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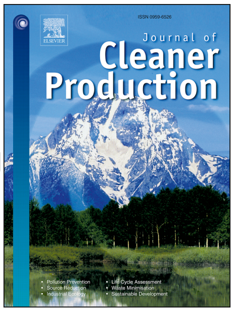

Temporal-Spatial Measurement and Prediction between Air Environment and Inbound Tourism: Case of China

Yuqing Geng, Rui Wang, Zejun Wei, Qinghua Zhai

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Credit Author Statement

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Temporal-Spatial Measurement and Prediction between Air Environment and Inbound Tourism: Case of China

Abstract: Air environment and inbound tourism has intricate interactions so that exploring the relationship of coupling coordination between them is contributory to discover the mutual interaction mechanism. The study firstly constructs a correlation model and an aggregated evaluation system to illustrate the interaction mechanism between these two factors; secondly evaluates the development degrees of both air environment and inbound tourism in China with the combined methods of information entropy weight and the technique for order preference by similarity to the ideal solution; thirdly analyzes the spatial-temporal differences of the coupling coordination situations between air environment and inbound tourism with the coupling coordination model; fourthly predicts the coupling coordination status of the regions in China with the gray prediction GM(1,1) model. The results show that the development degrees of air environment are more fluctuated than the ones of inbound tourism in China. The coupling coordination statuses are mildly fluctuating and the gaps among regions gradually narrow, while in the next four years the trend will be different: the spatial variations among regions will increase. The contributions include illustrating the interaction mechanism between the two subsystems theoretically, constructing the evaluation system and processing cross-regional spatial-temporal comparisons of the coupling coordination statuses, and predicting the trend of the coordination statuses, which helps to the proposal of more effective and efficient countermeasures.

Keywords: coupling coordination; air environment; inbound tourism; China

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1. Introduction

There are intricate correlations between air environment and inbound tourism; however, how these two subsystems interact and how they achieve coordinated development are not quite clear (Zhou et al., 2018; Lu et al., 2018; Qureshi et al., 2017). In previous academic literature, it has been researched that air environment plays an important role in affecting inbound tourism both positively and negatively: benign air environment is attractive for international tourists and encourages local authorities to enhance air quality in order to promote inbound tourism, whereas poor air environment causes inbound tourism related problems such as decreasing tourism willingness of international tourists, tourism destination images or reputations, inbound tourism revenue, etc. (Li et al., 2017; Zhou et al., 2019; Xu et al., 2020a; Awan et al., 2020; Khan et al., 2017; Barker et al., 2010) It also has been researched that inbound tourism affects air environment both positively and negatively. In specific, inbound tourism contributes to air environment enhancement if inbound tourism industry is well planned, while inbound tourism activities also increase the vulnerability of air environment by emitting more air pollutants, increasing difficulties in air governance, etc. (Pablo-Remero et al., 2019; Dong et al., 2019; Li and Weng, 2016; Guerranti et al, 2016) However, the actual gap, the interactive coupling coordination relationship between air environment and inbound tourism is not clear, exists; therefore, it is needed to explore the correlation coordination mechanism, and use effective systems and approaches to evaluate and predict the interactions between them so that the coordinated improvement of air environment and inbound tourism can be achieved.

In order to fulfil this research gap, by using the data of the 31 provincial regions in China for 15 years, this study aims to firstly theoretically explore the coordination mechanism to discuss the coupling coordination relationship of the two subsystems (air environment and inbound tourism); secondly empirically discover the evolution and distribution rules of development degrees (DD) of air environment and inbound tourism, and the coupling coordination degrees (CCD) with the

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coupling coordination evaluation system; thirdly predicts the trend of CCD for the next 4 years and proposes countermeasures according to the results.

In this study, air environment is the status where the air environment's structure and the function are stable; the air environment can support individuals' activities through air eco-services (Wang et al., 2013; Takii et al., 2004). Air environment reflects potential benefits and problems of eco-environment and inbound tourism activities. Meanwhile, inbound tourism is the term depicturing activities of travelling, living, and entertainments of an individual for a period in places outside of his or her nationality (Wu et al., 2019a; Araban et al., 2016). Inbound tourism relates to business such as tourism transportation, tourism agencies, tourism accommodation, etc. Air environment and inbound tourism are two different subsystems, whereas they share similarities – they share the same affecting elements such as transportation and carbon emissions – so that the interactions between these subsystems are complicated and the study on the interaction mechanism is significant (Bai et al., 2020).

1.1. Air Environment's Effect on Inbound Tourism

Air environment affects inbound tourism both positively and negatively. From the positive perspective, air environment provides abundant resources for inbound tourism activities. Firstly, as one of the tourism resources, benign air environment improves the positive image of tourism destinations, is attractive to international tourists and therefore enhances the competitiveness of inbound tourism (Li et al., 2016; Zhou et al., 2019; Deng et al., 2017; Min et al., 2017; Robaina-Alves et al., 2016). Secondly, the benign air environment requires less discharge of air pollutants, upgraded transportation facilities, use of low-carbon and renewable technologies, improved hospitality equipment, etc., which are beneficial to inbound tourism (Liu and Nijkamp, 2019; Xu and Reed, 2019). Thirdly, air environment related governance provides benefits to inbound tourism. In specific, taxes from air governance offers financial support to air pollution reduction, tourism destination renovation, and inbound tourism development (Mou et al., 2020; Geng et al., 2020a; Sato et al., 2019; Wang et al., 2019; Anser et al., 2020); education about air governance enhances awareness and determination for both local residents and international tourists to protect air environment during inbound tourism activities (Tiago et al., 2016; Awan et al., 2020).

From the negative perspective, air environment hinders the development of inbound tourism. Firstly, the improper or over use of air related resources in the inbound tourism activities negatively affects inbound tourism development; for instance, improper use of air resources leads to haze pollution, whose spillover effects negatively impact on the inbound tourism of surrounding regions (Xu et al., 2020a; Xu et al., 2020b; Qiao et al., 2019). Secondly, unsatisfactory air environment decreases the expectation and evaluation of inbound tourists so that the international images of the tourism sites are likely to decrease; it is researched that air environment is a main cause in inbound tourism, and places with poor air environment are examined less expected by international tourists (Awan at al., 2020; Chiu et al., 2014; Zhang et al., 2019). Thirdly, inbound tourists themselves can be affected by the deteriorating air environment and can generate negative behaviors such as dissatisfaction with the tourism sites, physical or psychological discomfort, getting air related illness, etc. (Xu and Reed, 2017; Xu et al., 2019; Awan at al., 2018) Current research has started to focus on the sustainable development of inbound tourism on the basis of air governance, such as low-carbon tourism, tourism competitiveness, etc. (Chi et al., 2019; Tang, 2018); however, it is still less clear how air environment interactively affects inbound tourism with coordination.

1.2. Inbound Tourism's Effect on Air Environment

Inbound tourism, affected by air environment, in turn affects air environment both positively and negatively. From the positive perspective, inbound tourism contributes to the upgrade of infrastructure, improvement of urban or community functions, and optimization of industrial structures, which are beneficial to air environment (Liu et al., 2019; Saenz-de-Miera and Rosselló, 2014; Malik et al., 2016; Guizi, 2019). Cases in certain areas have proved that inbound tourism is playing a role in enhancing air environment (Tang, 2015; Kumar et al., 2020). Besides, inbound

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tourism business accelerates the improvement of air environment mainly because inbound tourists are more sensitive to air environment than domestic tourists; increasing numbers of critical inbound tourists help local authorities to improve air environment so that the tourism destinations can receive better praises and recommendations (Qiu and Qi, 2020; Gu et al., 2019; Xu at al., 2019; Chiu et al., 2014). Furthermore, some well-organized inbound tourism activities use air environment friendly transportations and accommodations, and arrange visits to exhibition halls or museums, which directly reduce the discharge of carbon emissions and provides opportunities to learn knowledge of air environment protection, which contributes to better air environment. It is researched that these activities are more obvious in developed countries (Worobiec et al., 2008; McCartney and Leong, 2018; Drummond, 2018).

From the negative perspective, inbound tourism causes serious problems in air environment. Firstly, inbound tourism activities, especially environment-polluting tourism activities such as car racing and fireworks, increase carbon emission and aggravate air environment pollution. Inbound tourism related transportations and accommodations increase traditional energy consumption so that there is more pressure in air environment (Qureshi et al., 2017; Yan et al., 2019; Yuan et al., 2014). Secondly, the educational background, personal values, attitudes or ethics towards air environment protection vary for different inbound tourists; the egoism attitudes or ethics of some international tourists, believing that "air environment of the host country is none of my business", determine their further actions and hinder better air environment protection (Wu et al., 2019b; Pan et al., 2017). Current research has focused on inbound tourism's effects on air environment, but how inbound tourism achieve coordinated effects on air environment is not quite clear, which needs more in-depth research.

1.3. Interaction between Air Environment & Inbound Tourism

The interactions of the two subsystems are intricate: they support and hinder each other with time. Coupling coordination refers to the status where subsystems interact and have effects on each other (Liu et al., 2018; Sofowote et al., 2010), and it is proper to analyze the interactions between the subsystems of air environment and inbound tourism. Coupling coordination reflects how the subsystems interact each other and how the system evolves from disorder to harmony (Ding et al., 2015). Coupling coordination has been applied to evaluate the coordination relationship among the systems of environment and tourism in certain regions, and the research results have shown that coupling coordination is important to reveal the interactive mechanisms between eco-environment and tourism (Wang et al., 2011; Shaheen et al., 2019; Gal et al., 2010); however, there are not many studies regarding the coupling coordination relationship between air environment and inbound tourism in the background of regional comparisons both temporally and spatially.

The study of the coupling coordination relationship between air environment and inbound tourism is important because such study will help us understand the interactive mechanism of the two subsystems and thus take specific corresponding countermeasures to stimulate the development of the subsystems; however, it is difficult to evaluate such coupling coordination relationship mainly because the coordination mechanism structure between the two subsystems has not been constructed yet, and there are few proper and consensual evaluation indicators currently to dynamically and precisely measure this coordination relationship. What is more, though beneficial and instructive to this study, former research mainly focuses on the coupling coordination relationship between ecological environment and tourism industry, and focuses on individual regions while ignoring regional comparisons, while regional comparisons temporally and spatially will be more meaningful in exploring the coupling coordination relationship between air environment and inbound tourism. So, more detailed study in the coupling coordination relationship between air environment and inbound tourism in different regions is quite necessary, which is also the purpose of this study.

2. Methods

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2.1. Evaluation Model and Evaluation System

In the air environment-inbound tourism system, the two subsystems, namely air environment subsystem and inbound tourism subsystem, have intricate interactions. Effective air governance brings benign air environment status and decreases environmental pressure from air pollution, which supports inbound tourism attractiveness, performance and scale; whereas pressure from air pollutant emissions and poor air conditions restricts the performances and scales of the tourism destinations; on the other hand, incomes from benign inbound tourism activities contribute to monetary devotion into air environment protection and governance, and the increasing scale of inbound tourism industry requires efficient use of air environment resources and enhanced state of air environment, whereas inbound tourism activities increases the burden of air governance and threat the outcome or state of air environment governance. The air environment-inbound tourism system is therefore a system with coupling coordination relationship which is significant to measure the interactive mechanisms between the air environment subsystem and the inbound tourism subsystem. Based on this, a correlation model is constructed to measure the CCD of the air environment-inbound tourism system (Figure 1).

