Hindawi
Mobile Information Systems
Volume 2022, Article ID 9696973, 12 pages
https://doi.org/10.1155/2022/9696973

Research Article

Internet Development, Collaborative Innovation, and Carbon Emissions

Xuemeng Ding[1] **and Qiang Zhao**[2]

[1]*School of Humanities and Laws, Hebei University of Technology, Tianjin 300401, China*
[2]*School of Insurance, University of International Business and Economics, Beijing 100029, China*

Correspondence should be addressed to Xuemeng Ding; 2020095@hebut.edu.cn

Received 2 March 2022; Revised 25 March 2022; Accepted 30 March 2022; Published 23 April 2022

Academic Editor: Hasan Ali Khattak

In order to promote the deep integration of "Internet" and "green ecology," it is of great significance to realize the high-quality development of China's economy. *Methods*. Based on the panel data of 30 provinces from 2011 to 2018, this paper explores the mechanism of Internet development affecting carbon emission intensity by using the dynamic spatial Durbin model combined with the mediating effect model. The findings are as follows: first, spatially, within the whole region, Internet development not only significantly suppresses the carbon emission intensity of the region but also has a negative spatial spillover effect on the carbon emission of the surrounding areas. Second, in terms of regional heterogeneity, the impact of Internet development on carbon emission reduction is greater in the eastern region compared to the central and western regions and small cities. Third, in the aspect of influence mechanism, collaborative innovation is an important path for Internet development to promote carbon emission reduction, and collaborative innovation partially plays a mediating role in this mechanism. Through the development of regional new energy, high-tech, and other low-carbon technologies, enhance the potential of regional emission reduction, form a "strong by strong" development model, achieve the overall goal of regional carbon emission reduction, and improve the high-quality development of China's economy.

1. Introduction

Since China's reform and opening up, environmental pollution and increasing carbon emissions have attracted increasing national attention. To cope with climate change, the government has set a series of emission reduction targets, thus achieving a win-win development of economic growth and CO_2 emission reduction. For China, it is particularly important to complete the task of green and low-carbon transformation in the process of industrialization and urbanization development and embark on a low-carbon development path while taking into account the expansion of energy demand. In 2020, China's GDP per capita reached 72,000 yuan, higher than the average level of middle-income countries. The country is reported to have won the battle against poverty in all aspects, with 98.99 million rural poor people under the current standard being lifted out of poverty. However, this crude development model, which is mostly oriented to "high consumption, high pollution, and low efficiency," has brought about "quantitative" growth but failed to produce "qualitative" breakthroughs and has cost China a huge environmental price. Developing a green economy is considered an effective way to reduce pollutant emissions, save energy, and achieve sustainable economic growth [1]. The Fifth Plenary Session of the 19th CPC Central Committee proposed to accelerate the transformation of the green economy and promote the formation of green production and lifestyle. Therefore, the proposed target of energy conservation and emission reduction is both a challenge to China's future economic development and an important opportunity and lever for the green transformation of China's economy.

At present, the world economy has not fully recovered, and China's economy is currently undergoing transformation. At this stage, the urgent problem to be solved in China is the overcapacity and low innovation ability of

manufacturing industry. In such a special period, "Internet +manufacturing" is undoubtedly a strategic issue and an important link in the integration of two industries [2]. Since its birth, the Internet has been the most dazzling technological innovation in history, leading the information revolution with far-reaching significance for human society and bringing human civilization into a new stage of unprecedented prosperity and efficiency. In recent years, digital technologies represented by the Internet, big data, and artificial intelligence have been continuously integrated with various fields of economy and society, gradually becoming an important driving force to promote the upgrading of consumption and the transformation of economic structure in China [3] and being given the role of a new driving force of economic growth.

While paying attention to the contribution of the Internet to economic development, the environmental impact of Internet development cannot be ignored. On the one hand, this type of development promotes the sharing economy and effectively reduces the waste of resources [4]. For example, the widespread use of shared bicycles has greatly reduced the frequency of private car travel, which not only improves urban transportation but also reduces energy consumption. On the other hand, the development of the Internet can promote the progress of clean technology, thereby reducing greenhouse gas emissions [5]. These raise a question that has yet to be empirically verified, i.e., in the context of promoting the "Digital China and Network Power" strategy, can the development of the Internet effectively reduce CO_2 emissions? If the answer is yes, what are the mechanisms behind it? To give a definitive answer, this paper investigates the relationship between Internet development and carbon emission intensity through empirical analysis and tries to explore the mechanism of the impact of Internet development on regional carbon emission.

The rest of the paper is structured as follows. Part II contains the literature review and research hypotheses; Part III introduces the data and methods; Part IV is the findings; and Part V gives the conclusions and implications.

2. Literature Review and Research Hypothesis

2.1. Internet Development and Carbon Emissions. The Internet has the unique advantage of spanning time and space in terms of information dissemination, access, and application, enabling the integration of information in the global community at high speed [6]. Endogenous growth theory suggests that innovative activities formed by the accumulation of knowledge throughout society constitute an important driver of economic growth, and the efficiency of information production and dissemination is crucial for knowledge accumulation [7]. The Internet has broken the space-time limitation and improved the ability to condense, integrate, and diffuse distributed fragmented information, enabling everyone to reprocess favorable information through the Internet, thus promoting the technological progress of the whole society, which can effectively promote the process of carbon emission reduction.

Internet development affects carbon emissions mainly through the following ways. First, it improves the efficiency of resource allocation and reduces production costs. Through real-time remote monitoring of the use of the Internet in the production process, through real-time communication with customers, enterprises can quickly adjust production and business activities according to the needs of the market, so as to improve the efficiency of resource allocation and labor productivity and reduce transaction costs [8]. Smart factory uses the "Internet+energy management" model to improve the energy efficiency of the production system and achieve energy conservation, emission reduction, and green production. Second, companies are able to scale on-demand. The traditional mass production model is unsustainable due to the diversity of network-derived customer needs, but in the Internet era, enterprises can realize large-scale on-demand production by interacting and communicating with customers in real time through the Internet and responding to their personalized needs in a timely manner [9]. This model not only reduces the R&D cost of enterprises but also reduces the waste of resources and improves the efficiency and quality of product production. While shortening the R&D cycle, it reduces the inventory of products, which is in line with the innovative concept of low-carbon production. Third, the enterprise can achieve intelligent process supervision. Enterprises use the Internet to establish smart factories to achieve full control and process optimization of product design, production, transportation, sales, and service [10]. Intelligent monitoring is particularly important for polluting industries and enterprises. By introducing intelligent monitoring systems, polluting enterprises can greatly improve the detection efficiency of pollutant generation and emission, which in turn can facilitate the implementation of relevant pollution control management measures in polluting industries and enterprises, thus improving the efficiency of clean production [11] and achieving carbon emission reduction goals.

