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Analyzing Key Variables in Recurrent Carbon Reduction Policies Using a Hybrid Approach: A Focus on Pharmaceutical Distributors in Iran

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ABSTRACT

Objective: This research aims to identify recurring carbon reduction policies and their key variables, and analyze their relationships within pharmaceutical distribution in Iran.

Methods: A mixed-method of qualitative and quantitative approaches was adopted. Firstly, a systematic literature review was employed to identify the policies and variables. Afterward, the Intuitive Fuzzy DEMATEL (Decision Making Trial and Evaluation Laboratory) method was used to analyze the causal relationships among identified variables in uncertain conditions. Following snowball sampling, data were gathered through expert questionnaires from 15 specialists in five groups, selected based on relevant expertise in carbon reduction policies, particularly for pharmaceutical distribution companies in Iran.

Results: The study identified three key carbon reduction policies—cap-and-trade, subsidy allocation, and financial penalties—all shaped by distinct variables. Cap-and-trade includes the emission cap, carbon selling price, and demand for carbon emission permits. Subsidy allocation and financial penalties cover the subsidy amount and the penalty rate, respectively. Notably, carbon emission level emerged as the most influential factor in shaping policy effectiveness, while carbon reduction cost was identified as the most impactful variable. These two variables are integral to all three policies, highlighting their pivotal role in policy formulation. While the demand for carbon emission permits remains neutral regarding influence and susceptibility, other variables demonstrate complex interdependencies, creating a dynamic system where policies interact directly through primary variables or indirectly through shared criteria.

Conclusion: This study contributes to environmental policy research by offering an analytical framework that integrates uncertainty logic to assess relationships among key variables. The findings suggest that implementing a single policy may not be sufficient—a combination of strategies is recommended for more effective carbon reduction. Understanding how variables interact can help policymakers and businesses design targeted and efficient pharmaceutical distribution strategies in Iran.

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Introduction

The increase in greenhouse gas emissions and, consequently, the rise in temperature and climate change have attracted global attention as one of the most significant challenges of the current century (Zegord & Shahid, 2022; Bakri Zadeh & Shohani, 2024). Various countries are striving to adopt effective policies to reduce carbon dioxide emissions, which are the primary greenhouse gas (Padash & Mohammadizadeh, 2024; Hojjat et al., 2019), to combat the increase in greenhouse gas emissions and their consequences, such as global warming and climate change (Nsabiyeze et al., 2024). In this regard, three countries— the United Kingdom, Japan, and the United States—with compound annual growth rates of greenhouse gas emissions of -1.2%, -0.7%, and -0.1%, respectively, during the period from 1990 to 2023 (Crippa et al., 2024), are leading nations in reducing greenhouse gas emissions and can serve as models for planning such reductions.

A review of credible scientific and news sources from leading countries indicates that the path to reducing greenhouse gas emissions lies in the effective implementation of carbon reduction policies (Pan et al., 2021; Arimura & Abe, 2021). These policies have successfully resulted in annual reductions in emissions in these nations (Padash & Mohammadizadeh, 2024). Consequently, identifying effective and consistent carbon reduction strategies is an environmental imperative for addressing rising emissions in developing countries, where carbon emissions continue to increase annually, and a moral and social obligation to current and future generations (Ramani et al., 2024).

Furthermore, these policies are interconnected through key variables. To improve strategic planning for their implementation, it is vital to recognize these main factors and assess their interactions (Zhao et al., 2020). Analyzing the relationships among these key variables is crucial, as they affect the success of carbon reduction policies and exhibit complex interactions. Gaining a deeper understanding of these relationships can facilitate the design of more effective and targeted carbon reduction initiatives.

Despite advancements in research within this field, significant gaps remain in understanding the interactions among key variables in recurrent carbon reduction policies. While some studies have assessed the impact of specific policies using mathematical modeling (Quinn et al., 2023), classical game theory (Ambec et al., 2024), statistical analysis (Jung & Song, 2023), and simulation methods (Pan et al., 2021), the combined effects of these policies and the interrelationships among key variables have received less attention within a comprehensive analytical framework that incorporates uncertainty logic. For instance, while studies such as Zhao et al. (2020) and Nsabiyeze et al. (2024) have explored the interactions between financial penalties and cap-and-trade systems, there is still a need for a systematic analysis of the relationships among variables like subsidy levels, carbon prices, penalty rates, and demand levels.

Overall, this study is motivated by two significant research gaps. The first gap is the lack of a comprehensive analytical framework that examines key variables' interrelationships and combined effects in carbon reduction policies (see Table 1). Addressing this gap requires innovative approaches, such as Intuitionistic Fuzzy DEMATEL (Decision Making Trial and Evaluation Laboratory), to identify and prioritize causal relationships among these variables (Abdullah et al., 2023). The second gap is the limited research that simultaneously analyzes the impact of various variables together (see Table 1). This highlights the need for studies integrating quantitative and qualitative methods to better understand the complex interactions among these factors. Hence, gaining a deeper understanding of the interrelationships among key variables in commonly used carbon reduction policies is crucial. This research area has the potential to contribute to developing more effective strategies for reducing carbon emissions, thereby helping combat the increase of greenhouse gas emissions, global warming, and climate change.

The systematic literature review method is unbiased and can effectively identify standard carbon reduction policies in leading countries and their key variables (Browning et al., 2023). Given the complexity and multidimensional nature of carbon reduction issues, it is essential to use systematic and comprehensive methods to analyze the relationships among these key variables (see Table 1). The DEMATEL method, a powerful tool in multi-criteria decision-making, allows for analyzing causal and structural relationships among different variables (Si et al., 2018). Researchers can identify both direct and indirect effects of variables in uncertain environments by combining this method with new uncertainty analysis techniques, such as intuitionistic fuzzy sets (Atanassov, 1986). This integration enhances the understanding of their interactions and helps prioritize policy actions grounded in reality. Thus, the intuitionistic fuzzy DEMATEL method is a structured analytical tool incorporating uncertainty logic, providing deeper insights into the causal relationships among factors in complex systems (Abdullah et al., 2023). Using this method, researchers can systematically examine the interrelationships among criteria and support evidence-based decision-making.

This research aims to achieve two research objectives: (RO1) Identify the key variables influencing recurrent carbon reduction policies by conducting a systematic literature review, and (RO2) Analyze the interrelationships among these key variables using the intuitionistic fuzzy DEMATEL method, focusing on the pharmaceutical distribution sector in Iran. Accordingly, three research questions have been followed to do so: (RQ1) What carbon reduction policies have been most frequently implemented by leading countries to effectively reduce emissions?, (RQ2) What are the key variables associated with each commonly adopted carbon reduction policy?, and (RQ3) How do the identified key variables interact within a relationship framework in the uncertain environment, specifically in the context of pharmaceutical distributors in Iran?

This research follows a two-phase approach: First, a systematic literature review will be conducted to identify and classify influential variables within recurrent carbon reduction policies. Then, the intuitionistic fuzzy DEMATEL method will be applied to examine these variables' causal and structural relationships, providing insights into their role within the carbon reduction policy framework.

The decision to select pharmaceutical distributors in Iran as a case study is based on several key factors. First, the country has had a consistent annual increase in greenhouse gas emissions (Crippa et al., 2024), with the transportation sector accounting for a significant portion of these emissions. It ranks second in emissions, following the electricity and energy production sector (Crippa et al., 2024). Furthermore, the distribution of temperature-sensitive pharmaceutical products results in carbon emissions that are one to two times higher than those associated with the distribution of other products (Bazazan & Khosrovani, 2017). These factors contribute to the rationale behind choosing this case study. Eventually, the insights gained from this research can aid policymakers, planners, and practitioners in crafting and implementing more effective policies by offering a deeper understanding of how these variables interact.

