

Original Paper

Carbon Trading in BRICS Countries: Challenges and Recommendations

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Abstract

As one of the world's largest emerging economies, BRICS countries are playing an increasingly important role in addressing the global issue of climate change. To achieve their emissions reduction targets, these nations are actively promoting the construction of carbon trading markets. However, they face multiple challenges and obstacles in this endeavor, including issues related to market norms, financial support, technical capacity, social participation, and development needs. This research investigates the problems and challenges faced by BRICS countries in terms of building carbon trading markets through literature reviews and case studies. To address these challenges, this research strengthening international cooperation and technical support, improving market norms and provide following recommendations: conducting regulatory measures, enhancing social participation and communication, and balancing the relationship between economic development and environmental protection requirements. Furthermore, it is crucial for these nations to continue to strengthen international cooperation and collaboration, working together to promote the construction of carbon trading markets, achieving their emissions reduction targets, and ensuring long-term sustainability and economic development.

Keywords

BRICS, carbon trading market, challenges

1. Introduction

The BRICS countries, as major emerging economies, are assuming increasingly important responsibilities in addressing global climate change. Mitigating climate change has become a common

challenge for these countries, and controlling carbon emissions has become a key direction of their mitigation efforts. Emissions trading has emerged as a significant tool for carbon mitigation, and has been widely implemented on the international stage as a crucial part of global climate governance. However, the BRICS countries are facing various challenges and issues in implementing emissions trading, including market norms, financing support, technical capacity, social participation, and the balance between environmental protection and economic development.

This paper aims to explore the challenges and issues faced by the five BRICS countries in implementing emissions trading, analyze the causes and impacts, and propose solutions and recommendations. By conducting case studies and literature reviews of emissions trading in different countries, we can gain insights into their experiences and lessons learned in implementing this tool. We will also examine the role of international cooperation and technical support in the development of emissions trading, as well as the importance of community engagement and communication in promoting carbon mitigation. This study is significant in providing policymakers, businesses, and other stakeholders in the BRICS countries with a deeper understanding of emissions trading, and helping them better address the challenges of carbon mitigation, promote the development and operation of emissions trading, and contribute to global climate governance.

2. Literature Review

Global climate change is one of the most challenging issues facing mankind, and it has become an urgent issue on a global scale. Human activities since the Industrial Revolution have led to the emission of a large amount of greenhouse gases, mainly carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O) and freon. Carbon dioxide, as the main greenhouse gas, accounts for 72% of the total greenhouse gas emissions (Miroslav, Elma, & Aqib, 2022). These greenhouse gases form an insulating layer in the atmosphere, causing the Earth's temperature to rise and triggering abnormal global climate changes. Global warming has resulted in an increase in extreme weather events, including heatwaves, floods, droughts and storms, with widespread impacts on ecosystems, agriculture and human society (Yanlong, Zefang, Fuxin, et al., 2022; Prisyazhniuk, 2022; Guiyang, Jie, Xinyan, et al., 2022). The United Nations Framework Convention on Climate Change (UNFCCC) was established in 1992 to coordinate the international response to climate change. Countries reduce emissions through national emission reduction targets and policies, and seek reasonable market mechanisms to achieve emission reduction targets, among which the carbon trading market has become an important way.

The BRICS countries - Brazil, Russia, India, China, and South Africa - play a crucial role in global climate governance. As the world's five emerging economies, they have large populations and abundant resources, but also face complex challenges between development and climate change. With the rapid development of economic globalization, the vertical division of labor mode of the global industrial chain has led to the transfer of industries with high emissions, high consumption and low output to the BRICS countries, and the change of lifestyle has led to an increase in energy demand and energy use

(Nemec, 2019; Anonymous, 2020; Ermida, 2015). The governments of the BRICS countries have taken active measures, committed themselves to formulating emission reduction targets and policies, and actively participated in global emission reduction efforts. China, the world's largest carbon emitter, has taken a number of measures to achieve carbon neutrality, including establishing a carbon market, promoting green energy development, and improving energy efficiency (Guan, Meng, Reiner, et al., 2018). India, the world's third-largest carbon emitter, has pushed ahead with large-scale investments in renewable energy and clean technologies to reduce its dependence on fossil fuels. Brazil is working to reduce carbon emissions from deforestation by implementing a Zero deforestation program (Kumar & Archana, 2022). Russia has focused on promoting clean energy and energy efficiency and reducing the use of fossil fuels. South Africa is also actively promoting clean energy and carbon emission reduction policies to achieve sustainable development.