Based on the above analysis, the first hypothesis proposed in this paper is as follows:

Hypothesis 1. Internet development helps to promote carbon emission reduction.

2.2. Internet Development, Collaborative Innovation, and Carbon Emissions. Factors that have been recognized to influence regional carbon emissions include population size, economic development, and technological progress, but few studies have focused on synergistic innovation efficiency and carbon intensity. Bjerregaard [12] argues that R&D synergy can facilitate the integration of external knowledge and technology, promote scientific cooperation and information sharing, and achieve regional synergistic innovation development. Alam et al. [13] argues that technological innovation can motivate enterprises to eliminate outdated technologies, use energy-saving technologies, form green industrial chains, and reduce carbon emission intensity. Therefore, the key to energy conservation and emission reduction lies in vigorously strengthening the inherent technological innovation and improving regional energy use efficiency. However, the

technological innovation capacity of individual subjects or regions may not effectively enhance the overall development strength of the region, and the difference in technology level between different regions will also directly affect the difference in energy use efficiency. Therefore, while improving individual innovation capacity, it is more important to focus on improving interregional collaborative innovation capacity and promoting the rational use and distribution of resources in various production links in different regions [14], so as to promote coordinated regional development and realize regional integration. Studies have shown that there is a long-term dynamic relationship between carbon emission reduction and technological innovation efficiency [15]. Improving regional collaborative innovation capacity can increase the flow of technology and knowledge between regions and achieve the integration of innovation resources, thus effectively enhancing the multidimensional spillover effect of collaborative innovation, which plays a key role in enhancing technological innovation and carbon emission reduction potential. On the whole, the efficiency of collaborative innovation can reduce the carbon emission intensity of the region, and this impact has an obvious spatial spillover effect. The improvement of collaborative innovation efficiency can not only reduce the cost of emission reduction and improve the energy structure and industrial structure of the synergistic region in order to achieve emission reduction; it may also internalize the problem of resource externality and achieve regional green development through the technology scale effect, which reflects the main advantages [16, 17].

However, in recent years, the Internet has also developed into a powerful engine for driving innovation-driven development in the social economy, and the development of Internet technology can bring about an increase in a country's technological efficiency. Bertschek et al. [18] analyzed the Internet and firm performance using a sample of German firms and showed that the Internet facilitated the innovation process of firms; the emergence of the Internet increased the knowledge dissemination power and increased the possibility of people to benefit from the available knowledge, further boosting firms' innovative activities [19]. All these studies in the literature show that the development of the Internet has a positive effect on the improvement of the efficiency of regional collaborative innovation. (1) First of all, the Internet, as a revolutionary invention that overturns the characteristics of information delivery, has largely eliminated the barriers to information delivery and geographic time and space limitations. On the one hand, the information readily obtained via Internet empowers enterprises' knowledge accumulation, thus promoting innovation [20]; on the other hand, the Internet can promote knowledge diffusion within enterprises, which is conducive to transforming knowledge into high-quality innovation results [21]. (2) Secondly, Internet development can promote the cross-regional integration of resource elements, thus improving the collaborative innovation capability. The Internet can realize the cross-regional reorganization of innovation factors such as capital, talents, and technology through the multiplier effect of network link points [22] and efficiently integrate innovation resources in breadth and depth with the help of network platforms and subjects. In addition, the superb "link" integration capability of the Internet can indirectly realize the reconstruction of regional economic structure and promote the formation of the triple cycle of business, manufacturing and R&D ecosystem, thus realizing the incremental returns to scale of the new economic structure under the integrated utilization of cross-regional innovation resources [23] and further enhancing the level of regional collaborative innovation. (3) Finally, Internet technology has injected new vitality into organizational change [24]. The asset-light model of the Internet has facilitated changes in the organizational model of enterprises by reducing intermediate links, lowering transaction costs, and improving transaction efficiency, which has changed the supply chain structure from supply-oriented to customer demand-oriented [25]. Through the Internet's modular division of labor, production organizations can achieve a close combination of extreme division of labor and extreme cooperation, promoting continuous innovation in production organization and division of labor [26]. All in all, the Internet is accelerating the transformation of industry organizations, changing the relationship between organizations, leading to a major structural change in enterprises, industries, and even society, and completing the innovative realization of intelligent organizational models.

Based on the above analysis, the second hypothesis is proposed:

Hypothesis 2. Internet development promotes carbon emission reduction by improving the efficiency of collaborative innovation.

3. Data and Methodology

Given the availability of data, this paper selects panel data of 30 provinces in China from 2011 to 2018. Among them, data on carbon emission intensity are from the China Energy Statistical Yearbook, data on Internet development are from the China Statistical Yearbook, data on mediating variables, i.e., proxy variables for collaborative innovation, are from the China Science and Technology Statistical Yearbook, and data on other control variables are from the China Statistical Yearbook. To eliminate the effect of price fluctuations, economic variables are deflated with 2011 as the base period.

3.1. Variable Selection

3.1.1. Explained Variables. Carbon emission intensity (cg): its measurement method is borrowed from the carbon emissions formula for energy consumption in IPCC [27], which is calculated as

$$cgijt = \sum_{j=1}^{n} En_{ijt} \times \eta j \times \theta j \times \gamma j \times \frac{44}{12}, \tag{1}$$

where cg_{ijt} denotes the carbon emission of the ith province; En_{ijt} denotes the physical quantity of the jth energy

consumed in the ith province in year t; η_j, θ_j, and γ_j denote the average low-level heat generation (kg CO_2/TJ), carbon dioxide emission factor (KJ/kg·m^3), and carbon oxidation factor of the jth energy, respectively; and 44/12 denotes the carbon dioxide gasification factor. To eliminate the effect of heteroskedasticity, they are treated as logarithmic (lncg).

