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Coordinated Development and Sustainability of the Agriculture, Climate and Society System in China: Based on the PLE Analysis Framework

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Abstract: Nowadays, frequent climate extremes exert a serious impact on agricultural production and social development, which is seldom studied in the previous literature. Production–Living–Ecological (PLE) is a useful analysis framework, and China is a suitable model for such study. This paper takes the Huai River Eco-Economic Belt (HREB), an important agricultural zone in China, to study the relationship among agricultural production (P), society (L), and climate change (E), which is referred to as APLE. This paper constructs a coupled coordination evaluation index system for the APLE system and uses coupling coordination degree models and geographic detector to study the spatial and temporal evolution of the coordinated development of 34 counties (cities) in the HREB from 2009 to 2018. The results show the following: (1) The development of the agricultural subsystem and the social subsystem formed a "scissors difference" from 2009 to 2014, and the three subsystems showed a slight upward trend during 2014–2018. (2) The coupling and coordinated development of the APLE system in the HREB was generally stable, and the coupling coordination degree was improved from low-grade and slightly uncoordinated to barely and primarily coordinated. Furthermore, the spatial differentiation of the coupling coordination degree shows a clear pattern of being high in the southeast and low in the northwest. (3) The main influencing factors are the drought and flood protection rate, the effective irrigation rate, the per capita electricity consumption in agriculture, the number of beds in healthcare facilities per 10,000 people, the per capita disposable income of urban residents, the annual average temperature, and the annual precipitation. (4) The spatial–temporal evolution of the coupling and coordinated development of the APLE system is the result of the comprehensive effect of internal driving forces such as food security, the consumption level of rural residents, and the development level of urbanization construction, and external driving forces such as government public welfare and natural conditions.

Keywords: agriculture; climate; society; coupling coordination; spatial—temporal evolution; driving mechanism

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1. Introduction

Regional sustainable development is a crucial issue of great concern among countries worldwide and a basic requirement for the achievement of the SDGs at regional scales. As a traditional agricultural country, the development of Chinese agriculture plays a fundamental role in the sustainable development of the regional economy and society [1]. Since the reform and opening-up, China has effectively promoted the process of agricultural modernization through agricultural technology advancement and land system reform [2,3]. As shown by the statistics, China's grain production in 2021 was as high as 682.85 million tons, and the grain yield was as high as 387 kg/mu. Food security is effectively guaranteed, and agricultural productivity is significantly improved. On this basis, the living standards of rural residents have also been significantly improved. From 2000 to 2021, the rural per capita disposable income rapidly increased by RMB 2282 to RMB 18,931, and the per capita consumption expenditure also increased by RMB 1714 to RMB 15,916. More importantly, China eliminated absolute poverty in 2020. China's rapid development of agricultural production and social living spaces is well recognized throughout the world.

However, the continued deterioration of ecological spaces is a serious challenge to the sustainability of agriculture, especially regarding the impact of climate change. In recent years, anthropogenic climate changes have placed tremendous pressure on global food systems [4,5], not only significantly reducing food production and agricultural productivity growth [6,7], but also seriously threatening the livelihoods of smallholder farmers and increasing rural poverty [8]. Meanwhile, in 2021, the Chinese government promulgated its 14th Five-Year Plan, which clearly set out the important goal of promoting coordinated regional development, and stated that important functional regions should be used as supports to maintain national food security and ecological safety. The PLE framework has been widely used and recognized in regional sustainable development studies. PLE refers to the functions or characteristics of different types of territorial space formed under the joint influence of its internal components and external factors on the production and living activities of residents [9]. There are equivalents among the 17 SDGs from the perspective of economy, society, environment with production space, living space, and ecological space, respectively. Balancing the relationship between production, life, and ecology is not only necessary for the construction of an ecological civilization, but also necessary for the harmonious coexistence between man and nature. Therefore, based on the PLE framework, it is quite important to explore the spatial and temporal evolution and drivers of coupling and coordinated development among agricultural production (Production), society (Living), and climate change (Ecological) in China under the dual needs of solving real-life problems and achieving national strategic goals.

