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Carbon Market Transformation in Asia Pacific Countries for Sustainable Economic Development: A Systematic Literature Review

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ABSTRACT

Carbon markets play a crucial role in supporting sustainable development through environmentally friendly technologies, energy conservation, and efficient resource management. This study employs the PRISMA method to analyze 30 studies from Scopus and Web of Science databases, focusing on factors influencing carbon market development in Asia-Pacific. The findings reveal that effective energy policies, such as carbon taxes and clean energy pricing, facilitate the transition to clean energy and decarbonization. Integrating carbon markets with the energy and financial sectors, alongside adopting innovative technologies like new energy vehicles, renewable power plants, and biofuels, accelerates carbon emission reductions. Carbon price volatility highlights the need for price stabilization policies and connectivity among markets. Post-pandemic economic recovery focused on sustainability offers opportunities to accelerate clean energy transitions and achieve Paris Agreement targets. Fair carbon pricing and robust carbon market governance stimulate green innovation and significantly reduce emissions. These findings provide critical implications for policymakers, carbon market practitioners, and researchers, particularly in the Asia-Pacific region. High-emission countries must expedite renewable energy transitions and strengthen emission reduction regulations. Regional collaboration is essential to develop carbon markets as strategic instruments for addressing climate change and supporting sustainable economic development.

Keywords: *carbon market; sustainable development; Asia-Pacific; climate change; systematic literature review.*

1. INTRODUCTION

The dynamics of climate change have intensified over the past few decades, marked by an increase in the frequency and intensity of extreme weather events worldwide, including in the Asia-Pacific region. These changes affect the environment and pose significant challenges to sustainable economic development (IPCC Report, 2023). According to the latest data from the World Meteorological Organization (WMO Report 2022, n.d.), countries in this region face high risks associated with natural disasters such as floods, tropical storms, and droughts. This situation highlights the need for policy transformation, including in the management of carbon markets, which serve as a key instrument for reducing greenhouse gas emissions.

Carbon trading is a market mechanism that allows companies or countries to buy and sell carbon emission allowances to meet emission reduction targets. This system encourages emission reduction efficiency, promotes green technology innovation, and supports more effective climate change policies (Y. Liu, Dong, & Fang, 2023). Carbon markets, including emissions trading and carbon credit-based mechanisms, have been recognized as strategic tools for achieving sustainable development goals. In the Asia-Pacific region, countries such as China, South Korea, and Japan have implemented carbon trading policies with varying schemes (Das & Bank, 2024).

Carbon trading effectively reduces the economic costs of climate change mitigation by enabling more efficient and flexible resource allocation for global emission reductions, particularly in countries with large industrial sectors (J. Liu, Huang, & Wang, 2020). Meanwhile, the (Pacific, 2024) states that carbon trading supports the development of Measurement, Reporting, and Verification (MRV) technologies, which are crucial for ensuring transparency and accountability in transactions, as well as for building a more organized market for climate change mitigation research.

Research by (Park, Khue, & Lee, 2024), emphasizes that carbon trading plays a significant role in influencing both the environmental and financial performance of listed companies in Korea. The Korean Emissions Trading System (ETS), introduced in 2015, aims to reduce carbon emissions through market regulation. Although emission reductions have not been fully achieved, there have been improvements in the environmental ratings of companies. However, financial profits have

only slightly increased, while company value has declined due to the rising systematic risks related to future carbon emissions. This study highlights the importance of monitoring the impact of environmental policies on corporate sustainability.

The success of carbon market management heavily depends on a strong regulatory framework and support from various sectors, as noted by (Zheng, Omori, Cao, & Guo, 2023). Carbon market reforms in China have significantly reduced CO_2 emissions, although challenges remain in terms of transparency and reporting (Zeng et al., 2024). On the other hand, studies (Forward, 2024) highlight that developing countries in Southeast Asia, such as Indonesia and the Philippines, still require substantial efforts to build effective carbon market infrastructure. Carbon markets can play a crucial role in poverty eradication through sustainable green investments, but they require more inclusive policies to avoid economic inequalities (Eradication, 2019). The application of blockchain technology can enhance transparency, security, and efficiency in various sectors, including carbon trading. This technology enables real-time transaction tracking, reduces fraud risks, and accelerates emission verification processes in climate change mitigation efforts (G. Zhang, Chen, & Yue, 2024).

The phenomenon of carbon trading has shown great potential in promoting global emission reductions. These studies explain that carbon trading allows for more efficient resource allocation for climate change mitigation through market mechanisms. New technologies such as blockchain also play an essential role in improving transparency and efficiency in these markets, ensuring that carbon transactions are accurately recorded. Additionally, they highlight the challenges faced, including regulatory issues and the uncertainty of carbon prices in international markets. However, the successful implementation of carbon markets in the region still faces challenges, including regulatory issues, ineffective governance, and limited technical capacity, according to (G. Zhang et al., 2024).

To delve deeper into the phenomenon of carbon trading in Asia-Pacific countries, the researchers employed the Systematic Literature Review (SLR) method. According to (Staffs, 2007), SLR allows researchers to systematically and transparently identify, assess, and synthesize findings from various previous studies. The Sustainable Livelihoods Approach (SLR) is an approach for understanding and managing resources that support sustainable livelihoods. This approach emphasizes the importance of access to assets, opportunities, and policies to enhance community welfare and resilience (Ludeña, de Miguel, & Schuschny, 2016).

This study utilizes the SLR method to provide deeper insights into the challenges and opportunities in carbon market management. This method not only enriches the understanding of carbon market dynamics but also provides practical guidance for policymakers in designing more effective strategies. With solid literature support and an evidence-based approach, this research aims to make a significant contribution to the development of climate policies in the Asia-Pacific region and promote the implementation of more inclusive and sustainable carbon markets to achieve sustainable economic development goals.