3.1.2. Core Explanatory Variable. Internet development (intel): based on the measurement of Internet development level by scholars worldwide, this paper selects indicators such as Internet penetration rate, the proportion of Internet-related employees to all employed persons, the proportion of Internet-related output value to GDP, and the number of mobile Internet users and uses principal component analysis to construct a comprehensive Internet development index for expression. The convenience and improvement of Internet digital platforms have given rise to a variety of emerging business models represented by shared low-carbon travel and crowdfunding, which in turn bring about a reduction in carbon emissions.

3.1.3. Mediating Variable. Collaborative innovation (eci): collaborative innovation is mainly reflected in many aspects among the subjects in the region, such as capital flow, personnel flow, and factor flow. According to the connotation of collaborative innovation and the actual situation of input and output, considering the cooperation among enterprises, universities, and research institutions, the following input and output indicators are selected for calculation:

(1) Input indicators: human input and capital input are the basic core resource elements of regional collaborative innovation. Starting from the traditional production function, this paper chooses the full-time equivalent of R&D personnel to reflect labor input and R&D expenditure to reflect capital input

(2) Output indicators: from the economic perspective of collaborative innovation, the green benefits of regional collaborative innovation are considered to enhance regional economic benefits and improve the environment. Therefore, in this paper, the number of domestic patent applications in selected regions reflects the original innovation capability and comprehensive scientific and technological strength of a region; the number of Chinese scientific and technological papers included in major foreign search tools reflects China's achievements in basic and applied research and exchanges with the outside world. The amount of technology export contracts can more intuitively reflect the level of technological achievements into real market value, and the combination of the three can more comprehensively reflect the output effect of innovation inputs

3.1.4. Control Variables. Referring to the studies on the factors influencing carbon emissions, the following indicators were selected as control variables to be included in the model.

(1) Level of economic development (lngdp): measured by the natural logarithm of regional GDP per capita. Regions with higher levels of economic development have strong capital, convenient infrastructure development, and easier access to adequate labor resources and are more sensitive to environmental quality requirements

(2) External opening level (open): measured by the share of imports and exports in GDP, and the US dollar is converted at the midpoint of the annual exchange rate of the RMB in processing. The openness to foreign investment can help attract foreign firms with more developed energy-saving and emission-reducing technologies to carry out "green" production activities, thus promoting carbon emission reduction [28]. At the same time, the entry of foreign capital may also cause "pollution refuge" effects and "carbon leakage" problems due to the low environmental standards and environmental regulation in developing countries [29]

(3) Urbanization level (city): measured by the proportion of the urban population to total population. The urbanization process will lead to a large demand for energy consumption [30], which may cause a corresponding increase in carbon emissions

(4) Energy consumption (lne_c): measured by the per capita coal consumption. The per capita coal consumption directly determines the magnitude of the carbon intensity of energy consumption (i.e., carbon emissions per unit of energy consumption), and when the per capita coal consumption is high, it is not conducive to the reduction of carbon emission intensity [31, 32]

Table 1 gives the description of the main variables in this article.

3.2. Model Construction

3.2.1. Collaborative Innovation Efficiency Measurement. Data envelopment analysis (DEA) is one of the most commonly used methods to measure the relative efficiency of decision-making units (DMUs) of the same type. Most of the existing literature on collaborative innovation efficiency measurement adopts DEA method, which can effectively solve the problem of multiple inputs and outputs of decision-making units. In view of the difficulty in determining the production function relationship of collaborative innovation, this paper adopts the input-oriented BCC model to calculate the regional collaborative innovation efficiency, and the model is introduced as follows:

The national interprovincial region is used as the basic decision unit to measure its collaborative innovation efficiency, and for any decision unit, there are i inputs and r outputs. For the jth decision unit i, x_j and y_j are the input

Table 1: Summary statistics of the main variables.

Variable	Index selection	Signature	Mean	SD	Min	Max
Explained variables	Carbon emissions	lncg	5.6543	0.7675	3.7966	7.4250
Core explanatory variables	Internet development	intel	2.69e-09	1.4576	-4.0848	4.2783
Mediating variables	Collaborative innovation	eci	0.7266	0.2223	0.2390	1.0000
Control variables	Economic development	lngdp	10.3939	0.4049	9.4288	11.5379
	External opening level	open	0.2844	0.3040	0.0175	1.4637
	Urbanization	city	0.5708	0.1243	0.3436	0.9378
	Energy consumption	lne_c	1.2234	0.4163	0.4373	2.3025

and output column vectors, respectively, and X and Y are the input matrix of $(i \times n)$ and the output matrix of $(r \times n)$, respectively, and then, the comprehensive technical efficiency θ_j of the jth decision unit can be obtained by the following set of linear equations:

$$\text{Max } \theta_j \, s.t. -\theta_j y_j + Y\lambda \geq 0 \, ; x_j - X\lambda \geq 0 \, ; \lambda \geq 0, \tag{2}$$

The pure technical efficiency can be obtained by adding the convexity constraint $\sum \lambda j = 1$ to the CCR model, representing the variable payoff to scale assumption, so that the pure technical efficiency δ_j of the jth decision unit can be obtained by the following set of linear equations:

$$\text{Max } \delta_j \, s.t. -\delta_j y_j + Y\lambda \geq 0 \, ; x_j - X\lambda \geq 0 \, ; \lambda \geq 0 \, ; \sum \lambda_j = 1. \tag{3}$$

Finally, the scale efficiency value of each decision unit is found based on the formula that scale efficiency equals the combined technical efficiency divided by the pure technical efficiency.

3.2.2. Selection of Spatial Econometric Models

(1) Spatial Econometric Regression Model Selectivity Test. First, the Hausman test was conducted on the panel data from 2011 to 2018, and the results are shown in Table 2, indicating that the fixed effects model was chosen to be superior to the random effects model. From the LM test results, LM-Lag, Robust LM-Lag, LM-Error, and Robust LM-Error are all significant at the 1% level, and it is reasonable to choose the spatial econometric model for the empirical study. Second, the LR likelihood ratio and Wald test show that the test statistics pass the 5% significance test, and the selection of the spatial Durbin model is more appropriate. In summary, the spatial Durbin model with fixed effects is selected in this paper.