The carbon trading market is a market mechanism that promotes emission reduction by buying and selling carbon emission allowances (Mansoor, Chuanmin, & Maqsood, 2022; Lucon, Romeiro, & Pacca, 2013). The basic principle is to assign emission reduction targets to enterprises or countries, and enterprises need to ensure that emissions do not exceed the assigned target. If they do, they need to buy additional emission allowances; if emissions fall below the allocated target, the remaining emission allowances can be sold. Such a market mechanism can encourage enterprises and organizations to take emission reduction measures to achieve a win-win situation of economic and environmental benefits. The carbon trading market mainly includes two forms: emissions trading and carbon offset. Emissions trading refers to the trading of carbon emission allowances between companies or countries in the market to form a carbon price (Jing, Yijing, & Jian, 2023; Haijing & Qin, 2022). Carbon offsetting refers to reducing or offsetting emissions by supporting environmentally friendly projects and obtaining corresponding emission reduction credits (FeiFei, LongHao, HaiTian, et al., 2022; Asrin & Salah, 2023). Carbon offset projects include forest conservation, renewable energy development, waste disposal, and more (Tian, Xuantao, Yuhe, et al., 2023; Yao, 2022). The development of carbon markets has gone through several stages.

The international carbon trading market experience and case studies provide valuable reference for BRICS countries in the construction of carbon trading markets. The EU Emissions Trading System (EU ETS), for instance, is one of the world's largest carbon trading markets, launched in 2005 and covering a wide range of industrial sectors across Europe (Mingzhi, Hongyu, Jianxu, et al., 2022; Andriana & Georgios, 2022; Sustainability Research, 2019). The EU ETS has accumulated a wealth of experience through years of development and continuous improvement of market design and management. Through the study of EU ETS, we can understand the EU's policy experience in carbon market design, quota allocation, market price fluctuation, and so on. Other countries such as Ontario, Canada, Australia, and New Zealand have also launched carbon trading markets. Academic literature on carbon trading markets, climate change, and global governance can provide valuable insights into the design, implementation, and evaluation of carbon trading markets.

In conclusion, global climate change poses a significant challenge that requires urgent attention and action. The BRICS countries have a critical role to play in global climate governance. The carbon trading market can be an effective mechanism for achieving emission reduction targets while promoting economic growth and environmental sustainability. By learning from the international experience and case studies, BRICS countries can construct well-designed and effective carbon trading markets to achieve their emission reduction targets and contribute to global efforts to address climate change.

3. Carbon Trading Development in BRICS Countries

Between 2010 and 2019, India's carbon emissions from fossil energy consumption increased by 68.26%, from 1383.81 million tonnes to 2328.44 million tonnes. Brazil's carbon emissions from fossil energy consumption increased by 29.65% during the same period, from 360.29 million tonnes to 416.77 million tonnes in 2019. South Africa's CO₂ emissions from fossil energy consumption decreased by 8% from 2010 to 2019, from 391.33 million tonnes to 360.02 million tonnes. Russia's CO₂ emissions from fossil fuels increased by about 5.62% from 1433.32 million tons to 1513.81 million tons in 2019 (Sustainability Research, 2019). Figure 1 shows the trend of CO₂ emissions in BRICS countries.

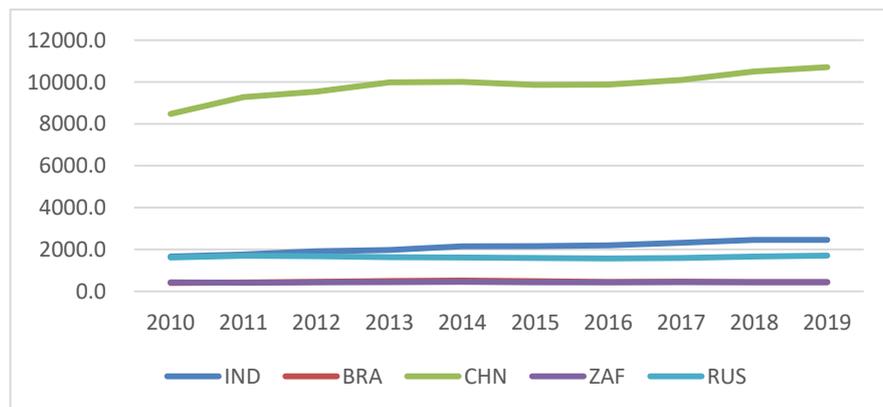


Figure 1. The Trend of CO₂ Emissions in BRICS Countries (Million Tons)