The Huai River Eco-Economic Belt (HREB) is a very suitable sample area to study the coupling and coordinated development among the three subsystems of PLE. Since ancient times, the HREB has been an important agricultural production area in China. With 11% of the country's arable land, it contributes 17% of food production and 25% of commercial food for the country [9]. However, due to the hazardous weather conditions and anthropogenic activities, the HREB suffers from severe pollution problems [10,11] and extreme climate problems such as frequent floods, droughts, and storm surges [12,13]. For a long time, these problems have had a profound impact on the production and livelihoods of people living along the HREB [14]. According to statistical data, in 2020, the population suffering from flooding in Anhui Province was 10,463,300, and 14 people died. The area of crops affected was 1221.31 hectares, and the area of extinction accounted for 32.24%. At the same time, the direct economic losses caused by floods were up to 60.065 billion yuan, including 24.158 billion yuan of infrastructure losses. Therefore, considering the important agricultural production function of the HREB, the construction of an agricultural PLE (APLE) framework for coupled coordination studies will help the HREB and the broader region to achieve regional sustainable development.

Based on the HREB county data from 2009 to 2018 in Anhui Province, this paper constructs a coupling and coordination evaluation index system and uses the coupling coordination degree model and geographic detector technique to solve the following two questions: (1) What is the degree of coupling and coordination of the three subsystems of APLE, and what are the pattern changes in time and space? (2) What are the influencing factors and driving mechanisms of regional sustainable development? By answering these questions, the research goal of this paper is to construct a coupled and coordinated development path in the APLE system, with a view to providing policy references for the pursuit of sustainable development in the HREB.

2. Literature Review

Exploring the coupling and coordinated development of the APLE system requires a deep understanding of the relationship among the three subsystems of agriculture, climate, and society: (1) The climate and agriculture subsystem: In the long term, climate change has a significant negative impact on cereal crop yields in China [15,16]. In particular, agricultural production is more sensitive to climate change in major grain-producing areas [17,18]. At the same time, the excessive consumption of fertilizers, pesticides, and fossil energy caused by agricultural production also increases agricultural carbon emissions, thus further exacerbating the threat of climate change [19]. (2) The climate and social subsystem: Climate change and frequent climate extremes can increase rural poverty, resulting in lower incomes and adverse effects on the health of the population [20,21]. At the same time, the lack of education, healthcare, and employment opportunities makes it difficult for poor people to cope with the risks posed by climate change, and thus makes them more likely to fall into the poverty trap [22,23]. (3) The agriculture and social subsystem: Sustainable agricultural development is the basis for sustainable social development. For a long time, China's agricultural sector has provided an important material basis for sustainable social development [24]. At the current stage, changes in urban–rural relations have further opened up channels for factor flows between the agricultural subsystem and the social subsystem, forming a close relationship in which they are mutually complementary [25].

Many scholars have conducted in-depth studies on the sustainable development of the HREB, and the existing studies are mainly focused on the following directions: (1) The regional high-quality development path: studies have been conducted to construct a regional high-quality development path that includes macro strategies such as increasing innovation and technological progress, promoting regional synergistic development, and creating a national ecological corridor [26,27]. (2) Agricultural development: Studies have been conducted to discuss the agricultural production base of the HREB and point out the objective problems of its poor ecological carrying capacity and serious vegetation degradation [28–30]. On this basis, the current realistic problems in agricultural development, including the lack of human capital, serious agricultural surface pollution, and cultivated land fragmentation, have been further analyzed [9,31,32]. (3) Climate change: some scholars have analyzed the causes and spatial and temporal characteristics of extreme climate events such as droughts and floods in the HREB [12,33,34]. (4) Social development, which mainly includes the evaluation of the urban competitiveness and industrial development level of the HREB [35,36].