(2) Setting of Spatial Durbin Model. The carbon emission intensity is not entirely influenced by the role of Internet development in a certain region; instead, the flow and spillover of resources, factors and technologies, etc., may also play their role in this regard, meaning that the intensity is also subjected to the influence of other regions. Considering that the panel model ignores the bias brought by spatial effects on the model estimation results, a spatial econometric model is introduced. Therefore, this paper mainly adopts the spatial Durbin model to conduct empirical tests. In addition, considering the possible time-dependent path of carbon emission changes, i.e., the time-lag effect, and the endogeneity problem brought about by the two-way causality between carbon emissions and economic growth [33], this paper introduces the lag phase of carbon emission variables into the standard static spatial panel Durbin model and constructs the following dynamic space panel Durbin model:

Table 2: LR test and LM test in the spatial model.

Test	Model	W	Statistic	P value
LM test	SEM	LM-Error	1.387	0.039
		Robust LM-Error	0.014	0.015
	SAR	LM-Lag	1.517	0.018
		Robust LM-Lag	0.144	0.075
LR test	SEM VS SDM		13.28	0.021
	SAR VS SDM		13.42	0.019
Hausman test			-246.53	0.001

$$\begin{aligned} cg_{it} = {} & \beta_0 + \beta_1 cg_{i,t-1} + \rho_1 \sum_{i=1}^{n} w_{ij} \text{intel}_{jt} + \beta_2 \text{intel}_{it} \\ & + \rho_2 \sum_{i=1}^{n} \text{intel}_{ij} df_{jt} + \beta_3 eci_{it} + \rho_3 \sum_{i=1}^{n} w_{ij} eci_{jt} \\ & + \theta \sum_{i=1}^{n} x_{it} + \lambda \sum_{i=1}^{n} w_{ij} x_{jt} + \mu_i + \eta_t + \varepsilon_{it}, \end{aligned} \tag{4}$$

where cg_{it} (regional carbon intensity) is the explanatory variable; intel_{it} (Internet development) is the key explanatory variable; eci_{it} (collaborative innovation) is the mediating variable; and x_{it} is the control variable. β_0 is a constant term; β_1 represents the regression coefficient of carbon emissions lagged by one period $cg_{i,t-1}$; ρ is the spatial autoregressive coefficient of the core explanatory variable; μ_i represents the individual fixed effect; η_t represents the time fixed effect; ε_{it} is the residual term; and w_{ij} is the element used to describe the spatial weight matrix of geographical distance between regions.

(3) Selection of Spatial Weight Matrix. Considering the fit and operability of the research problem, this paper refers to the spatial measurement-based approach to study carbon emissions and then describe the spatial panel model with a geographic distance matrix, and the specific calculation method is as follows:

Geographical distance spatial weight matrix:

$$w_{ij} = \begin{cases} 1/d_{ij}^{\ 2}, & i \neq j, \\ 0. \end{cases} \tag{5}$$

d_{ij} is the geographic Euclidean distance between region i and the provincial capital city of region j.

(4) Intermediary Effect Model. Studying the reduction of regional carbon emission intensity by Internet development only at the macrolevel is not in-depth enough, and the mediating transmission mechanism for the reduction needs to be further explored. Based on the previous theoretical hypothesis that Internet development may have an impact on carbon emission intensity through collaborative innovation, this work adopts a typical mediating effect model and conducts further empirical studies based on spatial econometric techniques to verify the role played by collaborative innovation. The indirect effect of explanatory variables on the explanatory variables through intermediate variables is known as the mediating effect [34], and the more widely used method to test the mediating effect is the stepwise method proposed by Baron and Kenny [35].

According to the hypothesis, this paper uses carbon emission intensity (cg_{it}) as the explanatory variable Y, collaborative innovation (eci_{it}) as the mediating variable M to be tested, and Internet development (intel_{it}) as the explanatory variable X. The control variables of the mediating variable model include time lagged and spatial lagged terms of carbon emission intensity, spatial lagged terms of Internet development (intel_{it}) and collaborative innovation (eci_{it}), and other control variables. The specific mediating effect model is set as follows:

$$\begin{aligned} cg_{it} = {} & \alpha_0 + \alpha_1 cg_{i,t-1} + \pi_1 \sum_{i=1}^{n} w_{ij} cg_{jt} + \alpha_2 \text{intel}_{it} \\ & + \pi_2 \sum_{i=1}^{n} w_{ij} \text{intel}_{jt} + \varphi x_{it} + \pi_3 \sum_{i=1}^{n} w_{ij} x_{jt} + \mu_i + \eta_t + \varepsilon_{it}, \end{aligned} \tag{6}$$

$$\begin{aligned} M_{it} = {} & \eta_0 + \eta_1 M_{i,t-1} + \omega_1 \sum_{i=1}^{n} w_{ij} M_{jt} + \eta_2 \text{intel}_{it} \\ & + \omega_2 \sum_{i=1}^{n} w_{ij} \text{intel}_{jt} + \kappa x_{it} + \omega_3 \sum_{i=1}^{n} w_{ij} x_{jt} + \mu_i + \eta_t + \varepsilon_{it}. \end{aligned} \tag{7}$$

Table 3: Main variables Moran's I index.

Year	Internet development		Carbon emission	
	Moran's I	Z-value	Moran's I	Z-value
2011	0.229	2.855***	0.172	2.226**
2012	0.213	2.691***	0.171	2.211**
2013	0.170	2.224**	0.183	2.349***
2014	0.159	2.152**	0.178	2.288**
2015	0.147	2.017**	0.181	2.331**
2016	0.180	2.426***	0.171	2.211**
2017	0.171	2.305**	0.158	2.074**
2018	0.146	2.029**	0.149	1.976**

Note: ***, **, and * represent 1%, 5%, and 10% significance levels, respectively.

4. Research Results

4.1. Spatial Autocorrelation Test. Before conducting the empirical analysis, the spatial autocorrelation analysis of carbon emission intensity in the regions of the explanatory variables was first conducted. The method of Moran's I index was used to measure the spatial correlation between the level of Internet development and the carbon emission intensity, which was calculated by the formula

$$\text{Moran}'\text{s}\, I = \frac{\sum_{i=1}^{n}\sum_{j=1}^{n} W_{ij}\left(Y_i - \bar{Y}\right)\left(Y_j - \bar{Y}\right)}{S^2 \sum_{i=1}^{n}\sum_{j=1}^{n} W_{ij}}, \tag{8}$$

where Y_i represents the Internet development level and carbon emission intensity of the ith region, respectively; n is the total number of regions; and W_{ij} is the standardized geographical distance space weight matrix.