China is expected to be the world's highest carbon emitter in 2022, with total carbon emissions of about 12.1 billion tons, contributing to the world's total carbon emissions of about 36.8 billion tons. However, China has pledged to achieve the peak of carbon emissions before 2030 and carbon neutrality before 2060, as announced at the General debate of the United Nations General Assembly in 2020 (Hengge, Panizza, & Varghese, 2023). These targets demonstrate China's commitment to tackling climate change and reducing greenhouse gas emissions. China has also taken steps to establish a national carbon market, with the Ministry of Ecology and Environment and other ministries announcing the opening of a unified national carbon trading market in June 2021 (Xiang, Dingyu, Xuanta, et al., 2022; Xiaosong, Qian, Sha, et al., 2023).

Brazil, as one of the world's largest rainforest countries and carbon sinks, has set a target of reducing emissions by 20% by 2020 and becoming carbon neutral by 2050. To achieve these goals, the Brazilian government has formulated comprehensive and appropriate low-carbon economic policies to promote the development of bioenergy and increase the international influence of domestic CDM (Anonymous, 2008). However, the approval process of CDM projects in Brazil has been criticized for being cumbersome, opaque, and inefficient, which has affected the development of the carbon trading market. Brazil has launched programs like the Amazon Fund and REDD+ to protect the Amazon rainforest, reduce deforestation, and sell forest carbon sinks to the international community.

India, as the world's third-largest carbon emitter, has growing energy needs and environmental problems like air pollution and climate change. The Indian government has implemented policy initiatives like the PAT mechanism and carbon financial derivatives trading to encourage energy efficiency and carbon financing (Barman & Chakraborty, 2013). In 2021, the Indian government announced the National Carbon Market program to establish a national carbon market, covering industries like steel, power, cement, and textiles.

South Africa, as one of the most industrialized and developed countries in Africa, has taken proactive measures to reduce greenhouse gas emissions by 34% by 2030 and achieve carbon peak by 2050 (Qu, Suphachalasai, Thube, et al., 2023). The South African government has implemented the Carbon Tax, the first African country to do so, to encourage companies to reduce their carbon emissions. South Africa has also developed the Renewable Energy Independent Power Producer Procurement Program to encourage private companies to invest in and build renewable energy projects (Research and Markets, 2018). The African Carbon Markets Initiative, launched at the 27th Conference of the Parties to the United Nations Framework Convention on Climate Change (COP27), aims to accelerate the development of voluntary carbon markets in Africa.

Russia, as the world's largest producer of natural gas and one of the world's largest oil producers, has faced challenges in reducing its carbon emissions while maintaining its economic growth. Russia has set a target of reducing its greenhouse gas emissions by 30% below its 1990 levels by 2030. To achieve this target, Russia has implemented policies like the Energy Strategy of Russia and the Clean Energy Plan, which aim to increase the use of renewable energy and improve energy efficiency. However, Russia has also been criticized for its lack of ambition in tackling climate change and its dependence on fossil fuels.

4. Challenges and Recommendations in the Carbon Trading

4.1 Challenges Facing the Carbon Trading

In the process of reviewing the development of carbon trading markets in BRICS countries, it is clear that these countries are facing a challenge in balancing economic growth with environmental protection. For instance, Russia has been slow to promote the construction of a carbon trading market and achieve carbon emission reductions due to economic constraints. The construction of carbon trading markets

requires enterprises to reduce emissions and transform their operations, but in some industries, such as those with high energy intensity and carbon emissions, this may result in economic pressures and job losses (Chunyang, Zhili, Hui, et al., 2013).

