A Study on the Coupling Coordination between Forestry Production Efficiency and Regional Economic Development in China

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Abstract

Forestry production is one of the fundamental industries of the national economy, and enhancing production efficiency can aid in balancing the contradiction between the economic growth of forestry and forest resource conservation. Therefore, studying the coupling coordination between forestry production efficiency and regional economic development is of great practical significance for obtaining the development philosophy of green and circular economies and implementing supply-side structural reform in forestry. In this study, the forestry production efficiencies and economic development levels of 31 provincial-level administrative regions of China during 2009 to 2018 are estimated using the super efficiency slacks-based measure model and the entropy weight method. Additionally, the coupling coordination and development trends of forestry production efficiencies and regional economic development levels are investigated by means of the coupling coordination model and GM (1,1) model. Research findings suggest that forestry production efficiencies and economic development levels of 31 provincial-level administrative regions in China maintained steadily growing trends during 2009 to 2018; however, there was middle to low-level coupling coordination between regions. Such coupling coordination remains to be improved because it indicated a spatial pattern of high in the east and south and low in the west and north. To conclude, some suggestions for promoting sound and coordinated interactions between forestry production efficiency and regional economic development are offered.

As 'the lungs of the Earth,' forests are generally accepted as a major force affecting the terrestrial ecological balance. Forestry is not only one of the primary industries in the national economy but also an important part of public welfare undertakings. Therefore, forestry development plays a significant role in supporting the development of the social economy and conservation culture. China has stepped into a critical period of switching, accelerating, upgrading, and transforming forestry development in the context that China has ceased commercial logging of natural forests and set the ecological conservation redline. Hence, understanding and improving forestry productivity is not only a general requirement of sustainable forestry operation but also a practical issue associated with the development of human society.

Researchers at home and abroad made clear and accurate elaborations on the concepts, measurement methods and influencing factors of forestry productivity, whereas little attention was paid to the interactive relations between forestry productivity and regional economic development. Mynarski et al. (2018) provide an overview of forest management efficiency assessment, giving the definition of economic entity efficiency and productivity and the categories of efficiency assessment methods (ratio analysis, parametric and nonparametric methods to measure forest efficiency; Diaz-Balteiro and Romero 2008, Mynarski 2018). Šporčić et al. (2009) assessed the efficiency of basic organizational units in the forestry goals and forest offices by applying Data Envelopment Analysis (DEA). In a study by Zhang and Kang (2017), the super efficiency DEA–Tobit model was used to identify the factors influencing China's forestry productivity based on the data collected from 30

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provinces (cities and districts) during 2000 to 2014. When studying the influence of labor transfer and cooperative operation on household-based forestry productivity, Han et al. (2018) found that labor transfer had an inhibitory effect on forestry productivity, while forestry cooperative business showed the reverse. Kovalčík (2018) used DEA to assess forestry efficiency in European countries during 2005 to 2008. The results show that the average efficiency of forestry in Slovakia is lower than average compared with other European countries, and the efficiency varies greatly from country to country (Kovalčík 2018). Based on the sample data of 364 farmers, the influence of the reform policy of the collective-owned forest tenure system on farmers' forestry productivity was investigated by Yang et al. (2019), the results of which indicated that policies such as forestry insurance, forestry cooperatives, and forestry sci-tech services, played a positive role. The DEA–Malmquist Index and panel Tobit model were used by Cao and Wang (2019) to probe the regional difference and temporal variation in China's forestry productivity and the influence of fiscal support and forestry tenure reform on forestry productivity. Neykov et al. (2019) revealed the results of the efficiency of forestry and forest-based industries throughout the European Union and have concluded that Bulgaria is inefficient. Advanced manufacturing technology and investment have important influence on efficiency. Lundmark et al. (2020) found that improving the efficiency of the forestry sector will significantly affect our likelihood of achieving long-term sustainability and mitigation of climate change. By analyzing the coupling coordination between the economic development efficiencies and the ecological conservation levels of key state-owned forest zones using the coupling coordination degree model, Cao et al. (2017) concluded that the coupling degree between the economic development efficiency and the ecological conservation level of key state-owned forest zones was antagonistic and showed a moderately to highly coordinated coupling trend. Considering the significant difference in economic development level between Chinese provincial regions, it is difficult to determine whether current forestry productivity can satisfy the requirements of regional economic development without identifying the evolutionary law of China's forestry productivity and the situation of regional economic development, as well as creating a win–win situation for forestry conservation and sustainable economic development. To this end, this study aims to calculate the forestry productivities and the overall evaluation indexes of the regional economic development levels of various Chinese provincial regions and investigate the coupling coordination between forestry productivity and the regional economic development level using the coupling coordination degree model, thereby providing evidence for boosting the coordinated development of forestry productivity and the regional economy and offering scientific and targeted suggestions for the sustainable utilization of forest resources, as well as the sound and environmentally friendly development of the social economy.