Table 3 shows the Moran's I indices of Internet development level and carbon emission intensity for 30 provinces in China from 2011 to 2018. As can be seen from the table, the Moran's I indices of regional Internet development levels are all around 0.2 and pass the test at different significance levels. The Moran's I indices of regional carbon emission intensity are all around 0.2 and pass the test at different levels of significance. The results show that there is a significant positive spatial correlation of carbon emissions in 30 Chinese provinces from 2011 to 2018, so the carbon emission intensity based on spatial analysis is reasonable, which lays an important foundation for the next empirical analysis.

4.2. Benchmark Regression Results. From the above analysis, it can be seen that there is a spatial correlation between Internet development and carbon emission. Despite China's rapid economic growth and increasing GDP, carbon emission intensity still shows a slow growth trend.

Meanwhile, Table 4 gives the results of benchmark regression tests. The coefficient of the key variable of this paper, Internet development index, is significantly negative; i.e., the higher the level of Internet development, the lower the carbon emission intensity, which indicates that Internet development is conducive to reducing carbon emission

Table 4: Benchmark regression result.

Variable	OLS M1	General panel M2	Static SDM M3	Dynamic SDM M4
L.lncg				0.5919***
				(12.24)
intel	-0.1068**	-0.0261*	-0.0074**	-0.0155**
	(-1.97)	(-1.66)	(-0.25)	(-0.55)
lngdp	1.1407***	0.2396**	0.4143***	0.0769*
	(4.05)	(2.34)	(2.93)	(0.61)
open	-0.2791	-0.1749*	-0.0723*	-0.0761*
	(-1.05)	(-1.91)	(-0.61)	(-0.79)
city	3.1234***	0.0008	0.1857	0.3212
	(3.62)	(0.00)	(0.34)	(0.70)
lne_c	0.5382***	0.9783***	0.9666***	0.4752***
	(4.19)	(9.07)	(8.68)	(4.52)
W∗intel			-0.0297	-0.0593*
			(-0.85)	(-0.84)
W∗lngdp			0.5176**	0.2646
			(2.43)	(1.01)
W∗open			0.3648**	0.1366
			(2.00)	(0.68)
W∗city			-0.7940	-0.8797
			(-0.97)	(-0.80)
W∗lne_c			-0.6259**	-0.2716*
			(-2.25)	(-0.85)
R^2	0.1192	0.0268	0.0317	0.8850
Obs	240	240	240	240

Note: ∗∗∗, ∗∗, and ∗ represent 1%, 5%, and 10% significance levels, respectively.

intensity. This also proves the correctness of Hypothesis 1. This paper argues that Internet development promotes carbon emission reduction in two main ways. First, it promotes the technological progress of green innovation. The development of the Internet directly reduces the cost of information search and realizes knowledge sharing. Besides, emerging green technologies are developed, disseminated, and applied more effectively through the Internet, which helps to enhance the progress of green innovation technologies. Secondly, it improves the efficiency of green innovation technology: in the R&D stage of green innovation results, innovation subjects rely on Internet technology to achieve efficient accumulation of innovation resources, thus reducing the waste of resources, enhancing the efficiency of using innovation resources, and further reducing carbon emissions. The negative W∗intel estimate at the 10% significance level indicates that there is a spillover effect of Internet development on the reduction of regional carbon intensity, and Internet development in the region has a positive effect on the reduction of carbon intensity in the surrounding regions.

For the control variables, (1) the direct effect of the level of economic development (lngdp) is significantly positive, and the spatial spillover effect is positive but not significant. The reason may be that the agglomeration effect generated by economic development makes the concentration of high-quality factors in economically developed areas obvious and leads to the loss of factors from neighboring areas, thus undermining environmental governance. (2) The coefficient of openness to the outside world (open) is generally negative overall and passes the significance test at the 10% level, indicating that the introduction of foreign investment can play a positive role in the improvement of environmental quality and carbon emission reduction in the host country through higher environmental protection standards and more advanced energy-saving and emission reduction technologies in the host country. (3) Urbanization (city) corresponds to a positive coefficient but does not pass the significance test, which may be due to the accelerated urbanization process, resulting in a gradual increase in urban population, which in turn increases urban carbon emissions. (4) The coefficient of energy consumption (lne_c) is positive and significant at the 1% level, indicating that the higher the per capita coal consumption, the higher the carbon emission intensity, which again verifies that the current "high carbon" energy consumption structure with an abnormally high proportion of coal in China is an important reason for the decrease in carbon emission intensity.

Table 5: Effect decomposition results of dynamic spatial Durbin model.

Variable	Short-term effects			Long-term effects		
	Direct effect	Indirect effect	Total effect	Direct effect	Indirect effect	Total effect
intel	-0.0163*	-0.0583*	-0.0746*	-0.0397*	-0.1540*	-0.1937*
	(-0.59)	(-0.81)	(-0.93)	(-0.57)	(-0.64)	(-0.73)

Note: ∗∗∗, ∗∗, and ∗ represent 1%, 5%, and 10% significance levels, respectively.

Model 4 shows that the lag first-order term CGI of carbon emission intensity and the regression coefficient of T-1 are positive and significant at the level of 1%. This shows that there is an obvious time lag in China's regional carbon emission, and the early carbon emission intensity has a significant impact on the current carbon emission intensity.

Since the estimated coefficients of the spatial Durbin model cannot accurately reflect the direct effect of coinnovation efficiency on carbon emission intensity, it is necessary to consider the effect of dynamic changes, and the spatial effect of the explanatory variables should be further decomposed into direct effect, indirect effect, and total effect. In this way, the trend situation of carbon emission intensity under different effects can be studied more in-depth. Meanwhile, the dynamic Durbin model has both short-term and long-term effects, and it is also decomposed into short-term and long-term effects. The specific estimation results are given in Table 5.