This research is organized as follows: Section 2 presents a systematic literature review and identifies the key variables associated with recurrent carbon reduction policies in leading countries. Section 3 explains the research methodology used in the study. In Section 4, the findings are reported. Finally, Section 5 discusses the results and presents the conclusion and future recommendations.

Literature Background

Reducing carbon emissions requires adopting methods and policies that mitigate environmental impacts, enhance resource efficiency, and improve profitability (Padash & Mohammadizadeh, 2024; Hojjat et al., 2019). As concerns about global warming, climate change, and the depletion of natural resources continue to grow, researchers, companies, and governments have increasingly focused on implementing effective environmental policies (Browning et al., 2023). These policies help preserve the environment and natural resources, enhance productivity, and lower operational costs (Nsabiyeze et al., 2024). Therefore, this section aims to identify commonly used carbon reduction policies in leading countries such as the United Kingdom, Japan, and the United States, as well as their key variables and research gaps, through a systematic review of the relevant literature.

To achieve this, a keyword search was conducted in the Scopus database. As illustrated in Figure 1, the initial search using the keyword "carbon reduction policies" in the title, abstract, and keywords identified 2,426 research works. By applying a time restriction to the last five years (from 2020 to January 2025) and limiting the subject areas to economics and finance, social sciences, business, management, accounting, and decision sciences, the number of works was reduced to 398. Further filtering by document type and language to include only articles in English narrowed the count to 360. Please note that applying a filter for the source type (journal) did not alter the number of works. Next, by selecting more specific keywords such as "carbon reduction" and "emission control," the number of research works was reduced to 126. Finally, by applying a geographical restriction to the three target countries of interest—namely, the United Kingdom, Japan, and the United States—the number of studies was narrowed down to 21 final works.

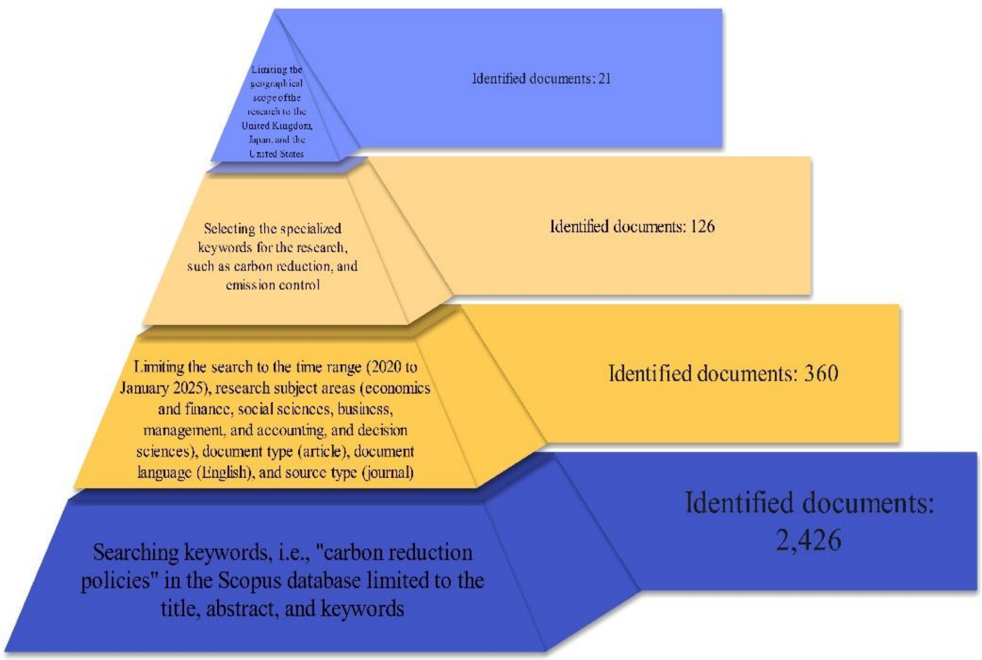

Figure 1. Results of systematic literature review process (Source: Researcher)

As a result, 21 final articles were selected for in-depth review and detailed analysis. A summary of the findings from this review is presented in Table 1.

Table 1. Summary of reviewing 21 research studies related to the carbon reduction policies

Scholar(s)	Year	Aim	Carbon reduction policy	Data analysis approach	Case study
Bruninx et al.	2020	Examining the long-term impact of the market stability reserve on the carbon trading system	Cap-and-Trade	Mathematical modeling	The electricity generation sector of the European Union
Dissanayake et al.	2020	Examining carbon reduction policies in advanced countries	Cap-and-Trade, subsidize, and penalize	Simulation	The European Union
Jin et al.	2020	Analyzing permit allocation in the carbon trading system	Cap-and-Trade	Mathematical modeling	The electricity generation sector of Japan
Li & Peng	2020	Evaluating the impact of carbon reduction policies on carbon emissions	Subsidize, and penalize	Mathematical modeling	England
Zhang et al.	2020	Calculating the impact of the carbon trading system on the reduction of carbon emissions	Cap-and-Trade	Mathematical modeling	Japan
Zhao et al.	2020	Analyzing the impact of individual and combined carbon reduction policies	Cap-and-Trade, and penalize	Mathematical modeling	England
Abe & Arimura	2021	Assessing the impact of implementing carbon reduction policies on performance	Cap-and-Trade	Statistical analysis	University Buildings in Japan (Tokyo)
Arimura & Abe	2021	Examining the impact of implementing carbon reduction policies on performance	Cap-and-Trade	Date analysis	Japan (Kyoto)
Pan et al.	2021	Analyzing the effectiveness of carbon emission trading policies	Cap-and-Trade	Simulation	Japan
Shojaei & Mokhtar	2022	Carbon reduction through the allocation of emission allowances	Cap-and-Trade	Mathematical modeling	The European Union
Browning et al.	2023	Examining scenarios for achieving carbon neutrality	Cap-and-Trade, and penalize	Literature review	America
Harvey et al.	2023	Development of carbon reduction policies and forecasting carbon emissions	Cap-and-Trade	Thematic analysis	Britain and America
Jung & Song	2023	Examining the impact of trading policies on carbon emission rates	Cap-and-Trade	Statistical analysis	Britain, America, and Japan
Quinn et al.	2023	Examining the impact of setting carbon emission reduction targets on carbon prices	Cap-and-Trade	Mathematical modeling	Japan (Kyoto)

Scholar(s)	Year	Aim	Carbon reduction policy	Data analysis approach	Case study
Yao et al.	2023	Exploring the requirements for achieving carbon neutrality goals	Cap-and-Trade	Literature review	America
Abajian & Pretnar	2024	Reducing carbon Emissions Through Decreasing Demand for Grid Electricity	Subsidize	Mathematical modeling	America
Ambec et al.	2024	Evaluating carbon leakage reduction policies from an economic perspective	Subsidize, emission allowance, cap-and-trade	Classical game theory	The cement, iron, and steel industry in Britain
Bai & Ru	2024	Analyzing carbon reduction policies in environmental conservation	Cap-and-Trade, and penalize	Concept analysis	100 countries
Feng et al.	2024	Examining the effectiveness of carbon reduction policies	Cap-and-Trade	Statistical analysis	Japan
Nsabiyeze et al.	2024	Examining the effectiveness of carbon reduction policies	Cap-and-Trade, subsidize, and penalize	Literature review	Britain and America
Ramani et al.	2024	Examining the effectiveness of various carbon reduction policies	Cap-and-Trade, and subsidize	Classical game theory	England

(Source: Researcher)

A review of recent research on carbon reduction policies reveals that many studies have primarily focused on examining the impact of these policies on carbon emissions in three target countries (e.g., Bruninx et al., 2020; Jin et al., 2020; Zhang et al., 2020). Additionally, another group of studies (e.g., Pan et al., 2021; Arimura & Abe, 2021) has evaluated the effectiveness of these policies. Furthermore, a separate set of articles (e.g., Browning et al., 2023; Yao et al., 2023) has emphasized the role of carbon reduction policies as a crucial scenario for achieving the global goal of carbon neutrality.

