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The Neighborhood Effects of National Climate Legislation: Learning or Competition?

Ying Liu [1,2], Uma Murthy [1,*] and Chao Feng [3]

[1] Taylor's Business School, Taylor's University, Subang Jaya 47500, Malaysia; lywf89@163.com
[2] School of Economics and Business Administration, Weifang University of Science and Technology, Weifang 262700, China
[3] School of Economics and Business Administration, Chongqing University, Chongqing 400030, China; littlefc@126.com
* Correspondence: uma.murthy@taylors.edu.my

Abstract: This study aims to explore the spatial spillover effects of national climate legislation on carbon emission reduction by using cross-country panel data from 2002 to 2021. The results show the following: First, the estimation outcomes confirm the presence of spatial correlations between carbon dioxide emissions and climate legislation across countries. Second, the study shows that the spillover effect of climate legislation on CO_2 emissions is significantly negative. Hence, the outcomes indicate that being surrounded by nations with more climate laws positively impacts environmental quality. Third, regarding direct impact and spillover effects, the carbon reduction impact of parliamentary legislative acts is stronger than that of governmental executive orders. Finally, even with the spillover effect, we uncover robust evidence supporting an inverted-U-shaped EKC linkage between carbon emissions and GDP per capita, even under the spatial spillover effect.

Keywords: climate legislation; spatial spillover; policy diffusion; spatial Durbin model

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1. Introduction

Combating climate change and mitigating carbon emissions have garnered a worldwide consensus. According to the National Bureau of Economic Research, the worldwide average temperature is expected to keep rising by 0.04 °C yearly without appropriate climate governance. By 2100, the real GDP per capita will decline by around 7.22%. And the economy of all regions, whether poor or rich, cold or hot, will be greatly affected [1]. Therefore, determining how to minimize the terrible impacts of climate change has remained the most important and potent menace facing humanity in the 21st century [2]. The cost of inaction is high despite the significant climate financing gap. The total cost of inaction is estimated to be $1266 trillion, representing the difference in economic losses between the "business as usual" scenario and the 1.5 °C temperature control scenario from 2025 to 2100 [3]. Against this backdrop, various countries have begun to develop climate legislation to deal with more and more frequent climate disasters and create a better living environment.

A growing number of nations are passing climate laws [4,5]. Since effective action catering for climate change requires a legal foundation, climate legislation is crucial for climate change regulation. Without legally enforceable targets and measures, emission pledges lack credibility. Although the scope and ambition of climate laws and policies vary widely (that is, at the intensive margin), their increasing number (the extensive margin) is a key sign of a nation's commitment to combating climate change. Almost all significant greenhouse gas (GHG) emitters now have laws that regulate emissions, save energy, prevent deforestation, or support more environmentally friendly methods of energy production. Meanwhile, those nations most at risk from climate change are also taking action to deal with climate effects. Nearly 2300 climate change laws are identified in the 200 countries that the Climate Change Laws of the World dataset includes (Climate Change Laws of the World dataset. Available at: https://climate-laws.org/ (accessed on 20 January 2024).

Some researchers have focused on the effects of climate change legislation on greenhouse gas emissions [6–8] and renewable energy [9]. However, the existing studies fail to incorporate considerations for spatial dependence when exploring the relationship between climate legislation and carbon emissions. Indeed, numerous topics concerning economic and environmental matters exhibit inherent spatial correlation [10,11]. According to Kang et al. [12], spatial panel data models are becoming increasingly important in empirical research because they consider both temporal dynamics and spatial dependence. Such models can better capture interactions and spillover effects across regions and thus avoid biased estimates. Therefore, this study aims to fill several critical gaps in the existing literature on the relationship between climate legislation and carbon emissions. First, theoretical mechanisms of spatial interaction of climate legislation have not been adequately addressed. Second, much of the research about the effectiveness of climate legislation has relied on classical regression models, which cannot capture the spatial spillover effects effectively. In addition, prior studies have not adequately addressed the differences in the spatial spillover effects of different types of climate legislation. Third, most studies have been limited to investigating the effects of environment and climate policies on specific countries and regions, especially the OECD and European Union. By addressing these gaps, our study advances theoretical and methodological knowledge and has practical implications for global climate governance.

Considering that global climate change is a collective challenge requiring coordinated efforts [13], analyzing the spatial interactions among nations is crucial. For instance, European countries with robust climate laws often influence their neighboring countries through economic ties or climate regulations. This study focuses on 142 countries globally, making it a highly relevant and comprehensive analysis of the global impact of climate legislation, with particular attention to how these laws can affect carbon emissions domestically and in surrounding regions.

The primary contributions of the paper are outlined below. First, drawing upon a literature review, this paper clarifies the spatial interaction mechanisms of climate legislation and carbon emissions at the theoretical level. This shall furnish a robust theoretical underpinning for the subsequent design of empirical models. Second, this study examines the relationships between climate legislation and CO_2 emissions using spatial econometric methodology to enrich environmental research and offer guidance for crafting climate governance policies. The models can help to identify both the direct and indirect impacts of climate laws on carbon emissions. The spatial econometric model can effectively enhance the accuracy of the measurement by considering cross-sectional dependence, which would lead to distortions in the parameter estimates. Third, applying a global country sample allows for a robust analysis of the relationship between climate legislation and carbon emissions across diverse economic, political, and environmental contexts.

The subsequent content of the paper is organized in the following manner. Section 2 illuminates the relevant literature for this research. Section 3 outlines the theoretical mechanisms and research hypotheses. Section 4 illustrates the spatial econometric models and related data utilized in this paper. In Section 5, we present the empirical estimations. Section 6 summarizes the conclusions and proposes some countermeasures.

2. Literature Review

2.1. Carbon Emissions and Climate Legislation

With the increasingly prominent situation of climate warming, more and more studies have begun to focus on the influencing factors and their driving mechanisms on carbon emissions [14–18]. The IPAT model [19] and the extended STIRPAT model [20–22] are widely recognized regarding the research methodologies. They are models employed to explore the effects of affiliation, population, and technology on environmental indicators.

In particular, as far as environmental regulation is concerned, many scholars have discussed its effect on CO_2. Many researchers believe that environmental regulation can increase investment in technological innovation for carbon emission reduction and then reduce carbon emissions [23–26]. However, according to the "green paradox hypothesis", studies have also demonstrated that suppliers' response to environmental regulation will make the supply path of energy suppliers move forward, accelerate energy consumption, and result in a rise in carbon emissions [27–30]. However, the above literature tends to proxy environmental regulation by employing relevant indicators of regulatory intensity (proxied by pollution control investment as a share of GDP) [31–33] or paying attention to the impact of specific environmental regulations, including market-based instruments (e.g., carbon tax, emissions trading system) and command-and-control instruments (e.g., emission standards) [34–36]. Little literature has focused on the effects of climate legislation directly and comprehensively. Eskander and Fankhauser [7] analyzed the trend of global climate legislation in detail and explored the impact of climate legislation on carbon intensity based on panel data regression. It is estimated that the current global climate legislation system has reduced 38 $GTCO_2$ during 1999–2016. Omri and Boubaker [8] explored the impact of environmental policies and legislation on carbon emissions. They indicated that the climate change legislation is relatively weak in highly polluted countries. However, they failed to consider the spatial effects of carbon emissions and climate legislation.

2.2. Spatial Spillover Effects of Carbon Emissions

Due to the intricate interplay of atmospheric motion, commercial interactions, and other contributing factors, it is very important to consider the spatial autocorrelation of carbon emissions. For example, Zhou et al. [37] analyzed the spillover effects of carbon emissions between regions in China. They demonstrated a positive and significant spatial correlation between regional carbon emissions. The spatial autocorrelation of carbon emissions means that the haze control effect brought by climate legislation in the host country will affect the carbon concentration in neighboring countries through the spatial spillover of carbon emissions. For instance, an augmentation in investments directed toward air pollution governance within the local country shall enhance local environmental quality, thereby yielding an amelioration in the ecological quality of neighboring areas. Some scholars began to pay attention to the spatial effect by introducing spatial econometrics into the research field of carbon emission driving mechanisms [38–43]. For instance, Wei et al. [44] assessed both the direct and indirect spatial spillover effects of multi-dimensional urbanization and *FDI* on carbon emissions utilizing panel data from Belt and Road countries spanning from 2000 to 2018 and the spatial Durbin model.

In conclusion, previous studies mainly focus on the environmental regulation intensity or specific environmental regulation tools. Though few studies have discussed the impact of climate legislation on carbon emissions, they ignore the potential spatial dependence between carbon emissions and climate legislation, both theoretically and empirically. Unlike prior research, we used spatial econometric methodologies to examine the direct and indirect spatial spillover effects of national climate legislation on carbon emissions based on the theoretical analyses of spatial interaction mechanisms. Furthermore, most empirical studies' geographical coverage is limited to specific countries or regions. Unlike those studies, our analysis utilizes a comprehensive global sample, thereby providing a broader perspective on the spatial effectiveness of climate legislation globally.

3. Theoretical Analysis and Research Hypotheses

A multifaceted theoretical framework supports the hypothesis that climate legislation leads to a reduction in carbon emissions. First, climate legislation often establishes a legal framework that directly limits carbon emissions through specific regulations and standards to internalize the cost of carbon emissions, thereby incentivizing a shift to low-carbon production. Second, climate legislation catalyzes technological innovation through tax incentives and subsidies, which is a critical factor in reducing carbon emissions. Third, climate legislation influences not only firms and markets but also consumer behavior and societal norms, indirectly contributing to carbon emission reductions. Climate legislation can enhance consumer awareness of the environmental impact of their choices, steering them toward low-carbon products and services and reducing aggregate emissions. Therefore, Hypothesis 1 is proposed as follows:

Hypothesis 1. *Climate legislation leads to a reduction in carbon emissions.*

The climate legislation of neighboring regions will affect the climate legislation of the local region and then affect the carbon emissions within the local area. The spatial interaction mechanisms of climate legislation include "race to the top" and "race to the bottom".