Material and Methods

Methodology and index system establishment

Super efficiency slacks-based measure (SBM) model.—Forestry productivity is measured using the super efficiency slacks-based measure (SBM) model in this study. Compared with traditional data envelopment analysis, the super efficiency SBM model considers the influence of loose variables, random errors, and the external environment on efficiency measurement and resolves the disadvantage that the comparison cannot be made when the efficiency value exceeds one. The super efficiency SBM model can be denoted as follows (Chang et al. 2014, Cheng 2014):

$$\min\rho = \frac{1+\frac{1}{m}\sum_{i=1}^{m} s_i^- \Big/ x^{ik}}{1-\frac{1}{s}\sum_{r=1}^{s} s_r^+ \Big/ y^{rk}}$$

$$\sum_{j=1,j\neq k}^{n} x_{ij}\lambda_j - s_i^- \le x_{ik}$$

$$\sum_{j=1,j\neq k}^{n} y_{rj}\lambda_j + s_r^+ \ge y_{rk}$$

$$\lambda, s^-, s^+ \ge 0$$

$$i = 1,2,\ldots m; r = 1,2\ldots q; \mathrm{j} = 1,2,\ldots,\mathrm{n}(\mathrm{j} \neq k) \quad (1)$$

Entropy weight Mmethod.—The comprehensive evaluation index of the regional economic development level is measured using the entropy weight method. Based on the original data information, this method assigns weight to each index according to the information each index contains and the correlation between indexes, which reduces the bias incurred by subjective factors during weighting. The calculation procedure of the entropy weight method is shown as follows (Shannon 1948, Tang et al. 2018):

$$\text{Standardized initial data:} \quad x_{ij} = \frac{x_{ij} - \min(x_{ij})}{\max(x_{ij}) - \min(x_{ij})} \quad (2)$$

$$\text{Standardized value:} \quad P_{ij} = \frac{x_{ij}}{\sum_{i=1}^{m} x_{ij}} \quad (3)$$

$$\text{Information entropy:} \quad e_j = -K\sum_{i=1}^{m} P_{ij}\ln(P_{ij}) \quad (4)$$

$$\text{Weight:} \quad w_j = \frac{D_j}{\sum_{j=1}^{n} D_j} \quad (5)$$

$$\text{Comprehensive index:} \quad U_i = \sum_{j=1}^{n} w_j P_{ij} \quad (6)$$

Coupling coordination degree model.—Coupling describes the overall effect generated by the interactions between inter- or intrasystem factors, which are stronger than those generated by a single system. Coordination is the concentrated reflection of the positive correlation formed based on such interactions, indicating a trend where the system evolves from disorder to order. Together, coupling coordination shows the correlation between forestry productivity and regional economic development level in a more comprehensive manner because it can help identify whether the coupling relationship between them is positive and sustainable. The higher the coupling coordination degree between forestry productivity and regional economic development level is, the better they can positively interact with each other and promote mutual development. The calculation procedure of this model is shown as follows (Li et al. 2012, Tang et al. 2018, Cui et al. 2019):

$$\text{Coupling degree:} \quad C = \frac{2\sqrt{(U1 \times U2)}}{U1 + U2} \tag{7}$$

$$\text{Comprehensive coordination index:} \quad T = \alpha U1 + \beta U2 \tag{8}$$

$$\text{Coupling coordination degree:} \quad D = \sqrt{(C \times T)} \tag{9}$$

where α and β are the coefficients of the comprehensive coordination index to be estimated and $\alpha + \beta = 1$. In this study, we consider that forestry productivity and regional economy should develop coordinately, and the latter slightly outweighs the former. Therefore, α is set to 0.4 and β is set to 0.6, based on which the coupling coordination degree between forestry productivity and regional economy is graded (as shown in Table 1).

GM (1,1).—In this study, the coupling coordination degree between forestry productivity and regional economic development level is predicted using GM (1,1). Considering that it is unnecessary to consider the a priori characteristics of the original data in GM (1,1) buildings, GM (1,1) is random and can weaken the time series. With fewer data required, GM (1,1) prediction can be made as long as the data size exceeds four. Given space limitations, the modeling process and model accuracy standard are not covered here (Sheu et al. 2014, Javed and Liu 2018, Lu et al. 2020).

Index system establishment

Forestry productivity.—Forestry productivity refers to the capacity of forestry production to convert various inputs into an output subject for the constraints of the external economic environment and internal management. It is the ratio of forestry input to forestry output that shows the optimization process of forestry production factor allocation from the perspective of output or input. According to the theory of economics, capital, labor, and land play a critical role in production input. Forestry output not only includes the economic benefit of forestry but also ecological and social benefits. The forestry productivity input index system of this study is built based on three factors: land, capital, and labor; the forestry productivity output index system is built on another three factors: economic, ecological, and social benefits (Table 2; Mlynarski and Predki 2017, Tian et al. 2017, Liu et al. 2018, Nikolay et al. 2018;).