2. METHOD

SLR Source of Reference

This study's Systematic Literature Review (SLR) approach employs the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) method. PRISMA enables a meticulous search of relevant terms, particularly concerning the responses of farmers in Asia to climate change and its impacts. It also provides coded information for future environmental management reviews (Shaffril, Krauss, & Samsuddin, 2018). The PRISMA method can also be applied to monitor various factors influencing the transformation of carbon markets in the Asia-Pacific region through articles from Scopus and Web of Science, which discuss the transformation of carbon market management in Asia-Pacific countries in a more comprehensive manner, as proposed by (Durach et al, 2017) (Sierra-Correa & Cantera Kintz, 2015); (Shaffril et al., 2018).

Formulation of Research Question

The formulation of research questions is based on PICo, which is a tool that helps the author develop research questions that align with the Research Question. PICo is based on three main concepts: population, interest, and context. The PICo approach has several advantages in SLR research, including: 1) PICo helps researchers formulate more specific questions, which lead to a search for more relevant and focused literature; 2) With the clear elements in PICo (population, interest, context), researchers can determine more accurate and efficient search keywords; 3) With its clear structure, the review process becomes more systematic, minimizing bias and improving the objectivity of the synthesis results sintesis (Snyder, 2019). PICo also allows researchers to better clarify the study’s objectives, ultimately enhancing the quality and reliability of the research findings (Al, 2016).

3. Systematic Searching Strategy

To enrich the keywords, the researchers employed a search technique that maximizes the number of databases (Elliott, 2023).

The keywords were developed based on the research question, specifically the factors influencing the transformation of carbon markets in Asia-Pacific countries. Keyword searches should include synonyms, related terms, and variations to ensure comprehensive literature coverage (Andrew Booth & Papaioannou, 2016). This variation is crucial as terms for similar concepts may differ across databases or academic disciplines (Gough, Oliver, & Thomas, 2017). A comprehensive search that incorporates various terms increases the likelihood of finding relevant literature to support the research findings (Abas, 2023) emphasizes that to maximize the number of articles retrieved, researchers conducting an SLR should enrich the keyword list by searching for synonyms, related terms, and variations, referring to online thesauruses.

Database Identification

Identification is the process of searching for synonyms, related terms, and variations for the main keywords. After generating the keywords, the next step in article searching involves the use of Boolean operators, phrase searching, wildcards, truncation, and field code functions in several databases. These functions allow researchers conducting a systematic literature review (SLR) to combine all potential keywords into a single search string using symbols and coding according to specific keyword combinations, which are applied through phrase searching functions and Boolean operators (OR, AND). The search process is carried out in major databases such as Scopus and Web of Science (Shaffril et al, 2021). These two databases are also capable of serving as primary databases in systematic literature reviews due to several advantages, such as having advanced search functionalities, and comprehensive indexing (covering more than 5,000 publishers). These databases also include high-quality articles focused on environmental management studies (Martín et al, 2018); (Gusenbauer, 2020). Subsequently, the data extraction results from the search strings used in the selected databases, from searches in Scopus and Web of Science, are shown in Table 1 below.

Table 1. Search string used in the selected databases

Database	Search Strings
Scopus	TITLE-ABS-KEY ("carbon sale*" OR "emission trad*" OR "carbon exchange*" OR "carbon pric*" OR "carbon credit*" OR "carbon market*" OR "greenhouse gas market*" OR "carbon offset*" OR "carbon finance*" OR "carbon trad*" OR "climate market*" OR "carbon emission market*" OR "CO2 market*")
Web of Science	TS=((“carbon sale*” OR “emission trad*” OR “carbon exchange*” OR “carbon pric*” OR “carbon credit*” OR “carbon market*” OR “greenhouse gas market*” OR “carbon offset*” OR “carbon finance*” OR “carbon trad*” OR “climate market*” OR “carbon emission market*” OR “CO2 market*”))

The search process was conducted using the search string applied in the selected databases. The results were then analyzed through a screening process to identify the inclusion and exclusion criteria.

Screening

The articles were screened based on their methodology, title, and abstract to ensure they met the requirements for analysis in line with the research objectives. The screening process was carried out using selection criteria automatically applied through the sorting function in the database. Given the challenge of reviewing all published articles, , (Okoli, 2015) recommends that researchers establish a time frame for the analysis. The inclusion and exclusion criteria were set as follows: 1) Only articles from journals presenting empirical data were selected, while review articles, book series, books, book chapters, and conference proceedings were excluded; 2) This study focused solely on articles published in English, thus excluding publications in languages other than English; 3) The research period was limited to a five-year span, from 2019 to 2023. This period was deemed relevant for observing recent developments in related research and publications. The complete inclusion and exclusion criteria are presented in Table 2 below:

Table 2. The inclusion and exclusion criteria

Criterion	Eligibility	Exclusion
Literature type	Journal (research articles)	Journals (systematic review), book series, book, chapter in book, conference proceeding
Language	English	Non-English
Time line	Between 2019 hingga 2023	< 2019
Indexes	Scopus Index, Web of Science index	
Countries and territories	Asian Pasific countries	Non-Asian Pasific countries

The selection of scientific articles in this study is heavily dependent on various quality and impact indicators. One of the most commonly used methods is evaluation based on indices and quartiles, ensuring that the sources used have significant influence in their respective fields.

Eligibility Assessment

Eligibility assessment in a Systematic Literature Review (SLR) refers to the systematic evaluation process of articles that have been screened based on inclusion and exclusion criteria. The purpose is to ensure that only relevant, valid, and high-quality articles are included in the final analysis. This process is crucial for maintaining the accuracy and reliability of the research findings. The eligibility process in this SLR follows several steps, such as an initial screening where articles are filtered based on titles and abstracts to identify their relevance to the research topic. Articles that pass this initial step are further evaluated to ensure they meet the inclusion criteria, which include topic relevance, publication year, research methods, and language. Meanwhile, exclusion criteria typically include duplicates, articles with incomplete data, or those that are not aligned with the research context. Finally, the decision to include or disqualify an article is documented for transparency.