Regarding "race to the top", the climate legislation would exhibit spatial autocorrelation tendencies, as climate governance attitudes and practices can trigger a contagious influence among neighboring countries or culturally, politically, and economically interconnected countries based on a peer effect [45–48]. Collaboration and knowledge sharing among nations can have a pivotal impact on promoting global initiatives to address climate change [49]. On the one hand, advanced countries propagate policies through knowledge sharing and collaboration, aiming to promote similar climate laws in other countries to maintain their competitive edge [50]. On the other hand, the countries tend to emulate the policies of their political peers, which are usually close to each other geographically to form a climate coalition. In times of policy choice uncertainty, governments will resort to imitation to reduce uncertainty and transaction costs while enhancing policy effectiveness [50–52]. According to Fankhauser et al. [53], international policy diffusion occurs in the context that the policy decisions of a particular country are influenced by previous choices made in other countries, resulting in a systematic impact on government policies. Some literature has pinpointed several cases of reformatory environmental policy instruments spreading from one nation to another. For example, eco-labels originated in Germany in 1978 and then expanded to Scandinavia, the United States, and Japan during the 1980s. Eventually, they became prevalent across Europe, as well as in Australia and New Zealand.

On the contrary, the "race to the bottom" theory, which is a cornerstone of the environmental politics literature [54,55], offers a distinct analytical logic for understanding spatial interactions in climate legislation. The existence of regulatory competition among governments implies that their actions of regulation are interconnected and mutually influenced [56]. From one aspect, climate action taken by other nations can foster a tendency toward free-riding. When others tackle the challenge, there might be a reduced incentive for individual countries to take action by themselves [47,57,58]. From another aspect, the theory posits that when faced with economic competition, governments are driven to adopt overly lenient environmental standards to attract capital investment. These incentives, coupled with governments potentially acting strategically, may prompt countries to lower the standards to obtain a competitive advantage over their counterparts. If all governments reason similarly, this could lead to an ongoing reduction in standards, eventually reaching the level of the country with the least stringent regulations and resulting in a suboptimal equilibrium [56,59]. Finally, the differences in the enforcement intensity of climate governance in different regions may induce the motion of production factors in the region and lead to the relocation of polluting enterprises that cannot adapt to strict climate governance, affecting regional climate improvement.

According to the mechanism analysis above, the theoretical framework of spatial interactions between climate legislation and carbon emissions is depicted in Figure 1.

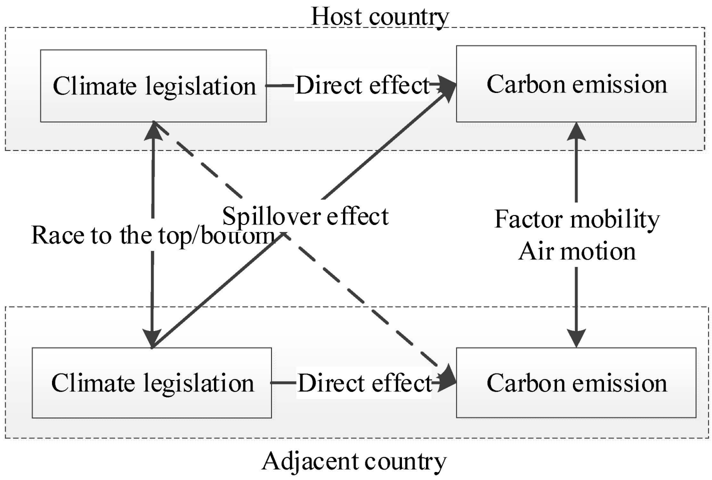


Figure 1. The spatial interactions between climate legislation and carbon emissions.

Hypothesis 2. *Climate legislation has spatial spillover effects on carbon emissions.*

Legislative acts tend to substantially impact carbon emissions more than executive orders due to several key factors. First, legislation's stability and binding nature ensure these measures are more permanent and less susceptible to reversal, providing long-term certainty for businesses, investors, and consumers. This stability encourages more direct and spatial spillover effects on carbon emissions. Second, legislative acts are often accompanied by enforcement mechanisms, ensuring more rigorous compliance and implementation than executive orders. This transparency and predictability are more likely to have a cross-regional demonstrative effect, prompting neighboring countries to adopt the same legislative behavior.

Hypothesis 3. *Legislative acts have a greater impact on carbon emissions than executive orders, with more pronounced spillover effects between neighboring regions.*

4. Methodology and Data

4.1. Extended STIRPAT Model

The extended STIRPAT model (stochastic impacts by regression on population, affluence, and technology) established by Dietz and Rosa [60] provides a flexible framework for analyzing the impact of socio-economic and environmental factors on ecological outcomes. It allows for incorporating various independent variables [61], making it ideal for examining complex relationships in environmental studies across different regions or periods. In addition, the STIRPAT model has been widely used in empirical studies, providing confidence in its validity and reliability [62]. While alternative models have also been used to explore the influencing factors of carbon emissions [63], such as the IPAT model and factor decomposition approach, they lack the flexibility to incorporate additional socio-economic variables. Therefore, the STIRPAT model's strengths in accommodating non-linear relationships, multiple variables, and empirical robustness make it the most suitable choice for our empirical analysis.

The standard design of the STIRPAT model is as follows:

$$I = \alpha P^{\beta} A^{\gamma} T^{\lambda} \mu \quad (1)$$

where I denotes environmental change, such as waste emission and energy consumption. I (environmental change) is influenced by P (population factor), A (affluence factor), and T (technique factor). α, β, γ, and λ are the model's parameters for the variables of population, affluence, and technique, respectively. μ is the item of model error. Then, we use population density (*PD*) and urbanization (*URB*) to reflect the demography impacts [64], per capita GDP (*PGDP*) to reflect affluence [65], and industrial activity with respect to total production (*IS*) and share of renewable energy consumption (*REC*) to proxy technology level [66]. The squared term of *PGDP* is also integrated into the estimation process following the EKC hypothesis. The expanded form of the STIRPAT model can be represented as below.

$$\underbrace{\ln PC}_{Environment} = \beta_0 + \underbrace{\beta_1 \ln PGDP + \beta_2 (\ln PGDP)^2}_{Affluence} + \underbrace{\beta_3 \ln PD + \beta_4 \ln URB}_{Population} + \underbrace{\beta_5 \ln IS + \beta_6 \ln REC}_{Techno\log y} + \varepsilon_{it} \quad (2)$$

In reality, in addition to demography, affluence, and technology, other factors also can affect carbon emissions. According to York et al. [67], additional variables can be incorporated into the STIRPAT model if they align conceptually with its multiplicative structure. Based on the pollution paradise and pollution halo theories, the impact of foreign direct investment (*FDI*) on carbon emissions is complex. The pollution paradise theory suggests that *FDI* promotes introducing highly polluting industries, thereby increasing carbon emissions. The pollution halo effect suggests that multinational corporations may introduce higher environmental standards and technologies in host countries, thereby improving local environmental conditions [68]. The rule of law can improve the efficiency and fairness of government institutions and better regulate social behavior, which helps organizations take action to reduce carbon emissions when facing regulatory pressure [69]. The effect of climate legislation on carbon emissions is the core of this research. Therefore, based on the above analysis, we introduce climate legislation (*CLAW*), foreign direct investment (*FDI*), and rule of law (*RL*) as supplementary variables in this study. With the above analysis, the panel econometric model for the per capita carbon emissions can be written as follows (it is necessary to point out that taking the natural logarithms of the indicators is efficient in reducing the heteroscedasticity, but this method is not suitable in all cases. When the absolute value of some variables is small or negative, logarithmic processing will create large errors and be inapplicable to the estimation results. Hence, this study used logarithms of the indicators except for LAW, *FDI*, and rule of law to weaken heteroscedasticity [69]):

$$\begin{aligned} \ln(PC_{it}) = \alpha_i + \lambda_t + \beta_1 \ln(PGDP_{it}) + \beta_2 (\ln PGDP)^2 + \beta_3 \ln(PD_{it}) + \beta_4 \ln(URB_{it}) \\ + \beta_5 \ln(IS_{it}) + \beta_6 \ln(REC_{it}) + \beta_7 CLAW_{it} + \beta_8 FDI_{it} + \beta_9 RL_{it} + \varepsilon_{i,t} \end{aligned} \quad (3)$$

4.2. Spatial Econometric Model

4.2.1. Spatial Weight Matrix and Spatial Autocorrelation Tests

Before launching the spatial econometrics analysis, it is prerequisite to construct the spatial weighting matrix. Following Zambrano-Monserrate et al. [70], this paper used the binary matrix of 5 nearest neighbors. The weights adhere to the condition w_{ij} = 1 when country *j* is among the five closest neighbors of country *i*. Conversely, w_{ij} = 0 if country j is not within this proximity. Additionally, for robustness checks, this paper also considers the inverse squared distance matrix (both k-5 nearest matrix and inverse squared matrix are geographic matrices that become increasingly important [65]. We chose this kind of criterion because a greater geographic distance between countries hampers trade and impedes cultural interaction [71,72]). The specification of w can be constructed as follows:

$$W = \begin{cases} w_{ij} = 1/d_{ij}^2, i \neq j \\ w_{ij} = 0, i = j \end{cases}.$$

$d_{ij} = arcos\left[(\sin\eta_i \times \sin\eta_j) + (\cos\eta_i \times \cos\eta_j \times \cos(\Delta\sigma))\right] \times r$, η_i, and η_j represent the latitude and longitude of the capital cities of nations *i* and *j*, respectively. $\Delta\sigma$ indicates the longitudinal difference between nations *i* and *j*. *r* signifies the radius of the Earth.