To summarize, most of the existing studies focus on a single perspective, such as agriculture, climate, or economy, and there are few studies from a coupled system perspective, and even fewer studies exploring the coupling of the three systems from the perspective of "PLE". However, regional agricultural production, climate change, and social life are closely related and mutually constrained, especially in the HREB, which has unique climatic conditions. Thus, in this paper, the three subsystems of agriculture, climate, and society are included in the PLE analysis framework, forming the APLE, in order to provide sufficient theoretical support in exploring the coupling and coordinated development of agricultural production, life, and the ecosystem.

3. Research Design

This paper is divided into five sections. Section 1 provides an introduction to the research. Section 2 provides a rationale for the research based upon an extensive literature review, and Section 3 describes the study area and the methodology employed, as well as the sources of data used. Section 4 presents and discusses the empirical results, whereas Section 5 presents the conclusions and policy recommendations.

3.1. Study Area

The Huai River is located in the central and eastern regions of China, with the Yellow River in the north and the Yangtze River in the south, and the main stream flows through the four provinces of Henan, Hubei, Anhui, and Jiangsu. It is known as the "mother river" of people along the Huai River. Historically, the Yellow River has repeatedly encroached on the estuary of the Huai River, resulting in silt accumulation and flooding, which has had a serious impact on the production and lives of residents along the coast. However, this also formed the Huang-Huai Great Plain, which has fertile soil and is suitable for agricultural production. The area of cultivated land in the HREB is 914.7 million hectares, accounting for 11 percent of the national total. Its grain output accounts for one-sixth of the national total, and commodity grain accounts for one-fourth of the national total, thus providing a solid guarantee for national food security. The Huaihe River has been a natural dividing line between north and south China since ancient times. It is a warm temperate zone with a subhumid monsoon climate, with characteristics of winter and spring droughts with less rain, and summer and autumn sultry and rainy. High and low temperatures and early waterlogging change sharply. In order to alleviate the frequent flood occurrence of the Huai River and the uneven distribution of water resources, a series of water conservancy facilities, such as the Bengbu Gate and Wangjiaba, have been built and put into use, but, with the acceleration of the process of agricultural modernization, environmental pollution and ecological damage are not uncommon, and unique abnormal weather occurs from time to time. By the end of 2017, the permanent population of the HREB was 146 million, accounting for 10.50% of the total population. Per capita GDP was approximately 46,233 yuan, lower than the national average. The production quality index and quality of life index have significant differences within the region. The high-level and medium–high-level areas are mainly distributed in the middle and downstream areas, while the medium–low-level and low-level development areas are mainly distributed in the upstream areas, which are closely related to the urban scale, economic size, development mode, geographical location, and traffic conditions.

In October, 2018, the successful approval of the "Development Plan for the HREB" fully reflected the development concept of "innovation, coordination, green, openness, and sharing" and raised the development of cities along the Huai River to a new height. The high-quality development of the HREB is conducive to the comprehensive deployment of the three major strategies of the Yangtze River Delta integration, the Anhui River Urban Belt, and the Central Plains Economic Zone. It is important for the expansion of the new pattern of opening up to the outside world and provides waterway advantages for the construction of the "Belt and Road". Eight cities in the Anhui Province—Bengbu, Huainan, Fuyang, Lu′an, Bozhou, Suzhou, Huaibei, and Chuzhou—are located along the Huaihe River belt. They are rich in natural resources, and are important grain and oil production bases, animal husbandry production advantage areas, and coal energy bases in China, as well as agricultural population-intensive areas and economically and ecologically fragile areas (as shown in Figure 1).

3.2. Index System

Agriculture is closely related to farmers' lives and the ecological environment. Therefore, on the basis of production indicators, further indicators related to farmers' lives and rural ecology are added. Specifically, this includes indicators of agricultural production inputs and outputs, indicators of rural living and consumption levels, and indicators of environment-friendly agricultural inputs. In the climate system, on the basis of the commonly used temperature and humidity, the meteorological statistical indicators provided by the Anhui Meteorological Information Center were added, including altitude, sunshine, freezing, wind, etc. The social system itself is a comprehensive concept, and this paper selects indicators of urban–rural integration, residents' income and consumption, education and cultural services, healthcare, and social security based on the development goals of "having access to labor, housing, education and medical care" proposed in the report of the 19th National Congress. Therefore, following the principles of science, comprehensiveness, and systematization, and drawing on previous research results, this paper constructs a coupling and coordinated evaluation index system consisting of 24 indicators (Table 1). Regarding the weights of each indicator, in this paper, after standardizing the original panel data, the entropy value method is used to assign weights to each indicator, which can effectively avoid the subjectivity of human evaluation.