Quality Appraisal

The quality appraisal process is conducted by four researchers with expertise in the relevant field to ensure independence and objectivity. Each article is assessed based on established parameters such as research design, validity of methods, consistency of results, and relevance of findings to the research questions. The appraisal process involves evaluating each article using a quality assessment tool or checklist. If there are discrepancies between the evaluators, a discussion is held to reach a consensus. Articles are then scored based on their quality and classified into categories (e.g., high, medium, low). Only articles with high or medium quality are included in the final analysis.

Table 3. Quality Assessment Criteria

Research Design	**Assessment Criteria**
Qualitative	QA1: Are the research objectives regarding the dynamics of the carbon market explained in-depth and relevant?
	QA2: Are the data collection methods (e.g., interviews, document analysis, observations) described in detail and aligned with the transformation of carbon management?
	QA3: Are the qualitative data analysis strategies (e.g., thematic or narrative analysis) appropriate and systematic for exploring the transformation of carbon management?
	QA4: Are the research findings supported by relevant data citations (e.g., interviews or documents related to the carbon market in the Asia-Pacific)?
	QA5: Do the conclusions and recommendations reflect robust findings and align with the data analysis on sustainable economic development?
Quantitative	QA1: Are the hypotheses or research questions on the carbon market clearly articulated and relevant?
	QA2: Is the quantitative research design (e.g., experiments, surveys) described in detail and appropriate for analyzing the transformation of the carbon market?
	QA3: Are the data on the carbon market and sustainable economic development valid, reliable, and relevant?
	QA4: Are the statistical analyses used appropriate for the data and objectives of understanding carbon management?
	QA5: Are the research results presented transparently (e.g., tables/graphs) and relevant to the hypotheses or research questions?
Mixed	QA1: Is the integration of quantitative and qualitative methods clearly explained and relevant to the transformation of the carbon market in the Asia-Pacific?
	QA2: Is the mixed-methods research design (e.g., sequential, concurrent, or embedded) suitable for analyzing extreme climate change and the carbon market?
	QA3: Are the data from both quantitative and qualitative methods valid, reliable, and relevant for understanding the dynamics of climate change and sustainable development?
	QA4: Is the integration of data analysis from both methods conducted systematically and does it yield complementary findings?

	QA5: Do the conclusions and recommendations consistently reflect the findings from both methods and align with the objectives of sustainable development?

Table 4. Result of Quality Assessment

Study	Research Design	Criteria					The number of criteria fulfilled	Inclusion in the review
		QA1	QA2	QA3	QA4	QA5		
Liao D.; Tan B. 2023	QUAN	✓	✓	✓	✓	✓	5/5	Yes
Alkathery M.A.; et al. 2022	QUAN	✓	✓	✓	✓	✓	5/5	Yes
Kumar S.; et al. 2019	QUAN	✓	✓	✓	✓	✓	5/5	Yes
Hu Y.; et al. 2023	QUAN	✓	✓	✓	✓	✓	5/5	Yes
Nie Q.; et al. 2022	QUAN	✓	✓	✓	✓	✓	5/5	Yes
Kang S.W.; Yim M.-S. 2023	MIXED	✓	✓	✓	✓	✓	5/5	Yes
Paltsev S.; et al. 2022	QUAN	✓	✓	✓	✓	✓	5/5	Yes
Ren X.; et al. 2022	QUAN	✓	✓	✓	✓	✓	5/5	Yes
Wang Q.; et al. 2019	QUAN	✓	✓	✓	✓	✓	5/5	Yes
Chen Y.; et al. 2023	QUAN	✓	✓	✓	✓	✓	5/5	Yes
Feng T.; et al. 2020	QUAN	✓	✓	✓	✓	✓	5/5	Yes
Wu L.; et al. 2023	QUAN	✓	✓	✓	✓	✓	5/5	Yes
Herath H.M.S.A.; Jung T.Y. 2021	MIXED	✓	✓	✓	✓	✓	5/5	Yes
Meng B.; et al. 2023	QUAN	✓	✓	✓	✓	✓	5/5	Yes
Sadayuki T.; Arimura T.H. 2021	QUAN	✓	✓	✓	✓	✓	5/5	Yes
Pradhan B.K.; Ghosh J. 2021	MIXED	✓	✓	✓	✓	✓	5/5	Yes
Smith L.V.; et al. 2021	QUAN	✓	✓	✓	✓	✓	5/5	Yes
Han M.; et al. 2019	QUAN	✓	✓	✓	✓	✓	5/5	Yes
Yuan X.; et al. 2023	QUAN	✓	✓	✓	✓	✓	5/5	Yes
Duan K.; et al. 2021	QUAN	✓	✓	✓	✓	✓	5/5	Yes
Li C.; et al. 2022	QUAN	✓	✓	✓	✓	✓	5/5	Yes
Wu B.; et al. 2023	MIXED	✓	✓	✓	✓	✓	5/5	Yes
Huang Q.; Xu J. 2023	QUAN	✓	✓	✓	✓	✓	5/5	Yes
Zhang W.; et al. 2023	QUAN	✓	✓	✓	✓	✓	5/5	Yes
Chen B.; et al. 2023	QUAL	✓	✓	✓	✓	✓	5/5	Yes
Jie D.; Xu X.; Guo F. 2021	QUAN	✓	✓	✓	✓	✓	5/5	Yes
Chu J.; et al. 2021	QUAN	✓	✓	✓	✓	✓	5/5	Yes
Chai S.; et al. 2023	MIXED	✓	✓	✓	✓	✓	5/5	Yes
Yu Z.; et al. 2022	QUAN	✓	✓	✓	✓	✓	5/5	Yes
Tan X.; et al. 2020	QUAN	✓	✓	✓	✓	✓	5/5	Yes

The remaining articles were evaluated and analyzed, followed by data extraction and comprehensive analysis.