Once the spatial weights matrix is created, a diagnostic evaluation of spatial autocorrelation can be performed for each year employing Moran's I test. Considering the mobility of factors between regions, Moran's I was first employed to examine the global spatial correlation of variables. Moran's I is estimated by Equation (4) as follows:

$$I = \frac{n \sum_{i=1}^{n} \sum_{j=1}^{n} w_{ij}(x_i - \overline{x})(x_j - \overline{x})}{\sum_{i=1}^{n} \sum_{j=1}^{n} w_{ij}(x_i - \overline{x})^2} \tag{4}$$

where w_{ij} is a weighting matrix symbolizing the spatial weight of points i and j; x_i is the sample value at point i; $\overline{x}$ is the mean value of the whole sample's observing index; and n is the number of observations. As a global spatial autocorrelation indicator, Moran's I can unveil the overall spatial dependence of variables, but it has not yet pointed out which local areas have spatial agglomeration. Local Moran's I is a test index to see whether there is a similar or distinct aggregation of observations between local regions, which is calculated by Equation (5) as follows:

$$I_i = \frac{n(x_i - \overline{x})}{\sum_{i=1}^{n} (x_i - \overline{x})^2} \sum_{j=1}^{n} w_{ij}(x_j - \overline{x}) \tag{5}$$

4.2.2. Spatial Panel Econometric Technique

If the spatial autocorrelation test indicates that the variables have spatial correlation, it is necessary to build a spatial econometric model to analyze the spatial effect of variables. Considering the spatial influence of factors, the spatial regression model is constructed based on Equation (3) in Section 4.1. There are three primary spatial econometric models: the spatial lag model (SLM), the spatial error model (SEM), and the spatial Durbin model (SDM). Since the SDM is the general mode of the SLM and SEM, the following basic SDM model is constructed:

$$Y_t = \theta_1 I_N + \rho W Y_t + \theta_2 X_t + \theta_3 W X_t + \varepsilon \tag{6}$$

where Y_t is the $n \times 1$ column vector of the dependent variable; X_t is the $n \times k$ notion of independent variables' matrix; W is the matrix for spatial weight; I_N represents an $n \times n$ unit vector that is connected with the estimated parameter θ_1 in terms of the constant; ρ, θ_2, and θ_3 are the parameters that need to be determined; ε is the random error; and $\rho W Y_t$ is the spatial lag term of the dependent variable, indicating the spatial spillover impact of local dependent variables on other regions' dependent variables. Similarly, $\theta_3 W X_t$ is the independent variables' spatial lag term; SLM and SEM are two special forms of SDM. When the value of θ_3 is zero, the SDM will be reducible to the SLM; when $\theta_3 + \rho\theta_2 = 0$, the SDM model will be simplified to the SEM.

Model (6) only provides the general equation of the SDM. Then, according to model (3), the concrete form of SDM can be organized as follows:

$$\ln(PC_{it}) = \rho \sum_{j=1}^{N} W_{ij} \ln(PC_{it}) + \beta_1 CLAW_{it} + X_{it}^{control}\beta + \gamma_1 \sum_{j=1}^{N} W_{ij} CLAW_{it} + \sum_{j=1}^{N} W_{ij} X_{it}^{control}\gamma + \mu_i + \varphi_t + \varepsilon_{it} \tag{7}$$

where $X_{it}^{control}$ includes population density (PD), urbanization (URB), per capita GDP ($PGDP$) and the squared term, industrial activity with respect to total production (IS) and share of renewables consumption (REC), foreign direct investment (FDI), and rule of law (RL). μ_i denotes fixed effects of the spatial individual. φ_t represents fixed effects of the time.

Given that the model incorporates the spatial correlation, the estimates provided in Equation (7) cannot be employed to show the marginal impact of independent variables. As suggested by LeSage and Pace [71], it is more appropriate to examine the partial derivatives of the predicted value of Y concerning the independent variables. The overall structure is observed to be as follows:

$$\left[\frac{\partial E(Y)}{\partial x_{1q}} \cdots \frac{\partial E(Y)}{\partial x_{nq}}\right] = \begin{bmatrix} \frac{\partial E(y_1)}{\partial x_{1q}} & \cdots & \frac{\partial E(y_1)}{\partial x_{Nq}} \\ \vdots & \ddots & \\ \frac{\partial E(y_N)}{\partial x_{1q}} & \cdots & \frac{\partial E(y_N)}{\partial x_{Nq}} \end{bmatrix} = (I - \rho W)^{-1}\left[\beta_q I_N + r_q W\right] \quad (8)$$

where β_q and r_q are the qth elements of β and r, respectively. The partial derivative of emissions for climate legislation (CLAW) is depicted as follows:

$$\frac{\partial E(y_t)}{\partial CLAW_t} = \underbrace{(I - \rho W)^{-1}[I_N \beta_1]}_{direct\ effects} + \underbrace{(I - \rho W)^{-1}[W\gamma_1]}_{indirect\ effects} \quad (9)$$

Further, based on the above discussion, the impact of climate legislation on carbon emissions may be impacted by the *FDI*. Then, the partial derivative of emissions is presented as follows:

$$\frac{\partial E(y_t)}{\partial CLAW_t} = \underbrace{(I - \rho W)^{-1}[I_N \beta_1 + I_N \beta_2 \times diag(FDI_t)]}_{direct\ effects} + \underbrace{(I - \rho W)^{-1}[W\gamma_1 + W\gamma_2 \times diag(FDI_t)]}_{indirect\ effects} \quad (10)$$

4.3. Data

Due to data availability, this study collects data on 142 economies across the globe for the period spanning from 2002 to 2021. The sample countries are listed in Table A1 (Appendix A) This paper uses per capita carbon emissions (*PC*) instead of absolute emissions to reduce the effect of confounding factors such as population size. Since there is a temporal hysteresis in the response of carbon emissions to climate legislation, the stock of climate legislation (*CLAW*) was employed as a climate legislation indicator based on Eskander and Fankhauser [7]. The specific calculation formula is as follows:

$$CLAW_{it} = \sum_{k=1}^{t-1} L_{ik} + S_{i0} \quad (11)$$

where L_{ik} is the number of climate legislation in the year k. S_{i0} is the stock of laws before 2002. This paper also incorporates other explanatory variables as control variables based on the relevant literature and the above analysis.

As for the data sources, the data for L_{ik} and S_{i0} can be obtained from the Climate Change Laws of the World. The *FDI*, *IS*, *PGDP*, *RL*, and *URB* data come from the World Bank. The data for *REC* are derived from the Energy Information Administration (EIA) database. The data for *PC* and *PD* come from OUR DATA IN WORLD. The descriptive statistics for the variables employed in this study are reported in Table 1.

Table 1. Descriptive statistics of variables.

Variables	N	Mean	Standard Deviation	Min	Max
CO_2 emissions (PC, metric tons per capita)	2840	4.350	5.017	0.0160	33.30
Carbon emissions (CE, total, tonnes)	2840	211.7	895.3	0.103	11,472
Stock of climate legislation (CLAW)	2840	6.529	6.667	0	54
Stock of climate legislation (legislative act)	2840	2.881	3.456	0	22
Stock of climate legislation (executive order)	2840	3.649	4.649	0	43
Per capita gdp (PGDP, constant 2015 US$)	2840	12,365	16,618	255.1	88,967
Industry, value added (IS, % of GDP)	2840	26.95	11.13	2.759	74.16
Urban population (URB, % of total population)	2840	56.88	22.01	8.682	100
Population density (PD, people per sq. km of land area)	2840	186.9	625.7	1.602	8274
Share of renewables consumption (REC, %)	2840	0.185	0.191	−0.0786	0.878

Table 1. *Cont.*

Variables	N	Mean	Standard Deviation	Min	Max
Foreign direct investment, net inflows (FDI, % of GDP)	2840	5.665	18.65	−117.4	449.1
Rule of law (RL)	2840	−0.0343	0.945	−1.850	2.125
Total population (POP, million)	2840	46.65	159.2	0.0683	1426

Table 1 displays the main descriptive statistics of the dependent and independent variables of the model. The average carbon emissions per capita across the 142 analyzed countries during this timeframe is 4.35 metric tons. However, the dataset reveals significant variation, with some countries reporting remarkably low emissions, as low as 0.016 metric tons per capita. In contrast, others demonstrate substantially higher figures, reaching up to 33.3 metric tons per capita. Then, the average stock of climate laws is 6.

5. Empirical Results

5.1. Temporal and Spatial Variations in Carbon Emissions and Climate Legislation

To provide a clearer temporal view of the evolution of carbon emissions and climate laws worldwide, we computed the annual carbon emissions per capita and climate laws from 2002 to 2021. The results are illustrated in Figure 2.

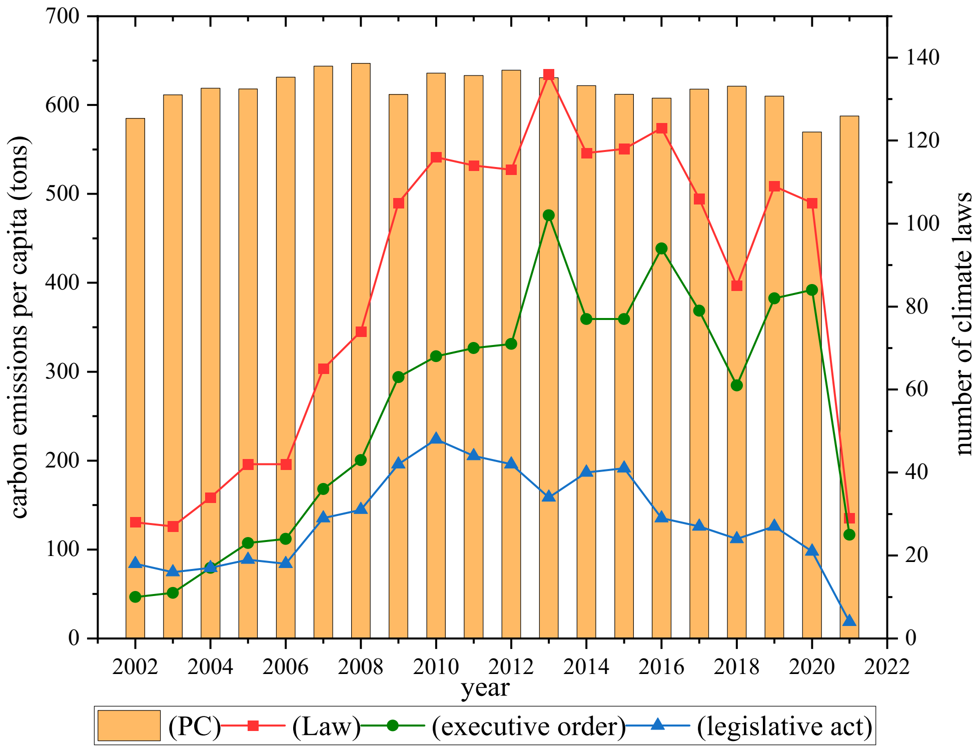


Figure 2. Carbon emissions per capita and number of climate laws worldwide from 2002 to 2021.