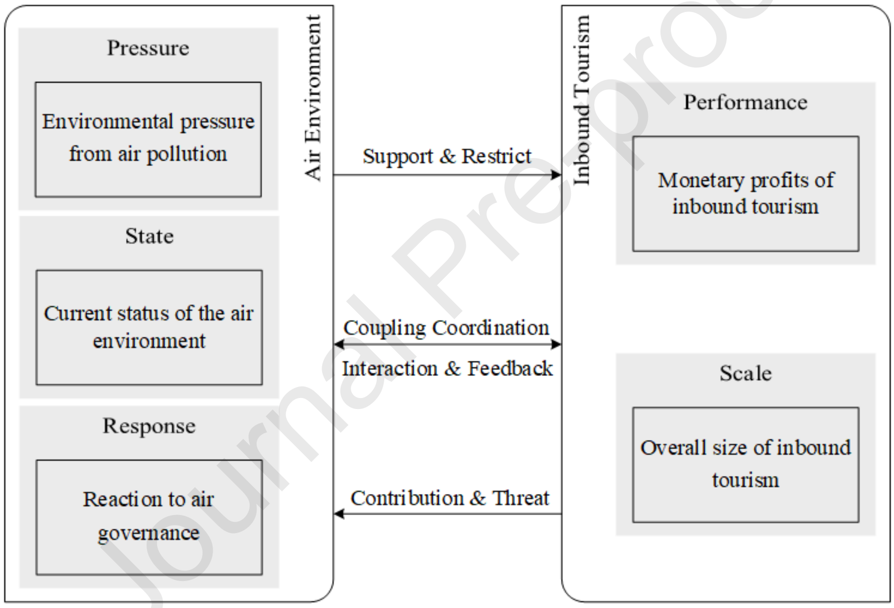

Figure 1. Correlation Model of Air Environment-Inbound Tourism System.

Then an evaluation system based on the correlation model is constructed. The selection of the evaluation indicators in this system follows several principles (Guo et al., 2018; Pasquini and Pozzi, 2005; Geng and Zhao, 2020; Geng and Zhang, 2020). First, the indicators should reflect the national strategy and policies; second, the indicators should reflect the key components of air environment and inbound tourism; third, the indicators should be widely accepted and have been cited; fourth, the indicators should be simple and logically clear; fifth, the multicollinearity of the indicators should be eliminated; sixth, the data of the indicators can be obtained. After qualitative analysis and the tests of correlation coefficients and significance, 15 indicators (9 for air environment subsystem and 6 for inbound tourism subsystem) are determined, and thus the air environment-inbound tourism evaluation system is finally constructed which is applicable to measure the coupling coordination relationship between air environment and inbound tourism (Table 1).

Table 1. Evaluation System.

Subsystem	Dimension	Indicator	Interpretation
Air Environment	Pressure	Pollutant emission in smoke & dust	Environmental pressure in smoke and dust
		Pollutant emission in	Environmental pressure in nitrogen oxides

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		nitrogen oxides	
		Pollutant emission in Sulphur dioxide	Environmental pressure in Sulphur dioxide
	State	Days of air quality no lower than Grade 2	Current status of air environment in general
		Annual concentration of PM_{10}	Current status of air environment in PM_{10}
		Annual concentration of NO_2	Current status of air environment in NO_2
		Annual concentration of SO_2	Current status of air environment in SO_2
	Response	Investment in waste gas treatment projects	Response quality to air governance
		Proportion of air treatment investment in GDP	Response efficiency to air governance
Tourism	Performance	Revenue from inbound tourism	Monetary performance quality in inbound tourism
		Proportion of inbound tourism in GDP	Monetary performance efficiency in inbound tourism
	Scale	Number of inbound tourists	Scale of inbound tourists
		Number of hotels	Scale of inbound tourism accommodation
		Number of travel agencies	Scale of inbound tourism service
		Number of employees in this industry	Scale of inbound tourism service participants

The subsystem of air environment is consisted of 3 dimensions: pressure, state, and response, which come from the pressure-state-response model which has been widely used to evaluate the effects of environment (Geng et al., 2020a). Pressure dimension is consisted of 3 indicators: pollutant emissions in smoke & dust, nitrogen oxides, and Sulphur dioxide; this dimension reflects the environmental pressure from air pollution, and these three indicators are chosen because these pollutants are representative in emission pressure (Geng and Tan, 2020; Wang et al., 2012). State dimension is consisted of 4 indicators: days of air quality no lower than Grade 2, and annual average concentration of PM_{10}, NO_2, and SO_2; this dimension reflects the current status of the air environment, and these indicators are chosen because they correspond to the indicators in the pressure dimension (Geng et al., 2020a; Geng and Tan, 2020). Response dimension is consisted of 2 indicators: investment in waste gas treatment projects, and proportion of air treatment investment in GDP; this dimension reflects the reaction to air governance quantitatively and qualitatively, and has been accepted widely to represent the response dimension (Geng et al., 2020a; Geng and Tan, 2020; Wang et al., 2012). The subsystem of inbound tourism is consisted of 2 dimensions: performance and scale (Chi et al., 2019). Performance dimension is consisted of 2 indicators: revenue from inbound tourism, and the proportion of inbound tourism in GDP; this dimension illustrates the monetary profits of inbound tourism from the quantitative and qualitative perspectives; such choice has been accepted in measuring tourism performance (Kumar et al., 2020; Geng et al., 2020b). Scale dimension is consisted of 4 indicators: numbers of inbound tourists, hotels, travel agencies, and employees in the industry; this dimension illustrates the overall size of the inbound tourism, and the indicators also well represent this dimension (Deng et al., 2017; Tang, 2015).

2.2. Methods Selection

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Generally, there are two types to evaluate the temporal and spatial coupling coordination mechanism: the subjective approaches and the objective approaches. The subjective ones include Delphi approach, analytic hierarchy process approach, etc. These approaches determine the weights of indicators via personal experiences and judgements; therefore, the weights are likely to be subjective, leading to biased coordination results (Geng and Zhao, 2020; Tan and Geng, 2020). The objective ones include cluster analysis approach, information entropy weight approach (IEW), gray correlation approach, principle component approach, technique for order preference by similarity to an ideal solution approach (TOPSIS), etc. These objective ones measure the weights of indicators via data calculation; therefore, the weights are more objective and less biased, making the results more convincing. However, there are some disadvantages for the objective approaches, for instance, gray correlation approach and cluster analysis approach are considered valid to enhance the preciseness of the results only after they are jointly used with other approaches; principle component approach is relatively easy to miss some important indicators and distort the analysis results when classifying indicators (Geng and Tan, 2020; Wang et al., 2012).

The joint use of IEW and TOPSIS is more appropriate in measuring the weights of indicators and coordination mechanism with limited data size (Wang et al., 2019; Chung et al., 2017). IEW is useful in measuring the status uncertainty of the system via objective data, and higher IEW means higher balance of the system and less variations of indicators; thus, the weights of indicators can be objectively calculated by IEW. What is more, TOPSIS is useful in ranking the alternatives within the indicator sets; this approach uses data and objectively calculates the distance between the ideal solution and the calculated alternative, and reflects the relative importance of the alternatives within the indicator sets. There are some highlights of the joint use of IEW and TOPSIS in this study: first, the combined use of IEW-TOPSIS is new in analyzing the coordination mechanism between air environment and inbound tourism, though in fact it has been applied in former studies in other fields; second, this approach guarantees objectivity and preciseness of the results and avoids personal preferences with limited data size (Geng et al., 2020b).

2.3. Study Area

China is consisted of 34 provincial regions, and in this study 31 regions are selected as research cases (Taiwan, Hong Kong and Macau are excluded due to the statistical differences). China as the case is representative: the air environment varies spatially, e.g. there is more hazy weather in the northern regions than the southern ones; besides, the inbound tourism resources and development are apparently variant across the regions, e.g. the region with the most inbound visits (Guangdong) was approximately 560 times as many as the region with the least inbound visits (Ningxia). The differences of air environment and inbound tourism among the regions in China are so obvious that such regional differences have causes problems in air governance and inbound tourism development with coordination. Therefore, the 31 regions in China as research cases are meaningful and representative to compare temporal and spatial differences in air environment and inbound tourism, to accelerate air governance and inbound tourism development, and to act as examples and references to explore the coupling coordination relationship in other countries.

3. Calculation

3.1. Data Processing

Related data are from China Statistical Yearbook on Environment, China Statistical Yearbook and the Yearbook of China Tourism Statistics (2009-2018); data in some indicators are calculated. The data are all collected by the National Bureau of Statistics of China; thus, they share high quality and guarantee the reliability and objectivity of the results. Besides, the data are collected for continuously 15 years, the size of which is reliable for analysis.

3.2. DD Calculation

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(1) Standardize data to enhance indicator comparability. x_{ij} is the matrix X where i is the alternative under the indicator j of all the years. Formula (1) is used when the indicator is positive and formula (2) is used when the indicator is negative. Here $i = 1, 2, \ldots, \mathrm{m}$; $j = 1, 2, \ldots, \mathrm{n}$.

$$x'_{ij} = \frac{x_{ij}}{\sum_{i=1}^{n} x_{ij}} \tag{1}$$

$$x'_{ij} = 1 - \frac{x_{ij}}{\sum_{i=1}^{n} x_{ij}} \tag{2}$$

$x' = \left(x'_{ij}\right)_{m\times n}$ is the standardized matrix; $\max_{1\le j\le n} x_{ij}$ and $\min_{1\le j\le n} x_{ij}$ are the maximum and the minimum values of indicator j of all the years.