Regional economic development level.—The regional economy is the production complex created by the interactions between internal and external economic development factors within a specific region. The rationality of index selection and data availability are comprehensively considered based on a literature review. In this study, the regional economic development-level index system is built based on three factors: the scale, structure, and potential of the economy. State fiscal revenue per capita = state fiscal revenue / the total regional population; social fixed asset investment per capita = total social fixed asset investment / total regional population; education expenditure per capita = education expenditure / total regional population; and sci-tech expenditure per capita = sci-tech expenditure / total regional population (Table 3; Li and Cui 2018 and Yao and Men 2020). In particular, education expenditure and sci-tech expenditure are the expenditure items in the general public budget.

Data sources

The data used in this study are collected from the China Statistical Yearbook and China Forestry Statistical Yearbook of 2009 to 2018. The missing data are supplemented by means of linear interpolation.

Results and Discussion

Forestry productivity and regional economic development coupling coordination means boosting forestry productivity and economic development level, narrowing the relative gap, and contributing to a sound and orderly coupling system of forestry productivity–regional economic development based on the actual situations of various regions and objective laws. Regional economic development is the foundation for improving forestry production factors. Forestry development requires support from a variety of resources, including policy, capital, workforce, and technology, all of which depend on regional economic development. The regional economy plays an important role in increasing forestry factor input, stimulating forestry output, and ultimately improving forestry production factors. Regional economic growth is subject to the influence of forestry productivity. Forestry production factor improvement means concentrated, efficient, and intensive utilization of land, capital, and labor. Moreover, the effective allocation of forestry production factors, such as land, labor, and capital, can boost industrial structure optimization, which further promotes regional economic growth.

Table 1.—Grading of coupling coordination degree.

Coupling coordination degree	Coordination level	Coupling coordination degree	Coordination level
$0 \leq D < 0.1$	Extremely imbalanced	$0.5 \leq D < 0.6$	Barely coordinated
$0.1 \leq D < 0.2$	Seriously imbalanced	$0.6 \leq D < 0.7$	Primarily coordinated
$0.2 \leq D < 0.3$	Moderately imbalanced	$0.7 \leq D < 0.8$	Moderately coordinated
$0.3 \leq D < 0.4$	Mildly imbalanced	$0.8 \leq D < 0.9$	Well-coordinated
$0.4 \leq D < 0.5$	Minimally imbalanced	$0.9 \leq D < 1$	Highly coordinated

Table 2.—Forestry productivity evaluation index system.

Evaluation subject	Index type	Index system	Unit
Forestry productivity	Input	Forestland area	10,000 ha
		No. of forestry practitioners	n/a
		Forestry investment completed	10,000 yuan (RMB)
	Output	Total output of forestry	10,000 yuan
		Forest stock	10,000 m^3
		Average annual wage of forestry workers	Yuan

Measurement of forestry productivity and regional economic development level

Forestry productivity measurement—The super efficiency SBM model is used to measure the forestry productivities of 31 Chinese provincial regions (provinces, municipalities, and autonomous regions) during 2009 to 2018, and the calculation results are shown in Table 4. During this period, China's forestry productivity was <1 on average, ranging between 0.502 and 0.587. This evidence indicates that both the input and output factors of forestry production were inefficiently allocated, which led to a low overall forestry productivity and a large gap between the actual output and the optimal output at the current input level. Thus, there is still plenty of room for forestry output improvement. This result coincides with the research findings obtained by Luo et al. (2017) and Wei (2016). The forestry productivities of eastern, central, and western China were far from efficient during that decade. Although the forestry productivities of most provincial regions showed a rising tendency, they differed among provinces. Specifically, the forestry productivities of the Tianjin, Jiangsu, Zhejiang, Guangdong, Hainan, and Sichuan Provinces and the Tibet Autonomous Region (Tibet) reached and maintained an efficient state since 2009. Of all the regions, Shanghai enjoyed the highest forestry productivity. The forestry productivities of the Fujian, Shandong, and Yunnan Provinces were improving year by year, developing from an inefficient level to an efficient level; the forestry productivities of the Hebei, Jilin, and Hunan Provinces; Inner Mongolia Autonomous Region (Inner Mongolia); and Xinjiang Uygur Autonomous Region (Xinjiang) fluctuated and dropped slightly. A fluctuating upward trend of forestry productivity observed in the rest of the provinces, but none of them had reached an efficient state.