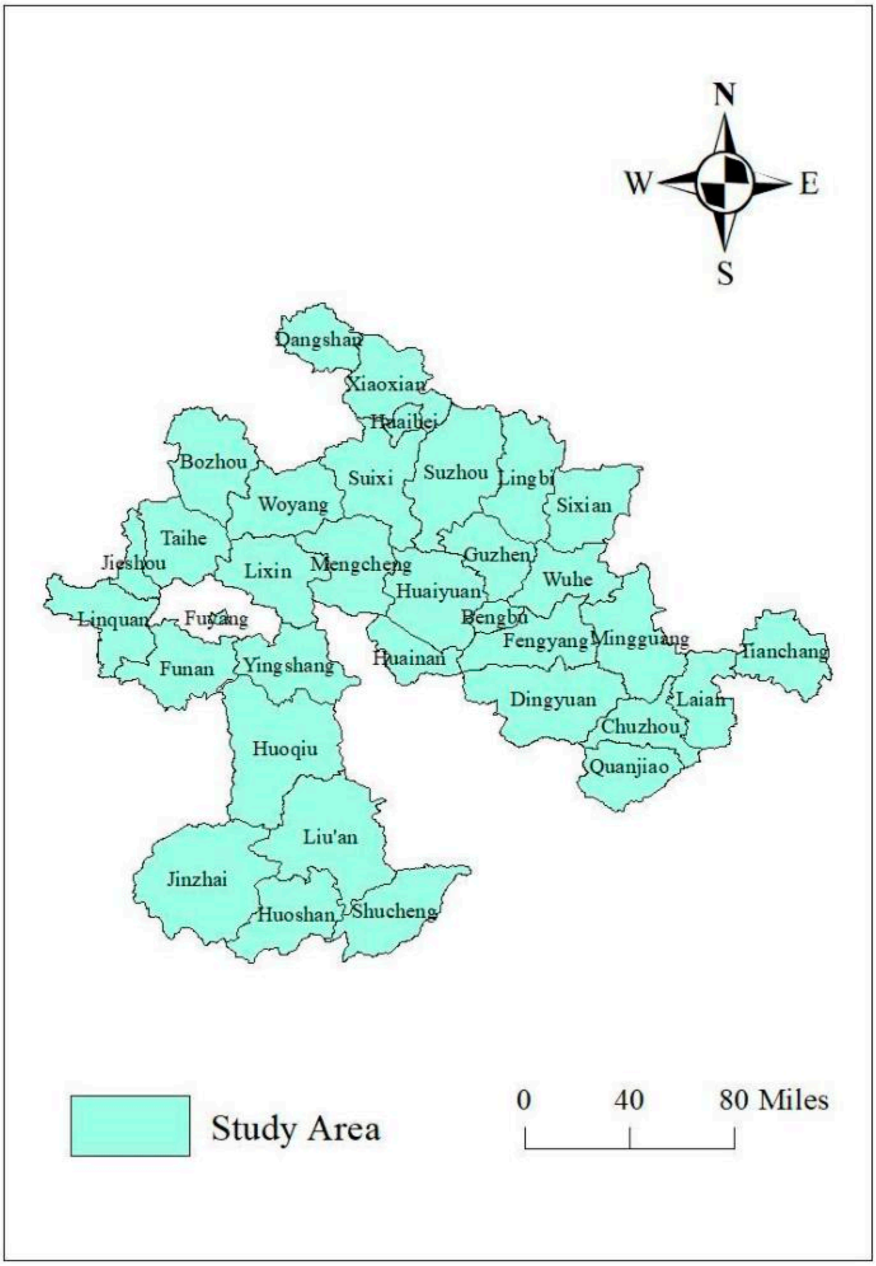

Figure 1. The location of the HREB.