In addition to economic challenges, BRICS countries also face challenges in terms of market norms and supervision during the construction of carbon trading markets. For example, while India has an active carbon trading market, there is a lack of regulation regarding how the market operates. The regulatory institutions and policy frameworks for carbon markets are not yet perfect. As a new market mechanism, countries may lack relevant experience and complete laws and regulations to ensure the stable operation of the market and fair competition. Coordination and cooperation among all relevant departments is also required for the complex cross-sector and cross-industry management of carbon markets (Peihong, Hui, Chunming, et al., 2023). Furthermore, the carbon trading market requires long-term policy support and regulatory guarantees from the government, as its stability and long-term nature are a challenge (Zhao, Jinghui, Ni, et al., 2022). Financing has also become a major issue in the development of carbon trading markets in BRICS countries due to the relatively volatile returns of the carbon market, which may cause some investors to be hesitant to participate. As such, attracting public and private capital to participate in the carbon trading market and improving market liquidity are urgent issues to be addressed.

Technical capacity building is a key link in the construction of carbon trading markets, as the market requires an efficient carbon emission data monitoring and verification system to ensure the accuracy and reliability of emissions data (Qunli, Xinxin, & Ye, 2021). Some BRICS countries may face insufficient technical capacity building. Additionally, the application of digital technology in the carbon trading market is crucial, such as blockchain technology, which can improve the transparency and security of transactions. BRICS countries need to strengthen international cooperation and technical support in the construction of carbon trading markets. The carbon market is a global issue that requires the cooperation of all countries. Therefore, the BRICS countries should strengthen information exchange and cooperation, learn from international advanced experiences, and jointly solve problems faced by the carbon trading market. Developed countries have rich technology and experience in the development of carbon markets, and BRICS countries can seek international technical support to accelerate the process of building carbon trading markets.

Building a carbon market involves many uncertainties and risks (Huan & Jingyu, 2022). The accuracy of carbon emission data, fluctuations in market prices, policy changes, and other factors may affect the stable operation of the market. In addition, the laws, regulations, and policy systems related to carbon markets in BRICS countries need to be improved. Establishing and improving laws and regulations that meet the needs of the carbon trading market, clarifying the rights and responsibilities of market participants, and standardizing market trading behaviors and supervision mechanisms are necessary. The success of carbon trading markets cannot be achieved without extensive social participation and information dissemination. However, in some countries, public understanding of the carbon trading market is limited, and social participation is low.

4.2 Recommendations

Achieving a balance between economic development and environmental protection is a critical consideration in the construction of carbon trading markets. Governments may implement differential policies to provide transitional support for industries with high carbon emissions, such as the manufacturing and energy sectors, that are vital to the economy. For instance, the government could provide tax incentives to encourage the adoption of cleaner production technologies or offer subsidies for the development of low-carbon industries. By gradually guiding these industries towards sustainable practices, the carbon trading market can facilitate a smooth transition to a low-carbon economy.

To address the financing problem, governments may establish a carbon trading development fund to provide loans and financial support to market participants. For example, the Chinese government created the China Carbon Market Development Fund to provide financial support to carbon trading companies. Encouraging financial institutions to participate in the carbon trading market can also promote the deep integration of financial capital and the carbon market, improving market liquidity. Furthermore, the establishment of a robust system of laws, regulations, and policies is crucial for the stable operation of the carbon trading market. Governments should strengthen legislation to clarify the management system and regulatory body of the market and establish a long-term and stable carbon emission reduction target and policy to provide a predictable market environment. This will attract more enterprises and investors to participate in the carbon trading market, promoting sustainable economic development.

The construction of carbon trading markets involves many uncertainties and risks, and it is necessary to establish a sound evaluation and monitoring mechanism. Governments may regularly assess the operation of the market and the effect of policy implementation and take timely adjustment measures when problems are found. A monitoring system may be established to strengthen the monitoring and verification of carbon emission data to ensure the accuracy and reliability of market data (Xiaolin, JunWei, Kai, et al., 2022). The establishment of a risk management system, coupled with timely release of market information and the strengthening of the monitoring and analysis of market fluctuations, can stabilize market expectations. Furthermore, enterprises may adopt risk management measures to improve their coping ability in the market.

In addition, international cooperation is crucial for the healthy development of carbon trading markets. BRICS countries may seek international technical support and cooperation, learn from international advanced experience, and enhance the technical level and management capacity of carbon trading markets (Weng & Xu, 2018). For example, developed countries may provide technical guidance and resource support to BRICS countries. Carbon trading summits and seminars may also be held to share experiences and best practices. To accelerate the development of carbon trading markets, BRICS countries may promote the integration of carbon markets with other markets, such as the energy market and financial market, to promote the diversification of market participants. The interaction of the

carbon market with the carbon offset market can also help achieve a broader reduction in carbon emissions.