The review of conducted studies highlights that the cap-and-trade system, subsidy allocation, and financial penalties are some of the most recurrently used policies in this area (see Table 1). The carbon cap-and-trade policy is a market-based approach to reduce greenhouse gas emissions (Yao et al., 2023). In this system, the government sets an overall cap on the permissible level of carbon emissions, and emission permits (allowances) are allocated to companies covered by the system. Companies can trade these permits among themselves. If a company emits less than its allocated cap, it can sell its surplus permits to other companies. A company must purchase additional permits if it exceeds its emission cap (Yao et al., 2023). This mechanism creates incentives for emission reduction and innovation in clean technologies. The ultimate goal of this system is to gradually lower the overall emission cap and move toward a low-carbon economy.

Therefore, as shown in Table 2, the key variables associated with the cap-and-trade policy include the emission cap, carbon price, and the demand for carbon emission permits.

Table 2. Key variables associated with recurrent carbon reduction policies

Carbon reduction policies	Key variables	Source
Cap-and-trade	The emission cap	(Bruninx et al., 2020; Dissanayake et al., 2020; Jin et al., 2020; Zhang et al., 2020; Zhao et al., 2020; Abe & Arimura, 2021; Arimura & Abe, 2021; Pan et al., 2021; Shojaei & Mokhtar, 2022; Browning et al., 2023; Harvey et al., 2023; Jung & Song, 2023; Quinn et al., 2023; Yao et al., 2023; Ambec et al., 2024; Bai & Ru, 2024; Feng et al., 2024; Nsabiyeze et al., 2024; Ramani et al., 2024)
	The carbon price	(Bruninx et al., 2020; Jin et al., 2020; Zhang et al., 2020; Zhao et al., 2020; Abe & Arimura, 2021; Arimura & Abe, 2021; Pan et al., 2021; Shojaei & Mokhtar, 2022; Browning et al., 2023; Harvey et al., 2023; Jung & Song, 2023; Quinn et al., 2023; Yao et al., 2023; Ambec et al., 2024; Feng et al., 2024; Ramani et al., 2024)
	The demand for carbon emission permits	(Bruninx et al., 2020; Jin et al., 2020; Zhang et al., 2020; Quinn et al., 2023; Yao et al., 2023; Ambec et al., 2024; Feng et al., 2024)
	The carbon emission level	(Bruninx et al., 2020; Dissanayake et al., 2020; Jin et al., 2020; Zhang et al., 2020; Zhao et al., 2020; Abe & Arimura, 2021; Arimura & Abe, 2021; Pan et al., 2021; Shojaei & Mokhtar, 2022; Browning et al., 2023; Harvey et al., 2023; Jung & Song, 2023; Quinn et al., 2023; Yao et al., 2023; Ambec et al., 2024; Bai & Ru, 2024; Feng et al., 2024; Nsabiyeze et al., 2024; Ramani et al., 2024)
	The carbon reduction cost	(Bruninx et al., 2020; Dissanayake et al., 2020; Jin et al., 2020; Abe & Arimura, 2021; Arimura & Abe, 2021; Pan et al., 2021; Shojaei & Mokhtar, 2022; Browning et al., 2023; Harvey et al., 2023; Quinn et al., 2023; Yao et al., 2023; Ambec et al., 2024; Bai & Ru, 2024; Feng et al., 2024; Nsabiyeze et al., 2024; Ramani et al., 2024)
Subsidize	The subsidy amount	(Dissanayake et al., 2020; Li & Peng, 2020; Browning et al., 2023; Abajian & Pretnar, 2024; Ambec et al., 2024; Nsabiyeze et al., 2024; Ramani et al., 2024)
	The carbon emission level	(Dissanayake et al., 2020; Li & Peng, 2020; Browning et al., 2023; Abajian & Pretnar, 2024; Ambec et al., 2024; Nsabiyeze et al., 2024; Ramani et al., 2024)
	The carbon reduction cost	(Browning et al., 2023; Abajian & Pretnar, 2024; Ambec et al., 2024; Ramani et al., 2024)
Penalize	The penalty rate	(Dissanayake et al., 2020; Li & Peng, 2020; Zhao et al., 2020; Bai & Ru, 2024; Nsabiyeze et al., 2024)
	The carbon emission level	(Dissanayake et al., 2020; Li & Peng, 2020; Zhao et al., 2020; Bai & Ru, 2024; Nsabiyeze et al., 2024)
	The carbon reduction cost	(Zhao et al., 2020; Bai & Ru, 2024; Nsabiyeze et al., 2024)

(Source: Researcher)

In addition to the cap-and-trade policy, which controls carbon emissions through trade regulations and emission limits, two other essential policies for reducing carbon pollution are the allocation of subsidies and the implementation of financial penalties (see Table 1). Subsidies are usually provided to promote carbon emission reductions, while penalties are imposed on companies that surpass standard emission levels (Nsabiyeze et al., 2024). Therefore, the key variables related to carbon reduction subsidies and penalties are the subsidy amounts and the penalty rates, respectively (see Table 2). Overall, factors such as carbon emission levels and the costs associated with carbon reduction are common across all three policy approaches (see Table 2).

Despite advancements in research in this field, a review of existing studies indicates that the interactions among key variables of carbon reduction policies have not been thoroughly analyzed. While some studies have assessed the impact of specific policies using mathematical modeling and classical game theory (e.g., Bruninx et al., 2020; Jin et al., 2020; Zhang et al., 2020; Li & Peng, 2020; Zhao et al., 2020; Pan et al., 2021; Shojaei & Mokhtar, 2022; Quinn et al., 2023; Abajian & Partenar, 2024; Feng et al., 2024), statistical analysis (e.g., Arimura & Abe, 2021; Abe & Arimura, 2021; Jung & Song, 2023), and simulation (e.g., Dissanayake et al., 2020; Pan et al., 2021), the combined effects of these policies and the relationships among key variables within a comprehensive analytical framework under high uncertainty have received insufficient attention.

For instance, studies by Zhao et al. (2020) and Nsabiyeze et al. (2024) have simultaneously explored the roles of financial penalties and cap-and-trade systems. However, a systematic analysis of the relationships between subsidy amounts, carbon prices, penalty rates, and demand levels still requires further investigation. In sum, while numerous policies have been proposed to reduce carbon emissions, a deeper understanding of the interrelationships among key variables in a combination of these policies is vital for effective research. Conducting more detailed studies in this area could assist decision-makers and policymakers in developing more effective strategies for reducing carbon emissions and achieving sustainable development goals.

To address this research gap, this study aims to enhance understanding of the interactions among various policies considering pharmaceutical distributors in Iran. We employ a systematic literature review as a robust and unbiased method to extract commonly used policies and their associated variables (Browning et al., 2023). Additionally, we utilize the intuitionistic fuzzy DEMATEL method as an analytical tool incorporating uncertainty logic, allowing us to identify cause-and-effect relationships among the key variables identified (Abdullah et al., 2023). This research aids in developing effective strategies to reduce carbon emissions among pharmaceutical distributors in Iran by analyzing the interplay of carbon reduction policies.