World per capita carbon emissions increased continuously from 2000 to 2008. Global economic growth, particularly industrialization in developing countries, led to increased carbon emissions, and global per capita carbon emissions declined slightly in 2009. This was due to a slowdown in economic activity as a result of the global financial crisis. Despite continued global economic growth, the increase in per capita carbon emissions slowed from 2010 to 2019. This was partly due to improvements in energy efficiency and the development of renewable energy sources. Global per capita carbon emissions declined due to a reduction in industrial activity, lower transportation, and lower energy demand in the context of the COVID-19 pandemic in 2020. A sharp decline in global economic activity led to a significant drop in per capita carbon emissions. 2021 saw a gradual global economy recovery and a per capita carbon emissions rebound.

Figure 2 also displays the yearly number of climate change laws. In the late 1990s, steady growth started and accelerated national climate action after the Kyoto Protocol 1997. A sharp growth after 2009 may be related to the much-hyped UNFCCC in December 2009 (COP15). The climate change laws and policies peaked in 2009–2017, when over 100 laws were passed yearly. However, the number of climate laws declined more sharply after 2017.

To depict spatial discrepancies in carbon emissions and climate laws, we show the spatial distribution of carbon emissions and climate laws in 2002 and 2021 by utilizing ArcGIS 10.8. The variables data are divided into five distinct categories.

Based on Figure 3a,b, the temporal analysis from 2002 to 2021 reveals a noticeable increase in per capita carbon emissions, particularly in regions like North America, Europe, and parts of Asia, where emissions were already high in 2002 and further intensified by 2021. This trend is especially pronounced in developing regions, where industrial growth has accelerated, leading to new high-emission areas, notably in parts of Asia such as China and India. Spatially, North America, Europe, and Australia consistently exhibit high per capita carbon emissions, reflecting their intensive energy consumption and industrial activities. In contrast, Sub-Saharan Africa, South Asia, and parts of Southeast Asia remain in the lower emission categories, likely due to lower levels of industrialization.

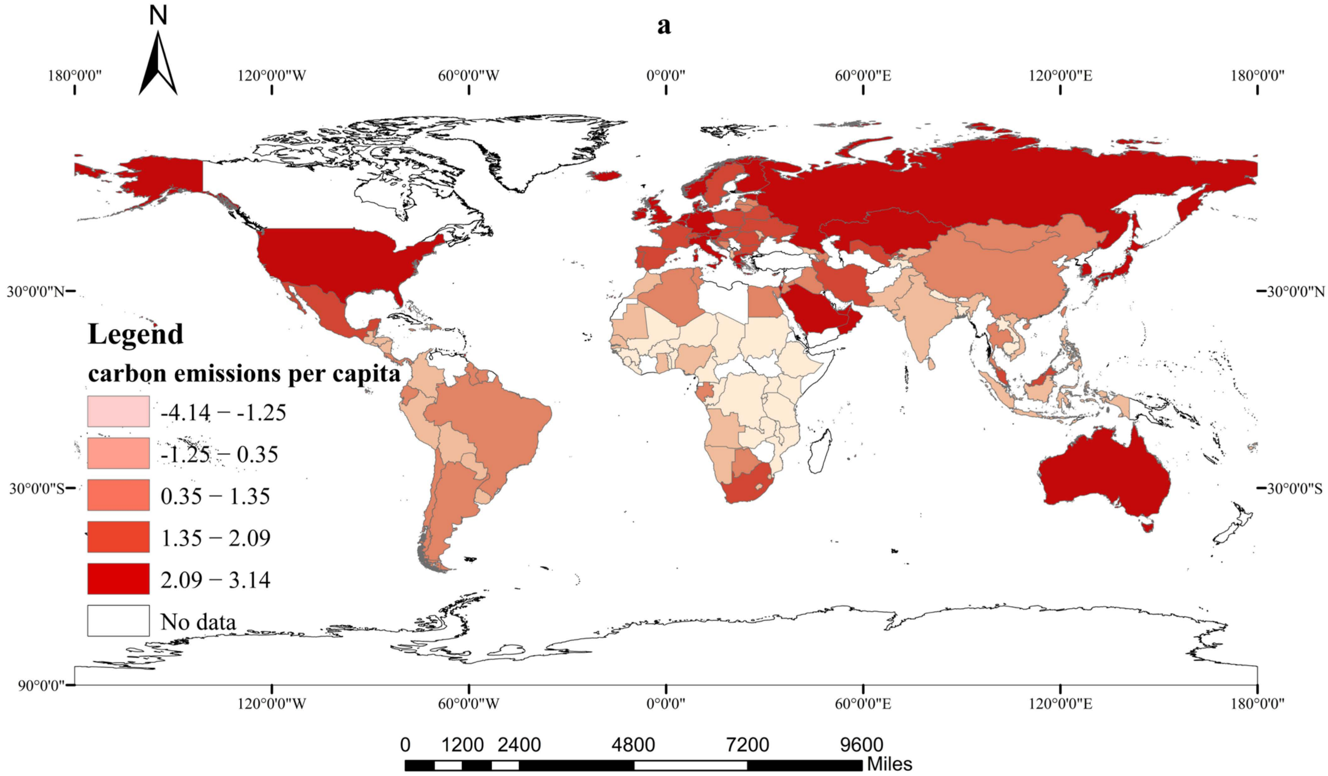
Figure 4a,b shows a clear increase in the number of climate laws globally from 2002 to 2021. The maps indicate that more countries adopted climate legislation over this period, as reflected in the transition from lighter to darker shades of blue. In 2002, many countries, particularly in Africa, South America, and parts of Asia, had few or no climate laws. However, by 2021, these regions showed substantial progress. This reflects not only a quantitative increase in climate legislation but also a broader global expansion. By 2021, climate legislation had become more widespread, extending beyond developed regions like Europe and North America to include numerous developing countries. Europe remained a leader in climate legislation from 2002 to 2021, with countries such as the United Kingdom, France, and Germany showing substantial increases, resulting in a more robust legislative framework. This analysis provides a foundation for further investigation into the effectiveness of these laws in mitigating the impacts of climate change.

5.2. Spatial Autocorrelation Test

Before studying the spillovers of climate legislation on carbon emissions, the spatial autocorrelation of the dependent variable carbon emissions and the primary explanatory variable climate legislation are examined to determine whether a country's carbon emissions and climate legislation are influenced by adjacent countries. We calculate the indicator of global Moran for the carbon emissions and legislation in 142 countries from 2002 to 2021 based on the K-nearest neighbors (5) matrix shown in Table 2.

As shown in Table 2, the Moran index of carbon emissions is significantly positive under the spatial weight matrix at the 1% level. Based on the calculation results of the Moran index, carbon emission has the characteristics of spatial agglomeration at the geospatial level. For climate legislation, the spatial correlation index shows an overall upward trend and also presents more obvious spatial correlation characteristics. According to the convergence mechanism of policies, climate legislation can easily form an imitation effect based on geographical distance. Geographically close countries tend to connect closely, with invisible knowledge disseminating and exchanging. Therefore, climate legislation has produced a spatial spillover effect through geography and economic ties.

According to Anselin [72], Moran's I scatter plot has proven to be an effective method for examining the spatial correlation, which more intuitively represents the local autocorrelation state. Subsequently, we proceeded to illustrate scatter plots of the Moran's I values for 2021. Based on Figure 2, both the carbon emissions and climate legislation of 142 countries are positively correlated in the first and third quadrants, which is featured by "H-H" and "L-L" spatial agglomeration, respectively.



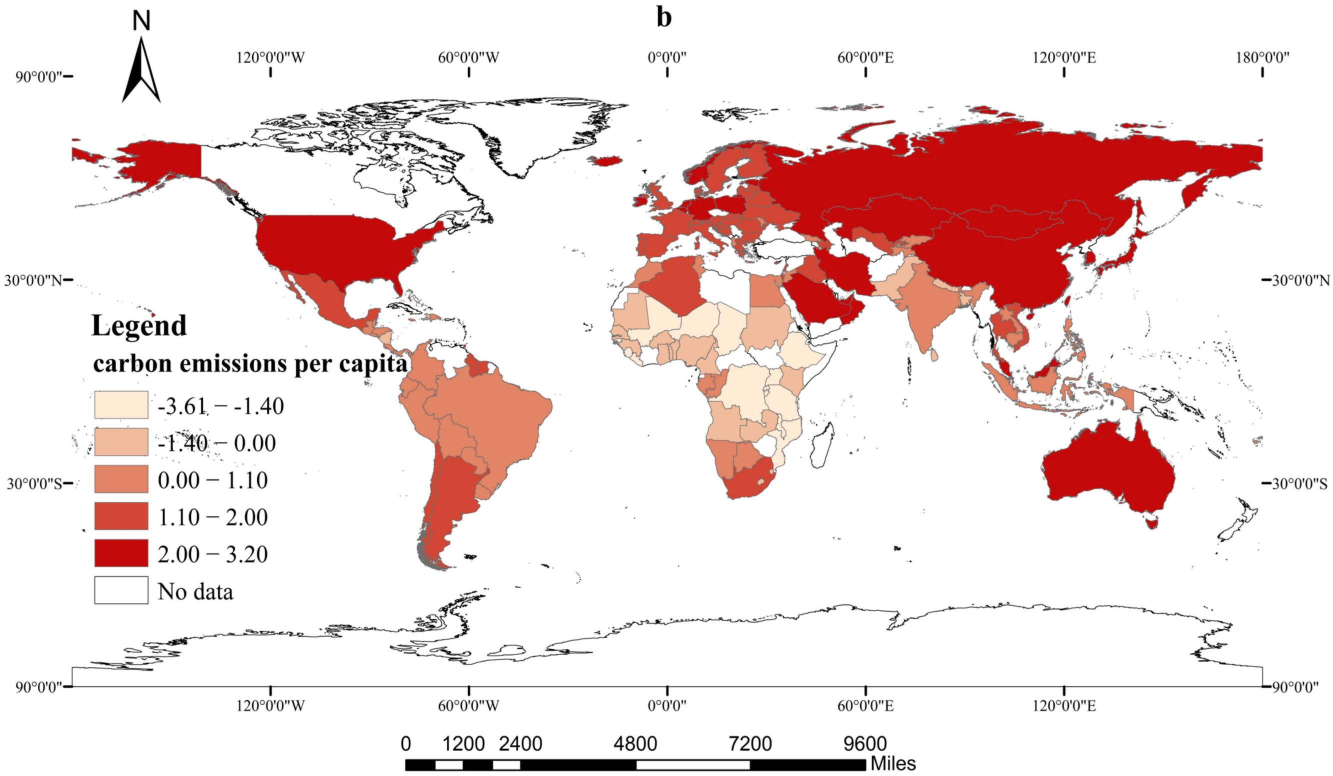


Figure 3. (**a**) Spatial distribution of carbon emissions in natural logarithms in 2002. (**b**) Spatial distribution of carbon emissions in natural logarithms in 2021.