Strengthening social participation is key to the success of the carbon trading market (Xiaosong, Qian, Sha, et al., 2022). Governments should strengthen the publicity and education of the carbon market, improving the public's awareness and understanding. Enterprises, non-governmental organizations, and citizens may be encouraged to participate in the carbon trading market and form diversified market players. By promoting cooperation among countries and stakeholders, the carbon trading market can contribute to the realization of global carbon emission reduction targets.

5. Case Study of Carbon Trading Market in China

On July 16, 2021, China inaugurated its unified carbon trading market on the Shanghai Environment and Energy Exchange, with the electric power sector being the sole industry currently included in the national carbon trading market. The market encompasses 2,162 key emission enterprises. As of July 16, 2023, after two years of market trading, the cumulative volume of carbon emission allowances has reached 240 million tons, with a turnover of 11.03 billion yuan. The opening price on the first day increased by 25% over the two-year period. Despite the 11.03 billion yuan turnover over two years, the national carbon market still exhibits a distinct seasonality. Specifically, statistics indicate that the volume of the first compliance period for the national carbon market concentrates towards the end of 2021, with November and December accounting for almost 90% of the total volume for the year. Trading prices have shown a steady upward trend, with the closing price on July 14 reaching 60 yuan/ton, representing a 9% increase from the first trading day of the year, and a 25% increase from the opening day of the national carbon market at 48 yuan/ton. CEA listed trading prices trend from January to July 2023 is shown in Figure 2.

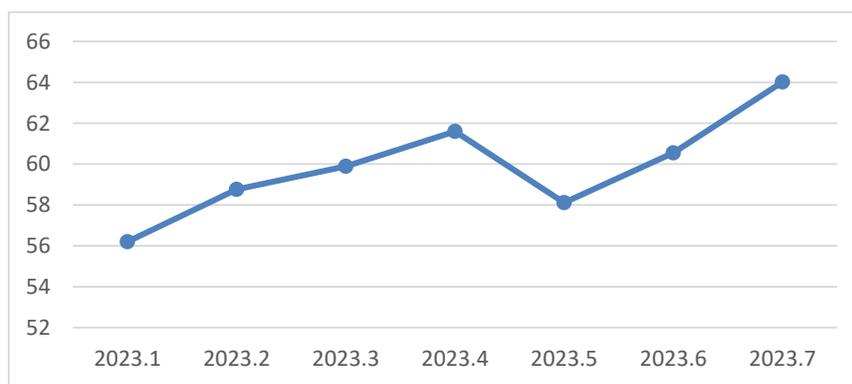


Figure 2. CEA Listed Trading Prices Trend from January to July 2023 (yuan)

At present, the national carbon trading market is beset by shortcomings and problems in various aspects. First, the turnover of the first year of the national carbon trading market remains too low, which is largely attributable to the limited number of players in the first compliance period and the restricted

industry scope to the electric power sector. The two types of traded products in the market are carbon emission allowances (CEAs) and Certified Voluntary Emission reductions (CCERs), which are allocated by the government to companies (Lu, Ma, Huang, et al., 2020). Due to a dearth of suitable dual-carbon professionals, many enterprises lack an understanding of the accounting, pricing, and trading of carbon sinks and carbon emission rights. Additionally, China's carbon trading market offers two basic products: CEA and CCER. Carbon emission allowances of emission control enterprises under the purview of the national carbon emission trading market are currently distributed free-of-charge by the ecological environment authorities in the province where the enterprises are located (Xiaoxia, Jialiang, & Hongda, 2022). The current situation of carbon emission quota allocation is mainly based on free allocation, which limits the value discovery of carbon price and leads to insufficient activity in carbon trading. Companies that sell carbon emission allowances are typically those with surplus allowances and no compliance pressure. They can either sell their surplus allowances in the market or carry them forward to the next year for compliance, usually taking into account their own energy-saving and carbon reduction costs, as well as the transaction price of current voluntary emission reduction projects. If the carbon price is too low, companies with surplus quotas will be unable to make profits through carbon trading, thereby reducing the enthusiasm of enterprises for green and low-carbon development, and squeezing or even eliminating the living space of emission reduction enterprises.