Materials and Methods

This study adopts a mixed-method approach, integrating qualitative and quantitative methods to ensure a comprehensive understanding of carbon reduction policies and their key variables. This combination allows for an in-depth exploration of existing policies while providing a structured analytical framework to assess variable relationships, particularly under conditions of uncertainty. The flowchart of the research methodology is presented in Figure 2.

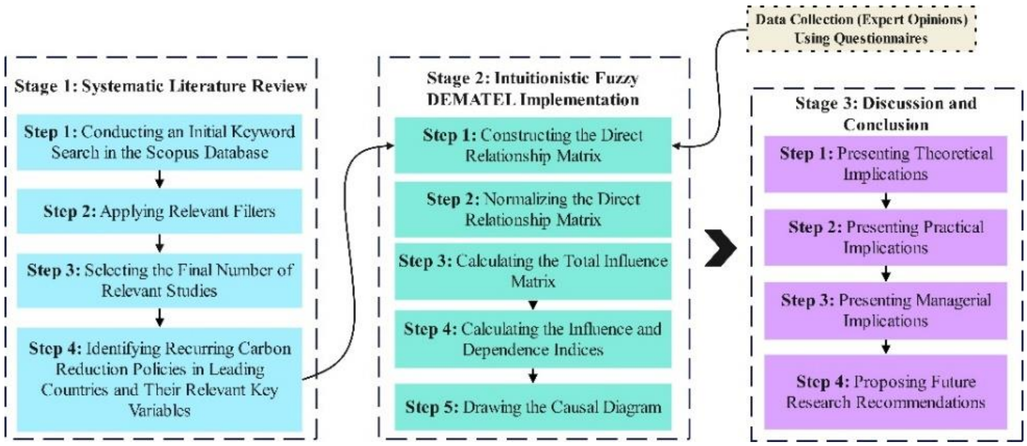

Figure 2. The flowchart of research methodology (Source: Researcher)

In the first step, a qualitative systematic literature review method was used to identify recurring carbon reduction policies in the three selected countries for benchmarking (the United Kingdom, Japan, and the United States) and the key variables associated with each of these policies. By systematically identifying, evaluating, and synthesizing previous studies, this method ensures a rigorous and unbiased assessment of key variables associated with these policies (Browning et al., 2023). Furthermore, it allows for benchmarking best practices from leading countries, offering valuable insights into effective carbon reduction strategies (Yao et al., 2023). The findings from the literature review serve as a strong foundation for the subsequent quantitative analysis, enabling the integration of theoretical understanding with practical applications. Ultimately, this approach enhances decision-making by providing policymakers and industry leaders with evidence-based recommendations for sustainable carbon reduction policies.

Following the systematic literature review, the intuitionistic fuzzy DEMATEL method was employed as a quantitative analytical approach to assess the relationships among key variables identified for pharmaceutical distribution companies in Iran, considering uncertainty logic (Sadeghi et al., 2023). Unlike traditional techniques, this approach integrates membership and non-membership degrees, allowing for a more nuanced representation of ambiguity in decision-making (Rostamizadeh et al., 2021). Besides, this method was selected for its ability to distinguish between influential and influenced relationships, enabling a structured examination of the interactions among variables in a high-uncertainty environment (Si et al., 2018). By incorporating intuitionistic fuzzy logic, DEMATEL enhances the analysis by capturing ambiguity and complex dependencies, ensuring a more comprehensive understanding of variable dynamics (Abdullah et al., 2023).

The insights gained from these two methodological steps serve as a foundation for extracting managerial implications and guiding strategic decision-making. Specifically, the findings provide policymakers and industry leaders with a data-driven framework for adopting carbon reduction policies more effectively. In the following sections, each research step and the details of data collection are discussed in depth.

Stage 1: Systematic Literature Review. To conduct the systematic literature review, a keyword search was initially performed in the Scopus database. Specifically, the keyword "carbon reduction policies" was searched in the title, abstract, and keywords sections. To narrow down the number of studies found, a time restriction was applied to the last five years (from 2020 to January 2025), and the subject areas were limited to economics and finance, social sciences, business, management, and accounting, as well as decision sciences. Additionally, the document type was restricted to scientific articles, the language to English, and the source type to Journals. Furthermore, by focusing on specialized keywords such as "carbon reduction" and "emission control," additional research works were excluded. Subsequently, a geographical restriction was applied to the three target countries for benchmarking—the United Kingdom, Japan, and the United States—to determine the final number of studies. Finally, the selected articles were thoroughly reviewed and analyzed in detail. As a result, recurring carbon reduction policies and their key variables were identified.

Stage 2: Intuitionistic Fuzzy DEMATEL Implementation. The DEMATEL method, developed in 1971 by the Battelle Memorial Institute in Geneva, is a powerful analytical technique for examining causal relationships and mutual influences among criteria in complex systems (Si et al., 2018). This method is widely used in various fields such as management, performance evaluation, and multi-criteria decision-making. It helps researchers by transforming qualitative relationships between factors into a quantitative structure, enabling the identification of direct and indirect influences among criteria and providing a better understanding of the system's structure.

Intuitionistic fuzzy sets are an extension of the classical fuzzy set concept, introduced by Krassimir Todorov Atanassov in 1986. They are used to model uncertainty and ambiguity in complex systems. In these sets, in addition to the membership function ($\mu_A(x)$), a non-membership function ($\nu_A(x)$) is also defined (Atanassov, 1986). ($\mu_A(x)$) represents the degree of membership of an element to set A, and ($\nu_A(x)$) represents the degree of non-membership of an element to set A, with both values ranging between 0 and 1 ($\mu_A(x), \nu_A(x) \in [0,1]$). Another constraint of intuitionistic fuzzy sets is that the sum of the membership and non-membership functions must be less than or equal to 1 ($\mu_A(x) + \nu_A(x) \leq 1$). Below, the steps of the intuitionistic fuzzy DEMATEL method, based on Abdullah et et al. (2023), are described in detail.

Step 1: Formation of the Direct Relationship Matrix. Initially, the outputs from the first stage, i.e., the key variables of recurring carbon reduction policies identified through the systematic literature review, are defined as the criteria for the intuitionistic fuzzy DEMATEL method. Then, pairwise comparison matrices $\left(Z_{e=1,\dots,n=5}\right)$ are constructed through expert surveys $(e = 1, \dots, n = 5)$.

In these matrices, each element represents both degrees of influence and non-unifluence of factor i on factor j $(i = j = 1, \dots, m = 7)$. The values indicating the influence degree between factors in this matrix are determined based on Likert scales such as: {very high influence (1), high influence (0.8), moderate influence (0.6), low influence (0.4), very low influence (0.2), and no influence (0)}. The values indicating the non-influence degree between factors in this matrix are determined based on Likert scales such as: {very high non-influence (1), high non-influence (0.8), moderate non-influence (0.6), low non-influence (0.4), very low non-influence (0.2), and influential (0)}.