(2) Use IEW to calculate weights of indicators. Calculate $\ln f_{ij}$ to guarantee the significance.

$$f_{ij} = \frac{1 + x'_{ij}}{\sum_{i=1}^{m}\left(1 + X'_{ij}\right)} \tag{3}$$

(3) Calculate information entropy depending on $x' = \left(x'_{ij}\right)_{m\times n}$.

$$IE_j = -\left(\sum_{i=1}^{m} f_{ij} \ln fij\right), \tag{4}$$

(4) Calculate the weight w_j.

$$w_j = \frac{1 - IE_j}{n - \sum_{j=1}^{n} IE_j} \tag{5}$$

(5) Use TOPSIS to calculate DD. Calculate the positive ideal solution with Formula 7 and the negative ideal solution with Formula 8.

$$X^{+} = \left(\max_{1\le i\le m} x_{i1}, \max_{1\le i\le m} x_{i2}, \ldots, \max_{1\le i\le m} x_{in}\right) \tag{6}$$

$$X^{-} = \left(\min_{1\le i\le m} x_{i1}, \min_{1\le i\le m} x_{i2}, \ldots, \min_{1\le i\le m} x_{in}\right) \tag{7}$$

(6) Calculate the separation degree from X^{+} to X^{-} of alternatives. SDM is the most preferred alternative, and SDL X- is the least preferred alternative.

$$SDM = \sqrt{\sum_{j=1}^{n} w_j\left(x_{ij} - X_j^{+}\right)^2} \quad 8)$$

$$SDL = \sqrt{\sum_{j=1}^{n} w_j\left(x_{ij} - X_j^{-}\right)^2} \quad 9)$$

(7) Calculate DD_i, the relative closeness to the ideal solution of alternative i.

$$DD_i = \frac{SDL}{\mathrm{SDM} + \mathrm{SDL}} \quad 10)$$

(8) Construct DD's classification grade. The evaluation grade is divided into 5 grades according to the principle of interval equalization (Table 2). The 5 grades are poor (0-0.2), ordinary (0.2-0.4), fair (0.4-0.6), good (0.6-0.8), and perfect (0.8-1.0). These 5 grades objectively illustrate the DD status of the subsystems.

Table 2. DD Classification Grade.

Value	**DD ≥ 0.8**	**0.6 ≤ DD ＜ 0.8**	**0.4 ≤ DD ＜ 0.6**	**0.2 ≤ DD ＜ 0.4**	**DD ＜ 0.2**
Grade	Excellent	Good	Fair	Ordinary	Poor

3.3. CCD Calculation

CCD demonstrates the subsystems' interactive mechanism and motional relationships. The calculation procedures are as follows.

(1) Calculate CD, the system's coupling degree, where DD(a) is the DD of air environment subsystem and DD(t) is the DD of inbound tourism subsystem.

$$\mathrm{CD} = \left\{ \frac{\mathrm{DD}(a) \times \mathrm{DD}(\mathrm{t})}{\left(\frac{\mathrm{DD}(a) + \mathrm{DD}(t)}{2}\right)^2} \right\}^{\frac{1}{2}}$$ 11)

(2) Calculate EI, the system's evaluation index, where the coefficients φ = τ = 0.5 because of the equal importance of two subsystems in the interactive mechanism (Geng et al., 2020a; Geng and Tan, 2020).

$$EI = \varphi\mathrm{DD}(a) + \tau\mathrm{DD}(\mathrm{t}) \quad (12)$$

(3) Calculate CCD of the system.

$$\mathrm{CCD} = \sqrt{\mathrm{CD} \times \mathrm{EI}}$$ 13)

(4) Construct CCD's classification grade, which is divided into 10 grades according to the principle of interval equalization (Table 3).

Table 3. CCD Classification Grade.

Range	Value	Classification
Coordinated	1 ≥ CCD ≥ 0.9	Highly coordinated
	0.9 ＞ CCD ≥ 0.8	Favorably coordinated
	0.8 ＞ CCD ≥ 0.7	Moderately coordinated
	0.7 ＞ CCD ≥ 0.6	Slightly coordinated
Transitional coordinated	0.6 ＞ CCD ≥ 0.5	Approaching coordinated
	0.5 ＞ CCD ≥ 0.4	Approaching uncoordinated
Uncoordinated	0.4 ＞ CCD ≥ 0.3	Slightly uncoordinated
	0.3 ＞ CCD ≥ 0.2	Moderately uncoordinated
	0.2 ＞ CCD ≥ 0.1	Seriously uncoordinated
	0.1 ＞ CCD ≥ 0	Highly uncoordinated

3.4. CCD Prediction

The gray prediction GM (1,1) model is used to predict the CCD tendency of the air environment-inbound tourism system. GM (1,1) is valid to make relatively precise predictions especially when there are limited sample sizes and relatively unsure situations of the system (Wang et al., 2018); therefore, GM (1,1) model is useful in this study where the data sizes are relatively limited (15 years of data). The calculation procedures of CCD predictions are as follows.

(1) For the time series $X_0 = \{x_0(1), x_0(2), \cdots x_0(n)\}$, there are n observations; generate the sequence $X_1 = \{x_1(1), x_1(2), \cdots x_1(n)\}$ with the accumulation of the original sequence $x_1(t) = \sum_{i=1}^{t} x_0(i)$; calculate differential equation with Formula 14, where μ is endogenous control gray value, and α is development gray value.

$$\mu = \frac{dx_1(t)}{dt} + \alpha x_1(t) \quad (14)$$

(2) Calculate $\hat{a} = (B^T B)^{-1} B^T Y$ with the least square method, where $\hat{a} = \binom{\alpha}{\mu}$ is the estimated parameter vector, $B = [-Z_1(2), -Z_1(3), \cdots, -Z_1(n), 1,1, \cdots 1]^T$, and $Y = [x_0(2), \cdots, x_0(n)]^T$. Solve the differential equation and construct the sequence prediction model. The data are applicable to predict the medium-term and long-term tendency if $a \leq 0.3$; the data are applicable to predict the short-term tendency if $0.3 < a \leq 0.5$. α is the most applied one to determine the accuracy of the model (Geng et al., 2020b; Wang et al., 2018).

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$$\hat{x}(t+1) = \left[x_0(1) - \frac{\mu}{\alpha}\right] e^{-\alpha t} + \frac{\mu}{\alpha} (t = 1,2,\cdots,n) \quad (15)$$

(3) Process the posterior error test and the residual error test to determine the prediction's accuracy with the following equations. Calculate $\varepsilon_0(t)$, the residual difference, with Formula 16; calculate $q(t)$, the relative error value of x_0, with Formula 17.

$$\varepsilon_0(t) = x_0(t) - \hat{x}_0(t) \quad (16)$$

$$q(t) = \frac{\varepsilon_0(t)}{x_0(t)} \times 100\% \quad (17)$$

$\bar{\varepsilon}_0 = \frac{1}{n-1}\sum_{t=2}^{n} \varepsilon_0(t)$ is the mean of $\varepsilon_0(t)$; $S_\varepsilon^2 = \frac{1}{n-1}\sum_{t=2}^{n}(\varepsilon_0(t) - \bar{\varepsilon}_0)^2$ is the variance of $\varepsilon_0(t)$; $\bar{x}_0 = \frac{1}{n-1}\sum_{t=2}^{n} x_0(t)$ is the mean of $x_0(t)$; $S_x^2 = \frac{1}{n-1}\sum_{t=2}^{n}(x_0(t) - \bar{x}_0)^2$ is the variance of $x_0(t)$. Calculate the small error probability $P = p(|\varepsilon_0(t) - \bar{\varepsilon}_0| < 0.6745 S_x)$. The accuracy determination grades are listed in Table 4.

Table 4. Accuracy Determination Grades.

Accuracy	*r*	*P*
Unaccepted	＜ 0.60	＜ 0.60
Accepted	≥ 0.60	≥ 0.60
Moderate	≥ 0.70	≥ 0.70
Favorable	≥ 0.80	≥ 0.80
Excellent	≥ 0.90	≥ 0.95

4. Results and Discussions

4.1. Temporal and Spatial Analysis of DD

The DD of air environment subsystem is shown in Table A.1, A.2 and Figure 2. The temporal fluctuations of air environment DD are generally large over time, and the 31 regions are categorized into two grades according to the average value of DD and the classification grades in Table 2. The first grade is "Ordinary" (0.2-0.4), in which most regions (22 of the 31 regions) fall, which proves the ordinary performances in air governance for these regions. Besides, there are obvious declines for certain regions: for instance, Qinghai witnessed two grades of declining. The second grade is "Fair" (0.4-0.6), which contains only a few regions (9 regions), and which proves relative better performances in air environment than other regions. The fluctuations are relatively large in this grade: for example, Shanxi fluctuated among 3 grades. The results that DDs of air environment in most regions of China are apparently fluctuating and declining contradict former literature and common sense (Xu et al., 2020c); in fact, the fluctuations depend on the financial investments in air governance, and the large fluctuations of investments every individual year increase the variations of DD; besides, the devotion of air governance in previous years can make continuous effects so that the decreasing investments in later years are possible, making DD decline.

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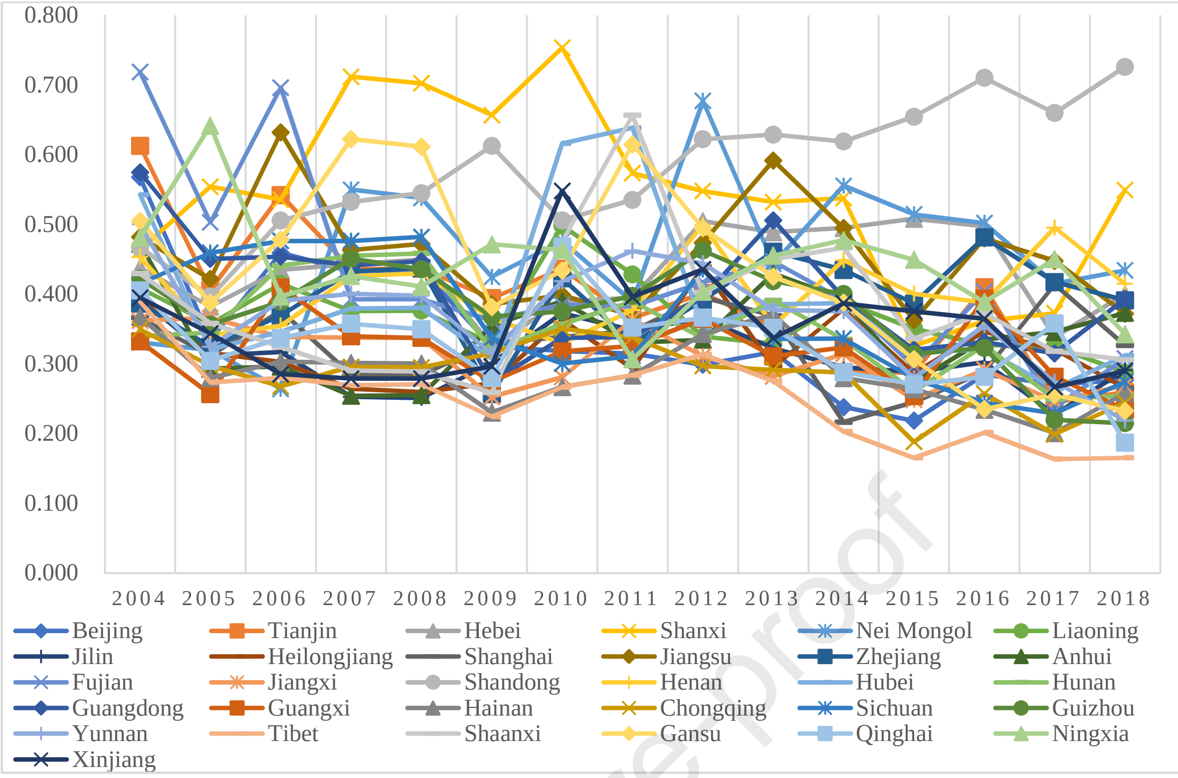

Figure 2. DD of Air Environment.