Measurement of regional economic development levels.—The comprehensive indexes of regional economic development levels of 31 Chinese provincial regions during 2009 to 2018 are measured using the entropy weight method, and the calculation results are shown in Table 5. The Chinese provincial economies were not only significantly different from each other in terms of development level, but they were also concentrated, wherein eastern coastal regions—such as the Guangdong Province, Jiangsu Province, Shandong Province, and Shanghai—enjoyed high levels of economic development, and regions in central and western China—such as the Qinghai Province, Tibet, Jilin Province, Liaoning Province, and Heilongjiang Province—showed low levels of economic development. This finding suggests that strengthening economic cooperation between eastern, central, and western China to narrow the interregional economic development gap is still a major issue demanding a prompt solution.

Analysis of the coupling coordination degree between forestry productivity and regional economic development

The coupling coordination degree model is used to measure the coupling coordination between the forestry productivities and the regional economic development levels of 31 Chinese provincial regions during 2009 to 2018, based on which their development stages and trends are identified, and the calculation results are shown in Table 6. In general, the coupling coordination degree between the forestry productivity and economic development level in China rose steadily at a slow rate from 0.458 to 0.532, suggesting that it developed only from the minimally imbalanced stage to the barely coordinated stage. From a regional perspective, eastern China enjoyed the highest coupling coordination degree, followed by western China and central China. Eastern China was in the primarily coordinated stage; although its coupling coordination degree rose slightly, it had not reached the moderately coordinated stage. Central China was in the mildly imbalanced stage; its coupling coordination degree also improved slightly, but it had not reached the minimally imbalanced stage. Western China developed from the mildly imbalanced stage to the minimally

Table 3.—Regional economic development level evaluation index system. GDP is gross domestic product.

Evaluation subject	Index type	Index system	Unit
Regional economic development	Economic scale	GDP per capita	Yuan
		State fiscal revenue per capita	Yuan
		Social fixed assets investment per capita	Yuan
	Economic structure	The proportion of the output attributable to the secondary industry	%
		The proportion of the output attributable to the tertiary industry	%
	Economic potential	GDP growth rate	%
		Education expenditure per capita	Yuan
		Sci-tech expenditure per capita	Yuan

Table 4.—Measurement results of forestry productivity during 2009 to 2018.

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Beijing	0.094	0.058	0.078	0.083	0.098	0.086	0.085	0.088	0.099	0.120
Tianjin	1.251	1.000	1.478	1.871	1.513	1.279	1.292	1.567	1.258	1.402
Hebei	0.174	0.143	0.124	0.139	0.179	0.160	0.170	0.165	0.159	0.134
Shanxi	0.058	0.040	0.044	0.052	0.063	0.060	0.074	0.088	0.091	0.084
Inner Mongolia	0.105	0.093	0.072	0.065	0.075	0.074	0.082	0.081	0.082	0.055
Liaoning	0.218	0.212	0.199	0.239	0.280	0.243	0.261	0.280	0.248	0.232
Jilin	0.377	0.308	0.306	0.304	0.424	0.379	0.357	0.337	0.295	0.295
Heilongjiang	0.187	0.193	0.142	0.185	0.229	0.224	0.237	0.218	0.181	0.206
Shanghai	2.229	2.932	2.591	2.376	2.502	2.718	2.382	2.244	2.799	2.063
Jiangsu	1.291	1.186	1.189	1.173	1.090	1.091	1.107	1.149	1.109	1.201
Zhejiang	1.174	1.126	1.170	1.151	1.116	1.096	1.091	1.110	1.127	1.141
Anhui	0.251	0.217	0.296	0.357	0.402	0.406	0.449	0.454	0.511	0.588
Fujian	0.608	0.530	0.534	0.563	0.686	0.592	0.603	0.623	0.624	1.021
Jiangxi	0.239	0.199	0.215	0.209	0.269	0.274	0.360	0.345	0.332	0.372
Shandong	0.428	1.011	1.053	1.100	1.115	1.125	1.101	1.103	1.093	1.082
Henan	0.192	0.145	0.133	0.157	0.192	0.182	0.189	0.212	0.222	0.236
Hubei	0.227	0.174	0.180	0.180	0.240	0.243	0.286	0.308	0.301	0.336
Hunan	0.295	0.249	0.233	0.197	0.233	0.209	0.255	0.247	0.251	0.247
Guangdong	1.219	1.221	1.136	1.191	1.160	1.226	1.195	1.199	1.187	1.163
Guangxi	0.174	0.197	0.151	0.180	0.224	0.247	0.270	0.276	0.253	0.296
Henan	1.156	1.025	1.048	0.299	0.327	1.051	1.107	1.066	1.202	1.130
Chongqing	0.216	0.126	0.152	0.190	0.236	0.246	0.282	0.360	0.383	0.446
Sichuan	1.040	1.048	1.041	1.014	1.021	1.020	1.025	1.035	1.046	1.051
Guizhou	0.176	0.107	0.104	0.116	0.151	0.149	0.219	0.211	0.311	0.285
Yunnan	0.321	0.338	0.254	0.303	0.388	0.326	0.345	0.381	0.355	1.031
Xizang	1.471	1.447	1.474	1.430	1.453	1.483	1.480	1.457	1.468	1.462
Shanxi	0.136	0.100	0.103	0.126	0.153	0.141	0.160	0.164	0.158	0.168
Gansu	0.083	0.060	0.064	0.070	0.080	0.083	0.093	0.120	0.103	0.087
Qinghai	0.027	0.016	0.023	0.050	0.049	0.046	0.051	0.035	0.032	0.038
Ningxia	0.033	0.032	0.033	0.037	0.048	0.054	0.075	0.048	0.053	0.066
Xinjiang	0.163	0.134	0.139	0.156	0.190	0.173	0.187	0.202	0.176	0.171
China	0.504	0.505	0.508	0.502	0.522	0.538	0.544	0.554	0.565	0.587
Eastern area	0.895	0.949	0.964	0.926	0.915	0.970	0.945	0.963	0.991	0.972
Central area	0.228	0.191	0.194	0.205	0.256	0.247	0.276	0.276	0.273	0.295
Western area	0.329	0.308	0.301	0.311	0.339	0.337	0.356	0.364	0.368	0.430