Next, by converting the linguistic variables determined by the experts into their equivalent numerical values, the average of the experts' opinions can be calculated to create the intuitionistic fuzzy direct relationship matrix. Subsequently, by defuzzifying the obtained intuitionistic fuzzy values $\left(a_{ij} = \left(\mu_{ij}, v_{ij}\right)\right)$ through calculating their scores using Equation (1), the direct relationship matrix (Z) is formed.

$$Score\ a_{ij} = \left(\mu_{ij} - v_{ij}\right) \tag{1}$$

Step 2: Normalization of the Direct Relationship Matrix. To normalize the initial matrix, Equation (2) is used:

$$X = \frac{Z}{Max\ s_i} \tag{2}$$

Here, X represents the normalized direct relationship matrix, and $s_{i=1,\dots,m=7}$ is the value of the row sums of the matrix Z. This step ensures that all values in the matrix are scaled to a range between 0 and 1, facilitating further analysis.

Step 3: Calculation of the Total Influence Matrix. In this step, the total influence matrix (T) is calculated using Equation (3):

$$T = X(I - X)^{-1} \tag{3}$$

Here, X is the normalized direct relationship matrix obtained in Step 2, and I represents the identity matrix. The total influence matrix (T) captures both the direct and indirect influences among the factors, providing a comprehensive understanding of their interrelationships.

Step 4: Calculation of Influence and Dependence Indices. From the total influence matrix (T), two main indices are calculated:

- Influence Index $(\mathrm{R}_{\mathrm{i}=1,\ldots,\mathrm{m}=7})$: This is derived from summing the rows of the total influence matrix (T), and illustrates how much each factor influences the others.
- Dependence Index $(\mathrm{C}_{\mathrm{i}=1,\ldots,\mathrm{m}=7})$: This is calculated by summing the columns of the total influence matrix (T), reflecting how much each factor is affected by others.

These indices help identify the causal relationships and the relative importance of each factor within the system.

Step 5: Drawing the Causal Diagram. Using the values of $R_{i=1,\ldots,m=7}$ and $C_{i=1,\ldots,m=7}$, a causal diagram is plotted. In this diagram, the horizontal axis represents $(R_{i=1,\ldots,m=7} + C_{i=1,\ldots,m=7})$ (centrality index), which indicates the overall importance of each factor. The vertical axis represents $(R_{i=1,\ldots,m=7} - C_{i=1,\ldots,m=7})$ (causal index), which determines whether a factor is more influential or more dependent. Factors with $(R_{i=1,\ldots,m=7} - C_{i=1,\ldots,m=7}) > 0$ are considered influential, while those with $(R_{i=1,\ldots,m=7} - C_{i=1,\ldots,m=7}) < 0$ are considered dependent.

To draw the relationships between the criteria, a threshold value is first determined, which is equal to the average of the elements in the total influence matrix (T). Each element of the total influence matrix is then compared to this threshold. If an element is greater than or equal to the threshold, it is replaced with 1; otherwise, it is replaced with 0. This results in a binary (0-1) matrix. Finally, based on this binary matrix, the relationships between the criteria are plotted.

Stage 3: Discussing Insights Extraction and Conclusion. Finally, by analyzing the total influence matrix and the causal diagram, the key relationships among the critical variables of recurring carbon reduction policies are identified. This analysis assists decision-makers in pinpointing the main influential factors and designing appropriate strategies to improve the system. The insights gained from this step enable the formulation of effective policies and interventions to achieve carbon reduction goals.

Data Collection. The data required for the first step of the intuitionistic fuzzy DEMATEL method were collected through questionnaires completed by experts. In the questionnaire, experts were asked to fill out pairwise comparison tables indicating the degree of influence and non-influence of each variable on the others using the linguistic variables from the two Likert scales presented in the first step of the intuitionistic fuzzy DEMATEL method.

The selection of experts was conducted using the snowball sampling method and based on expert qualification criteria, including (i) expertise in carbon reduction policy mechanisms, (ii) academic background, (iii) professional position, and (iv) level of experience.

Specifically, efforts were made to select experts with research (publications) or practical (applied projects) experience in environmental sustainability, particularly in reducing air pollution related to pharmaceutical product distribution. Additionally, experts were limited to those with graduate-level education or currently pursuing graduate studies in management (e.g., industrial management, financial management, strategic management, and marketing management) and industrial engineering. From a professional position perspective, the focus was on experts active or previously active in academia, industry, or government executive agencies. Specifically, the workplaces of these experts were limited to universities, pharmaceutical distribution companies, and government agencies under the executive branch involved in carbon reduction policy-making. Furthermore, the selected experts had previously held or currently hold positions as professors, specialists, middle managers, or senior managers in policy-making, sales, operations, and finance departments. In terms of experience, the primary focus was on experts with over three years of experience in their resumes.

Considering these expert qualification criteria, 15 experts were selected using the snowball sampling method. To gather collaborative raw data, the researcher divided the experts into five groups of three. The details of the experts in each of these five groups are presented in Table 3.

Table 3. Experts' characteristics

Expert ID	Type of Expert Activity		Field of Study	Academic Degree	Professional Domain	Job Position	Years of Experience
	Scientific-Research Articles	Applied Projects					
G1/E1	✓	✓	Industrial Management	PhD	Academic	Associate Professor	25
G1/E2	✓		Industrial Management	PhD	Academic	Associate Professor	15
G1/E3	✓		Industrial Engineering	Master's	Industry	Senior Manager	10
G2/E1	✓	✓	Industrial Management	PhD Candidate	Academic	PhD Candidate	7
G2/E2		✓	Industrial Engineering	PhD	Industry	Senior Manager	9
G2/E3		✓	Financial Management	PhD Candidate	Administrative Agencies	Middle Manager	4
G3/E1	✓		Financial Management	Master's Candidate	Industry	Specialist	6
G3/E2	✓		Industrial Management	PhD Candidate	Industry	PhD Candidate	8
G3/E3	✓	✓	Industrial Engineering	PhD	Academic	Full Professor	30
G4/E1	✓	✓	Strategic Management	PhD Candidate	Administrative Agencies	Specialist	6

Expert ID	Type of Expert Activity		Field of Study	Academic Degree	Professional Domain	Job Position	Years of Experience
	Scientific-Research Articles	Applied Projects					
G4/E2	✓		Industrial Engineering	PhD	Academic	Assistant Professor	5
G4/E3	✓	✓	Financial Management	PhD Candidate	Industry	Specialist	10
G5/E1	✓		Industrial Management	PhD	Academic	Associate Professor	17
G5/E2		✓	Strategic Management	Master's	Administrative Agencies	Senior Manager	20
G5/E3	✓		Business Management	Master's	Industry	Specialist	4

(Source: Researcher)

To collect the required data, the researcher organized a formal two-hour online meeting for each group via the Google Meet platform. During these meetings, the first half-hour was dedicated to an initial explanation by the researcher, while the remaining one-and-a-half hours were allocated for expert discussions and collaborative input to complete the questionnaire. By collecting responses from 15 experts divided into five groups of three, the researcher achieved data saturation. Therefore, the input from these 15 experts was deemed sufficient, and the five questionnaires completed by the five groups of three were used as the primary data for the intuitionistic fuzzy DEMATEL method in this study.

Results

The findings from the first stage, i.e., the systematic literature review (Tables 1 and 2), indicate that the recurring carbon reduction policies, particularly in the three countries that annually experience reductions in greenhouse gas emissions (the United Kingdom, Japan, and the United States), are as follows: cap-and-trade, subsidy allocation, and imposition of financial penalties. For the cap-and-trade policy, the key variables identified are the emission cap(C_1), the carbon price(C_2), and the demand for carbon emission permits(C_3). In the case of subsidy allocations and financial penalties, the critical variables are the subsidy amount (C_4) and the penalty rate(C_5), respectively. Lastly, two key variables that are relevant to all three policies are the overall carbon emission level (C_6) and the cost of carbon reduction (C_7).