Data Extraction and Analysis

Extraction process, this stage involves reviewing the entire article to identify relevant information. The data is then synthesized by identifying various aspects predefined in the extraction criteria. The main objective of this synthesis phase is to analyze and evaluate the findings from multiple studies and select the most appropriate method to integrate explanations and interpretations of these diverse findings. The data extraction process is carried out through the identification and collection of relevant information from the selected research articles, following these steps: 1). Determining Extraction Criteria: The data to be extracted includes elements such as the Title, Authors, Year of Publication, Journal/Conference, Methodology Used, Findings, Relevant Keywords, and Future Research Directions; 2). Manual or Automated Extraction: This is done through a selection process (inclusion/exclusion), and the data is then entered into a data extraction form and organized based on predefined categories to facilitate analysis; 3.) Validation of Extraction: Conducted by an independent researcher to ensure the accuracy and consistency of the data (Schmidt et al., 2024). Type of Analysis & Explanation: This study employs descriptive analysis to summarize basic information from the selected articles, such as the number of articles published per year, the geographical distribution of the research, the methodologies used, and the main topics discussed. The results will provide insights into research trends, focal regions, and article distribution.

The systematic stages of the process conducted in this systematic literature review (SLR) are comprehensively illustrated, encompassing the steps of identifying, screening, and assessing the quality of relevant articles. This begins with the identification of potential articles through searches in reliable academic databases, followed by an initial screening based on inclusion and exclusion criteria. The process concludes with a final quality appraisal to ensure that the selected articles meet high methodological standards, as depicted in Figure 1: The Flow Diagram from Identification Process to Quality Appraisal.

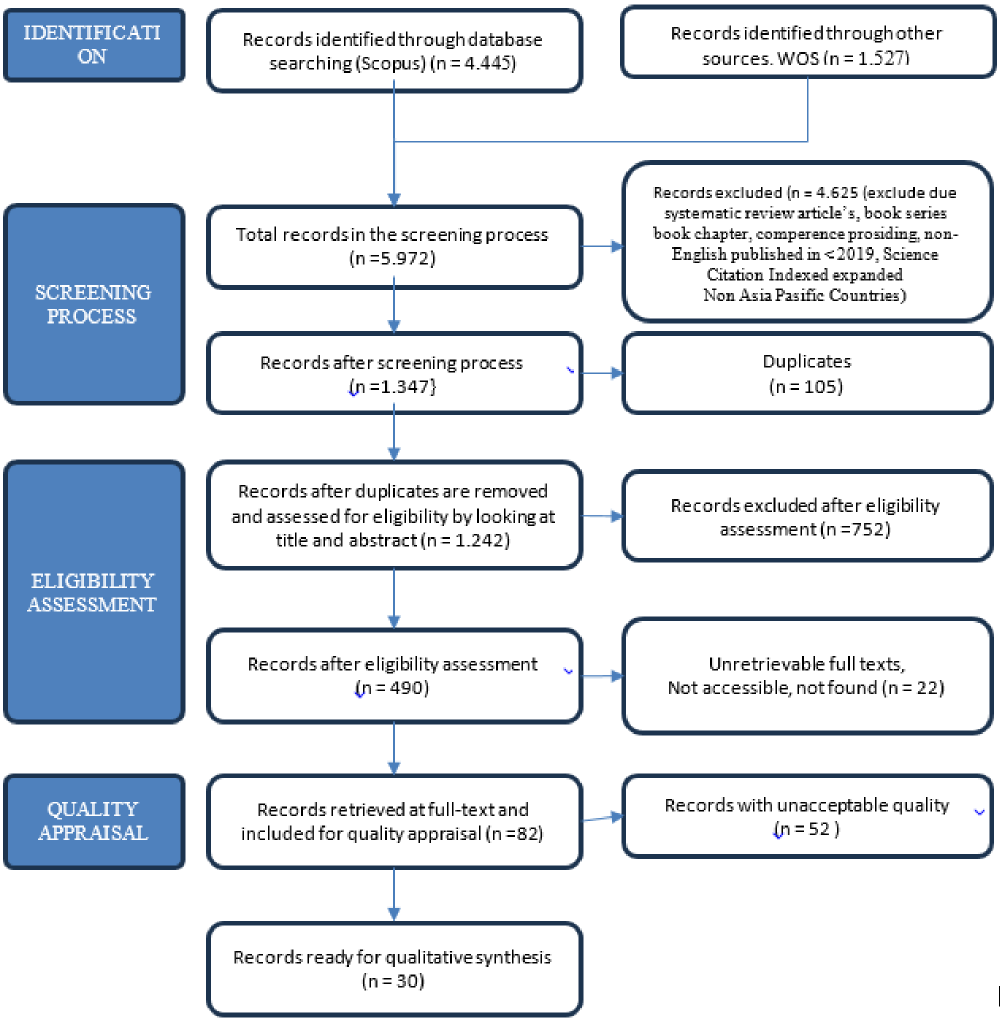

Figure 1 The Flow Diagram from Identification Process to Quality Appraisal

3. RESULTS

This section addresses the answers to the research questions. It discusses the following aspects: (1) the development and validation of review protocols guided by publication standards, reporting standards, or established guidelines; (2) formulating the research questions; (3) systematic search strategy; (4) quality assessment; (5) data extraction; (6) data synthesis; and (7) demonstration of findings. The complete details are presented in the table below.

Table 5. Selected Journals and Ranking

No	Journal	Count of selected articles	Indexed by WOS	WOS Quartiles*	Indexed by Scopus	Scopus Quartiles**
1	Energy Economics	16	Yes	Q1	Yes	Q1
2	Energy	9	Yes	Q1	Yes	Q1
3	Energy & Environment	1	Yes	Q2	Yes	Q2
4	Carbon Management	4	Yes	Q2	Yes	Q2

Note: *WoS journal's quartile at Journal Citation Reports (JCR), **Scopus database quartile in Scimago

The selection of subsequent articles is based on themes and sub-themes, allowing the writing process to be structured. This approach ensures the identification and selection of relevant articles according to the main topic and subtopics of the research (Schmeisser, 2013); (Okoli & Schabram, 2015). The main focus of this research is a collection of articles analyzing the factors influencing the dynamics of the carbon market. The themes include energy policies, market behavior, new energy technology innovations, the economy and sustainability, carbon pricing, and carbon market governance.