(1) Spatial direct effect: the estimated coefficient of the spatial direct effect of the level of Internet development (INTEL) is significantly negative; i.e., the increase in the level of Internet development helps promote the reduction of carbon emission intensity in the region. Moreover, the long-term spatial direct effect is larger than the short-term spatial direct effect, which is consistent with the cumulative effect in economics. Carbon emission reduction is a long-term and arduous task, and the formulation of a region's emission reduction measures is the current situation-based and its implementation can also take some time, meaning that the reduction of carbon emission intensity in the region does not fully benefit from the current policy. Therefore, the reduction work in the early period may also be reflected in the current period, so the long-term direct effect of carbon emission intensity is greater than the short-term direct effect

(2) Spatial indirect effect: whether it is a short-term effect or a long-term effect, the level of Internet development (intel) has a negative spillover effect on carbon emission intensity at a significant level of 10%, which is conducive to the reduction of carbon emission intensity, and the spatial spillover effect accounts for more than 80% of the total effect, indicating that the spatial spillover effect caused by factors such as the flow of resources and factors between regions plays an important role for neighboring regions

(3) Total effect: the estimated coefficients of Internet development level (intel) are all significantly negative, and the long-term effect is greater than the short-term effect; i.e., the deepening of Internet development can gradually increase the carbon emission reduction effect over time

4.3. Regional Heterogeneity. In order to further analyze the difference of the level of Internet development on carbon emissions in different regions, this paper divides the country into eastern, central, and western regions according to the national geographic region division criteria to study the spatial heterogeneity. As shown in Table 6, the direct, indirect, and total effects of Internet development on carbon emission intensity in the eastern region are significantly negative in both the short and long term. However, in the central region, the direct and indirect effects are not significant. In the western region, both the indirect and total effects are significantly positive during the short term, but not significant over the long term. This suggests that the western region consumes more energy in the short term at the level of domestic consumption as well as industrial development, thus exerting more pressure on carbon reduction efforts in the region and surrounding areas.

4.4. Robustness Test. First, replacing the explanatory variables, the logarithm of regional per capita carbon emissions (lncg_p) is used to remeasure the regional carbon emission intensity, and static spatial Durbin and dynamic spatial Durbin regressions are conducted on them. The results are shown in the first and second columns of Table 7. It can be seen that the data of each variable changes slightly, but the sign and significance of most of the variables do not change significantly, verifying the robustness of the results of this paper. Second, the results after replacing the spatial weight matrix and selecting the adjacency matrix for static spatial Durbin as well as dynamic spatial Durbin regression are shown in the third and fourth columns of Table 7. It can be seen that the data of each variable changes slightly, but the positive and negative signs and significance do not change significantly, which can further indicate that the results of this paper are robust.

4.5. Mediating Effect of the Collaborative Innovation on the Relationship between Internet Development and Carbon Emissions. The above empirical results indicate that Internet development helps to curb regional CO_2 emissions; however, the path through which Internet development affects the intensity of CO_2 emissions is the focus of this paper. Therefore, the effect of the mediating variable of collaborative

Table 6: Results of effect decomposition of dynamic spatial Durbin model in the eastern, central, and western regions.

Region	Short-term effects		Long-term effects			
	Direct effect	Indirect effect	Direct effect	Indirect effect	Direct effect	Indirect effect
Eastern	-0.0111*	-0.0844*	-0.0956*	-0.0187*	-0.2075*	-0.2262*
	(-0.40)	(-1.64)	(-1.42)	(-0.13)	(-0.27)	(-0.26)
Central	0.0209	-0.2331	-0.2122	0.0235	-0.2167	-0.1931
	(0.14)	(-0.37)	(-0.28)	(0.23)	(-0.57)	(-0.41)
Western	0.0348	0.2615**	0.2963***	-0.0819	0.4571	0.3752
	(0.55)	(3.36)	(3.45)	(-0.03)	(0.18)	(3.20)

Note: ∗∗∗, ∗∗, and ∗ represent 1%, 5%, and 10% significance levels, respectively.

Table 7: Robustness check.

Variable	Replace the explanatory variable		Replace the spatial weight matrix	
	Static SDM	Dynamic SDM	Static SDM	Dynamic SDM
L.lncg				0.5711***
				(8.67)
L.lncg_p		0.5546***		
		(11.40)		
intel	-0.0034**	-0.0144**	-0.0403**	-0.0695**
	(-0.12)	(-0.52)	(-1.25)	(-2.19)
lngdp	0.5417***	0.1003*	0.3664*	0.1158*
	(4.15)	(0.81)	(2.46)	(0.80)
open	-0.0087*	-0.0815*	-0.0421*	-0.3231*
	(-0.08)	(-0.85)	(-0.35)	(-2.65)
city	0.9071	0.1047	0.0105	0.3310
	(1.82)	(0.23)	(0.02)	(0.64)
lne_c	1.0241***	0.4612***	0.9001***	0.5760***
	(10.24)	(4.51)	(6.85)	(4.71)
W∗intel	-0.0356	-0.0650*	-0.0215	-0.1444*
	(-1.07)	(-0.94)	(-0.52)	(-1.73)
W∗lngdp	0.2717*	0.1019	0.7306*	0.3325
	(1.37)	(0.40)	(3.52)	(1.07)
W∗open	0.3682*	0.2116	0.3879*	0.2157
	(2.67)	(1.08)	(2.10)	(0.86)
W∗city	-0.9097	-1.3420	-1.6303	-0.0495
	(-1.17)	(-1.26)	(-1.84)	(-0.04)
W∗lne_c	-0.3642*	-0.3189*	-0.1124*	-0.0324*
	(-1.41)	(-1.02)	(-0.33)	(-0.08)
R^2	0.6326	0.8616	0.0492	0.8249
Obs	240	240	240	240

Note: ∗∗∗, ∗∗, and ∗ represent the significance levels of 1%, 5%, and 10%, respectively.

innovation on reducing carbon emission intensity will be analyzed below to further investigate the impact mechanism in depth. Model 1 in Table 8 is the baseline model without any mediating variable, and models 2~3 are the spatial dynamic Durbin models constructed to test the mediating variable and explore the mediating effect of collaborative innovation.

For the mediating variables collaborative innovation, (1) from the benchmark model 1, it can be seen that the level of Internet development in the region has a negative and significant effect on the regional carbon emission intensity. (2) In model 2, local Internet development has a significant positive effect on collaborative innovation, indicating that the increase in the level of Internet development helps

Table 8: Mediation effect test.