3.3. Data Resource

This study uses data from 34 counties in the HREB from 2010 to 2019. Data for the agriculture and society subsystems were collected from the Anhui Provincial Statistical Yearbook, the Anhui Rural Statistical Yearbook, and the statistical yearbooks of each county. The data of the climate subsystem were obtained from the annual statistics of meteorological stations set up by the Anhui Meteorological Information Center in each county. In order to improve the validity of the panel data, this paper used the weighted average method and trend extrapolation method to fill in a small amount of missing data.

Table 1. Coupling coordinated evaluation index system for APLE system.

Subsystem	Indicator Layer	Metric Definition	Indicator Direction	References
Agriculture (Production)	AO	Agricultural output per capita (10,000 yuan)	+	Li et al., 2022 [37] Deng et al., 2022 [38]
	CA	Cultivated area per capita (hectare)	+	Wang et al., 2022b [39]
	EI	Effective irrigation rate (%)	+	Chen et al., 2022 [40]
	DFPY	Drought and flood protection yield (%)	+	Yang et al., 2022 [41]
	MP	Mechanical power per capita (KW)	+	Chen et al., 2019 [42]
	EC	Per capita electricity consumption in agriculture (degree)	+	Wang et al., 2022b [39]
	FCF	Fertilizer consumption per unit of farmland (ton)	+	Chen et al., 2019 [42]
	FCS	Per capita food crops are sown (hectare)	+	Cai et al., 2021 [43]
Society (Living)	IFA	Per capita investment in fixed assets (10,000 yuan)	+	Zhang, 2021 [44] Yang et al., 2022 [41]
	TRS	Total retail sales of consumer goods per capita (10,000 yuan)	+	Wang et al., 2022 [45]
	FR	Fiscal revenue per capita (10,000 yuan)	+	Tang et al., 2022 [46]
	UR	Level of urbanization (%)	+	Gan et al., 2022 [47]
	BHF	Number of beds in healthcare facilities per 10,000 people	+	Zhang et al., 2021 [44]
	DIU	Per capita disposable income of urban residents (10,000 yuan)	+	Liu et al., 2022a [48]
	EXP	Expenditure on science, education, culture, and public health per capita (10,000 yuan)	+	Fan et al., 2019 [49]
Climate (Ecological)	AL	Altitude (m)	–	Liu et al., 2022b [50]
	AAT	Average annual temperature (°C)	+	Liu et al., 2022b [50]
	AP	Annual precipitation (mm)	+	Liu et al., 2022b [50]
	NDAR	Number of days of annual rainstorms (day)	–	Wang et al., 2018 [51] Jia et al., 2018 [52]
	RD	Rainy days per year (day)	+	Paramesh et al., 2022 [53]
	AARH	Average annual relative humidity (%)	+	Liu et al., 2022c [54]
	ASH	Annual sunshine hours (h)	+	Liu et al., 2022c [55]
	MAPD	Maximum annual permafrost depth (cm)	+	Wang et al., 2019a [33]
	AAWS	Average annual wind speed (m/s)	+	Wang et al., 2019a [33]

3.4. Methods

3.4.1. Coupling Degree Model

Coupling refers to the linkage phenomenon between two or more systems or forms of motion that interact with each other and influence each other [43,56]. The coupling degree model is shown in Formula (1), where C is the degree of coupling of the system (value range 0~1); $f(x)$, $g(y)$ and $h(z)$ represent the combined scores of the 3 subsystems of APL obtained by the entropy method of calculation.

$$C = \left\{ \frac{f(x) \times g(y) \times h(z)}{\left[\frac{f(x)+g(y)+h(z)}{3}\right]^3} \right\}^{\frac{1}{3}} \quad (1)$$