Table 6. Themes and Sources

Sources	Themes																						
	A (Energy Policy)					B (Market Behavior)				C (New Energy Technology Innovations)			D (Economy and Sustainability)				E (Carbon Price)			F (Carbon Market Governance)			
	Sub Themes					Sub Themes				Sub Themes			Sub Themes				Sub Themes			Sub Themes			
	AA	AB	AC	AD	AE	BA	BB	BC	BD	CA	CB	CC	DA	DB	DC	DD	EA	EB	EC	FA	FB	FC	FD
(Liao & Tan, 2023). An evolutionary game analysis of new energy vehicles promotion considering carbon tax in post-subsidy era	✓			✓	✓		✓	✓		✓						✓					✓		✓
(Alkathery et al., 2022). Implications of clean energy, oil and emissions pricing for the GCC energy sector stock				✓	✓		✓	✓		✓													
(Kumar, 2019). CO2 mitigation policy for Indian thermal power sector: Potential gains from emission trading		✓		✓	✓							✓				✓					✓		✓
(Hu et al., 2023).Exploring the dynamic behaviour of commodity market tail risk connectedness during the negative WTI pricing event					✓	✓			✓														
(Nie et al., 2022). Strategies for applying carbon trading to the new energy vehicle market in China: An improved evolutionary game analysis for the bus industry	✓				✓																✓		✓
(Kang & Yim, 2023) Coupled system model analysis for a small modular reactor cogeneration (combined heat and power) application			✓							✓													

(Paltsev et al., 2022). Economic analysis of the hard-to-abate sectors in India		✓										✓	✓	✓	✓							
(Ren et al., 2022), Carbon prices forecasting in quantiles													✓	✓		✓					✓	
(Wang et al., 2019). Distributional impact of carbon pricing in Chinese provinces																✓				✓		✓
(Y. Chen et al., 2023). Does the carbon emission trading scheme foster the development of enterprises across various industries? An empirical study based on micro data from China															✓				✓	✓		✓
(Feng et al., 2020), Carbon transfer within China: Insights from production fragmentation												✓										
(L. Wu et al., 2023). Point and interval forecasting of ultra-short-term carbon price in China																	✓				✓	
(Herath & Jung, 2021). Carbon pricing and supporting policy tools for deep decarbonization; case of electricity generation of Sri Lanka	✓	✓							✓						✓							
(Meng et al., 2023). Information spillovers between carbon emissions trading prices and shipping markets: A time-frequency analysis					✓			✓	✓		✓											✓
(Sadayuki & Arimura, 2021) . Do regional emission trading schemes lead to carbon leakage within firms? Evidence from Japan									✓										✓	✓		✓
(Pradhan & Ghosh, 2021). COVID-19 and the Paris Agreement target: A CGE analysis of alternative economic recovery scenarios for India													✓	✓	✓							
(Smith et al., 2021), Assessing the impact of COVID-19 on global fossil fuel consumption and CO2 emissions													✓	✓								
(Han et al., 2019), Forecasting carbon prices in the Shenzhen market, China: The role of mixed-frequency factors																✓	✓				✓	
(Yuan et al., 2023). Assessing the carbon offsetting potential of China's forest sector: reflection and outlook								✓	✓			✓										

(Duan et al., 2021). The marginal impacts of energy prices on carbon price variations: Evidence from a quantile-on-quantile approach					✓				✓	✓					✓	
(Li et al., 2022). Does a carbon emissions trading scheme spur urban green innovation? Evidence from a quasi-natural experiment in China									✓							✓
(B. Wu et al., 2023). Economic and environmental viability of biofuel production from organic wastes: A pathway towards competitive carbon neutrality							✓	✓	✓		✓		✓			
(Huang & Xu, 2023). Carbon tax revenue recycling for biomass/coal co-firing using Stackelberg game: A case study of Jiangsu province, China						✓		✓			✓					
(W. Zhang et al., 2023). An ensemble dynamic self-learning model for multiscale carbon price forecasting									✓	✓					✓	✓
(B. Chen et al., 2023). The legal governance of the carbon market: challenges and application of private law in China	✓											✓				✓
(Guo, 2020) .The future of coal supply in China based on non-fossil energy development and carbon price strategies		✓		✓									✓			
(Junfei Chu, Caifeng Shao, Ali Emrouznejad, Jie Wu, 2021). Performance evaluation of organizations considering economic incentives for emission reduction: A carbon emission permit trading approach						✓							✓			
(Xinyu, 2023). An optimized GRT model with blockchain digital smart contracts for power generation enterprises						✓		✓					✓			
(Yu et al., 2021). China's unconventional carbon emissions trading market: The impact of a rate-based cap in the power generation sector		✓	✓					✓					✓			
(Tan et al., 2020). How connected is the carbon market to energy and financial markets? A systematic analysis of spillovers and dynamics					✓	✓		✓	✓		✓	✓				

Note: AA = Carbon tax policy and new energy. AB = CO2 mitigation policy in power plants. AC = Carbon pricing policy in the power generation sector. AD = Carbon policy in the electricity market. AE = Non-fossil energy development strategies. BA = Dynamics of commodity market risks. BB = Carbon transfer in production. BC = Carbon trading and shipping markets. BD = Carbon markets integrated with energy markets. CA = Integrated carbon trading systems. CB = Organic waste management for carbon neutrality. CC = Models for power generation companies. DA = Forestry sector and carbon emissions. DB = COVID-19, the Paris Agreement targets, and economic recovery. DC = Impacts of COVID-19 on global fossil fuel consumption and CO2 emissions. DD = Economic analysis and emission reduction. EA = Carbon price forecasting using a quantile approach. EB = Ultra-short-term carbon price forecasting. EC = Recycling carbon tax revenue. FA = Challenges and legal implementation in carbon markets. FB = Economic incentives in emission trading. FC = Dynamic models for carbon price forecasting. FD = Carbon trading strategies.