Therefore, the seven identified key variables have been considered as the criteria for the intuitionistic fuzzy DEMATEL method. Subsequently, the relationships among these seven criteria were identified using a questionnaire containing pairwise comparison matrices completed by experts. To this end, 15 experts with the specifications listed in Table 3, who are particularly specialized in the mechanisms of carbon reduction policies for pharmaceutical distribution companies in Iran, were selected based on expert qualification criteria using the snowball sampling method. These experts were then divided into five groups of three, and each group completed a questionnaire during a two-hour online meeting.

Specifically, the experts determined the degree of influence and non-influence between each pair of variables using the linguistic variables from the two Likert scales introduced in the first step of the intuitionistic fuzzy DEMATEL method. As a result, five pairwise comparison matrices were collected as primary data. Next, each linguistic variable was converted into its equivalent numerical value, and the average of the experts' opinions was used to achieve consensus, resulting in the intuitionistic fuzzy direct relationship matrix as shown in Table 4.

Table 4. The intuitionistic fuzzy direct relationship matrix

i/j	C_1	C_2	C_3	C_4	C_5	C_6	C_7
C_1	(0, 0)	(0.64, 0.36)	(0.84, 0.16)	(0.52, 0.48)	(0.36, 0.64)	(0.96, 0.04)	(0.72, 0.28)
C_2	(0.48, 0.52)	(0, 0)	(0.8, 0.2)	(0.36, 0.64)	(0.36, 0.64)	(0.76, 0.24)	(0.64, 0.36)
C_3	(0.68, 0.32)	(0.88, 0.12)	(0, 0)	(0.56, 0.44)	(0.4, 0.6)	(0.96, 0.04)	(0.76, 0.24)
C_4	(0.92, 0.08)	(0.48, 0.52)	(0.48, 0.52)	(0, 0)	(0.8, 0.2)	(0.88, 0.12)	(0.92, 0.08)
C_5	(0.88, 0.12)	(0.32, 0.68)	(0.36, 0.64)	(0.72, 0.28)	(0, 0)	(0.92, 0.08)	(0.8, 0.2)
C_6	(0.92, 0.08)	(0.76, 0.24)	(0.96, 0.04)	(0.88, 0.12)	(0.96, 0.04)	(0, 0)	(0.96, 0.04)
C_7	(0.72, 0.28)	(0.64, 0.36)	(0.72, 0.28)	(0.76, 0.24)	(0.28, 0.72)	(0.88, 0.12)	(0, 0)

(Source: Researcher)

By calculating the intuitionistic fuzzy values' scores in the table above using Equation (1), the direct relationship matrix (Z) has been created, as shown in Table 5.

Table 5. The direct relationship matrix (Z)

$i.j$	C_1	C_2	C_3	C_4	C_5	C_6	C_7
C_1	0	0.28	0.68	0.04	-0.28	0.92	0.44
C_2	-0.04	0	0.6	-0.28	-0.28	0.52	0.28
C_3	0.36	0.76	0	0.12	-0.2	0.92	0.52
C_4	0.84	-0.04	-0.04	0	0.6	0.76	0.84
C_5	0.76	-0.36	-0.28	0.44	0	0.84	0.6
C_6	0.84	0.52	0.92	0.76	0.92	0	0.92
C_7	0.44	0.28	0.44	0.52	-0.44	0.76	0

(Source: Researcher)

The direct relationship matrix (Z) was normalized using Equation (2), resulting in the normalized direct relationship matrix(X), as presented in Table 6.

Table 6. The normalized direct relationship matrix (X)

$i.j$	C_1	C_2	C_3	C_4	C_5	C_6	C_7
C_1	0	0.06	0.14	0.01	-0.06	0.19	0.09
C_2	-0.01	0	0.12	-0.06	-0.06	0.11	0.06
C_3	0.07	0.16	0	0.02	-0.04	0.19	0.11
C_4	0.17	-0.01	-0.01	0	0.12	0.16	0.17
C_5	0.16	-0.07	-0.06	0.09	0	0.17	0.12
C_6	0.17	0.11	0.19	0.16	0.19	0	0.19
C_7	0.09	0.06	0.09	0.11	-0.09	0.16	0

(Source: Researcher)

Then, the total influence matrix (T) was computed using Equation (3) and is shown in Table 7.

Table 7. The total influence matrix (T)

$i.j$	C_1	C_2	C_3	C_4	C_5	C_6	C_7
C_1	0	0.008	0.034	0.001	0.002	0.058	0.018
C_2	0.000	0	0.021	0.002	0.003	0.016	0.006
C_3	0.012	0.036	0	0.002	0.001	0.059	0.024
C_4	0.053	-0.001	-0.001	0	0.018	0.052	0.054
C_5	0.042	0.001	-0.003	0.015	0	0.052	0.030
C_6	0.061	0.023	0.064	0.040	0.036	0	0.074
C_7	0.016	0.008	0.018	0.017	0.005	0.043	0

(Source: Researcher)

As a result, the influence and dependence indices, along with the centrality and causality indices—whose calculation methods were explained in Steps 4 and 5 of the intuitionistic fuzzy DEMATEL method—were computed based on the total influence matrix (T). These results are presented in Table 8.

Table 8. The influence and dependence indices

i	R_i	C_i	$R_i + C_i$	$R_i - C_i$
C_1	0.12	0.18	0.31	-0.06
C_2	0.05	0.08	0.12	-0.03
C_3	0.13	0.13	0.27	0.00
C_4	0.17	0.08	0.25	0.10
C_5	0.14	0.06	0.20	0.07
C_6	0.30	0.28	0.58	0.02
C_7	0.11	0.21	0.31	-0.10

(Source: Researcher)

In Table 8, the indices R_i and C_i represent the degree of influence and dependence of each criterion, respectively. Accordingly, the ranking of the criteria in terms of their influence on other criteria is as follows: carbon emission level (C_6), subsidy amount (C_4), penalty rate (C_5), demand for carbon emission permits (C_3), emission cap (C_1), carbon reduction cost (C_7), and carbon price (C_2).

Furthermore, the ranking of the criteria in terms of their dependence on other criteria is as follows: carbon emission level (C_6), carbon reduction cost (C_7), emission cap (C_1), demand for carbon emission permits (C_3), subsidy amount (C_4), carbon price (C_2), and penalty rate (C_5).

The prominence vector ($R_i + C_i$) quantifies the degree of influence and dependence among various factors. A higher value indicates a greater interaction of that factor with others, signifying its overall importance in the system. In this context, the variable for carbon emission levels (C_6) has the highest importance value of 0.58. This indicates that this criterion is both influential and dependent, playing a crucial role in the system. Following (C_6), the emission cap (C_1) and the carbon reduction cost (C_7) exhibit significant prominence in terms of their interactions with other variables. The demand for carbon emission permits (C_3), subsidy amount (C_4), penalty rate

(C_5), and carbon price (C_2) rank third through sixth in terms of overall importance within the system, respectively.

$(R_i - C_i)$ indicates the net role of each criterion as either influential or dependent. Therefore, carbon reduction cost (C_7), emission cap (C_1), and carbon price (C_2), with negative $(R_i - C_i)$ values, represent the three highly dependent variables, respectively. Additionally, the subsidy amount (C_4), penalty rate (C_5), and carbon emission level (C_6) are the three key influential variables in the system, respectively. Furthermore, the demand for carbon emission permits (C_3) is neutral in terms of influence and dependence.