Variable	Benchmark model	M = eci	
	cg	eci	cg
L.lncg	0.5919***		0.6007***
	(12.24)		(11.80)
intel	-0.0155**	0.0179***	-0.0133**
	(-0.55)	(0.54)	(-0.47)
eci			-0.0068**
			(-0.12)
lngdp	0.0769*	0.3340**	0.0537*
	(0.61)	(2.36)	(0.40)
open	-0.0761*	0.0530	-0.0865**
	(-0.79)	(0.48)	(-0.89)
city	0.3212	0.8706*	0.3744
	(0.70)	(1.68)	(0.81)
lne_c	0.4752***	0.2132*	0.4856***
	(4.52)	(1.89)	(4.60)
W∗intel	-0.0593*	0.0408*	-0.0749**
	(-0.84)	(0.50)	(-1.02)
W∗eci			-0.1634*
			(-1.01)
W∗lngdp	0.2646	0.0196	0.2074
	(1.01)	(0.07)	(0.77)
W∗open	0.1366	0.1032	0.1480
	(0.68)	(0.46)	(0.74)
W∗city	-0.8797	1.5351	-1.1584
	(-0.80)	(1.22)	(-1.02)
W∗lne_c	-0.2716*	-0.4656*	-0.2655**
	(-0.85)	(-1.31)	(-0.82)
R^2	0.8850	0.2418	0.8575
Obs	240	240	240

Note: ∗∗∗, ∗∗, and ∗ represent 1%, 5%, and 10% significance levels, respectively.

to promote technological progress. Using the Internet as a medium accelerates the information communication and decision-making in the R&D process, thus facilitating the development of innovative technologies; in addition, at the stage of innovation transformation and application, Internet development reduces transaction costs, accelerates market transactions, and improves the efficiency of marketization of innovation results. (3) Model 3 adds collaborative innovation to model 1, and it can be found that the absolute value of the regression coefficient of digital finance in the region decreases from 0.0155 in model 1 to 0.0133 in model 3, and the coefficient is still significant. Then, it is clear from the judgment criterion of intermediary effect that collaborative innovation plays a certain intermediary effect in promoting regional carbon emission intensity by Internet development, which is consistent with Hypothesis 2. At present, the investment of funds and talents in industrial innovation in China is gradually increasing, which on the one hand helps to enhance the strength of low-carbon technological innovation of local enterprises and improve their comprehensive innovation level; on the other hand, it also helps to promote the development of regional low-carbon economy.

In summary, Internet development promotes regional collaborative innovation which is able to suppress CO_2 emissions. The ways by which regional collaborative innovation affects carbon emission efficiency include the following: first, the emission reduction cost is reduced. Regional synergy is mainly through the cooperation of enterprises, research institutes, and other innovation institutions to make up for their own shortcomings by bringing into play the advantages of their respective subjects. This process will effectively improve the technology level of enterprises and reduce production costs; therefore, the reduction of carbon emission reduction costs promotes a significant reduction of carbon emission intensity. Secondly, the technology scale effect is formed. Enterprises adopting collaborative innovation mode can engage in multidimensional interactions such as information exchange, knowledge transfer, and sharing to improve innovation capability and performance and stimulate subsequent innovation in related fields to form new technologies and production systems, ultimately reducing carbon emission intensity.

5. Conclusions and Implications

On the one hand, improve the strength of regional technological innovation and ensure the wide application of low-carbon and energy-saving technologies; on the other hand, we should promote exchanges and cooperation between different regions, strengthen technological exchanges, and promote the overall green development of the region through technological change and innovative development.

China currently has tremendous room for improvement in regional Internet development, so policymakers need to expand the scale and intensity of Internet investment, fasten the development process of the Internet and related derivative industries, and increase financial investment in basic information network technologies to make up for technical shortcomings. In addition, policymakers should pay attention to the innovation of emerging frontier technologies, build a new framework for Internet development using blockchain, big data, 5G, IPV6, and artificial intelligence, establish a new concept of Internet thinking, improve the application of the Internet by enterprises, and promote the progress of green technologies on the basis of ensuring a wider coverage of wireless networks.

In addition, more financial and policy supports for regional collaborative innovation development efforts are needed from local governments. This can be achieved by broadening investment and financing channels and improving capital utilization. A new pattern of regional collaborative innovation networks needs to be formed.

Finally, policies need to be tailored to local conditions and implemented in a targeted manner while promoting overall emission reduction in each region. Specifically, the differences in carbon emission reduction capacity among regions should be fully considered, and regions with higher levels of economic development and innovation strength

need to continue to promote vigorously, while regions with weaker economic strength and innovation need to draw on corresponding experiences and technologies to ensure that the development gap between regions can be continuously reduced. Under the influence of Internet technology development, the interaction effect of Internet technology development on carbon emission reduction in the eastern region is greater than that in the central and western regions, and the interaction effect of Internet technology development on carbon emission reduction is more obvious. There is a single threshold effect on the impact of technological progress on carbon emission intensity in the eastern and central and western regions. In areas where technological progress crosses the threshold, the inhibitory effect of technological progress on carbon intensity is more obvious.

Data Availability

The data underlying the results presented in the study are available within the manuscript.

Conflicts of Interest

There is no potential conflict of interest in our paper, and all authors have seen the manuscript and approved to submit to your journal. We confirm that the content of the manuscript has not been published or submitted for publication elsewhere.

References

[1] E. Loiseau, L. Saikku, R. Antikainen et al., "Green economy and related concepts: an overview," *Journal of Cleaner Production*, vol. 139, pp. 361–371, 2016.

[2] O. Bina, "The green economy and sustainable development: an uneasy balance?," *Environment and Planning C: Government and Policy*, vol. 31, no. 6, pp. 1023–1047, 2013.

[3] M. Zhonggen and Y. Lijiao, "Supply-side reform and the residents' consumption structure upgrade under the economic globalization background[J]," *Finance & Economics*, vol. 28, no. 3, pp. 069–080, 2017.

[4] S. Kirchner and E. Schüßler, "The organization of digital marketplaces: unmasking the role of internet platforms in the sharing economy[J]," *Organization Outside Organization*, vol. 10, no. 4, pp. 131–154, 2019.

[5] M. Ma, P. Wang, and C. H. Chu, "Data management for internet of things: challenges, approaches and opportunities," in *2013 IEEE International conference on green computing and communications and IEEE Internet of Things and IEEE cyber, physical and social computing*, pp. 1144–1151, Beijing, China, Aug. 2013.

[6] G. Negro, *Internet in China*, Palgrave Macmillan, 2017.

[7] Z. Acs and M. Sanders, "Endogenous growth theory and regional extensions[J]," *Handbook of Regional Science*, vol. 56, no. 9, pp. 615–634, 2021.

[8] F. Shrouf, J. Ordieres, and G. Miragliotta, "Smart factories in industry 4.0: a review of the concept and of energy management approached in production based on the internet of things paradigm," in *2014 IEEE international conference on industrial engineering and engineering management*, pp. 697–701, Selangor, Malaysia, Dec. 2014.