The DD of inbound tourism subsystem is shown in Table A.3, A.4 and Figure 3. Overall speaking, the grades of DD of inbound tourism are lower than those of air environment, and the temporal fluctuations of the inbound tourism DD are milder than the fluctuations of the air environment DD. The DD can be divided into four grades. The first one is "Excellent" (0.8-1.0), which includes Guangdong only. The inbound tourism development of Guangdong is obviously higher than other regions mainly because of its geographical advantage: it is geographically close to Hong Kong and Macau, the main sources of inbound tourists. The second grade is "Fair" (0.4-0.6), which includes Shanghai and Beijing. As two of the global megacities, Shanghai and Beijing attract inbound tourists all year round and perform fairly in inbound tourism. The third grade is "Ordinary" (0.2-0.4), including 15 regions which are nearly half of the total 31 regions. Among them, several regions encounter fluctuated declines such as Jiangsu (from Fair to Ordinary), while certain ones gradually and mildly increase such as Anhui and Chongqing (from Poor to Ordinary). The fourth grade is "Poor" (0-0.2), accounting for 13 regions, which illustrates the relatively poor performances in inbound tourism. The fluctuations of inbound tourism DD are milder and gentler than air environment DD, mainly because there are more other factors such as bi-lateral national relations, national political systems, etc. to jointly affect inbound tourism and make the DD mildly fluctuate (Farzanegan et al., 2020; Hanon and Wang, 2020).

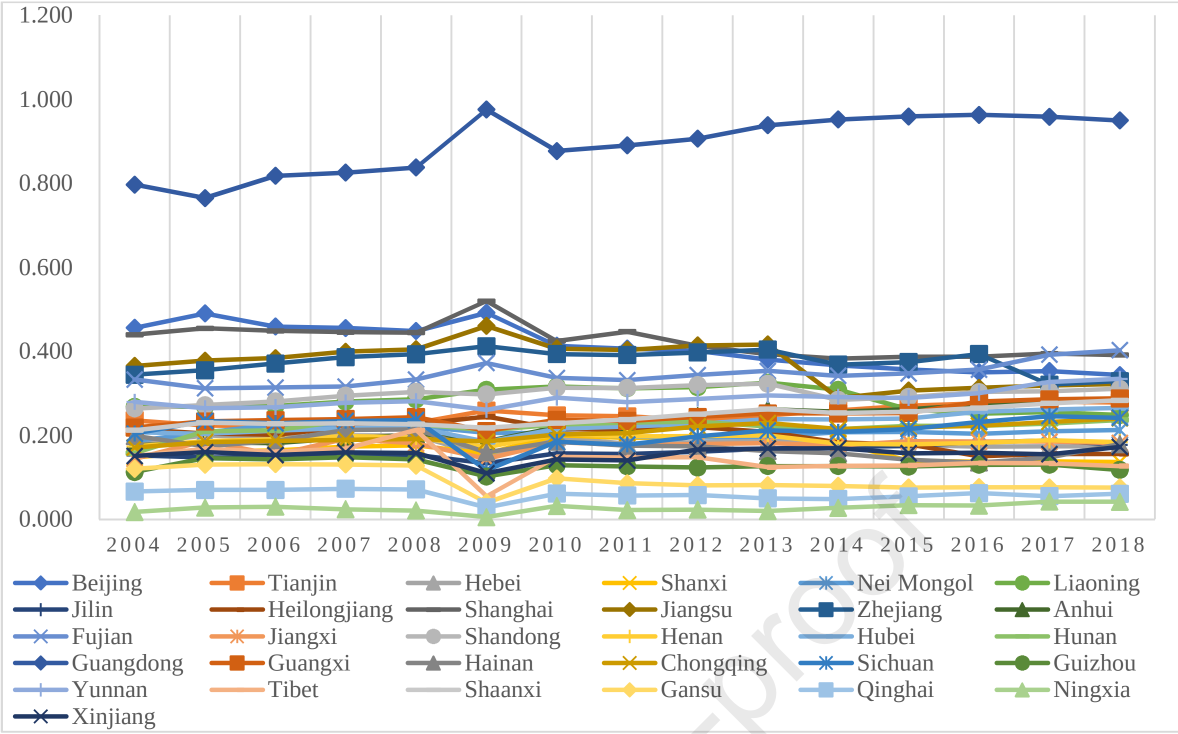

Figure 3. DD of Inbound Tourism.

Figure 4 shows the spatial distributions of the average DD in air environment and inbound tourism subsystems respectively. In general, there are obvious differences for the spatial distributions of the two subsystems' DD. For air environment subsystem, the northern parts have higher grades in DD than the other regions. Though relatively week in air quality, these regions have devoted much efforts and investment in air governance these years so that the DDs of air environment are higher. This result is consistent with our subjective feelings and former literature: there are decreasing air environment related issues in northern regions these years (Liu et al., 2020). For the inbound tourism subsystem, the spatial distributions of DD show two features: (1) the southern parts are relatively higher in DD; (2) the costal parts are relatively higher in DD. Southern regions enjoy abundant tourism resources and pleasant climate so that the inbound tourism development is relatively better. On the contrary, northern regions such as Henan, Shanxi, Hebei, Heilongjiang and Jilin are weak in tourism related facilities and resources so that the DDs are much lower. What is more, coastal regions are higher in DD mainly because of the geographical advantages, convenient transportation, scientific destination management and planning, etc., whereas regions in the inland are lower in DD mainly because of the drawbacks of the tourism related transportation, resources, facilities, management, etc. (Huang et al., 2020)

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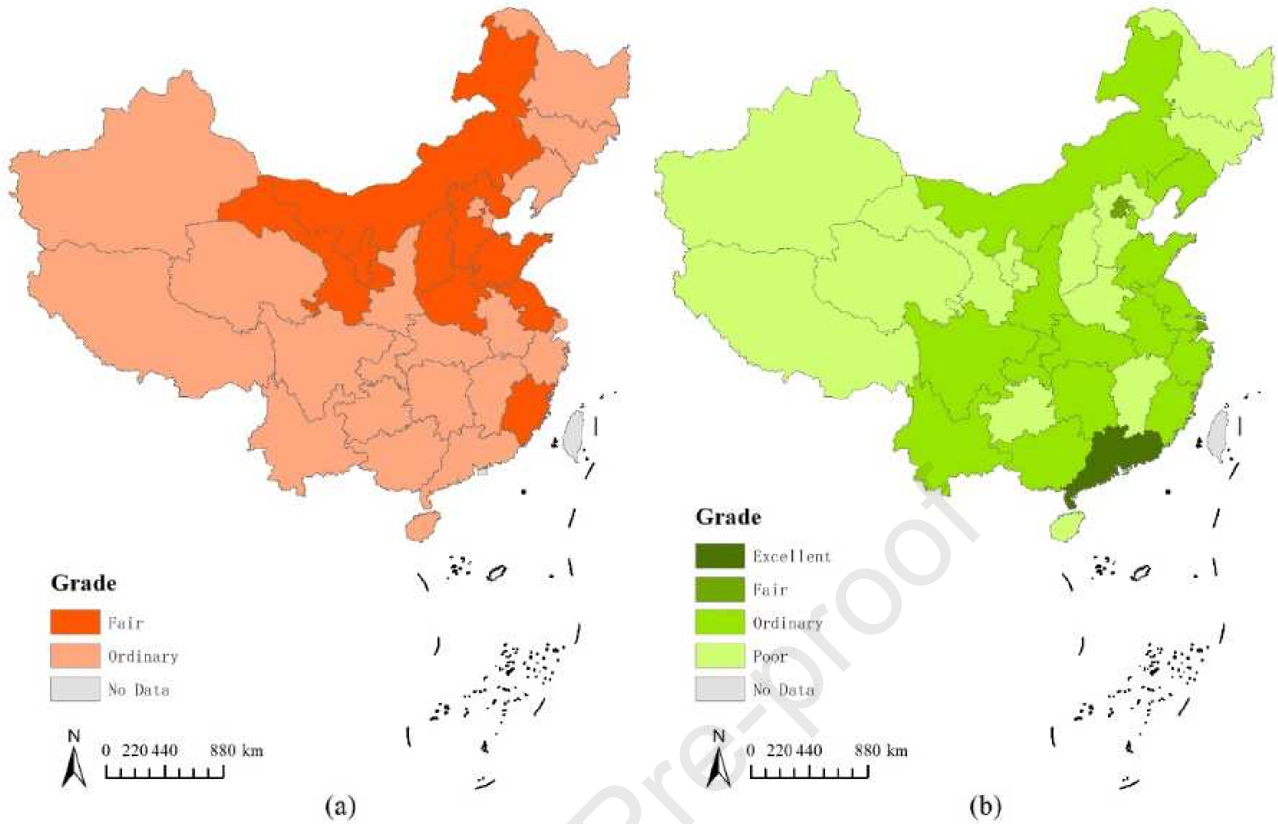

Figure 4. Spatial Distributions of DD. (**a**) Air Environment Subsystem; (**b**) Inbound Tourism Subsystem.

4.2. Temporal and Spatial Analysis of CCD

The temporal fluctuation of the air environment-inbound tourism system's CCD is shown in Table A.5, A.6 and Figure 5. It is found that the CCDs of most regions remain mild fluctuating at the transitional coordination range (0.4-0.6) these years, proving that the coupling coordination of the air environment-inbound tourism system was in the transitioning period. There are some exceptions: Guangdong kept the highest CDD (above 0.7), proving that the two subsystems develop with coordination; limited regions (e.g. Qinghai and Ningxia) remained low CCDs (below 0.4) in the incoordination range; Beijing witnessed obvious decline from the moderate coordinated status (0.6-0.7) to approaching coordinated status (0.5-0.6), meaning that the potential of CCD was getting worse and effective countermeasures should be taken. The temporal tendency of CCD, which is mild fluctuation, is supported by similar literature which finds that the coupling coordination development between tourism and eco-environment among different regions fluctuates with time sequence (Geng et al., 2020b).