imbalanced stage. The reasons for this phenomenon are listed as follows: (1) Eastern China performed better in economic development and conservation culture because of geographical and policy advantages, which contributed to a higher coupling coordination degree. (2) Hampered by the slow forestry transformation and upgrading, central China failed to efficiently transform the resource-dependent traditional economic development pattern, which had led to a lower coupling coordination degree than those of eastern and western China. (3) The Chinese central government introduced adequate ecological policies and provided sufficient financial support for western China over the past few years. Together with technological advancement, these factors enabled western China to boost forestry productivity, improve regional economic development, and ultimately promote a higher degree of coupling coordination.

From a temporal perspective, the coupling coordination degrees between the forestry productivities and the regional economic development levels of 31 Chinese provincial regions during 2009 to 2018 could be divided into three stages: fluctuating upward stage, fluctuating downward stage, and relatively stable stage. The coupling coordination degrees between forestry productivity and regional economic development level ranged between 0.2 and 1. Specifically, the Beijing, Anhui, Fujian, Shandong, Jiangxi, Henan, Hubei, and Guangdong Provinces; the Guangxi Zhuang Autonomous Region (Guangxi), Hainan Province, Chongqing, Guizhou Province, and Yunnan Province; and Ningxia and Xinjiang were in the fluctuating upward stage; the Hebei, Shanxi, Jiangsu, Zhejiang, Hunan, Sichuan, Qinghai, Shaanxi, and Gansu Provinces; and Tianjin, Shanghai, and Tibet were in the relatively stable stage; and Inner Mongolia, the Liaoning Province, Jilin Province, and Heilongjiang Province were in the fluctuating downward stage. The coupling coordination between the forestry productivity and the regional economic development level of each provincial region showed either an upward or downward trend, evidencing that there were multiple labile factors in regional economic development–forestry development mutual promotion that called for scientific and systematic promotion of coordinated development between forestry and regional economy based on local resources, environment, and other relevant factors. Although the overall coupling coordination degree between forestry productivity and the regional economic development level of China was less than ideal, it continued to progress.

From a spatial perspective, Chinese provincial regions featured low degrees of coupling coordination between

Table 5.—Comprehensive indexes of regional economic development level during 2009 to 2018.