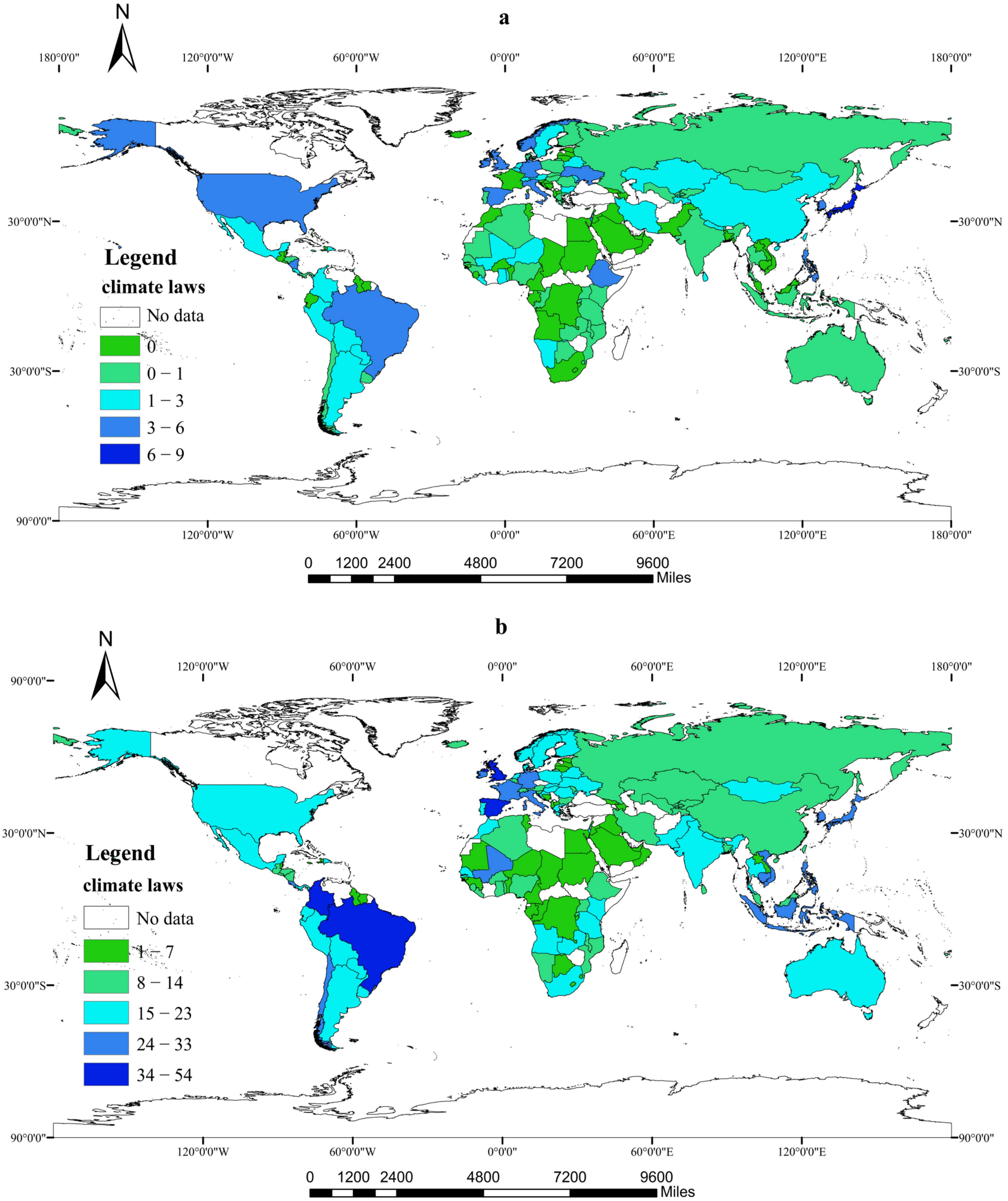


Figure 4. (**a**) Number of stock of climate laws in 2002. (**b**) Number of stock of climate laws in 2021.

Table 2. Global Moran's I of per capita carbon emissions and climate legislation.

Year	Moran's I (PC)	Moran's I (CLAW)	Year	Moran's I (PC)	Moran's I (CLAW)
2002	0.663 ***	0.094 **	2012	0.662 ***	0.141 ***
2003	0.671 ***	0.078 *	2013	0.668 ***	0.135 ***
2004	0.669 ***	0.029	2014	0.666 ***	0.161 ***
2005	0.667 ***	0.036	2015	0.669 ***	0.201 ***
2006	0.663 ***	0.047	2016	0.676 ***	0.196 ***
2007	0.658 ***	0.103 **	2017	0.682 ***	0.211 ***
2008	0.664 ***	0.124 ***	2018	0.679 ***	0.230 ***
2009	0.666 ***	0.169 ***	2019	0.677 ***	0.243 ***
2010	0.663 ***	0.160 ***	2020	0.676 ***	0.245 ***
2011	0.663 ***	0.122 ***	2021	0.677 ***	0.247 ***

Note: Significance is denoted by ***, **, and * at 1%, 5%, and 10% levels, respectively.

Further, combined with Figure 5, high–high carbon emission clusters are in North America, Asia, and Europe. In contrast "low–low" carbon emission clusters emerge in African countries and South America (see Figure 3b). In terms of climate legislation, European and American countries are almost high–high clusters. African and Asian countries are low–low clusters (see Figure 4b). Therefore, a distinct spatial clustering characteristic was present. Consequently, spatial econometrics becomes essential for examining the factors affecting CO_2 emissions and studying climate legislation's spillover effects.

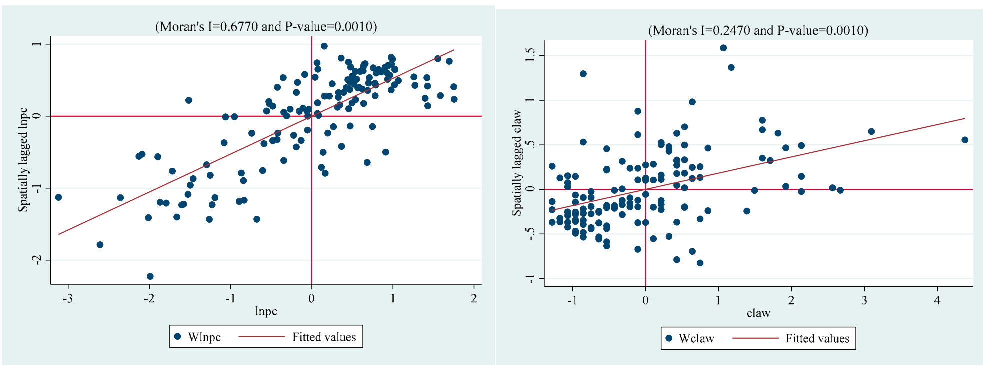


Figure 5. Moran's I scatterplots of carbon emissions and climate legislation based on geographical distance in 2021.

5.3. Econometric Regression Results

Before proceeding with regression analysis, confirming the optimized regression model with the relevant test is important. According to Elhorst [73], this study first estimates the models excluding the influence of spatial interactions and then carries out the requisite robust LM lag and LM error examinations for each spatial econometric estimation method. Table 3 displays the outcomes of the estimations for non-spatial panel methods, including pooled OLS, spatial fixed effects, and time fixed effects, as well as combined both spatial fixed effects and time fixed effects. The LM test results and robustness analysis are at the bottom of Table 3. The LM test results showed that the original hypothesis of no spatially lagged dependent variable could be strongly rejected across all model specifications at the 1% significance level. The original hypothesis of no spatially autocorrelated error factor is strongly refuted at the 1% significance level except for the two-way fixed effects model. Regarding the robustness test outcomes, across all model specifications, the original hypothesis of no spatially lagged dependent variable and the original hypothesis of no spatially autocorrelated error factor are firmly refuted at a 1% significance level. These results indicate the presence of spatial dependence among the data, consistent with the findings of the Moran's I index. The above spatial autocorrelation analysis confirms the significant spatial correlation between carbon emissions and climate legislation. By establishing a spatial econometric model, this study enables a more precise measurement of climate legislation's specific role and magnitude in influencing carbon emissions. Moreover, the model provides robust evidence supporting the diffusion of climate policies.

Table 3. Estimation results excluding spatial interaction impacts.

	Polled OLS	Spatial Fixed Effects	Time Period Fixed Effects	Spatial and Time Period Fixed Effects
claw	−0.0094 ***	−0.0086 ***	−0.0103 ***	−0.0049 ***
	(−5.3551)	(−9.6014)	(−4.436)	(−4.5873)
lnpgdp	3.4203 ***	3.0741 ***	3.4158 ***	2.9343 ***
	(33.5751)	(19.3003)	(33.4981)	(18.3836)
lnpgdp2	−0.1490 ***	−0.151 ***	−0.1487 ***	−0.1341 ***
	(−24.4217)	(−15.9543)	(−24.3699)	(−13.8546)
lnpd	0.014577 *	0.2341 ***	0.0149 **	0.4664 ***
	(1.7407)	(5.4656)	(1.7753)	(8.9362)
lnurb	0.28083 ***	0.8392 ***	0.2794 ***	0.9194 ***
	(7.5813)	(9.9177)	(7.5465)	(10.9245)
lnis	0.44407 ***	0.0461 *	0.4474 ***	−0.0027
	(14.5876)	(1.9516)	(14.5956)	(−0.1097)
lnrec	0.008565 **	−0.0023	0.0093 **	−0.0059 ***
	(2.01785)	(−1.0909)	(2.0773)	(−2.7374)
fdi	0.0004	0.0008 ***	0.0004	0.0009 ***
	(0.6141)	(3.8312)	(0.7495)	(4.2265)
rl	−0.0405	0.0503	−0.0432	0.0047
	(−0.4234)	(0.6301)	(−0.4488)	(0.0593)
Intercept	−19.8861 ***			
	(−49.3705)			
N	2840	2840	2840	2840
R2	0.8603	0.4410	0.8602	0.3770
FE R2		0.9877	0.8605	0.9881
Log L	−2463.4000	991.4462	−2641.0000	1032.7000
LM spatial lag	350.8466 ***	88.1969 ***	343.6846 ***	55.1181 ***
LM spatial error	1001.853 ***	39.2104 ***	989.0667 ***	1.8355
Robust LM spatial lag	27.9276 ***	57.7828 ***	28.1506 ***	115.4630 ***
Robust LM spatial error	678.934 ***	8.7963 ***	673.5328 ***	62.1804 ***

Note: The values inside the () indicate the t-statistic, while ***, **, * signify significance levels of 1%, 5%, and 10%, respectively.