4. DISCUSSION

From the results of a study regarding the factors influencing carbon market transformation in Asia Pacific countries, the following results were obtained.

Energy Policy

Research on energy policies highlights various innovative approaches to achieving decarbonization and sustainability. (Liao & Tan, 2023) developed an evolutionary game analysis to promote new energy vehicles through carbon taxes in the post-subsidy era. (Alkathery et al., 2022) examined energy pricing policies for clean energy, oil, and emissions in the GCC energy sector, as well as their impacts on the region's energy stock markets. They emphasized the importance of efficient pricing policies to support the clean energy transition in fossil fuel-rich countries. (Kumar, 2019) explored the potential of emission trading to reduce CO2 emissions in India's thermal power generation sector, while (Nie et al., 2022) implemented carbon trading strategies in the new energy vehicle market in China. (Kang & Yim, 2023) investigated policies for small modular reactors supporting combined heat and power applications. (Herath & Jung, 2021) highlighted the critical role of carbon pricing in decarbonizing Sri Lanka's electricity generation sector, whereas (Yuan et al., 2023) assessed the potential of China's forestry sector in offsetting carbon emissions. (Huang & Xu, 2023) proposed recycling carbon tax revenues to support biomass and coal co-firing, demonstrating the relevance of carbon pricing strategies in ensuring coal supply sustainability (Junfei Chu, Caifeng Shao, Ali Emrouznejad, Jie Wu, 2021). (Yu et al., 2021) and (Tan et al., 2020). underscored the necessity of integrating carbon markets with the energy and financial sectors to enhance policy effectiveness. (Pradhan & Ghosh, 2021) identified that sustainability-focused economic recovery could accelerate carbon emission reductions in India, aligning with the goals of the Paris Agreement. (Smith et al., 2021) investigated the impact of the COVID-19 pandemic on fossil fuel consumption and CO2 emissions, which declined significantly during the pandemic but risked increasing with economic recovery. This research highlights the importance of policies that support sustainability amid evolving economic challenges.

Market behavior

Market behavior provides critical insights into the dynamics and interconnections between markets. (Hu et al., 2023) revealed that tail risk connectivity in commodity markets can shift significantly during extreme events, such as the negative WTI price phenomenon, impacting global investment decisions. (Meng et al., 2023) highlighted the information spillover between carbon prices and the shipping market, demonstrating the complex interactions between the carbon and transportation sectors. (Tan et al., 2020) reinforced the notion that carbon markets are closely linked to energy and financial markets, where price volatility in one market can directly influence others. Meanwhile, (Ren et al., 2022) and (B. Wu et al., 2023) focused on carbon price prediction, finding that carbon market volatility is heavily influenced by external fluctuations such as energy prices and policy changes. (Duan et al., 2021) using a quantile approach, demonstrated the non-linear and price-level-dependent impact of energy prices on carbon prices. (Nie et al., 2022) developed a dynamic learning model for multi-scale carbon price prediction, offering a more accurate tool to understand the complexities of carbon market behavior. Furthermore, (Alkathery et al., 2022) examined market behavior related to clean energy and oil prices and their impact on the energy sector stock market in GCC countries. Energy pricing, including emission pricing, influences investment decisions and stock market volatility in the energy sector. These studies provide a robust foundation for policymakers and market participants to manage risks, seize market opportunities, and design more effective carbon trading policies.

Technological Innovations in New Energy

Recent studies on technological innovations in new energy reveal various approaches to support the transition toward cleaner and more efficient energy systems. (Liao & Tan, 2023) analyzed the implementation of carbon taxes to promote new energy vehicles in the post-subsidy era, focusing on their impact on the adoption of environmentally friendly technologies. (Nie et al., 2022)

explored carbon trading applications in China's new energy vehicle market, particularly in the bus sector, to encourage manufacturers to innovate in clean vehicle technologies. Similarly (Kumar, 2019) examined CO2 mitigation policies in India's thermal power generation sector, highlighting the benefits of emission trading systems to drive the adoption of clean energy technologies. (Feng et al., 2020) identified the effects of production fragmentation on inter-sectoral and inter-provincial carbon flows in China, offering critical insights into managing carbon emissions in fragmented economies. (Herath & Jung, 2021) investigated carbon pricing and policies for decarbonizing Sri Lanka's power generation sector, aiming to accelerate the transition to renewable energy. (Meng et al., 2023) analyzed the effects of carbon pricing on the shipping market and the role of technological innovations in enhancing energy efficiency. (Kang & Yim, 2023) developed a model to evaluate the implementation of small modular reactors (SMRs) in integrated energy generation systems as an alternative to traditional power plants. (B. Wu et al., 2023) explored the feasibility of biofuel production from organic waste, while (W. Zhang et al., 2023) created a dynamic model to predict carbon prices, supporting energy policy and technological innovation. (Huang & Xu, 2023) investigated the recycling of carbon tax revenues to fund biomass combustion, facilitating emissions reduction and the use of renewable energy. (Xinyu, 2023) introduced a blockchain-based GRT model to enhance the operational efficiency of power generation companies. (Yuan et al., 2023) highlighted the potential of China's forestry sector in offsetting carbon emissions through afforestation and improved forest management, emphasizing the importance of sustainable policies and stringent deforestation monitoring. Technological advancements and international collaboration are deemed essential for achieving ambitious carbon offset goals, underscoring the critical role of innovation in transforming carbon markets across the Asia-Pacific region.