3.4.2. Coupling Coordination Degree Model

The coupling degree reflects the interaction and degree of interaction of the APLE system, but it is impossible to judge the level of coordinated development. Therefore, the three-system coupling coordination model is further constructed as follows:

$$D = \sqrt{C \times T} = \alpha f(x) + \beta g(y) + \gamma h(z) \quad (2)$$

where D indicates the degree of coupling coordination, C indicates the degree of coupling, T represents a composite evaluation index of 3 subsystems, and α, β, and γ represent the weights of the agriculture subsystem, climate subsystem, and society subsystem, respectively. It is noteworthy that this paper does not use the equal weight method to assign values to them. This is due to the fact that, considering the HREB as an important functional agricultural production area in China, the sustainable development of agriculture is a more important goal of the HREB. Therefore, with reference to previous studies [44,50,57], we assign α, β, and γ as 0.4, 0.3, and 0.3, respectively. The value range of D is [0,1], and according to the existing research [58–60], this paper classifies values in this range into 10 categories (as seen in Table 2).

Table 2. Classification of coordination level.

Degree	Coordination Level	Degree	Coordination Level
[0.0–0.1]	Extremely uncoordinated	(0.5–0.6]	Barely coordinated
(0.1–0.2]	Severely uncoordinated	(0.6–0.7]	Primarily coordinated
(0.2–0.3]	Moderately uncoordinated	(0.7–0.8]	Moderately coordinated
(0.3–0.4]	Low-grade uncoordinated	(0.8–0.9]	Highly coordinated
(0.4–0.5]	Slightly uncoordinated	(0.9–1.0]	Excellently coordinated

3.4.3. Geographical Detectors

Geographic detectors are tools for detecting spatial differentiation and its formation mechanism, and they are widely used due to their advantage of being less constrained by the premise; they primarily include differentiation and factor detection, interaction detection, risk zone detection, and ecological exploration [61]. After discretizing the index data and using the Jenkins natural breakpoint method, the first two detectors are mainly used to evaluate the agricultural–social–meteorological environment of the HREB. The q value is measured and calculated as in Formulas (3) and (4):

$$q = 1 - \frac{\sum_{h=1}^{L} N_h \sigma_h^2}{N\sigma^2} = 1 - \frac{SSW}{SST} \quad (3)$$

$$SSW = \sum_{h=1}^{L} N_h \sigma_h^2, \quad SST = N\sigma^2 \quad (4)$$

where h is the stratum of the variable or factor, taking values from 1 to L; N_h and N are the number of cells in stratum h and the whole area, respectively; and σ_h^2 and σ^2 are the variances. SSW and SST are the within sum of squares and total sum of squares.

Interaction detection is used to identify the interaction between different risk factors, i.e., whether the effects of factors on spatial differentiation are independent of each other or the two factors act together to increase or weaken the explanatory power of the effects. The calculation step is to calculate the q values of two factors: $q(X_1)$ and $q(X_2)$ respectively, and then calculate the q values of their interaction, namely, $q(X_1 \cap X_2)$, and compare $q(X_1)$, $q(X_2)$ with $q(X_1 \cap X_2)$ [62].

4. Model Regression Results and Analysis

4.1. The Overall Situation of the Development of Each Subsystem

The average value of the development quality of the agricultural, climatic, and social systems from 2009 to 2018 is shown in Figure 2. In general, the development level of each subsystem in the past decade has shown obvious phasic changes. From the perspective of the agricultural subsystem, from 2009 to 2014, there was a trend of an inverted "V"-type plus "V"-type change of first rising, then falling, and then rising again. The change was most pronounced between 2011 and 2012, with the mean dropping sharply from 0.940 to 0.205. This year, there was a rare phenomenon of drought in autumn, winter, and spring, and the acceleration of urbanization caused a sharp reduction in agricultural employment, and agricultural development encountered difficulties. From 2012 to 2013, the average temperature was higher than usual, the precipitation was moderate, the moisture was suitable, the summer grain production increased, the new water-saving irrigation area was further expanded, and the agricultural development achieved quality and efficiency, and the development was relatively stable thereafter—the value slowly rose from 0.205 to 0.239.