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Beijing	0.786	0.890	0.890	0.858	0.858	0.812	0.811	0.852	0.842	0.857
Tianjin	0.507	0.576	0.657	0.682	0.720	0.692	0.628	0.611	0.492	0.429
Hebei	0.103	0.110	0.112	0.098	0.097	0.089	0.088	0.091	0.102	0.115
Shanxi	0.138	0.168	0.159	0.153	0.162	0.135	0.140	0.117	0.122	0.138
Inner Mongolia	0.279	0.284	0.321	0.299	0.312	0.321	0.238	0.219	0.181	0.192
Liaoning	0.252	0.285	0.318	0.340	0.344	0.282	0.180	0.115	0.121	0.137
Jilin	0.164	0.165	0.175	0.196	0.185	0.159	0.151	0.144	0.140	0.128
Heilongjiang	0.103	0.133	0.131	0.134	0.117	0.094	0.093	0.091	0.097	0.082
Shanghai	0.855	0.817	0.829	0.789	0.753	0.687	0.706	0.853	0.790	0.779
Jiangsu	0.286	0.331	0.373	0.376	0.407	0.399	0.403	0.377	0.365	0.379
Zhejiang	0.292	0.329	0.336	0.320	0.347	0.337	0.365	0.356	0.351	0.380
Anhui	0.093	0.128	0.133	0.124	0.132	0.121	0.134	0.165	0.156	0.187
Fujian	0.182	0.200	0.210	0.225	0.249	0.252	0.267	0.225	0.239	0.269
Jiangxi	0.095	0.107	0.114	0.104	0.126	0.124	0.143	0.132	0.145	0.177
Shandong	0.162	0.174	0.199	0.199	0.224	0.216	0.225	0.194	0.194	0.202
Henan	0.072	0.083	0.079	0.073	0.083	0.090	0.103	0.083	0.103	0.124
Hubei	0.103	0.121	0.130	0.137	0.154	0.184	0.206	0.195	0.202	0.226
Hunan	0.100	0.106	0.104	0.102	0.111	0.109	0.130	0.107	0.125	0.147
Guangdong	0.244	0.258	0.255	0.233	0.279	0.248	0.317	0.366	0.349	0.372
Guangxi	0.070	0.108	0.095	0.087	0.096	0.089	0.106	0.078	0.086	0.109
Henan	0.135	0.190	0.199	0.204	0.219	0.204	0.212	0.188	0.185	0.202
Chongqing	0.172	0.170	0.207	0.215	0.209	0.217	0.247	0.201	0.205	0.208
Sichuan	0.086	0.099	0.093	0.095	0.098	0.092	0.116	0.105	0.118	0.144
Guizhou	0.089	0.080	0.111	0.128	0.141	0.128	0.183	0.142	0.150	0.171
Yunnan	0.080	0.083	0.102	0.105	0.113	0.081	0.106	0.090	0.106	0.117
Xizang	0.244	0.203	0.255	0.307	0.295	0.305	0.348	0.277	0.332	0.320
Shanxi	0.161	0.179	0.203	0.217	0.213	0.196	0.174	0.158	0.173	0.200
Gansu	0.080	0.095	0.094	0.089	0.097	0.090	0.096	0.101	0.093	0.109
Qinghai	0.168	0.200	0.240	0.296	0.218	0.237	0.222	0.184	0.184	0.201
Ningxia	0.190	0.221	0.238	0.212	0.226	0.217	0.232	0.204	0.217	0.233
Xinjiang	0.141	0.209	0.214	0.228	0.245	0.228	0.197	0.176	0.180	0.199
China	0.238	0.240	0.267	0.259	0.278	0.261	0.284	0.264	0.268	0.282
Eastern area	0.346	0.378	0.398	0.393	0.409	0.383	0.382	0.384	0.366	0.375
Central area	0.108	0.126	0.128	0.128	0.134	0.127	0.138	0.129	0.136	0.151
Western area	0.147	0.161	0.181	0.190	0.189	0.183	0.189	0.161	0.169	0.183

forestry productivity and regional economic development and differed significantly. Spatially, the overall coupling coordination between the forestry productivity and regional development level of China was high in the east and south and low in the west and north. By 2018, Shanghai and Tianjin enjoyed the highest coupling coordination degrees and were in the highly coordinated stage and moderately coordinated stage, respectively. Qinghai showed the lowest coupling coordination degree and was in the moderately imbalanced stage. A majority of the provincial regions were in the mildly imbalanced stage, the minimally imbalanced stage, the barely coordinated stage, or the primarily coordinated stage: Hebei, Liaoning, Jilin, Henan, Hunan, Guizhou, and Shaanxi Provinces, and Ningxia and Guangxi and Xinjiang; the Chongqing, Anhui, Jiangxi, Hubei, Sichuan, and Yunnan Provinces; the Beijing, Fujian, Shandong, and Hainan Provinces; and the Tibet, Jiangsu, Zhejiang, and Guangdong Provinces. The coupling coordination between the forestry productivities and the regional economic development levels of Shanghai, Tianjin, the Jiangsu Province, and Zhejiang Province had been maintained at a high level, which was closely associated with a profound local economic basis, substantial workforce support, high sci-tech levels, and macro policies. Although Inner Mongolia, and the Heilongjiang, Jilin, and Liaoning Provinces are famous for abundant forestry resources, the extensive forestry development pattern they followed resulted in low forestry productivity, which together with unsatisfactory economic development confined their coupling coordination to the moderately and mildly imbalanced stages.

Prediction for the coupling coordination degree between forestry productivity and regional economic development

GM (1,1) is used to predict the trend of coupling coordination between forestry productivity and regional economy over the next 5 years based on the coupling coordination degrees between the forestry productivities and the regional economic levels of Chinese provincial regions during 2014 to 2018 obtained above, thereby creating more targeted and practical policy suggestions. As shown in Table 7, $P = 1$, $C = 0.267$ and the mean relative error is 1.194 percent, suggesting that the prediction result satisfies the modeling requirements.

Overall, the coupling coordination degree between forestry productivity and the regional economic development in China exhibits a stable and slowly rising trend. The coupling coordination degree between forestry productiv-

Table 6.—Measurement results of coupling coordination degree during 2009 to 2018.