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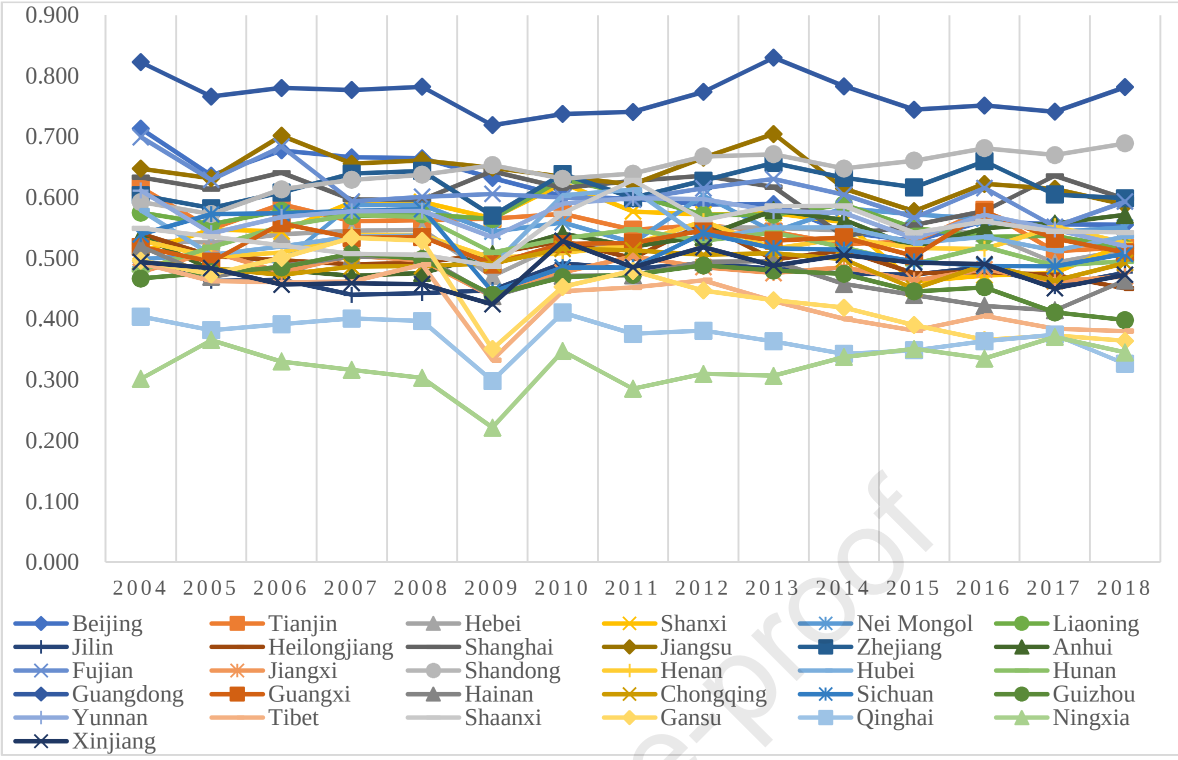

Figure 5. Temporal Fluctuation of CCD.

Figure 6 shows the spatial variations of CCD from 2004 to 2018. There are two findings regarding the spatial variations of CCD. The first finding is that the coastal regions have higher CCD while regions in the northwest have relatively lower CCD. Specifically, eastern and southern coastal regions (Shandong, Jiangsu, Shanghai, Zhejiang and Guangdong) kept relatively high statuses in CCD these years (mostly at the slight coordination or moderate coordination status, 0.6-0.8) mainly due to large numbers of good days with high quality, many inbound tourists, advanced inbound related facilities, and considerable revenue from inbound tourism. On the contrary, certain northwestern regions such as Gansu, Qinghai, and Ningxia maintained relatively low CCD (mainly at the slight incoordination status, 0.3-0.4) mainly because the investment in air governance was insufficient, air environment was not so satisfied that it could not act as a useful resource for inbound tourism, and the integral development of inbound tourism was relatively backward. Such spatial difference is also supported in former literature in other fields such as environmental governance (Geng et al., 2020a; Tan and Geng, 2020).

The second finding is that the gaps of CCD between the coastal regions and other regions are gradually and mildly narrowing. Most non-coastal regions upgraded to higher grades and the spatial differences were gradually diminishing. The narrowing of gaps is mainly due to the scientific planning and development of air governance and inbound tourism industry from the national strategy perspective. These years China has initiated related strategies such as blue-sky protection strategy, environment protection strategy, and poverty alleviation via tourism strategy, which have brought obvious benefits to certain non-coastal regions so that the differences of CCD among regions decline. The finding of the diminishing difference between the coastal regions and other ones is supported by previous established literature; it was researched that the spatial differences of higher education development among regions in China were gradually declining (Geng et al., 2020c).

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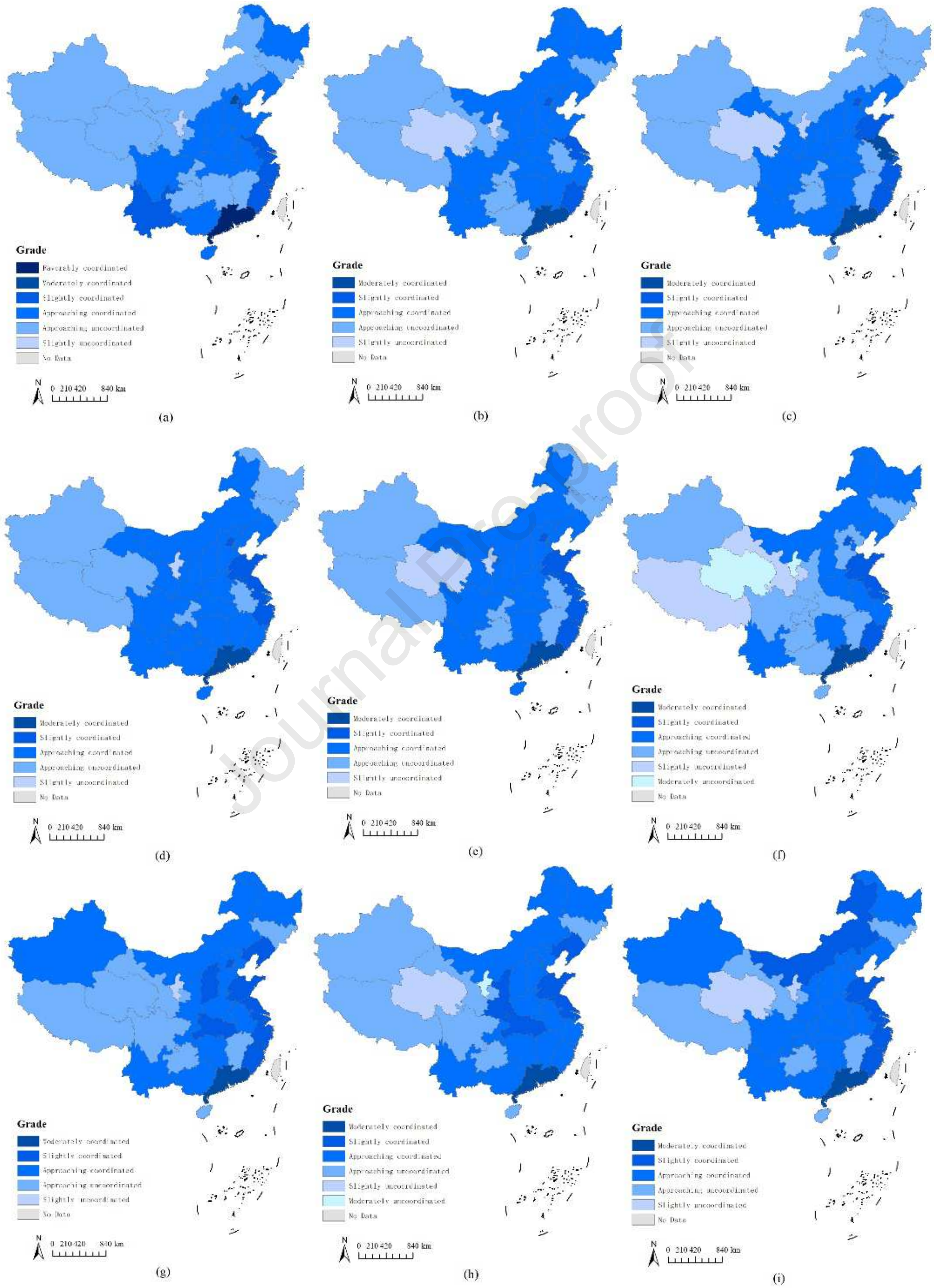

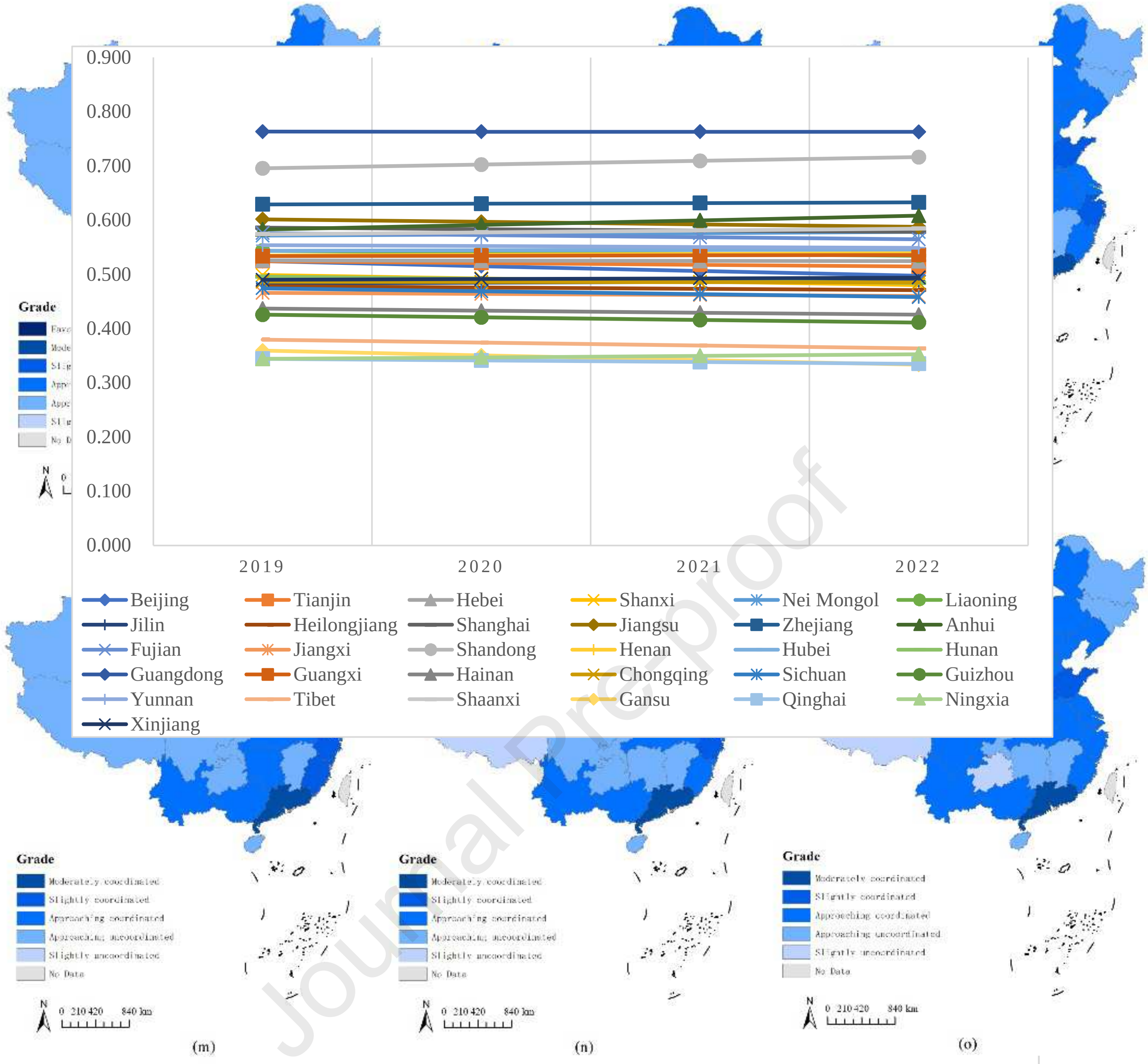

Figure 6. Spatial Variations of CCD. (a-o) 2004-2018.