Economy and Sustainability

Research on the relationship between the economy and sustainability has provided significant insights into carbon emission policies, energy pricing, and the renewable energy sector. (Liao & Tan, 2023) highlighted the role of carbon taxes in promoting new energy vehicles in the post-subsidy era, while (Kumar, 2019) evaluated emission trading policies in India's thermal power sector for CO_2 mitigation. In China, (Nie et al., 2022) and (Y. Chen et al., 2023) demonstrated that carbon trading mechanisms can support emission reductions in the new energy vehicle sector. (Wang et al., 2019) found that carbon pricing policies can influence the economic impact distribution across various regions in China. (Herath & Jung, 2021) and (Sadayuki & Arimura, 2021) examined the impact of carbon pricing policies on decarbonizing the power generation sector in Sri Lanka and Japan, respectively, which can accelerate the transition toward clean energy. (Kang & Yim, 2023) investigated the potential of small modular reactors in cogeneration energy systems to enhance energy efficiency. (Huang & Xu, 2023) and (Smith et al., 2021) discussed the recycling of carbon tax revenues and the effects of the COVID-19 pandemic on fossil energy consumption and global CO_2 emissions. (B. Wu et al., 2023) explored biofuel production from organic waste as a competitive pathway toward carbon neutrality. (Yu et al., 2021) examined the carbon emission trading market in China's power generation sector, while (Ren et al., 2022) and (Meng et al., 2023) investigated the relationship between energy prices and carbon prices in the global energy market. (Pradhan & Ghosh, 2021) analyzed the impact of COVID-19 on the Paris Agreement targets, focusing on sustainable economic recovery in India. Their findings indicate that recovery strategies emphasizing sustainability can accelerate the achievement of carbon emission reduction goals. (Yuan et al., 2023) emphasized the potential of China's forestry sector in offsetting carbon emissions through tree planting, improved forest management, and natural resource conservation. They highlighted the necessity of technology-driven policies and international collaboration to achieve ambitious carbon offset goals.

Carbon Pricing

Carbon pricing has emerged as a crucial topic in environmental economics research, with numerous studies examining various related aspects, such as price forecasting, its impact on specific sectors, and its correlation with energy prices. (Ren et al., 2022) and (B. Wu et al., 2023) focused on carbon price forecasting using statistical methods to predict price fluctuations in volatile markets. (Wang et al., 2019) highlighted variations in carbon prices across provinces in China, influencing local emission reduction policies, while (Duan et al., 2021) underscored the role of energy prices in carbon price fluctuations. (Tan et al., 2020). explored the interconnection between carbon markets, energy markets, and financial markets, revealing significant effects on carbon price volatility (Li et al., 2022) and (B. Chen et al., 2023) extended the understanding of the impact of carbon trading on green innovation and industrial development. (Feng et al., 2020) and (Meng et al., 2023) examined the effects of carbon trading policies and the information spillover between carbon markets and shipping markets. (Yu et al., 2021) highlighted the impact of unconventional carbon trading policies in China. (Han et al., 2019) research on the Shenzhen market and (Alkathery et al., 2022)) study on the effects of clean energy pricing policies in the GCC region also provided insights into the relationship between carbon pricing, energy policies, and the transition to clean energy. (Junfei Chu, Caifeng Shao, Ali Emrouznejad, Jie Wu, 2021) combined high-frequency data to forecast carbon price fluctuations in China's carbon market, while. (Junfei Chu, Caifeng Shao, Ali Emrouznejad, Jie Wu, 2021) demonstrated that higher carbon prices could drive the transition to renewable energy. (Smith et al., 2021) investigated the impact of the COVID-19 pandemic on fossil fuel consumption and carbon emissions, revealing a temporary decline in emissions due to reduced industrial activity but with the potential for increased fossil fuel consumption as economic recovery progresses. These studies collectively offer a comprehensive understanding of the role of carbon pricing in global emission reduction policies and the implementation of more effective carbon pricing strategies.

Carbon Market Governance

Research on carbon market governance highlights the critical role of effective policy design in supporting emission reductions and innovation in the clean energy sector. (Liao & Tan, 2023) employed evolutionary game analysis to explore the impact of carbon taxes on the adoption of new energy vehicles. (Kumar, 2019) emphasized the potential of emission trading systems (ETS) to reduce CO_2 emissions in India's thermal power sector, while (Wang et al., 2019) demonstrated that varying carbon prices across provinces in China affect economic sectors differently, underscoring the importance of equitable pricing mechanisms. (B. Chen et al., 2023) found that carbon markets can drive industrial innovation, contingent upon appropriate market design and mechanisms. (Meng et al., 2023) revealed the interplay between carbon price fluctuations and the global shipping market, while (Duan et al., 2021) stressed the need to account for energy pricing in carbon market management to mitigate price volatility. (Li et al., 2022) indicated that carbon trading schemes could stimulate urban green innovation but require supportive policies and incentives. (Y. Chen et al., 2023) also highlighted the role of legal governance in ensuring compliance with carbon market regulations in China. (Yu et al., 2021) investigated the power generation sector's carbon market in China, finding that cap-based emission trading tariffs could reduce emissions, despite persistent management challenges. (Sadayuki & Arimura, 2021) emphasized the necessity of coordinated regional policies to prevent carbon leakage between regions. Additionally, (Junfei Chu, Caifeng Shao, Ali Emrouznejad, Jie Wu, 2021) and (Alkathery et al., 2022) proposed that policies integrating economic incentives with emission trading permits could accelerate emission reductions. (Junfei Chu, Caifeng Shao, Ali Emrouznejad, Jie Wu, 2021) suggested that high carbon prices could drive a transition to renewable energy, while (Pradhan & Ghosh, 2021) identified sustainable economic recovery as a supportive factor for emission reductions. (Smith et al., 2021) revealed the impact of the COVID-19 pandemic on CO2 emission reductions, and (Han et al., 2019) underscored the importance of more responsive carbon price forecasting. Finally, (Yuan et al., 2023) highlighted the role of China's forestry sector in offsetting carbon emissions through sustainable forest management.