From the perspective of the market as a whole, the demand for quotas is relatively high, while the supplier's reluctance to sell is relatively apparent. The market trading activity is insufficient, and there is still significant room for carbon price to rise. China's national carbon trading market is in its infancy and inevitably faces various problems (Xiao-Qing, Chi-Wei, & Oana-Ramona, 2022). In order to further promote the healthy development of the national carbon trading market, it is necessary to address the following issues: Firstly, improve carbon trading legislation to enhance relevant laws and regulations governing carbon trading and clarify the responsibilities of market participants. Promulgation of relevant laws and regulations on carbon trading can specify the elements and conditions in the process of market operation. Furthermore, coordination among departments related to carbon trading should be strengthened to ensure effective implementation of regulatory tasks. Secondly, expand the trading body, as the current national carbon trading market only includes the electric power sector. According to the previous plan, during the "14th Five-Year Plan" period, China's eight high-emission industries - thermal power, building materials, steel, nonferrous metals, petrochemicals, chemicals, paper making, and aviation - will gradually and orderly be incorporated into the carbon market. Thus, on the second anniversary of the carbon trading market, the main body of the national carbon emission trading market will accelerate its expansion (Lin & Jia, 2019). Thirdly, enrich quota allocation methods. The cost of carbon emission reduction differs between the beneficiaries and the bearers under different quota allocation methods (Jianguo, Xuejing, Baoling, et al., 2019). Therefore, whether carbon trading can effectively play the advantages of market allocation is crucial. In the initial phase, free quotas can be issued primarily to improve the enthusiasm of market trading. However, with

the development and improvement of the carbon trading market, the bearing capacity of various industries and regions and the differences in the development level of emission reduction technologies should be fully considered. The proportion of auction allocation should be gradually increased to stimulate enterprise initiative in active emission reduction participation.

6. Conclusion

This paper examines the challenges and issues facing carbon trading markets in BRICS countries and offers corresponding solutions. Global climate change is one of the most pressing issues facing the world today. As significant economies in the world, BRICS countries are playing an increasingly pivotal role in tackling climate change. In order to meet their carbon emission reduction goals, BRICS countries have attempted to establish carbon trading markets. However, during this process, they have encountered a range of challenges, such as market regulation and oversight, financial support and financing, technical capacity building, social participation and information dissemination, and the balance between economic development and environmental protection. To address these challenges, this paper proposes several specific countermeasures and suggestions. These include establishing and refining the system of laws, regulations, and policies, enhancing technical capacity building, expanding financial support channels, and strengthening international cooperation and information exchange. Moreover, BRICS countries can learn from China's experiences in building carbon trading markets.

Moving forward, BRICS countries face both challenges and opportunities in constructing carbon trading markets and addressing climate change. First and foremost, the global climate change situation is alarming, and all countries must work together to form a coordinated global emission reduction force. To this end, BRICS countries can reinforce their cooperation by sharing their experiences and technologies in carbon market construction, and jointly promote the development of the carbon trading market. Additionally, the development of the carbon trading market necessitates more financial support and investment. BRICS countries can attract international investment, encourage financial institutions to participate in the carbon market, and enhance market liquidity. Simultaneously, the government should promote the development of green finance and facilitate the deep integration of carbon trading markets and financial markets. In terms of technology, BRICS countries can increase the utilization of digital technologies in carbon trading markets, such as blockchain technology, to improve the transparency and security of transactions. Furthermore, the monitoring and verification of carbon emission data should also be strengthened to ensure the accuracy and reliability of market data.