4.3. Temporal and Spatial Prediction of CCD

During the accuracy test of the GM (1,1) model, most data meet the criteria in Table 4 that a < 0.3, r > 0.6, and P ≥ 0.6 (shown in Table A7), proving that the model is accurate and the data can be applied to make predictions.

Table A.7 and Figure 7 show the temporal tendency of CCD for the next your years. The temporal tendency of the CCD will mostly keep the same trend as in the past years that most regions will remain relatively stable in the former coordination grades, while certain regions will upgrade or degrade the classifications with gentle fluctuations. This tendency is consistent with the performances in previous years, and is reliable to make corresponding countermeasures. For the regions with upgraded CCD (such as Shandong), it is a delightful expectation which proves that air governance and inbound tourism stimulus policies have taken coordinated effects, whereas for those with degraded CCD (such as Beijing), the degradation is not a good signal and corresponding specific countermeasures should be immediately taken. This argument is also supported by previous literature (Valadkhani and O'Mahony, 2018).

Figure 7. Temporal Fluctuation of the Tendency of CCD.

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The spatial distributions of the CCDs' tendencies are shown in Figure 8. It can be found that the coastal regions will remain the leading predominance in CCD compared with the inland areas for the next four years. This trend is the same as the evolvement rule in the former years. However, there is another tendency which tells a different story: the gaps of CCD among regions will be slightly enlarged for the next four years rather than being narrowed as in the former 15 years. Specifically, coastal regions (e.g. Shandong, Anhui, etc.) will enjoy benign coordination development trends whereas the inland areas will keep the status quo of CCD, so that the variations will be enlarged. This finding is different from the findings of existing studies, demonstrating that corresponding actions are required from both the regional and national strategy perspective in order to decrease such differences and enhance balanced CCD among regions.

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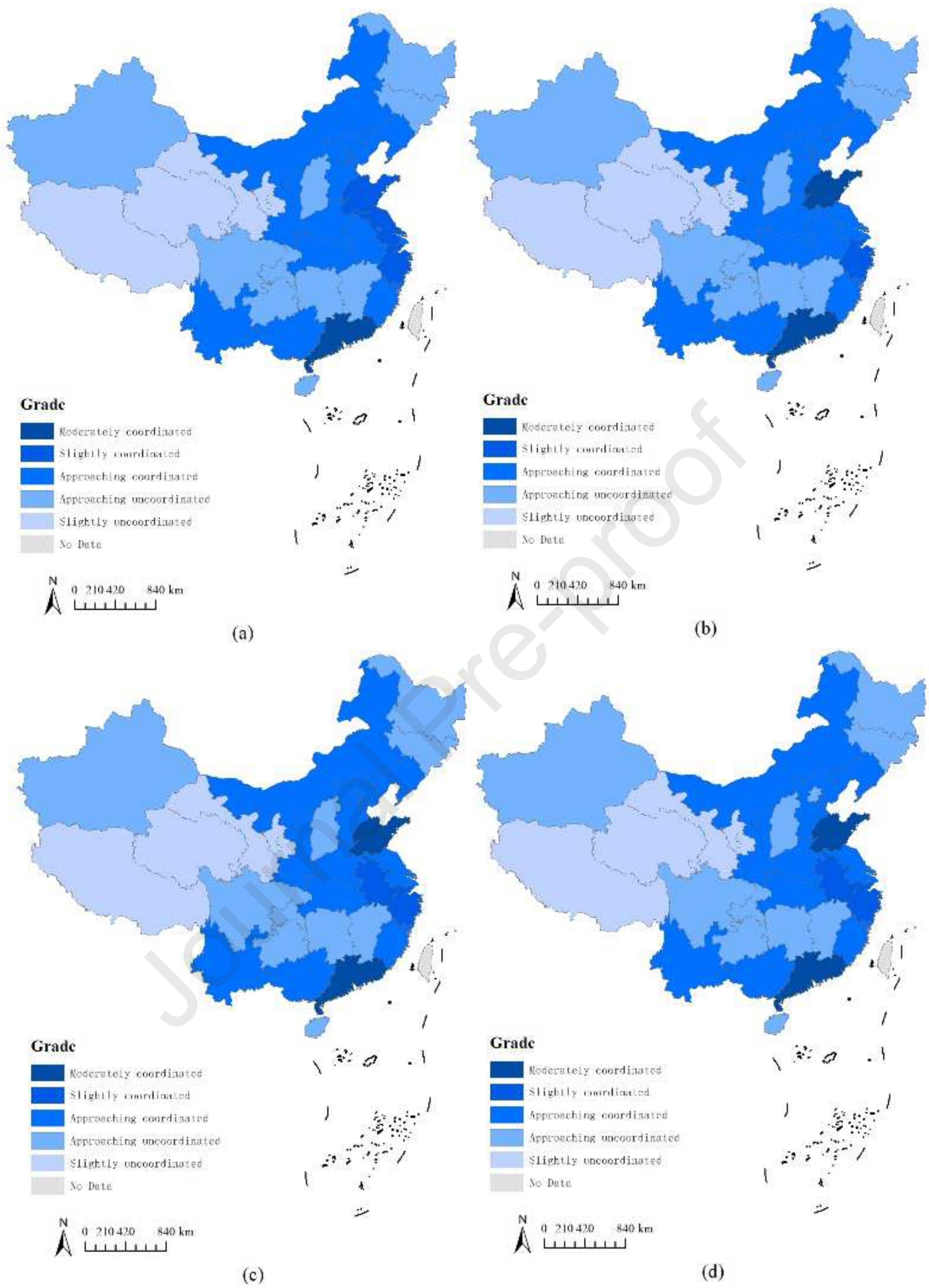

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Figure 8. Spatial Variations of the Tendency of CCD. (a-d) 2019-2022.

4.4. Countermeasures

The temporal tendencies of CCD between air environment and inbound tourism are mainly declining, and the spatial variations of CCD in different areas will be expanding, so it is important to take coordinated, cooperative, specific and differentiated approaches to prevent further trends of decline and polarization, and to increase the coordinated development between air environment and inbound tourism. Those involved in air environment and inbound tourism development should carefully consider the coupling coordination factors between the two subsystems, and take corresponding measures to improve the quality of air environment and the coordinated

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development of inbound tourism. Specific countermeasures for different regions are as follows, which will also help other places with the similar situations in the globe to increase the coupling coordination between the two subsystems.

For the regions where the CCD are high while the tendencies are declining, innovative measures should be taken in order to keep the coupling coordination between air environment and inbound tourism at the high level. First, these regions can innovatively use the air environment as inbound tourism resource and initiate new inbound tourism marketing campaigns. Second, they should invest more in air governance and try to relate the effects of air governance to inbound tourism development so that the tendency of CCD declining will be prevented. Third, they should enhance international and intranational cooperation in air governance and inbound tourism in order to realize the demonstration effects to other regions and to help other regions' coordination development.

For the regions where the CCD are fluctuating in the transitional coordination range, the goal of upgrade should be set up and great efforts should be taken to increase coupling coordination between air environment and inbound tourism. First, make clear strategies and schedules to incorporate air environment with inbound tourism, effectively make use of air environment into inbound tourism development, and use inbound tourism to promote air governance so that the two subsystems can realize benign interactive coordination. Second, consider the interaction mechanism of the two subsystems under the scientific and academic structure, facilitate governance mechanism's structural reform, enhance the effectiveness of administrative abilities of local governors, so that the coupling coordination between the two subsystems can be achieved via governance system improvement.

For the regions where the CCD are low, leapfrog and high-qualified coordination development are required in order to develop as quickly as possible and decrease the differences with other regions. First, these regions should take advantage of national strategies and attract more investment in air environment protection and inbound tourism growth. Second, they should reconsider their own advantages in air environment and inbound tourism resources, make re-positioning of inbound tourism and realize differentiation development. Third, they should learn from and cooperate with outstanding regions to find out new approaches to enhance the coordination effectiveness between air governance and inbound tourism.

From the macroscope national political framework perspective, there are several countermeasures for national or central authorities to enhance the balanced coordinated development in the country as a whole. First, introduce nation-wide stimulus strategies, set up preferential policies for backward regions, and encourage inter-regional cooperation, so that balanced development among regions can be effectively coordinated as a whole. Second, list the coordination development between air governance and inbound tourism as the annual target of the government, and set up specialized organizations such as the national coordination committee to take corresponding pathway to achieve the annual goal; local governments which don't meet the target are suggested to be held accountable.

5. Conclusions

This study aims at constructing a correlation model and an evaluation system to measure the coupling coordination interaction relationship between air environment and inbound tourism, regionally evaluating and predicting the development degrees and coupling coordination statuses of both subsystems temporally and spatially based on the correlation model, and then proposing countermeasures based on the results. Previous research has explored the correlations between air environment and inbound tourism, which gives insights to this study to find out the coupling coordination relationship between these two subsystems in the background of regional comparisons both temporally and spatially.

This study gets the following conclusions.

(1) The DD of air environment and inbound tourism vary temporally: DD of air environment is higher and more fluctuated than that of inbound tourism; besides, the spatial distributions of the

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two subsystems vary: the northern regions are higher in air environment DD, and the coastal and southern regions are higher in inbound tourism DD.

(2) Temporally, the CCDs of most regions remain relatively stable with mild fluctuations. Spatially, the coastal regions have higher CCD while regions in the northwest have relatively lower degrees, and the gaps of CCD among regions are gradually mildly narrowing.

(3) The prediction of CCD shows that the CCD trends of most regions will have temporal similarities with the previous years (remain stable), while the tendency of the spatial variations will be different: the gap of CCD will be enlarged for the next four years rather than being narrowed. Therefore, specific countermeasures are required to realize the coupling coordination between air environment and inbound tourism.

The novelties of this study are as follows.

(1) The interaction mechanism between air environment and inbound tourism from the view of academic rationality is demonstrated, which is rarely seen in previous studies; then the correlation model for the coupling coordination relationship between them is innovatively constructed, which is less focused in the past and which is beneficial to understand the interaction mechanism between these two subsystems theoretically.

(2) By transferring abstract theories to specific indicators, the evaluation system is updated innovatively to meet the specific situations of air governance and inbound tourism development, thus it is more useful to empirically measure the coupling coordination interactions between air environment and inbound tourism objectively; furthermore, the combined cross-regional, temporal, and spatial comparisons between the two subsystems contribute to prior literature in the field of air governance and tourism development.