For choosing the most suitable spatial model for optimal fitting, we initially assessed the spatial Durbin model (SDM). The Wald and LR tests were conducted to explore the possibility of simplifying the SDM into either the spatial lag model (SLM) or the spatial error model (SEM). The test results, as shown in Table 4, rejected the original hypothesis at the 1% level of significance, indicating that the SDM outperformed both the SAR and SEM. Therefore, our analysis of the spatial impact of climate legislation on carbon emissions is conducted based on the SDM. Simultaneously, employing Hausman statistics, we confirmed that the two-way fixed effect is more appropriate for our study. Consequently, the SDM processing two-way fixed effects was ultimately selected for empirical analysis.

Table 4. Estimation results including spatial interaction impacts.

	(1) SAR Model		(2) SEM Model		(3) SDM_FE Model		(4) SDM_RE Model	
	Coefficient	t Values	Coefficient	t Values	Coefficient	t Values	Coefficient	t Values
claw	−0.0048 ***	−4.4999	−0.0044 ***	−4.1839	−0.0047 ***	−4.4341	−0.0050 ***	−4.9093
lnpgdp	2.8875 ***	18.1933	2.8287 ***	17.6537	2.9300 ***	18.4072	3.1029 ***	20.4483
lnpgdp2	−0.1308 ***	−13.5795	−0.1273 ***	−13.0792	−0.1330 ***	−13.7829	−0.1452 ***	−16.3219
lnis	0.0014	0.0563	0.0025	0.1024	0.0025	0.1046	0.0231	0.9632
lnurb	0.9460 ***	11.3012	0.9159 ***	10.9196	0.9207 ***	10.7836	1.0531 ***	14.5102
lnpd	0.4894 ***	9.4095	0.4916 ***	9.5066	0.4940 ***	9.3833	0.2120 ***	6.0865
lnrec	−0.0060 ***	−2.8156	−0.0055 ***	−2.5974	−0.0045 **	−2.1071	−0.0053 **	−2.5088

Table 4. *Cont.*

	(1) SAR Model		(2) SEM Model		(3) SDM_FE Model		(4) SDM_RE Model	
	Coefficient	t Values	Coefficient	t Values	Coefficient	t Values	Coefficient	t Values
fdi	0.0009 ***	4.467	0.0009 ***	4.5577	0.0008 ***	4.1441	0.0008 ***	3.839
rl	0.0148	0.1873	−0.0102	−0.1295	0.0402	0.5068	0.0357	0.4487
W * claw					−0.0120 ***	−4.8848	−0.0076 ***	−3.9578
W * lnpgdp					1.5067 ***	3.796	1.2340 ***	3.3114
W * lnpgdp2					−0.1048 ***	−4.4088	−0.0839 ***	−3.8444
W * lnis					−0.0566	−0.9692	−0.0620	−1.1414
W * lnurb					−0.1063	−0.5144	−0.2260	−1.3473
W * lnpd					−0.3859 ***	−3.0259	−0.1049	−1.5299
W * lnrec					−0.0035	−0.7585	−0.0038	−0.8812
W * fdi					−0.0020 ***	−3.8365	−0.0020 ***	−3.8604
W * rl					0.7681 ***	3.9245	0.7581 ***	4.1305
ρ	0.1433 ***	4.9914			0.1197 ***	3.6948	0.1204 ***	3.7456
LR test	76.76 ***		80.1 ***					
Wald test spatial lag					77.72 ***			
Wald test spatial error					81.25 ***			
Hausman test					130.60 ***			
Observations	2840		2840		2840		2840	
R-squared	0.666		0.661		0.641		0.793	

Note: Significance is denoted by ***, **, and * at the 1%, 5%, and 10% levels, respectively.

According to the results in column (3) of Table 4, it is important to highlight that the statistical significance of the spatial autocorrelation parameter ρ is observed at the 1% level. This signifies the presence of spatial dependence within the dataset. The outcomes imply that an escalation in carbon emissions among neighboring nations contributes to rising CO_2 emissions within the host country. The CLAW coefficient demonstrated a statistically significant negative effect, suggesting that climate change legislation implemented in a specific country reduces its carbon emissions. This finding verifies hypothesis 1. The coefficients of lnPGDP are positive and strongly significant at the 1% level. The estimated coefficients of its squared term (lnPGDP2) are negative at the 1% level of significance, denoting that there is clear evidence for the EKC hypothesis, i.e., there is a reversed U relationship between GDP per capita and carbon emissions [74]. At the 1% significance level, the coefficients of lnURB are significantly positive. Due to industrialization and high carbonization in the early stage of urbanization, it is generally believed that the more developed a country's urbanization is, the higher the per capita CO_2 will be. Therefore, the urbanization process will undoubtedly promote an increase in carbon emissions. However, the coefficient of industrialization was positive and insignificant. As demonstrated in numerous empirical studies by scholars, industrialization is a significant factor contributing to the increase in carbon emissions. However, some researchers have also found that due to industrial optimization and upgrading, there are inhibiting factors that impede the rise in carbon emissions [75,76]. Under such dual effects, the positive impact of industrialization on carbon emissions may no longer be statistically significant. The estimated population density coefficient implies that higher population density levels led to an increase in CO_2 emissions throughout the research timeframe. It can be understood as a result of the larger population contributing to greater energy consumption, consequently fostering the production of carbon dioxide emissions. The coefficient of renewables consumption share was significantly negative at the 1% significance level, showing that renewable energy consumption can reduce carbon emissions. Regarding *FDI*, the estimated coefficient was significantly positive at the 1% level, which supports the "pollution heaven hypothesis". The estimated coefficient of the rule of law was positive but statistically insignificant.

Numerous preceding studies concluded at this juncture have assessed spatial spillover's presence via point estimates. However, according to LeSage and Pace [71], the estimated coefficients in the SDM are incapable of inherently portraying the marginal impacts of the associated explanatory factors on the dependent variable. Hence, this study subsequently conducted estimations to ascertain the independent variables' direct, indirect, and cumulative effects, detailed in Table 5.

Table 5. Direct, indirect, and total effects.

	Direct Effects		Indirect Effects		Total Effects	
Variables	**Coefficient**	**t Values**	**Coefficient**	**t Values**	**Coefficient**	**t Values**
claw	−0.0049 ***	−4.4642	−0.0139 ***	−5.0973	−0.0188 ***	−6.1845
lnpgdp	2.9579 ***	19.3114	2.0647 ***	5.0425	5.0226 ***	11.3646
lnpgdp2	−0.1346 ***	−14.4754	−0.1338 ***	−5.2429	−0.2684 ***	−9.811
lnis	0.0007	0.0288	−0.0682	−1.0561	−0.0675	−0.9076
lnurb	0.9211 ***	11.4996	0.0193	0.0823	0.9404 ***	3.7502
lnpd	0.4930 ***	9.1734	−0.3631 **	−2.5561	0.1299	0.7918
lnrec	−0.0046 **	−2.1244	−0.0047	−0.9015	−0.0093	−1.5978
fdi	0.0008 ***	4.1453	−0.0021 ***	−3.3624	−0.0012 *	−1.8641
rl	0.0602	0.7586	0.8518 ***	3.7026	0.9119 ***	3.5239

Note: Significance is denoted by ***, **, and * at the 1%, 5%, and 10% levels, respectively.

Table 5 displays the direct, indirect, and total effects. Direct effects indicate how alterations in explanatory variables impact carbon emissions within a specific country. Indirect effects can be interpreted as the impact of changes in explaining variables of adjacent nations on the carbon emissions of the host nation or as the impact of changes in explaining variables within the host nation on the carbon emissions of adjacent nations. Then, the sum of the direct and indirect impacts is the total effects. In terms of the magnitudes and significance level, the direct impacts are comparable to the coefficients estimated in Table 4. The magnitude discrepancies between them could be due to the feedback effects. These feedback effects are partly caused by the coefficient of the spatially lagged dependent variable and partly by the coefficient of the explanatory variable's own spatially lagged value.

The empirical results shown in Table 5 indicate that, for climate legislation, the total effect coefficient of climate legislation is −0.0188 and statistically significant. It illustrates that a newly passed climate law on its own contributes to a reduction in all countries' CO_2 emissions per capita by around 1.88%. Further, the direct effect (−0.0049) was significantly negative, indicating that one newly passed climate change law reduced carbon emissions by 0.49% in the domestic country. Climate change legislation plays an important role in regulating and controlling carbon emissions. On the other hand, the spillover effect (−0.0139) was also significantly negative, indicating that CO_2 emissions per capita decreased by 1.39% in local countries for every unit increase in the stock of climate legislation in the neighboring countries. This finding supports Hypothesis 2. That is to say, more climate legislation in surrounding countries will reduce carbon emissions in the local area. The possible reason why a country's climate legislation has a significant spatial spillover effect is that the dissemination of implicit knowledge is subject to geographic distance [77]. Under the influence of knowledge dissemination and policy diffusion, the local country gradually imitates and learns the advanced management experience of climate governance to cope with the pressure of international carbon emission reduction.

More importantly, it is evident that the spillover effects surpass the direct effects in terms of magnitude. This outcome implies that the positive impact of a country's climate legislation on its environmental quality is modest when contrasted with the positive impact of climate legislation in neighboring nations on the local environmental quality. This makes sense since the direct effects focus only on the host nation, whereas the indirect spillover effects consider all the other neighboring nations. And that is why the total effects align with the significance level of the indirect effects. The result also highlights the importance of estimating the impact of climate legislation on CO_2 emissions by considering spatial dependence. Based on the spatial dependence between climate legislation and carbon emissions, it can be inferred that the diffusion of climate laws, with the spillover effect, mitigates carbon dioxide emissions.