Following Step 5 of the intuitionistic fuzzy DEMATEL method, the threshold value (0.02) was calculated as the average of the elements in the total influence matrix (T). By comparing each element of the total influence matrix (T) to this threshold, a binary matrix is created, as illustrated in Table 9. The binary matrix indicates whether a direct relationship exists between the criteria. In this matrix, the number 1 represents a direct influence of one criterion on another, while the number 0 signifies the absence of a direct relationship.

Table 9. The binary matrix

i/j	C_1	C_2	C_3	C_4	C_5	C_6	C_7
C_1	0	0	**1**	0	0	**1**	0
C_2	0	0	**1**	0	0	0	0
C_3	0	**1**	0	0	0	**1**	**1**
C_4	**1**	0	0	0	0	**1**	**1**
C_5	**1**	0	0	0	0	**1**	**1**
C_6	**1**	**1**	**1**	**1**	**1**	0	**1**
C_7	0	0	0	0	0	**1**	0

(Source: Researcher)

Eventually, using the calculated indices from Table 8 and the binary matrix formed in Table 9, the causal diagram for the seven key variables constituting the three recurring carbon reduction policies was drawn, as shown in Figure 3.

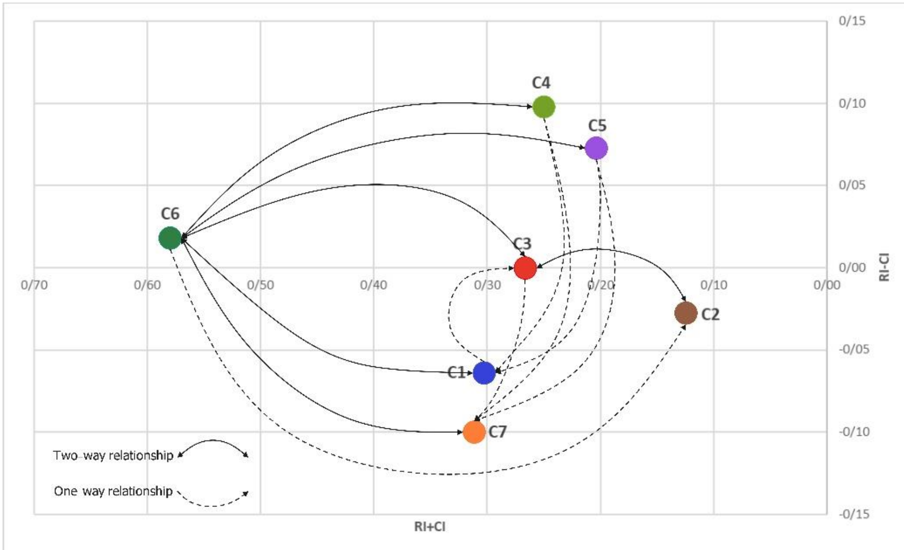

Figure 3. Causal digram (Source: Researcher)

According to the figure above, the emission cap (C_1) is directly influenced by all criteria except three variables: the demand for carbon emission permits (C_3), carbon price (C_2), and carbon reduction cost (C_7). However, the carbon reduction cost (C_7) also has an indirect influence on the emission cap (C_1). In contrast, the emission cap (C_1) directly affects only the demand for carbon emission permits (C_3) and the carbon emission level (C_6). Although it indirectly influences other variables, its role as a dependent variable in the system is more significant.

Additionally, the carbon price (C_2) has a higher degree of dependence. It is notably influenced by two factors: the demand for carbon emission permits (C_3) and the level of carbon emissions (C_6). Moreover, the carbon price (C_2) is indirectly influenced by other variables that affect the carbon emission level (C_6). However, it directly impacts the demand for carbon emission permits (C_3) and has an indirect effect on the carbon emission level (C_6) and the carbon reduction cost (C_7).

Furthermore, the demand for carbon emission permits (C_3) is both influential and dependent, making it a neutral variable. This is because, while it is directly influenced by the emission cap (C_1), carbon price (C_2), and carbon emission level (C_6), it directly affects the carbon price (C_2), carbon emission level (C_6), and carbon reduction cost (C_7).

The subsidy amount (C_4) has a direct impact on the emission cap (C_1), the carbon emission level (C_6), and the carbon reduction cost (C_7). However, it is only directly influenced by the carbon emission level (C_6). This means that the subsidy amount (C_4) is a significant influential variable within the system.

Similarly, the penalty rate (C_5) also directly influences the emission cap (C_1), the carbon emission level (C_6), and the carbon reduction cost (C_7), while being directly influenced solely by the carbon emission level (C_6). This suggests that the penalty rate (C_5) is another important influential factor in the system. Note that, the subsidy amount (C_4) and the penalty rate (C_5) are indirectly influenced by other variables that affect the carbon emission level (C_6).

The carbon emission level (C_6) is identified as the most influential criterion because it affects all other criteria except itself. This indicates that the carbon emission level (C_6) plays a central role in the system, meaning that changes to it can directly impact the other criteria. Additionally, the carbon emission level (C_6) is influenced by all factors except for the carbon price (C_2).

On the other hand, the carbon reduction cost (C_7) exhibits the highest dependence within the system, as it is directly influenced by all variables except for the emission cap (C_1) and the carbon price (C_2). However, it only directly affects the carbon emission level (C_6). This suggests that the carbon reduction cost (C_7) is the most reliant on other criteria. It is also worth noting that the carbon reduction cost (C_7) can indirectly influence other variables through the carbon emission level (C_6), which it directly affects them.

Discussion and Conclusion

This study initially employed a systematic literature review method to identify recurring carbon reduction policies, particularly in countries that are leaders in reducing greenhouse gas emissions. It also highlighted the key variables associated with each identified policy (see Tables 1 and 2). Following this, the study applied the intuitionistic fuzzy DEMATEL method to analyze the relationships among these variables, drawing on expert opinions from pharmaceutical distribution companies in Iran (see Figure 3 and 4).

Theoretically, this research has contributed to the enrichment of scientific literature in the field of carbon reduction policies and provided an analytical framework for evaluating the interrelationships among the key variables of these policies, specifically for the pharmaceutical distribution sector in a developing country like Iran (Nsabiyeze et al., 2024). Additionally, by employing the intuitionistic fuzzy DEMATEL method, this study has introduced a novel approach for analyzing causal relationships in environmental policies while considering uncertainty, which can serve as a foundation for future research in this domain (Abdullah et al., 2023). The findings of this research can benefit carbon-emitting companies, particularly those in pharmaceutical distribution, as well as policymakers in developing countries with conditions similar to Iran. These insights will aid in the design or revision of carbon reduction policies.

Practically, three widely used policies for reducing carbon emissions are cap-and-trade, subsidy allocation, and the imposition of financial penalties (see Table 1). Advanced countries such as the United Kingdom, Japan, and the United States currently implement these policies, resulting in annual reductions in greenhouse gas emissions (Crippa et al., 2024). Therefore, it is essential for developing countries, like Iran, to consider implementing or adapting such policies to address the increasing levels of greenhouse gas emissions. Besides, several key variables influence the effectiveness of these policies, including: the emission cap (C_1), the carbon price (C_2), the demand for carbon emission permits (C_3), the subsidy amount (C_4), the penalty rate (C_5), the carbon emission level (C_6), and the carbon reduction cost (C_7) (see Table 2). These variables should be taken into account during the planning processes for implementing these policies.

A conceptual model, as illustrated in Figure 4, facilitates the identification of influential and dependent variables, highlights their importance, and clarifies the relationships among them. Ultimately, this will help decision-makers create more effective policies for reducing carbon emissions, especially tailored for pharmaceutical distribution companies in Iran and other countries facing similar challenges.