(3) The predictions for the next four years provide us with new insights to understand the coordination tendencies between air environment and inbound tourism, and the corresponding countermeasures proposed in this study are useful for governors to explore the effecting factors and the future coupling coordination relationship temporally and spatially, and take effective actions beforehand to enhance coordination between the two subsystems and to promote air environment governance and inbound tourism growth.

Of course, some limitations exist in this study. First, due to the accessibility of data, only data of 15 years are collected, which is relatively limited in quantity. Second, 4 data points per year, which can include cyclic nature across seasons, are neglected. Third, some additional variables or indicators (such as emissions and concentration of $PM_{2.5}$, scale of inbound tourism related transportations, etc.) which could impact the coordination mechanism are also excluded because of data missing. In the future research, data of more years, data of the seasons per year, and data of certain other indicators should be selected in order to improve the reliability of the results, enhance comprehensive understanding of the interaction mechanism, and discover potential related biases due to exclusion of related indicators or data.

Appendix A

Table A.1. DD of Air Environment.

	2004	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
Beijing	0.568	0.334	0.459	0.433	0.435	0.325	0.318	0.315	0.299
Tianjin	0.612	0.406	0.542	0.436	0.436	0.394	0.436	0.365	0.401
Chongqing	0.349	0.297	0.268	0.296	0.295	0.315	0.350	0.338	0.297
Shanghai	0.366	0.312	0.376	0.284	0.284	0.330	0.338	0.347	0.395
Shanxi	0.463	0.554	0.535	0.712	0.702	0.657	0.753	0.573	0.548
Shaanxi	0.429	0.358	0.324	0.290	0.289	0.259	0.475	0.656	0.402
Shandong	0.467	0.396	0.505	0.532	0.545	0.612	0.506	0.535	0.622
Sichuan	0.415	0.459	0.476	0.476	0.482	0.337	0.300	0.311	0.435
Qinghai	0.405	0.304	0.337	0.357	0.349	0.279	0.468	0.352	0.366
Liaoning	0.409	0.357	0.415	0.376	0.376	0.329	0.498	0.428	0.339

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Jilin	0.392	0.312	0.317	0.253	0.251	0.301	0.373	0.348	0.365
Jiangxi	0.362	0.366	0.338	0.338	0.337	0.252	0.281	0.364	0.311
Jiangsu	0.482	0.422	0.632	0.463	0.472	0.385	0.398	0.370	0.474
Zhejiang	0.386	0.324	0.369	0.432	0.437	0.256	0.423	0.330	0.391
Fujian	0.718	0.503	0.696	0.393	0.393	0.362	0.385	0.382	0.417
Anhui	0.472	0.293	0.296	0.254	0.255	0.355	0.390	0.330	0.334
Heilongjiang	0.398	0.315	0.303	0.264	0.260	0.272	0.363	0.293	0.439
Henan	0.453	0.341	0.355	0.425	0.430	0.365	0.329	0.377	0.499
Hubei	0.542	0.321	0.346	0.379	0.380	0.307	0.616	0.638	0.352
Hunan	0.339	0.345	0.440	0.455	0.458	0.318	0.357	0.389	0.337
Hebei	0.438	0.382	0.435	0.443	0.450	0.327	0.389	0.395	0.504
Hainan	0.367	0.280	0.303	0.301	0.300	0.230	0.267	0.283	0.343
Yunnan	0.500	0.325	0.390	0.400	0.398	0.314	0.418	0.462	0.444
Guizhou	0.422	0.356	0.389	0.451	0.436	0.368	0.375	0.397	0.462
Guangdong	0.574	0.450	0.454	0.441	0.447	0.274	0.337	0.338	0.395
Gansu	0.505	0.387	0.478	0.622	0.611	0.381	0.433	0.614	0.495
Guangxi	0.332	0.256	0.409	0.339	0.337	0.274	0.318	0.325	0.364
Ningxia	0.481	0.641	0.396	0.426	0.411	0.471	0.463	0.306	0.403
Nei Mongol	0.330	0.320	0.264	0.550	0.538	0.425	0.476	0.389	0.677
Tibet	0.389	0.273	0.280	0.269	0.270	0.224	0.267	0.284	0.314
Xinjiang	0.395	0.343	0.285	0.279	0.279	0.296	0.548	0.396	0.435

Table A.2. DD of Air Environment (cont.).

	2013	2014	2015	2016	2017	2018	Mean	Grade
Beijing	0.317	0.238	0.218	0.285	0.271	0.277	0.339	Ordinary
Tianjin	0.353	0.288	0.287	0.410	0.245	0.259	0.391	Ordinary
Chongqing	0.291	0.288	0.188	0.257	0.199	0.244	0.285	Ordinary
Shanghai	0.369	0.216	0.245	0.288	0.413	0.326	0.326	Ordinary
Shanxi	0.532	0.537	0.326	0.361	0.372	0.549	0.545	Fair
Shaanxi	0.450	0.466	0.336	0.372	0.318	0.306	0.382	Ordinary
Shandong	0.629	0.619	0.654	0.710	0.660	0.726	0.581	Fair
Sichuan	0.336	0.336	0.279	0.244	0.229	0.274	0.359	Ordinary
Qinghai	0.352	0.288	0.270	0.281	0.358	0.187	0.330	Ordinary
Liaoning	0.329	0.389	0.350	0.327	0.325	0.287	0.369	Ordinary
Jilin	0.322	0.295	0.289	0.302	0.227	0.291	0.309	Ordinary
Jiangxi	0.282	0.314	0.248	0.292	0.246	0.269	0.307	Ordinary
Jiangsu	0.591	0.494	0.362	0.480	0.447	0.372	0.456	Fair
Zhejiang	0.461	0.435	0.386	0.481	0.417	0.391	0.395	Ordinary
Fujian	0.447	0.391	0.297	0.403	0.237	0.307	0.422	Fair
Anhui	0.429	0.393	0.273	0.335	0.346	0.373	0.342	Ordinary
Heilongjiang	0.295	0.378	0.287	0.346	0.320	0.265	0.320	Ordinary
Henan	0.354	0.448	0.400	0.388	0.495	0.415	0.405	Fair
Hubei	0.385	0.387	0.316	0.321	0.265	0.312	0.391	Ordinary
Hunan	0.391	0.335	0.260	0.327	0.249	0.254	0.350	Ordinary
Hebei	0.489	0.495	0.508	0.497	0.338	0.400	0.433	Fair
Hainan	0.371	0.280	0.263	0.234	0.201	0.258	0.285	Ordinary
Yunnan	0.377	0.375	0.279	0.355	0.274	0.219	0.369	Ordinary

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Guizhou	0.419	0.400	0.314	0.323	0.219	0.215	0.370	Ordinary
Guangdong	0.506	0.395	0.320	0.331	0.315	0.393	0.398	Ordinary
Gansu	0.425	0.388	0.306	0.235	0.256	0.232	0.425	Fair
Guangxi	0.311	0.323	0.254	0.393	0.281	0.234	0.317	Ordinary
Ningxia	0.455	0.477	0.449	0.388	0.450	0.342	0.437	Fair
Nei Mongol	0.443	0.555	0.514	0.502	0.415	0.434	0.455	Fair
Tibet	0.275	0.203	0.165	0.201	0.163	0.165	0.250	Ordinary
Xinjiang	0.337	0.387	0.375	0.365	0.266	0.290	0.352	Ordinary

Table A.3. DD of Inbound Tourism.

	2004	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
Beijing	0.456	0.490	0.459	0.455	0.448	0.491	0.413	0.406	0.401
Tianjin	0.235	0.223	0.222	0.227	0.229	0.259	0.247	0.245	0.236
Chongqing	0.171	0.184	0.187	0.189	0.191	0.185	0.202	0.205	0.221
Shanghai	0.439	0.454	0.449	0.445	0.444	0.519	0.424	0.446	0.412
Shanxi	0.147	0.162	0.164	0.173	0.176	0.156	0.200	0.193	0.195
Shaanxi	0.212	0.230	0.227	0.228	0.226	0.218	0.229	0.237	0.250
Shandong	0.264	0.272	0.280	0.294	0.303	0.297	0.313	0.312	0.319
Sichuan	0.204	0.234	0.228	0.234	0.236	0.116	0.184	0.178	0.197
Qinghai	0.066	0.070	0.070	0.072	0.071	0.028	0.061	0.057	0.057
Liaoning	0.268	0.268	0.269	0.280	0.286	0.308	0.316	0.312	0.314
Jilin	0.152	0.147	0.147	0.148	0.153	0.133	0.157	0.156	0.161
Jiangxi	0.144	0.186	0.153	0.192	0.180	0.144	0.184	0.176	0.179
Jiangsu	0.365	0.378	0.384	0.399	0.405	0.460	0.406	0.403	0.414
Zhejiang	0.344	0.355	0.371	0.386	0.393	0.412	0.393	0.391	0.397
Fujian	0.332	0.312	0.314	0.316	0.333	0.372	0.336	0.331	0.343
Anhui	0.176	0.183	0.181	0.194	0.201	0.186	0.219	0.221	0.246
Heilongjiang	0.215	0.204	0.201	0.218	0.226	0.244	0.214	0.213	0.219
Henan	0.173	0.186	0.190	0.198	0.195	0.171	0.203	0.197	0.198
Hubei	0.207	0.203	0.211	0.217	0.219	0.184	0.215	0.221	0.227
Hunan	0.157	0.209	0.211	0.234	0.226	0.212	0.225	0.230	0.232
Hebei	0.179	0.200	0.195	0.199	0.199	0.150	0.195	0.180	0.184
Hainan	0.198	0.174	0.186	0.212	0.214	0.159	0.185	0.175	0.174
Yunnan	0.279	0.264	0.267	0.277	0.281	0.260	0.289	0.279	0.287
Guizhou	0.112	0.145	0.142	0.147	0.142	0.102	0.129	0.126	0.123
Guangdong	0.796	0.765	0.817	0.825	0.837	0.975	0.876	0.890	0.906
Gansu	0.120	0.130	0.131	0.130	0.128	0.040	0.097	0.086	0.081
Guangxi	0.218	0.233	0.236	0.238	0.243	0.210	0.236	0.234	0.244
Ningxia	0.017	0.028	0.030	0.024	0.021	0.005	0.032	0.022	0.023
Nei Mongol	0.186	0.207	0.225	0.216	0.222	0.206	0.205	0.196	0.195
Tibet	0.151	0.167	0.161	0.168	0.212	0.054	0.148	0.147	0.147
Xinjiang	0.150	0.159	0.153	0.159	0.157	0.109	0.142	0.140	0.166

Table A.4. DD of Inbound Tourism (cont.).