For the control variables, we first emphasized the relationship between economic development and CO_2 emissions. Regarding GDP per capita, the total effect equals 5.0226 and is statistically significant. It shows that a 1% rise in GDP per capita in a country triggers an increase in all countries' CO_2 emissions per capita by approximately 5.0226%. The direct effect of GDP per capita amounts to 2.9579 and is statically significant at a 1% significant level, indicating that a 1% increase in GDP per capita within a country can lead to an approximately 2.9579% rise in its own per capita CO_2 emissions. The spatial spillover impact equates to 2.0647 and is significant at the 1% level. This result indicates that when economic development increases by 1% in the local country, it leads to a 2.0647% rise in CO_2 emissions within the neighborhoods of the local country. The total effect, direct effect, and indirect effect coefficients of its squared term are −0.2684, −0.1346, and −0.1338, respectively. They are statistically negative and significant at a 1% level. These results imply that the spatial spillover effect also substantiates the EKC hypothesis theory. For the industrial structure, all the effects display statistical insignificance. The direct effect of urbanization is 0.9211 and significant at the 1% level, while its indirect effect is insignificant. The results show that a 1% growth in urbanization in a country triggers an increase in its CO_2 emissions per capita by approximately 0.9211%. Population density's direct effects is 0.4930, and its indirect effect is −0.3631, which are significant at the 1% level. The positive direct effect suggests that a 1% increase in population density within a country directly contributes to a 0.493% increase in carbon emissions per capita. Conversely, the negative indirect effect implies that a 1% increase in population density in neighboring countries dampens the local carbon emissions per capita by 0.3631%. The estimated coefficient for the direct effect of renewables is −0.0046, which is statistically significant at the 5% level. It suggests that a 1% growth in the utilization of renewables can reduce the carbon emissions per capita by 0.0046% within the country. However, its indirect spatial spillover effect is not statistically significant, indicating that the influence of renewables does not extend meaningfully to neighboring countries. The total effect of *FDI* is estimated at −0.0012, which is statistically significant at the 10% level. This result indicates that an increase of one unit in *FDI* is associated with an approximate 0.12% reduction in per capita carbon emissions across all countries. The direct effect of *FDI* is estimated at 0.0008, while the indirect effect is −0.0021, with both effects being statistically significant at the 1% level. This finding implies that a one-unit increase in domestic *FDI* leads to a 0.08% increase in per capita carbon emissions within the host country. In contrast, the indirect effect of *FDI* results in a 0.21% reduction in per capita carbon emissions in neighboring countries. For the rule of law, the direct effect is not significant. However, the spillover effect is significant, with a positive value of 0.8518, which implies that an improved legal environment in the local country results in increased emissions for its surrounding countries. One possible reason is that as domestic regulations gain stronger enforcement, highly polluting companies might choose to invest in neighboring countries, aiming to circumvent stringent legal constraints. As a result, this behavior can contribute to an increased carbon emission level in the surrounding nations.

To test Hypothesis 3, we distinguish climate legislation into legislative acts (passed by parliament) and executive orders (issued by governments). The results are presented in Table 6.

Table 6. Direct, indirect, and total effects of different types of climate laws.

	Direct Effects		**Indirect Effects**		**Total Effects**	
Variables	**Coefficient**	**t Values**	**Coefficient**	**t Values**	**Coefficient**	**t Values**
			Legislative acts passed by parliament			
claw_leg	−0.0175 ***	−6.942	−0.0579 ***	−8.2387	−0.0755 ***	−9.5947
lnpgdp	2.8476 ***	18.7017	1.5796 ***	3.932	4.4272 ***	10.2296
lnpgdp2	−0.1284 ***	−13.9062	−0.1063 ***	−4.2509	−0.2347 ***	−8.7666
lnis	0.0045	0.1915	−0.0779	−1.2375	−0.0734	−1.0166
lnurb	0.8561 ***	10.6899	−0.1233	−0.5449	0.7328 ***	3.0148
lnpd	0.4643 ***	8.6361	−0.3822 ***	−2.7603	0.0821	0.5148

Table 6. *Cont.*

Variables	Direct Effects Coefficient	Direct Effects t Values	Indirect Effects Coefficient	Indirect Effects t Values	Total Effects Coefficient	Total Effects t Values
lnrec	−0.0032	−1.4731	0.0008	0.1584	−0.0024	−0.4169
fdi	0.0008 ***	3.9514	−0.0020 ***	−3.364	−0.0012 *	−1.9083
rl	0.0160	0.2045	0.5645 **	2.5295	0.5806 **	2.3147
Executive orders passed by the government						
claw_exe	−0.0032 **	−2.3105	−0.0092 ***	−2.6432	−0.0124 ***	−3.1795
lnpgdp	2.9471 ***	19.1206	2.2577 ***	5.426	5.2048 ***	11.5789
lnpgdp2	−0.1342 ***	−14.3584	−0.1457 ***	−5.6239	−0.2800 ***	−10.0722
lnis	−0.0047	−0.201	−0.0781	−1.1918	−0.0828	−1.0962
lnurb	0.9337 ***	11.5488	−0.0451	−0.1886	0.8886 ***	3.4674
lnpd	0.5071 ***	9.4563	−0.3377 **	−2.3507	0.1694	1.0177
lnrec	−0.0059 ***	−2.6992	−0.0086	−1.6443	−0.0144 **	−2.4685
fdi	0.0008 ***	4.1598	−0.0020 ***	−3.2994	−0.0012 *	−1.8114
rl	0.0740	0.9274	0.9198 ***	3.9164	0.9938 ***	3.7586

Note: Significance is denoted by ***, **, and * at the 1%, 5%, and 10% levels, respectively.

As shown in Table 6, the total effect of legislative acts is estimated at −0.0755, which is statistically significant at the 1% level. This result indicates that each new legislative act leads to an approximate 7.55% reduction in per capita carbon emissions across all countries. The direct effect is −0.0175, also significant, suggesting that each new legislative act results in a 1.75% decrease in per capita carbon emissions within the implementing country itself. In addition, the indirect effect is −0.0579, which is also significant, implying that adopting new legislative acts in one country contributes to a 5.79% reduction in per capita carbon emissions in neighboring countries. In terms of executive orders, the total effect is estimated at −0.0124 and is statistically significant at the 1% level. This result suggests that each new executive order results in an approximate 1.24% reduction in per capita carbon emissions across the overall sample of countries. The direct effect is −0.0032, indicating that each new executive order leads to a 0.32% decrease in per capita carbon emissions within the implementing country. Meanwhile, the indirect effect is −0.0092, also statistically significant, reflecting a 0.92% reduction in per capita carbon emissions in neighboring countries as a result of the newly passed executive order. As indicated in Table 6, despite the greater number of executive orders compared to legislative acts (refer to Figure 2), both the direct and spillover carbon reduction impacts remain inferior to those of legislative acts. Hypothesis 3 was verified. This conclusion aligns with the findings of Eskander and Fankhauser [7], who argue that legislative acts have a higher capacity to decrease emissions due to a substantial portion of them being primarily focused on aspirational objectives.

5.4. Robustness Check

Several robustness tests were used in this study to ensure that the estimated results were stable. First, this paper used the different spatial weight matrices (geographical inverse squared distance matrix) and eight-nearest neighbors matrix to confirm the results' sensitivity. As shown in Table 7, employing other spatial weight matrices did not alter our key conclusions.

Table 7. Direct, indirect, and total effects using different weight matrices.

Variables	Direct Effects Coefficient	Direct Effects t Values	Indirect Effects Coefficient	Indirect Effects t Values	Total Effects Coefficient	Total Effects t Values
Spatial inverse squared distance matrix						
claw	−0.0050 ***	−4.598	−0.0124 ***	−3.768	−0.0174 ***	−4.9827
lnpgdp	2.9688 ***	19.2884	1.3222 ***	2.6841	4.2910 ***	8.2719
lnpgdp2	−0.1343 ***	−14.338	−0.0901 ***	−3.0564	−0.2244 ***	−7.2396
lnis	−0.0181	−0.7666	−0.1490**	−2.4396	−0.1671 **	−2.3609

Table 7. *Cont.*

	Direct Effects		Indirect Effects		Total Effects	
Variables	**Coefficient**	**t Values**	**Coefficient**	**t Values**	**Coefficient**	**t Values**
lnurb	0.9628 ***	11.8663	0.9378 ***	3.3945	1.9006 ***	6.4327
lnpd	0.5238 ***	9.7498	0.0122	0.0729	0.5360 ***	2.9053
lnrec	−0.0058 ***	−2.6962	−0.0094 *	−1.7559	−0.0152 ***	−2.6246
fdi	0.0008 ***	4.2061	−0.0016 *	−1.689	−0.0008	−0.7833
rl	0.0708	0.9076	−0.1176	−0.4704	−0.0468	−0.1772
Eight-nearest neighbors spatial weight matrix						
claw	−0.0055 ***	−5.0142	−0.0134 ***	−3.9022	−0.0189 ***	−5.1972
lnpgdp	3.0101 ***	19.646	2.2737 ***	4.6319	5.2839 ***	10.2436
lnpgdp2	−0.1371 ***	−14.7596	−0.1425 ***	−4.6732	−0.2796 ***	−8.8032
lnis	−0.0091	−0.39	−0.1796**	−2.2316	−0.1887**	−2.1367
lnurb	0.9698 ***	12.3037	1.0439 ***	3.4025	2.0137 ***	6.2591
lnpd	0.4938 ***	9.0983	0.0492	0.2612	0.5430 ***	2.5929
lnrec	−0.0052 **	−2.4119	−0.0005	−0.0683	−0.0057	−0.7782
fdi	0.0008 ***	3.9092	−0.0025 ***	−3.1421	−0.0017 **	−2.0732
rl	0.0621	0.7888	0.2724	0.9629	0.3344	1.1017

Note: Significance is denoted by ***, **, and * at the 1%, 5%, and 10% levels, respectively.

Second, we changed the dependent variable to total carbon emission. Accordingly, the independent variable of population density was changed to total population to ascertain the stability of the effects of climate legislation. As seen from Table 8, climate legislation exerts a significant negative influence on total carbon emissions both directly and indirectly, indicating that our findings are robust.