Implications of Study

The study identifies key factors influencing the transformation of carbon markets in Asia-Pacific countries, yielding significant implications for various stakeholders, including national governments, the scientific community, carbon market practitioners, and other researchers. For Asia-Pacific countries, these findings provide a foundation for formulating more effective policies to address the challenges of climate change and sustainable development. High-emission countries are urged to accelerate their transition to renewable energy and strengthen regulations supporting emission reductions. The research highlights the critical importance of regional collaboration in developing carbon markets as an instrument to reduce emissions and support sustainable economic growth. Countries in the region can leverage these findings to enhance climate adaptation policies and design more targeted mitigation programs. From a scientific perspective, this study makes a substantial contribution to understanding the interplay between carbon markets, sustainable development, and carbon emission reductions. The findings pave the way for developing new theories in environmental economics, particularly regarding the effectiveness of carbon markets in reducing greenhouse gas emissions in the Asia-Pacific region. Additionally, the study enriches the literature on the nexus between climate policy and sustainable economic development, serving as a basis for designing more holistic policies. For carbon market practices and sustainable development, the study emphasizes the importance of creating efficient and inclusive carbon markets and integrating these markets with broader sustainable development policies. Asia-Pacific countries can draw lessons from these findings to optimize carbon trading mechanisms and strengthen the role of the private sector in achieving emission reduction targets. The study also underscores the need to integrate carbon markets with renewable energy policies and sustainable resource management to amplify their impact on climate change mitigation. For other researchers, the findings open avenues for further exploration of the dynamics of carbon markets in the Asia-Pacific region. Future studies can investigate the challenges and opportunities in implementing carbon markets and their impacts on local and global economies. The research also provides a foundation for examining the effectiveness of other policy instruments, such as carbon taxes and renewable energy incentives, in supporting emission reductions and sustainable development.

Gap

The study on the dynamics of extreme climate change and the transformation of carbon markets in the Asia-Pacific region identifies several critical gaps that warrant attention. First, existing literature provides limited insights into the impacts of extreme climate change on specific economic sectors, particularly in developing countries within the Asia-Pacific region. Most research has concentrated on the technical aspects of carbon markets and mitigation policies, with insufficient exploration of how local socio-economic factors influence the effectiveness of carbon markets. Future research should delve deeper into social inequalities, institutional capacities, and public awareness, which significantly affect participation in carbon markets and the achievement of Sustainable Development Goals (SDGs). Second, questions remain regarding the ability of carbon markets to drive behavioral changes in large industrial sectors and integrate these changes into broader economic development policies without compromising social equity. Third, disparities in the implementation of carbon markets across the region pose challenges, particularly concerning institutional capacity, public understanding, and limited infrastructure. Fourth, the lack of accurate and up-to-date data on carbon emissions and the economic impacts of carbon market policies hampers the assessment of their effectiveness. Finally, methodological gaps also present significant challenges. Many studies rely solely on quantitative analyses, overlooking the social, cultural, and political factors that influence carbon market governance. Addressing these gaps requires further research to ensure that carbon markets can effectively support inclusive and equitable sustainable economic development in the Asia-Pacific region.

Limitations & Suggestions for future research

Based on the SLR analysis regarding the transformation of carbon market management in Asia-Pacific countries for achieving sustainable economic development, several limitations and recommendations for future research have been identified. One of the main limitations is the scarcity of available data to analyze the impact of extreme climate change on carbon markets in the region. Much of the data used does not cover a long time frame or is not representative, and some countries have incomplete or inconsistent data. Additionally, the approaches often focus solely on the economic or technical aspects of the carbon market without considering the social and policy dimensions, which are also crucial, particularly in developing countries. The methodologies used in this research are also limited, with many studies relying on econometric models or simulations that may not fully reflect real-world conditions. Recommendations for future research include expanding the scope of data by involving underrepresented countries, as well as exploring the impact of extreme climate change on the most affected economic sectors. From a theoretical perspective, a more holistic framework needs to be developed that integrates economic, social, and political aspects in the management of carbon markets. Research methodologies should also be more interdisciplinary, utilizing dynamic systems models and both qualitative and quantitative approaches. From a practical standpoint, research should provide more detailed policy recommendations to enhance the efficiency of carbon markets and strengthen the capacity of local institutions. Conceptually, it is important to explore how carbon markets can contribute to inclusive and equitable climate change policies, while also supporting the achievement of sustainable economic development.

5. CONCLUSIONS AND RECOMMENDATIONS

From the analysis of the dynamics of extreme climate change and the transformation of carbon market management in Asia-Pacific countries, it can be concluded that effective energy policies, such as carbon taxes and clean energy pricing policies, play a crucial role in supporting the transition to clean energy and decarbonization. Proper policy approaches can encourage the adoption of environmentally friendly technologies, such as new energy vehicles and renewable power plants, as well as the integration of carbon markets with the energy and finance sectors for more optimal results. The behavior of carbon markets is also significantly influenced by external factors, including fluctuations in energy prices and government policies. The high volatility of carbon prices indicates the need for policies that can reduce price instability and strengthen connectivity between carbon, energy, and financial markets. Additionally, innovations in new energy technologies, such as new energy vehicles, renewable power plants, and biofuels, are essential to support this transition. Policies that support technological innovation and international collaboration will accelerate the achievement of carbon balancing goals. Furthermore, policies that promote economic sustainability can expedite carbon emission reductions. The post-COVID-19 economic recovery, focused on sustainability, can accelerate the transition to clean energy and support the achievement of the Paris Agreement targets. Carbon pricing plays a central role in emission reduction policies. The establishment of fair and effective carbon pricing, along with sound carbon market governance, is necessary to stimulate green innovation and reduce market volatility, thus driving significant emission reductions.

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