	2013	**2014**	**2015**	**2016**	**2017**	**2018**	**Mean**	**Grade**
Beijing	0.380	0.366	0.356	0.350	0.353	0.343	0.411	Fair
Tianjin	0.247	0.259	0.270	0.275	0.279	0.278	0.249	Ordinary
Chongqing	0.229	0.215	0.218	0.222	0.232	0.240	0.206	Ordinary
Shanghai	0.393	0.382	0.387	0.387	0.394	0.391	0.425	Fair
Shanxi	0.204	0.182	0.140	0.137	0.138	0.137	0.167	Poor

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Shaanxi	0.262	0.253	0.256	0.265	0.276	0.283	0.243	Ordinary
Shandong	0.323	0.284	0.291	0.303	0.305	0.310	0.298	Ordinary
Sichuan	0.212	0.207	0.215	0.231	0.245	0.242	0.211	Ordinary
Qinghai	0.050	0.048	0.055	0.062	0.055	0.061	0.059	Poor
Liaoning	0.325	0.308	0.261	0.251	0.255	0.248	0.285	Ordinary
Jilin	0.168	0.172	0.174	0.184	0.187	0.177	0.161	Poor
Jiangxi	0.181	0.176	0.186	0.185	0.185	0.181	0.175	Poor
Jiangsu	0.416	0.289	0.306	0.313	0.318	0.322	0.372	Ordinary
Zhejiang	0.404	0.368	0.374	0.393	0.320	0.329	0.375	Ordinary
Fujian	0.353	0.341	0.347	0.356	0.392	0.402	0.345	Ordinary
Anhui	0.262	0.256	0.262	0.272	0.279	0.286	0.228	Ordinary
Heilongjiang	0.208	0.183	0.178	0.150	0.155	0.155	0.199	Poor
Henan	0.199	0.180	0.178	0.182	0.188	0.184	0.188	Poor
Hubei	0.238	0.238	0.240	0.256	0.261	0.265	0.227	Ordinary
Hunan	0.221	0.215	0.223	0.222	0.227	0.236	0.219	Ordinary
Hebei	0.187	0.179	0.176	0.172	0.174	0.174	0.183	Poor
Hainan	0.162	0.157	0.142	0.135	0.147	0.179	0.173	Poor
Yunnan	0.295	0.291	0.288	0.300	0.327	0.334	0.288	Ordinary
Guizhou	0.127	0.127	0.125	0.130	0.130	0.117	0.128	Poor
Guangdong	0.938	0.952	0.959	0.963	0.958	0.949	0.894	Excellent
Gansu	0.081	0.079	0.076	0.076	0.076	0.076	0.094	Poor
Guangxi	0.252	0.252	0.253	0.280	0.285	0.288	0.247	Ordinary
Ningxia	0.019	0.027	0.034	0.032	0.042	0.041	0.026	Poor
Nei Mongol	0.197	0.207	0.208	0.203	0.209	0.212	0.206	Ordinary
Tibet	0.124	0.127	0.128	0.134	0.133	0.126	0.142	Poor
Xinjiang	0.168	0.169	0.157	0.159	0.155	0.172	0.154	Poor

522 **Table A.5.** CCD.

	2004	2005	2006	2007	2008	2009	2010	2011
Beijing	0.713	0.636	0.677	0.666	0.664	0.632	0.602	0.598
Tianjin	0.616	0.548	0.589	0.561	0.562	0.565	0.573	0.547
Chongqing	0.494	0.483	0.473	0.486	0.487	0.491	0.516	0.513
Shanghai	0.633	0.614	0.641	0.597	0.596	0.643	0.616	0.627
Shanxi	0.511	0.547	0.544	0.592	0.593	0.566	0.623	0.577
Shaanxi	0.549	0.536	0.521	0.507	0.506	0.487	0.574	0.628
Shandong	0.592	0.573	0.613	0.629	0.637	0.653	0.631	0.639
Sichuan	0.539	0.572	0.574	0.578	0.581	0.445	0.485	0.485
Qinghai	0.404	0.382	0.391	0.401	0.397	0.298	0.411	0.376
Liaoning	0.575	0.556	0.578	0.570	0.572	0.564	0.630	0.604
Jilin	0.494	0.463	0.465	0.440	0.443	0.447	0.492	0.482
Jiangxi	0.477	0.511	0.477	0.504	0.496	0.437	0.477	0.503
Jiangsu	0.647	0.632	0.702	0.656	0.661	0.649	0.634	0.621
Zhejiang	0.604	0.582	0.608	0.639	0.644	0.570	0.639	0.599
Fujian	0.699	0.629	0.684	0.593	0.601	0.606	0.600	0.597
Anhui	0.537	0.481	0.481	0.471	0.476	0.507	0.540	0.519
Heilongjiang	0.541	0.504	0.497	0.490	0.492	0.508	0.528	0.500
Henan	0.529	0.502	0.509	0.539	0.538	0.500	0.508	0.522
Hubei	0.579	0.505	0.520	0.536	0.537	0.488	0.604	0.613
Hunan	0.481	0.518	0.552	0.571	0.568	0.510	0.532	0.547
Hebei	0.529	0.526	0.540	0.545	0.547	0.470	0.525	0.516
Hainan	0.520	0.470	0.487	0.503	0.503	0.437	0.471	0.472
Yunnan	0.611	0.541	0.568	0.577	0.578	0.535	0.590	0.599

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Guizhou	0.467	0.477	0.485	0.508	0.499	0.440	0.469	0.473
Guangdong	0.822	0.766	0.780	0.777	0.782	0.719	0.737	0.741
Gansu	0.496	0.474	0.500	0.534	0.529	0.351	0.453	0.479
Guangxi	0.519	0.494	0.557	0.533	0.535	0.490	0.524	0.525
Ningxia	0.302	0.365	0.330	0.316	0.303	0.222	0.348	0.286
Nei Mongol	0.498	0.507	0.494	0.587	0.588	0.544	0.559	0.526
Tibet	0.492	0.463	0.460	0.461	0.490	0.332	0.446	0.452
Xinjiang	0.494	0.484	0.457	0.459	0.458	0.424	0.529	0.485

Table A.6. CCD (cont.).

	2012	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**
Beijing	0.588	0.589	0.543	0.528	0.562	0.556	0.555
Tianjin	0.555	0.544	0.523	0.528	0.580	0.511	0.518
Chongqing	0.506	0.508	0.498	0.450	0.489	0.463	0.492
Shanghai	0.635	0.617	0.536	0.555	0.578	0.635	0.598
Shanxi	0.572	0.574	0.559	0.462	0.472	0.476	0.523
Shaanxi	0.563	0.586	0.586	0.542	0.560	0.544	0.542
Shandong	0.667	0.671	0.648	0.661	0.681	0.670	0.689
Sichuan	0.541	0.516	0.514	0.495	0.487	0.487	0.507
Qinghai	0.381	0.363	0.343	0.349	0.363	0.374	0.326
Liaoning	0.571	0.572	0.588	0.550	0.535	0.537	0.517
Jilin	0.492	0.482	0.475	0.473	0.486	0.454	0.476
Jiangxi	0.485	0.476	0.485	0.463	0.482	0.462	0.470
Jiangsu	0.665	0.704	0.615	0.577	0.622	0.614	0.588
Zhejiang	0.628	0.657	0.632	0.617	0.659	0.605	0.599
Fujian	0.615	0.630	0.604	0.567	0.616	0.552	0.593
Anhui	0.535	0.579	0.563	0.517	0.550	0.557	0.571
Heilongjiang	0.557	0.498	0.513	0.475	0.477	0.472	0.450
Henan	0.561	0.516	0.533	0.517	0.515	0.552	0.525
Hubei	0.532	0.550	0.551	0.525	0.535	0.513	0.536
Hunan	0.529	0.542	0.518	0.491	0.519	0.488	0.495
Hebei	0.552	0.550	0.546	0.547	0.541	0.492	0.513
Hainan	0.494	0.495	0.458	0.440	0.422	0.414	0.464
Yunnan	0.597	0.578	0.575	0.533	0.571	0.547	0.520
Guizhou	0.488	0.480	0.474	0.445	0.452	0.411	0.398
Guangdong	0.774	0.830	0.783	0.744	0.751	0.741	0.782
Gansu	0.447	0.431	0.419	0.390	0.366	0.373	0.364
Guangxi	0.546	0.529	0.534	0.503	0.576	0.532	0.510
Ningxia	0.310	0.307	0.338	0.351	0.335	0.371	0.345
Nei Mongol	0.603	0.543	0.582	0.572	0.565	0.543	0.551
Tibet	0.464	0.430	0.400	0.381	0.405	0.384	0.380
Xinjiang	0.518	0.488	0.505	0.493	0.490	0.451	0.473

Table A.7. Prediction of CCD.

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	a	*r*	*P*	Prediction Year			
				2019	**2020**	**2021**	**2022**
Beijing	0.010	13.995	0.867	0.524	0.515	0.506	0.497
Tianjin	0.002	0.621	0.733	0.524	0.521	0.518	0.514
Chongqing	0.005	1.196	0.733	0.486	0.486	0.485	0.485
Shanghai	0.001	0.761	0.467	0.586	0.583	0.581	0.578
Shanxi	0.002	0.029	0.667	0.499	0.492	0.486	0.480
Shaanxi	0.011	1.005	0.733	0.574	0.577	0.581	0.584
Shandong	0.007	1.290	0.600	0.696	0.702	0.709	0.716
Sichuan	0.011	0.530	0.467	0.474	0.469	0.463	0.458
Qinghai	0.004	1.496	0.733	0.344	0.341	0.338	0.335
Liaoning	0.002	0.904	0.533	0.544	0.540	0.537	0.534
Jilin	0.006	0.714	0.600	0.482	0.484	0.486	0.488
Jiangxi	0.002	1.258	0.600	0.466	0.464	0.462	0.460
Jiangsu	0.001	0.913	0.467	0.602	0.597	0.592	0.587
Zhejiang	0.003	0.695	0.400	0.629	0.630	0.631	0.633
Fujian	0.002	0.993	0.800	0.576	0.572	0.568	0.564
Anhui	0.012	0.963	0.733	0.583	0.591	0.600	0.608
Heilongjiang	0.004	1.062	0.600	0.478	0.476	0.473	0.471
Henan	0.002	0.554	0.533	0.535	0.536	0.538	0.539
Hubei	0.006	0.952	0.533	0.544	0.544	0.545	0.546
Hunan	0.002	0.478	0.667	0.496	0.492	0.488	0.484
Hebei	0.001	0.086	0.467	0.526	0.525	0.525	0.524
Hainan	0.000	1.830	0.600	0.437	0.433	0.429	0.425
Yunnan	0.004	1.092	0.600	0.554	0.552	0.551	0.549
Guizhou	0.002	0.932	0.600	0.425	0.421	0.416	0.411
Guangdong	0.001	2.367	0.533	0.763	0.763	0.763	0.763
Gansu	0.011	0.893	0.667	0.359	0.350	0.342	0.333
Guangxi	0.001	0.223	0.600	0.533	0.534	0.535	0.536
Ningxia	0.008	0.341	0.667	0.344	0.347	0.350	0.353
Nei Mongol	0.004	0.749	0.467	0.571	0.573	0.576	0.578
Tibet	0.004	0.367	0.733	0.380	0.374	0.369	0.363
Xinjiang	0.006	1.357	0.667	0.490	0.491	0.493	0.494

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Conflicts of Interest

Temporal-Spatial Measurement and Prediction between Air Environment and Inbound Tourism: Case of China

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