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Beijing	0.464	0.398	0.441	0.465	0.465	0.436	0.449	0.465	0.452	0.512
Tianjin	0.727	0.682	0.788	0.806	0.819	0.770	0.770	0.803	0.689	0.718
Hebei	0.304	0.281	0.281	0.294	0.293	0.275	0.285	0.289	0.284	0.302
Shanxi	0.261	0.236	0.246	0.267	0.271	0.250	0.273	0.273	0.265	0.288
Inner Mongolia	0.362	0.332	0.333	0.331	0.335	0.331	0.322	0.319	0.288	0.287
Liaoning	0.413	0.401	0.419	0.463	0.465	0.419	0.384	0.345	0.327	0.355
Jilin	0.408	0.371	0.386	0.430	0.423	0.389	0.388	0.383	0.353	0.366
Heilongjiang	0.308	0.316	0.303	0.339	0.325	0.299	0.309	0.306	0.287	0.298
Shanghai	0.954	0.941	0.945	0.931	0.918	0.893	0.901	0.953	0.931	0.928
Jiangsu	0.616	0.599	0.636	0.631	0.647	0.632	0.653	0.653	0.614	0.671
Zhejiang	0.608	0.592	0.615	0.605	0.619	0.602	0.632	0.637	0.609	0.665
Anhui	0.317	0.321	0.354	0.371	0.378	0.362	0.392	0.423	0.408	0.470
Fujian	0.463	0.438	0.457	0.494	0.509	0.487	0.511	0.495	0.482	0.586
Jiangxi	0.315	0.298	0.316	0.324	0.344	0.338	0.382	0.374	0.366	0.422
Shandong	0.417	0.478	0.514	0.524	0.543	0.529	0.548	0.531	0.507	0.545
Henan	0.278	0.259	0.257	0.272	0.284	0.282	0.304	0.296	0.305	0.347
Hubei	0.320	0.300	0.317	0.344	0.356	0.370	0.407	0.411	0.396	0.445
Hunan	0.334	0.311	0.313	0.314	0.322	0.308	0.347	0.329	0.331	0.368
Guangdong	0.581	0.559	0.562	0.554	0.585	0.561	0.617	0.652	0.614	0.663
Guangxi	0.271	0.299	0.279	0.297	0.306	0.299	0.330	0.306	0.296	0.348
Henan	0.484	0.493	0.514	0.413	0.422	0.514	0.539	0.522	0.509	0.550
Chongqing	0.369	0.309	0.350	0.392	0.389	0.389	0.428	0.428	0.418	0.460
Sichuan	0.416	0.409	0.411	0.415	0.418	0.405	0.445	0.438	0.434	0.490
Guizhou	0.292	0.241	0.270	0.307	0.316	0.301	0.372	0.347	0.365	0.396
Yunnan	0.318	0.308	0.317	0.351	0.358	0.308	0.347	0.341	0.337	0.460
Xizang	0.604	0.539	0.593	0.630	0.622	0.620	0.663	0.625	0.631	0.663
Shanxi	0.329	0.298	0.319	0.358	0.356	0.335	0.343	0.340	0.330	0.372
Gansu	0.242	0.223	0.232	0.242	0.248	0.240	0.258	0.279	0.252	0.272
Qinghai	0.231	0.198	0.234	0.299	0.276	0.273	0.283	0.250	0.232	0.266
Ningxia	0.250	0.241	0.255	0.273	0.278	0.277	0.314	0.277	0.274	0.316
Xinjiang	0.329	0.332	0.347	0.380	0.388	0.366	0.368	0.366	0.342	0.373
China	0.483	0.458	0.486	0.487	0.498	0.483	0.510	0.507	0.489	0.532
Eastern area	0.606	0.596	0.622	0.618	0.625	0.610	0.623	0.634	0.601	0.641
Central area	0.326	0.311	0.321	0.342	0.347	0.333	0.358	0.356	0.345	0.385
Western area	0.384	0.368	0.389	0.407	0.406	0.396	0.415	0.402	0.391	0.439

ity and the regional economic development in China will still remain in the barely coordinated stage in the next 5 years. Eastern and western China will be in the primarily coordinated stage and the minimally imbalanced stage, respectively; central China may shift from the mildly imbalanced stage to the minimally imbalanced stage. Specifically, the Hebei, Anhui, Fujian, Henan, Guangdong, Sichuan, Guizhou, Yunnan, and Gansu Provinces are the provincial regions that will progress in coupling coordination, of which the Yunnan Province enjoys the fastest growth and may leap from the minimally imbalanced stage to the primarily coordinated stage. The Liaoning Province, Shandong Province, Qinghai Province, Ningxia, and Xinjiang are the provincial regions that will retrogress. The rest of the provincial regions will remain unchanged. These results suggest that the overall coupling coordination degree between forestry productivity and the regional economic development of China will improve modestly in the next 5 years, but at a low rate; there are even some provincial regions that will retrogress. Therefore, there is still a long way to go to realize mutual promotion and coordinated development between forestry productivity and regional economic development levels in all provincial regions of China.