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References

- Andriana, V., & Georgios, P. (2022). Energy Transitions: The Case of Greece with a Special Focus on the Role of the EU ETS. *Science & Society*, 86(4). <https://doi.org/10.1521/isis.2022.86.4.516>
- Anonymous. (2008). Mercuria Energy Trading Sa; Mercuria Wins Brazil Carbon Emissions Auction. *The Business of Global Warming*.
- Anonymous. (2020). EIA revises up oil price forecasts on declining inventories. *Oil & Gas Journal*, 118(7a).
- Asrin, S., & Salah, B. (2023). Facilitating Investment in Photovoltaic Systems in Iran Considering Time-of-Use Feed-in-Tariff and Carbon Market. *Energies*, 16(3). <https://doi.org/10.3390/en16031067>
- Barman, R. S., & Chakraborty, A. (2013). Carbon Trading in India – Issues and Prospects. *Asian Journal of Research in Business Economics and Management*, 3(12).
- Chunyang, G., Zhili, Y., Hui, C., et al. (2023). An optimal coordinated planning strategy for distributed energy station based on characteristics of electric vehicle charging behavior under carbon trading mechanism. *International Journal of Electrical Power and Energy Systems*, 147. <https://doi.org/10.1016/j.ijepes.2022.108884>
- Ermida, G. (2015). Energy outlook for the Arctic: 2020 and beyond. *Polar Record*, 52(2). <https://doi.org/10.1017/S0032247415000625>
- FeiFei, Y., LongHao, Y., HaiTian, L., et al. (2022). A novel data-driven decision model based on extended belief rule base to predict China's carbon emissions. *Journal of environmental management*, 318. <https://doi.org/10.1016/j.jenvman.2022.115547>
- Guan, D., Meng, J., Reiner, M. D., et al. (2018). Structural decline in China's CO2 emissions through transitions in industry and energy systems. *Nature Geoscience*, 11(8). <https://doi.org/10.1038/s41561-018-0161-1>
- Guiyang, W., Jie, C., Xinyan, S., et al. (2022). Impacts of Global Climate Warming on Meteorological and Hydrological Droughts and Their Propagations. *Earth's Future*, 10(3). <https://doi.org/10.1029/2021EF002542>
- Haijing, Y., & Qin, Z. (2022). Impact and mechanism of digital economy on China's carbon emissions: from the perspective of spatial heterogeneity. *Environmental science and pollution research international*, 30(4). <https://doi.org/10.1007/s11356-022-22552-5>
- Hengge, M., Panizza, U., & Varghese, R. M. (2023). Carbon Policy Surprises and Stock Returns: Signals from Financial Markets. *IMF Working Papers*, 2023(013). <https://doi.org/10.2139/ssrn.4343984>
- Jianguo, Z., Xuejing, H., Baoling, J., et al. (2019). The efficiency of carbon trading market in China: evidence from variance ratio tests. *Environmental science and pollution research international*, 26(14). <https://doi.org/10.1007/s11356-019-04778-y>

- Jing, W., Yijing, W., & Jian, S. (2023). The policy evaluation of China's carbon emissions trading scheme on firm employment: A channel from industrial automation. *Energy Policy*, 178. <https://doi.org/10.1016/j.enpol.2023.113590>
- Kumar, A. D., & Archana, S. (2022). Drivers and critical paths of carbon emissions in India: a structural path decomposition analysis. *Energy Sources, Part B: Economics, Planning, and Policy*, 17(1). <https://doi.org/10.1080/15567249.2022.2084185>
- Lin, B., & Jia, Z. (2019). Energy, economic and environmental impact of government fines in China's carbon trading scheme. *Science of the Total Environment*, 667. <https://doi.org/10.1016/j.scitotenv.2019.02.405>
- Lu, H., Ma, X., Huang, K., et al. (2020). Carbon trading volume and price forecasting in China using multiple machine learning models. *Journal of Cleaner Production*, 249(C). <https://doi.org/10.1016/j.jclepro.2019.119386>
- Lucon, O., Romeiro, V., & Pacca, S. (2013). Reflections on the international climate change negotiations: A synthesis of a working group on carbon emission policy and regulation in Brazil. *Energy Policy*, 59. <https://doi.org/10.1016/j.enpol.2013.04.058>
- Mansoor, A., Chuanmin, S., & Maqsood, A. (2022). Influencing factors of carbon emissions and their trends in China and India: a machine learning method. *Environmental science and pollution research international*, 29(32). <https://doi.org/10.1007/s11356-022-18711-3>
- Mingzhi, Z., Hongyu, L., Jianxu, L., et al. (2022). Modelling Dependency Structures of Carbon Trading Markets between China and European Union: From Carbon Pilot to COVID-19 Pandemic. *Axioms*, 11(12). <https://doi.org/10.3390/axioms11120695>
- Miroslav, V., Elma, S., & Aqib, M. (2022). Assessing the Driving Factors of Carbon Dioxide and Total Greenhouse Gas Emissions to Maintain Environmental Sustainability in Southeastern Europe. *International Journal of Environmental Research*, 16(6). <https://doi.org/10.1007/s41742-022-00486-7>
- Nemec, R. (2019). Northeast Energy Outlook, 2020: It Takes More than Good Vision. *Pipeline & Gas Journal*, 246(10).
- Peihong, Y., Hui, J., Chunming, L., et al. (2023). Coordinated optimization scheduling operation of integrated energy system considering demand response and carbon trading mechanism. *International Journal of Electrical Power and Energy Systems*, 147. <https://doi.org/10.1016/j.ijepes.2022.108902>
- Huan, Z., & Jingyu, W. (2022). The Energy Saving and Emission Reduction Effect of Carbon Trading Pilot Policy in China: Evidence from a Quasi-Natural Experiment. *International Journal of Environmental Research and Public Health*, 19(15). <https://doi.org/10.3390/ijerph19159272>
- Prisyazhniuk, A. V. (2022). Heat is a Cause of the Global Climate Warming. *International Journal of Environment and Climate Change*. <https://doi.org/10.9734/ijecc/2022/v12i1131203>