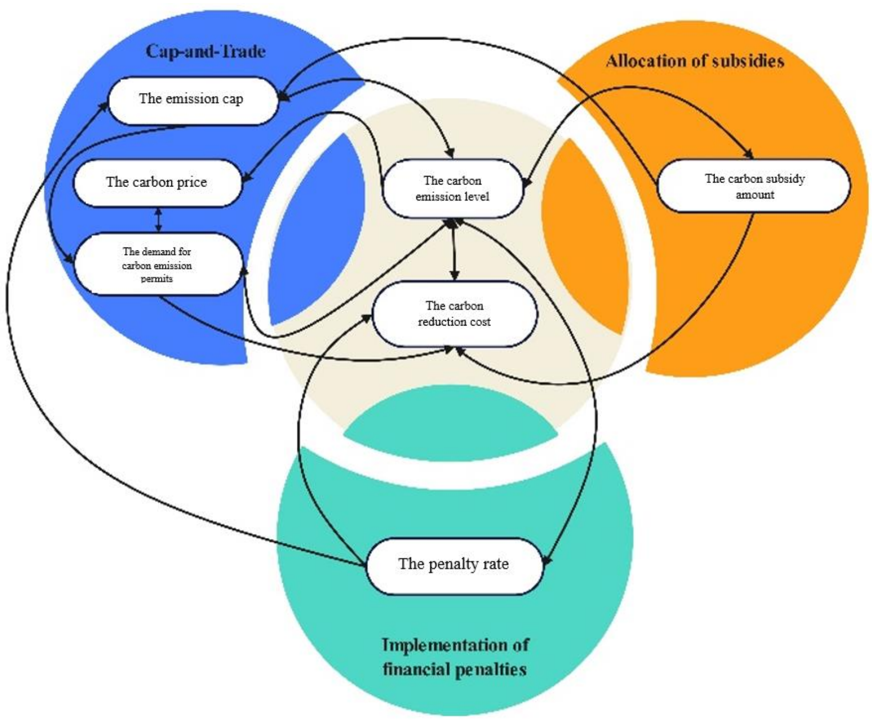

Figure 4. Conceptual model (Source: Researcher)

The framework above highlights the interrelationships among key variables in carbon reduction policies, emphasizing the central role of the carbon emission level (C_6) (Browning et al., 2023). With the highest $(R_i + C_i)$ value of 0.58, (C_6) is the most influential variable, directly impacting all other variables except itself. Reducing (C_6) should be a top priority, as it will positively affect dependent variables like the carbon reduction cost (C_7) and the emission cap

(C_1) (Nsabiyeze et al., 2024; Zhao et al., 2020). The model also identifies the subsidy amount (C_4), and penalty rate (C_5) as key influencers, with positive $(R_i - C_i)$ values of 0.10 and 0.07, respectively, suggesting that strategic use of subsidies and penalties can drive carbon reduction (Dissanayake et al., 2020). Meanwhile, (C_7) is highly dependent, with the lowest $(R_i - C_i)$ value of -0.10, making it sensitive to changes in (C_6) and (C_4) (Ramani et al., 2024). Moderately dependent variables such as (C_1) and (C_2) should be adjusted dynamically based on changes in (C_6) and (C_7). While (C_3) being neutral, serves as a balancing mechanism to align permit demand with emission targets (Nsabiyeze et al., 2024). Therefore, the cap-and-trade system, subsidies, and financial penalties not only affect carbon emission levels and carbon reduction costs independently but also have a compounded impact when they interact with each other (Nsabiyeze et al., 2024; Zhao et al., 2020).

Managerially, this research offers valuable insights for administrators related to environmental protection agencies, and pharmaceutical distributors in Iran, focusing on the goal of reducing carbon emissions. First, administrators should develop integrated policies that combine cap-and-trade systems, subsidies, and penalties into a cohesive framework to maximize effectiveness (Nsabiyeze et al., 2024). Given the importance of carbon emission levels, targeted measures should be implemented based on the emission levels. In this regard, subsidies should be optimized to promote innovation, while penalties must deter non-compliance, ensuring that financial incentives are directed toward high-impact areas, such as the adoption of clean technologies (Zhao et al., 2020). Additionally, administrators should regularly monitor and adjust carbon prices to reflect market conditions and progress in emission reduction. Moreover, enhancing transparency in the allocation of carbon emission permits, along with supporting research and development to reduce carbon reduction costs, will further strengthen the regulatory framework (Ramani et al., 2024). This will make it easier for companies to adopt sustainable practices and achieve their carbon reduction goals.

Moreover, pharmaceutical distributors in Iran should prioritize investments aimed at reducing carbon emissions, as the level of carbon emissions is the most significant factor in the system (Browning et al., 2023). For example, by adopting electric vehicles, distributors can make a meaningful contribution to national carbon reduction goals (Nsabiyeze et al., 2024). Furthermore, utilizing subsidies for green initiatives and adhering to emission caps are essential steps to lower the costs of emission reduction, avoid penalties, and comply with regulatory requirements (Dissanayake et al., 2020). Distributors should also keep an eye on carbon prices to minimize expenses related to carbon permits (Ramani et al., 2024). Engaging with policymakers is crucial to provide feedback on the effectiveness of subsidies and penalties. This collaborative approach ensures that policies are both practical and impactful, allowing distributors to play an active role in achieving carbon reduction targets.

This study has several limitations that inform the future research directions outlined earlier. Foremost, while the study provides insights into recurrent carbon reduction policies and their key variables, it is important to acknowledge the practical challenges associated with implementing such policies in Iran (Ambec et al., 2024). Political and economic factors can pose significant barriers. For instance, policy adoption may be influenced by government priorities, regulatory frameworks, and geopolitical constraints, which could hinder the effective execution of carbon reduction strategies. Additionally, economic constraints—such as sanctions, funding availability, industry resistance, and infrastructure limitations—can affect the feasibility of implementing sustainable practices.

To strengthen the practical implications of this research, future studies should explore these challenges in depth, examining how political dynamics and economic structures shape the adoption and effectiveness of carbon reduction policies in Iran. Addressing these barriers will provide policymakers and industry stakeholders with more actionable insights, ensuring realistic and adaptable strategies for carbon emissions reduction.

Second, the research primarily focuses on pharmaceutical distributors in Iran, which may limit its generalizability to other industries. To address this, future studies could investigate the impact of carbon reduction policies across diverse economic sectors, including energy, manufacturing, and agriculture, thereby broadening the applicability of findings. Additionally, investigating the implementation of carbon reduction policies in other developing countries that have not yet adopted such measures, or even developed countries, could provide further generalizable insights for global policy design.

Third, while the intuitionistic fuzzy DEMATEL method provides valuable insights into the relationships among key variables, it is only one approach among several multi-criteria decision-making (MCDM) methods. To enhance methodological robustness, future research could employ techniques such as the Analytic Network Process (ANP) or Interpretive Structural Modeling (ISM) to validate and complement the findings (Sadeghi et al., 2023). Moreover, other uncertain approaches such as Hesitant Fuzzy, Pythagorean Fuzzy, Spherical Fuzzy, etc., could be employed and compared. Furthermore, this study does not assess the long-term effects of carbon reduction policies on key variables. Future research could leverage predictive and simulation models to examine their long-term implications (Samadi Foroushani et al., 2023), offering a clearer understanding of policy sustainability.

Data Availability Statement

Data available on request from the authors.

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Conflict of interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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