connectedness among the carbon, financial, energy, and commodity markets and geopolitical uncertainty: A TVP-VAR-DY time-frequency spillover network approach. *Energy Reports*, 15. <https://doi.org/10.1016/j.egy.2026.109340>
- Zhang, T., & Zou, S. (2025). Study on the Nonlinear Volatility Correlation Characteristics Between China's Carbon and Energy Markets. *Risks*, 13(10). <https://doi.org/10.3390/risks13100205>