Table 8. Direct, indirect, and total effects when changing dependent variable.

	Direct Effects		Indirect Effects		Total Effects	
	Coefficient	**t Values**	**Coefficient**	**t Values**	**Coefficient**	**t Values**
claw	−0.0048 ***	−4.4634	−0.0139 ***	−5.0901	−0.0188 ***	−6.1776
lnpgdp	2.9616 ***	19.3446	2.0682 ***	5.0349	5.0299 ***	11.3399
lnpgdp2	−0.1348 ***	−14.5004	−0.1339 ***	−5.2349	−0.2687 ***	−9.7922
lnis	0.0007	0.0287	−0.0690	−1.0691	−0.0683	−0.919
lnurb	0.9190 ***	11.4792	0.0165	0.0706	0.9355 ***	3.7259
lnpop	1.4932 ***	27.8159	−0.3625 **	−2.5459	1.1307 ***	6.8973
lnrec	−0.0046 **	−2.1314	−0.0048	−0.9215	−0.0094	−1.6167
fdi	0.0008 ***	4.1538	−0.0020 ***	−3.3575	−0.0012 *	−1.859
rl	0.0594	0.7479	0.8553 ***	3.713	0.9147 ***	3.5272

Note: Significance is denoted by ***, **, and * at the 1%, 5%, and 10% levels, respectively.

The last definitional change concerns the climate laws in EU and OECD countries because the countries in the EU and OECD always have a shared agreement on economic, environmental, and political aspects. As a robustness check, we investigate what would happen if we excluded EU and OECD countries. Table 9 shows that the spatial spillover effect is negative and significant at a 1% level. The results indicate that excluding EU and OECD countries does not change the primary findings, and the spillover effects of climate legislation on carbon emission reduction remain.

Table 9. Direct, indirect, and total effects when excluding EU&OECD countries.

	Direct Effects		Indirect Effects		Total Effects	
Variables	**Coefficient**	**t Values**	**Coefficient**	**t Values**	**Coefficient**	**t Values**
claw	0.0016	1.0107	−0.0079 ***	−2.932	−0.0063 **	−2.5302
lnpgdp	2.4388 ***	13.102	−1.6333 ***	−4.3776	0.8056 **	2.034
lnpgdp2	−0.1100 ***	−9.495	0.1122 ***	4.6981	0.0022	0.0873
lnis	0.0228	0.8885	−0.0035	−0.0694	0.0193	0.3634

Table 9. *Cont.*

Variables	Direct Effects		Indirect Effects		Total Effects	
	Coefficient	t Values	Coefficient	t Values	Coefficient	t Values
lnurb	0.7876 ***	9.0427	1.0200 ***	6.0193	1.8076 ***	10.4927
lnpd	0.3009 ***	4.6113	−0.2486 **	−1.9791	0.0524	0.3892
lnrec	−0.0023	−0.9507	0.0200 ***	3.745	0.0177 ***	3.1702
fdi	0.0032 ***	4.598	0.0028 *	1.8194	0.0060 ***	3.8112
rl	−0.0055	−0.0618	1.5149 ***	7.2331	1.5094 ***	6.8644

Note: Significance is denoted by ***, **, and * at the 1%, 5%, and 10% levels, respectively.

5.5. Discussion

We compared the previous studies from two aspects: the spatial spillover characteristics of pollution and climate legislation. First, despite the large differences in study areas and times, there is a near consensus on the positive spatial spillover effects of carbon emissions. Elevated levels of carbon emissions in neighboring areas result in a subsequent rise in carbon emissions at the local level [42,78]. The results in this paper are similar to those of past studies, which revealed the spatial dependence of air pollution. Second, studies investigating the spatial spillover effect of environmental regulation and policy diffusion can support the positive spatial spillover effects of climate legislation. Khurshid et al. [79] and Wang et al. [80] showed that the spatial spillover effect of environmental regulation on green innovation is substantially positive, illustrating the learning response of regional environmental regulation. Zeng et al. [81] also hold that if a country enacts successful legislation for the environment, adjacent governments follow suit. On the contrary to the findings in this paper, some studies indicate that environmental policies may be ineffective in achieving global emissions reduction due to "carbon transfer" and "free-riding" [82]. Implementing environmental policies may lead firms to move pollution-intensive production to neighboring regions with less stringent policies, thus triggering negative spatial spillovers [83]. The divergence in conclusions may be attributed to the focus on different environmental policy instruments and varying geographical regions. This paper demonstrates that carbon emissions across global countries exhibit positive spatial spillover effects. Stricter climate legislation in neighboring countries reduces domestic carbon emissions and can mitigate air pollution worldwide. This study challenges the notion that environmental policies result in negative spatial spillover effects on environmental pollution. It provides a new perspective on how climate legislation transmits effects across regions. This study offers new perspectives to further understand the spatial interaction mechanisms between climate legislation and carbon emissions.

6. Conclusions and Policy Implications

Although several studies have revealed the issue of policy diffusion, a spatial econometric model has rarely been employed to investigate the impact of climate legislation on carbon emissions. Hence, the present study examined the effect of climate legislation on CO_2 emissions employing a spatial econometric panel model to avert the deviation of the coefficient estimation and provide new evidence for the diffusion of climate legislation. The empirical finding confirmed the presence of a spatial correlation between CO_2 emissions and climate legislation among countries. More prominently, national carbon emissions are influenced not just by a country's climate legislation but also by its neighboring nations. Moreover, legislative acts have a greater significant impact compared to the role of executive orders. The significant negative spatial spillover effect of climate legislation on carbon emissions offers significant empirical evidence of climate governance. In addition, our findings support the EKC hypothesis even under the spillover effect. Ultimately, the findings withstood various robustness tests, including utilizing alternate dependent and excluding samples.

Based on the empirical findings in this research, the following policy implications for global countries and groups are proposed and analyzed.

First, the main findings show that a country's climate legislation has a significant positive direct and spatial spillover effect on carbon emission reduction. At the international level, the international community should actively promote the process and optimization of climate legislation and improve the synergy mechanism of transnational climate governance to strengthen the collaborative linkage of regional climate legislation. Climate governance has never been a matter for a single country; it needs to be taken part in by all countries worldwide. The cooperation and exchange among regions can strengthen the spatial spillover effect of climate legislation and build a global community of interests. At the national level, governments should not only concentrate on the benefits of the host country but also consider the influence of bordering countries when proceeding with climate governance. They must particularly focus on the spatial implications of a policy with for rest of the world. By fostering proactive collaboration, sharing information, and coordinating policies, climate legislation can be formulated that is beneficial for domestic development and conducive to regional cooperation. This encourages nations to collectively strive within their cooperative efforts to achieve the global climate goal outlined in the Paris Agreement.

Second, concerning the form of climate legislation, it is imperative to prioritize the adoption of climate laws endowed with legal enforceability, ensuring the credibility and efficiency of climate governance. This amplifies the effectiveness of domestic climate governance and expedites the diffusion of climate policies, consequently upholding one's global reputation and competitive position.

Third, a spatial EKC relationship was observed in our study. In this regard, once a nation's economy crosses a certain threshold, it can exert a restraining effect on its and neighboring countries' carbon emissions. Economically advanced nations typically possess greater technological expertise, resources, and capital, enabling them to engage in technology transfer and collaboration in environmental protection. They can share advanced environmental technologies with neighboring countries, lowering their and neighbors' carbon emissions. Economically less developed countries should strike a balance between trade and environmental concerns. They should accelerate the advancement of climate legislation, learn from the climate legislative experiences of developed nations, and thereby better fulfill the entry requirements of developed markets while addressing their own developmental needs.

While the paper provides some novel insights into the relationship between climate legislation and carbon emission, it does come with certain limitations. It might be that the effects of climate legislation on carbon emissions vary across different regions, income levels, and legal origins. In the future, performing empirical research to test the effects of climate legislation on CO_2 emissions from a heterogeneous perspective would be noteworthy. Additionally, it is essential to consider the diverse set of potential alternative intermediary channels that underlie cross-country interactions in climate legislation and emissions, e.g., the green investment channel. This matter requires further investigation in the future.

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Appendix A

Table A1. Country sample incorporated in this study.

Country	Country	Country	Country	Country	Country
Angola	Democratic Republic of the Congo	Grenada	Lesotho	Poland	Uruguay
Albania	Republic of Congo	Guatemala	Lithuania	Portugal	United States
United Arab Emirates	Colombia	Guyana	Latvia	Paraguay	Uzbekistan
Argentina	Comoros	Honduras	Morocco	Romania	Vietnam
Antigua and Barbuda	Costa Rica	Croatia	Moldova	Russia	Samoa
Australia	Cyprus	Haiti	Mexico	Rwanda	South Africa
Austria	Germany	Hungary	Macedonia	Saudi Arabia	Zambia
Azerbaijan	Dominica	Indonesia	Mali	Sudan	
Burundi	Denmark	India	Malta	Senegal	
Belgium	Dominican Republic	Ireland	Mongolia	Singapore	
Benin	Algeria	Iran	Mozambique	Sierra Leone	
Burkina Faso	Ecuador	Iraq	Mauritania	El Salvador	
Bangladesh	Egypt	Iceland	Mauritius	Suriname	
Bulgaria	Spain	Israel	Malawi	Slovakia	
Bahamas	Estonia	Italy	Malaysia	Slovenia	
Bosnia and Herzegovina	Ethiopia	Jamaica	Namibia	Sweden	
Belarus	Finland	Jordan	Niger	Swaziland	
Belize	Fiji	Japan	Nigeria	Seychelles	
Bolivia	France	Kazakhstan	Nicaragua	Chad	
Brazil	Gabon	Kenya	Netherlands	Togo	
Barbados	United Kingdom	Kyrgyzstan	Norway	Thailand	
Brunei	Georgia	Cambodia	Nepal	Tajikistan	
Botswana	Ghana	South Korea	Oman	Trinidad and Tobago	
Switzerland	Guinea	Laos	Pakistan	Tunisia	
Chile	Gambia	Lebanon	Panama	Tanzania	
China	Guinea-Bissau	Liberia	Peru	Uganda	
Cameroon	Greece	Sri Lanka	Philippines	Ukraine	

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