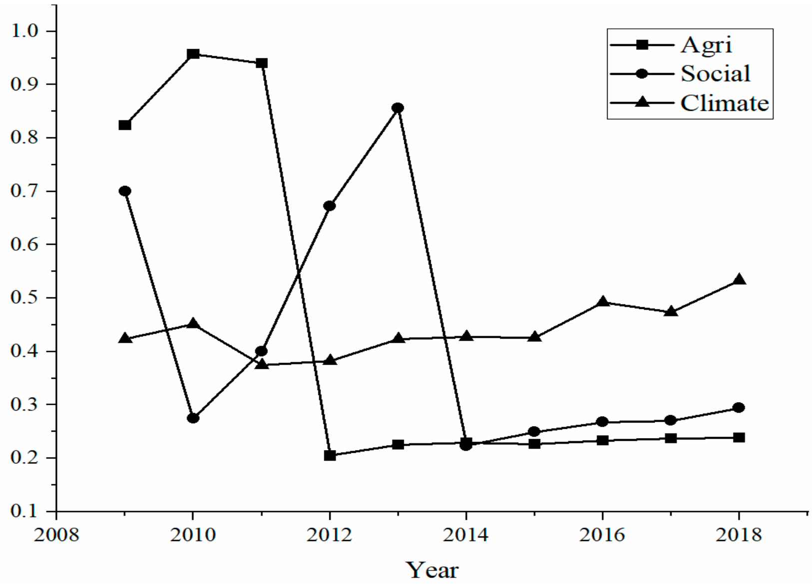

Figure 2. Average of the 3 subsystems of APLE in the HREB from 2009 to 2018.

From the perspective of the social subsystem, the average change between 2009 and 2014 fluctuated greatly, showing a "V"-type plus inverted "V"-type change trend of first falling, then rising, and then falling, and showing a slight increase in 2014–2018. Affected by the 2008 global financial crisis and the 2009 domestic swine flu epidemic, the price index rose, the real purchasing power of residents declined, and the average value of the social system decreased significantly between 2009 and 2010. From 2010 to 2011, the technological transformation of industrial and information industries was accelerated, investment in the financial industry doubled, the sales of commercial housing were notable, the growth of medical, health, and education expenditures accelerated, the urbanization rate was further improved, and the overall social development trend was good. From 2012 to 2013, the manufacturing industry developed rapidly, the momentum of real estate development investment was fierce, and the expenditure on culture, sports, and media, as well as energy conservation and environmental protection increased rapidly; moreover, the demand for high quality of life was rising. From 2013 to 2014, the world's economic recovery was difficult and tortuous. The downward pressure on the domestic economy was highlighted, the growth rate of fixed asset investment slowed down, the development of secondary and tertiary industries was weak, real estate investment slowed down, and the quality of social system development fell again.

Throughout 2009–2014, a "scissor difference" formed between the quality of two subsystems, agriculture and social. This was due to the contradictory conflict between the urbanization of the rural population and the process of agricultural modernization, which led to a negative phase correlation between agricultural and social system development. From 2014 to 2018, the overall temperature and precipitation were higher than usual, and the meteorological value increased by 10.611%. The total power of agricultural machinery and agricultural electricity consumption showed an increasing trend, and the process of agricultural scale and mechanization was accelerated. The amounts of chemical fertilizers and pesticides applied showed a downward trend, and green agriculture developed rapidly. The two-way circulation of agricultural products into the city and industrial products transported to the countryside became more convenient. An agricultural science and technology innovation system that closely integrates production, education, and research was established. The degree of agricultural industrialization, information dissemination, and science and technology steadily improved, and the level of agricultural development steadily advanced. Investment in industrial technological transformation and infrastructure investment grew rapidly, and the overall level of social development rose by 7.039%. In

2014, the quality of the development of the APLE systems was stable and balanced, and the coordination and mutual promotion began to emerge.