Conclusion and Suggestions

In this study, the coupling relationship between the forestry productivities and the regional economic development levels of 31 Chinese provincial regions during 2009 to 2018 and its development trend are analyzed and predicted using the coupling coordination degree model based on the coupling characteristics of forestry productivity and regional economic development level from both spatial and temporal perspectives. Research findings suggest that the coupling coordination between forestry productivity and the regional economic development of China is mostly in the minimally and mildly imbalanced stages; although the coupling coordination between the forestry productivity and the regional economic development level of each provincial region showed either an upward or downward trend, it maintains a positive momentum; and spatially, the overall coupling coordination between the forestry productivity and regional development level of China was high in the east and south and low in the west and north.

Based on the above analysis, the following suggestions for boosting positive and coordinated interactions between forestry productivity and regional economic development are proposed: Firstly, it is crucial to create forestry economic development plans for various forest zones to develop forest resources that are in line with local

Table 7.—GM (1,1) predictions for 2019 to 2023.

	2019	2020	2021	2022	2023
Beijing	0.508	0.526	0.546	0.566	0.588
Tianjin	0.688	0.668	0.649	0.632	0.617
Hebei	0.299	0.303	0.307	0.312	0.317
Shanxi	0.280	0.283	0.286	0.289	0.293
Inner Mongolia	0.271	0.259	0.248	0.237	0.226
Liaoning	0.313	0.301	0.291	0.281	0.271
Jilin	0.345	0.335	0.326	0.317	0.308
Heilongjiang	0.284	0.278	0.272	0.267	0.262
Shanghai	0.956	0.969	0.984	1.001	1.021
Jiangsu	0.638	0.636	0.636	0.635	0.635
Zhejiang	0.642	0.646	0.652	0.657	0.664
Anhui	0.477	0.501	0.528	0.556	0.585
Fujian	0.549	0.569	0.592	0.617	0.643
Jiangxi	0.403	0.414	0.425	0.438	0.451
Shandong	0.510	0.504	0.499	0.494	0.490
Henan	0.340	0.355	0.371	0.389	0.407
Hubei	0.431	0.440	0.450	0.460	0.471
Hunan	0.350	0.356	0.362	0.369	0.376
Guangdong	0.661	0.672	0.682	0.693	0.704
Guangxi	0.313	0.315	0.318	0.322	0.326
Henan	0.521	0.520	0.520	0.521	0.522
Chongqing	0.447	0.455	0.463	0.472	0.481
Sichuan	0.474	0.487	0.501	0.516	0.532
Guizhou	0.383	0.392	0.402	0.412	0.423
Yunnan	0.449	0.493	0.544	0.600	0.663
Xizang	0.631	0.630	0.630	0.630	0.630
Shaanxi	0.356	0.362	0.370	0.378	0.386
Gansu	0.275	0.281	0.288	0.297	0.307
Qinghai	0.223	0.213	0.205	0.197	0.190
Ningxia	0.277	0.274	0.273	0.272	0.271
Xinjiang	0.352	0.350	0.347	0.346	0.344
China	0.511	0.513	0.517	0.521	0.525
Eastern area	0.624	0.625	0.626	0.627	0.628
Central area	0.370	0.376	0.384	0.392	0.400
Western area	0.413	0.417	0.422	0.427	0.433

conditions with a prerequisite of sustainable development. The concrete measures include regulating factor input allocation based on marginal contributions from various production factors; combining governmental fiscal investment and social investment and perfecting the forestry fund supervision mechanism; establishing and perfecting a sci-tech support system to improve the quality of forestry practitioners; improving forestry supporting facilities and creating a natural environment appropriate for forest growth. Secondly, confronted with the new situation, challenges, and opportunities that the new normal brings about, it is advisable to strengthen investment and support for emerging industries and actively promote structural reform; increase investment in general education and science education by introducing science education programs and hastening the construction of competitive scientific workforce training institutions; and encourage developed regions to help underdeveloped regions to ensure that they develop simultaneously in a normalized, scientific, and institutionalized way. In addition, interregional in-depth cooperation should take place to share quality resources, complement each other's advantages, and ultimately improve their respective economic levels. Moreover, governments are supposed to serve roles in policy guidance and fiscal support to create a stable environment that ensures coordinated development between forestry and the regional economy. They should not only give full play to the boosting effect of forestry productivity on regional economic development, but also effectively improve the regional economy's support and resource allocation for forestry productivity in the environment, education, infrastructure, and workforce.

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