- Qu, H. M., Suphachalasai, S., Thube, D. S., et al. (2023). South Africa Carbon Pricing and Climate Mitigation Policy. *Selected Issues Papers, 2023*(040). <https://doi.org/10.5089/9798400247620.018>
- Qunli, W., Xinxin, X., & Ye, T. (2021). Research on enterprises emission reduction technology innovation strategies with government subsidy and carbon trading mechanism. *Managerial and Decision Economics, 43*(6). <https://doi.org/10.1002/mde.3510>
- Research and Markets; Growth Opportunities in the South Africa Carbon Composites Market, 2018-2023 - ResearchAndMarkets.com. *Defense & Aerospace Week*.
- Sustainability Research. (2019). Findings from COMSATS University Islamabad Update Understanding of Sustainability Research (Impact of urbanization on CO2 emissions in emerging economy: Evidence from Pakistan). *Ecology Environment & Conservation*.
- Tian, W., Xuantao, Z., Yuhe, M., et al. (2023). Risk contagion and decision-making evolution of carbon market enterprises: Comparisons with China, the United States, and the European Union. *Environmental Impact Assessment Review, 99*. <https://doi.org/10.1016/j.eiar.2023.107036>
- Weng, Q., & Xu, H. (2018). A review of China's carbon trading market. *Renewable and Sustainable Energy Reviews, 91*. <https://doi.org/10.1016/j.rser.2018.04.026>
- Xiang, S., Dingyu, W., Xuantao, Z., et al. (2022). A comparison of the operation of China's carbon trading market and energy market and their spillover effects. *Renewable and Sustainable Energy Reviews, 168*. <https://doi.org/10.1016/j.rser.2022.112864>
- Xiaolin, Y., JunWei, S., Kai, W., et al. (2022). Carbon trading market policies and corporate environmental performance in China. *Journal of Cleaner Production, 371*. <https://doi.org/10.1016/j.jclepro.2022.133683>
- Xiao-Qing, W., Chi-Wei, S., Oana-Ramona, L., et al. (2022). Is China's carbon trading market efficient? Evidence from emissions trading scheme pilots. *Energy, 245*. <https://doi.org/10.1016/j.energy.2022.123240>
- Xiaosong, R., Qian, M., Sha, S, et al. (2022). Can China's carbon trading policy improve the profitability of polluting firms: a retest of Porter's hypothesis. *Environmental science and pollution research international, 30*(12). <https://doi.org/10.1007/s11356-022-24530-3>
- Xiaoxia, W., Jialiang, H., & Hongda, L. (2022). Can China's carbon trading policy help achieve Carbon Neutrality? — A study of policy effects from the Five-sphere Integrated Plan perspective. *Journal of Environmental Management, 305*. <https://doi.org/10.1016/j.jenvman.2021.114357>
- Yanlong, G., Zefang, Z., Fuxin, Z., et al. (2022). The impact of global warming on the potential suitable planting area of Pistacia chinensis is limited. *The Science of the total environment*.
- Yao, C. (2022). Carbon Derivatives-Directed International Supervision Laws and Regulations and Carbon Market Mechanism. *Sustainability, 14*(23). <https://doi.org/10.3390/su142316157>
- Zhao, L., Jinghui, W., Ni, X., et al. (2022). Low Carbon Economic Dispatch Optimization of Regional Integrated Energy Systems Considering Heating Network and P2G. *Energies, 15*(15). <https://doi.org/10.3390/en15155494>