[9] B. H. Pei, "Towards factories of the future: migration of industrial legacy automation systems in the cloud computing and internet-of-things context," *Enterprise Information Systems*, vol. 14, no. 4, pp. 542–562, 2020.

[10] M. Browne, "Artificial intelligence data-driven internet of things systems, real-time process monitoring, and sustainable industrial value creation in smart networked factories," *Journal of Self-Governance and Management Economics*, vol. 9, no. 2, pp. 21–31, 2021.

[11] X. Gong, J. Zhang, H. Zhang, M. Cheng, F. Wang, and N. Yu, "Internet use encourages pro-environmental behavior: evidence from China," *Journal of Cleaner Production*, vol. 256, p. 120725, 2020.

[12] T. Bjerregaard, "Industry and academia in convergence: micro-institutional dimensions of R&D collaboration," *Technovation*, vol. 30, no. 2, pp. 100–108, 2010.

[13] M. S. Alam, N. Apergis, S. R. Paramati, and J. Fang, "The impacts of R&D; investment and stock markets on clean-energy consumption and CO2 emissions in OECD economies," *International Journal of Finance & Economics*, vol. 26, no. 4, pp. 4979–4992, 2021.

[14] M. Kangmei and Y. Fang, "The generation logic and cultivation path of individual innovation ability of talents since the reform and opening up – a text analysis based on the deeds of 100 reform pioneers," *Journal of Beijing Institute of Education*, vol. 33, no. 3, pp. 59–65, 2019.

[15] L. Wu and Z. Zhang, "Impact and threshold effect of Internet technology upgrade on forestry green total factor productivity: evidence from China," *Journal of Cleaner Production*, vol. 271, p. 122657, 2020.

[16] W. Fang, L. Tang, P. Cheng, and N. Ahmad, "Evolution decision, drivers and green innovation performance for collaborative innovation center of ecological building materials and environmental protection equipment in Jiangsu province of China," *International Journal of Environmental Research and Public Health*, vol. 15, no. 11, p. 2365, 2018.

[17] Y. Song, J. Zhang, Y. Song, X. Fan, Y. Zhu, and C. Zhang, "Can industry-university-research collaborative innovation efficiency reduce carbon emissions," *Technological Forecasting and Social Change*, vol. 157, article 120094, 2020.

[18] I. Bertschek, D. Cerquera, and G. J. Klein, "More bits - more bucks? Measuring the impact of broadband internet on firm performance," *Information Economics and Policy*, vol. 25, no. 3, pp. 190–203, 2013.

[19] C. Paunov and V. Rollo, "Has the Internet fostered inclusive innovation in the developing world?," *World Development*, vol. 78, pp. 587–609, 2016.

[20] K. Li, J. Qiu, and J. Wang, "Technology conglomeration, strategic alliances, and corporate innovation," *Management Science*, vol. 65, no. 11, pp. 5065–5090, 2019.

[21] M. Sawhney, G. Verona, and E. Prandelli, "Collaborating to create: the internet as a platform for customer engagement in product innovation," *Journal of Interactive Marketing*, vol. 19, no. 4, pp. 4–17, 2005.

[22] H. Meijers, "Does the internet generate economic growth, international trade, or both?," *International Economics and Economic Policy*, vol. 11, no. 1-2, pp. 137–163, 2014.

[23] M. Jiménez, J. A. Matus, and M. A. Martínez, "Economic growth as a function of human capital, internet and work," *Applied Economics*, vol. 46, no. 26, pp. 3202–3210, 2014.

[24] W. L. Tan, T. Menkhoff, and Y. W. Chay, "The effects of entrepreneurial growth orientation on organizational change and firm growth," *Small Enterprise Research*, vol. 15, no. 2, pp. 88–99, 2007.

[25] M. Čudanov, G. Savoiu, and O. Jaško, "Usage of technology enhanced learning tools and organizational change perception," *Computer Science and Information Systems*, vol. 9, no. 1, pp. 285–302, 2012.

[26] A. Hanelt, R. Bohnsack, D. Marz, and C. Antunes Marante, "A systematic review of the literature on digital transformation: insights and implications for strategy and organizational change," *Journal of Management Studies*, vol. 58, no. 5, pp. 1159–1197, 2021.

[27] Y. J. Zhang and Y. B. Da, "The decomposition of energy-related carbon emission and its decoupling with economic growth in China," *Renewable and Sustainable Energy Reviews*, vol. 41, pp. 1255–1266, 2015.

[28] Y. Zhang and S. Zhang, "The impacts of GDP, trade structure, exchange rate and FDI inflows on China's carbon emissions," *Energy Policy*, vol. 120, pp. 347–353, 2018.

[29] U. J. Wagner and C. D. Timmins, "Agglomeration effects in foreign direct investment and the pollution haven hypothesis," *Environmental and Resource Economics*, vol. 43, no. 2, pp. 231–256, 2009.

[30] B. Liddle, "Impact of population, age structure, and urbanization on carbon emissions/energy consumption: evidence from macro-level, cross-country analyses," *Population and Environment*, vol. 35, no. 3, pp. 286–304, 2014.

[31] G. Akhmat, K. Zaman, T. Shukui, D. Irfan, and M. M. Khan, "Does energy consumption contribute to environmental pollutants? Evidence from SAARC countries," *Environmental Science and Pollution Research International*, vol. 21, no. 9, pp. 5940–5951, 2014.

[32] M. E. H. Arouri, A. B. Youssef, H. M'henni, and C. Rault, "Energy consumption, economic growth and CO_2 emissions in Middle East and North African countries," *Energy Policy*, vol. 45, pp. 342–349, 2012.

[33] S. Shao, L. Yang, M. Yu, and M. Yu, "Estimation, characteristics, and determinants of energy-related industrial CO_2 emissions in Shanghai (China), 1994-2009," *Energy Policy*, vol. 39, no. 10, pp. 6476–6494, 2011.

[34] D. P. MacKinnon, J. L. Krull, and C. M. Lockwood, "Equivalence of the mediation, confounding and suppression effect," *Prevention Science*, vol. 1, no. 4, pp. 173–181, 2000.

[35] R. M. Baron and D. A. Kenny, "The moderator–mediator variable distinction in social psychological research: conceptual, strategic, and statistical considerations," *Journal of Personality and Social Psychology*, vol. 51, no. 6, pp. 1173–1182, 1986.