4.2. Analysis of Spatial—Temporal Evolution of the Coupling Coordination Degree of the APLE System

4.2.1. Time Change Characteristics of the Coupling Coordination Relationship

Following the overall analysis described above, this study further describes the time change characteristics of the coupling coordination relationship from the county level of 34 samples in the HREB (Table 3). Over time, the coupling coordination degree of the three subsystems in most counties shows a fluctuating upward trend—that is, from low-grade and slightly uncoordinated in 2009 to barely and primarily coordinated in 2018. However, there is still much room for improvement. In particular, by 2018, 8 counties had reached the primarily coordinated level and 22 counties had reached the barely coordinated level, but there were still 4 counties in the slightly uncoordinated category, namely Lingbi County, Xiao County, Lixin County, and Guzhen County. In terms of growth, Linquan County and Funan County rose by more than 20%; Lixin County, Huoqiu County, and Fengyang County rose by less than 5%.

Table 3. Results of coupling coordination degree by county.

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Bengbu	0.490	0.495	0.498	0.520	0.544	0.568	0.580	0.600	0.608	0.668
Bozhou	0.416	0.420	0.431	0.459	0.501	0.499	0.513	0.546	0.540	0.555
Chuzhou	0.492	0.595	0.568	0.562	0.622	0.607	0.586	0.616	0.610	0.630
Yanshan	0.417	0.428	0.442	0.455	0.476	0.487	0.465	0.516	0.523	0.526
Dingyuan	0.481	0.468	0.474	0.509	0.526	0.541	0.567	0.575	0.579	0.601
Fengyang	0.509	0.453	0.465	0.466	0.491	0.493	0.502	0.519	0.524	0.539
Funan	0.359	0.367	0.394	0.414	0.429	0.473	0.504	0.530	0.543	0.575
Fuyang	0.416	0.426	0.416	0.435	0.475	0.499	0.534	0.514	0.540	0.600
Guzhen	0.347	0.368	0.382	0.396	0.422	0.446	0.449	0.467	0.438	0.485
Huaiyuan	0.426	0.439	0.442	0.465	0.496	0.500	0.532	0.552	0.513	0.555
Huaibei	0.503	0.507	0.522	0.532	0.560	0.557	0.552	0.592	0.595	0.600
Huainan	0.540	0.554	0.555	0.574	0.588	0.575	0.609	0.591	0.626	0.643
Huoqiu	0.508	0.434	0.441	0.455	0.463	0.482	0.467	0.498	0.509	0.548
Huoshan	0.477	0.496	0.495	0.514	0.524	0.551	0.549	0.572	0.563	0.587
Jieshou	0.413	0.426	0.428	0.443	0.433	0.463	0.511	0.546	0.576	0.599
Jinzhai	0.421	0.437	0.439	0.453	0.480	0.504	0.508	0.543	0.540	0.536
Lai'an	0.494	0.506	0.517	0.528	0.605	0.601	0.620	0.644	0.623	0.668
Lisin	0.453	0.366	0.372	0.454	0.497	0.470	0.482	0.500	0.482	0.496
Linquan	0.311	0.326	0.339	0.351	0.402	0.446	0.481	0.471	0.500	0.529
Lingbi	0.347	0.361	0.373	0.395	0.426	0.502	0.443	0.483	0.487	0.500
Lu'an	0.462	0.480	0.555	0.579	0.553	0.574	0.571	0.568	0.564	0.577
Mencheng	0.476	0.422	0.440	0.457	0.506	0.530	0.532	0.556	0.549	0.563
Mingguang	0.414	0.467	0.481	0.492	0.523	0.528	0.532	0.556	0.560	0.577
Quanjiao	0.505	0.516	0.511	0.526	0.562	0.571	0.585	0.608	0.605	0.619
Shucheng	0.435	0.432	0.434	0.453	0.447	0.481	0.483	0.522	0.510	0.521
Si	0.416	0.400	0.426	0.468	0.489	0.470	0.463	0.497	0.509	0.529
Suzhou	0.429	0.429	0.444	0.463	0.463	0.464	0.467	0.522	0.502	0.514
Suixi	0.437	0.445	0.457	0.475	0.501	0.561	0.525	0.547	0.540	0.557
Taihe	0.373	0.385	0.385	0.394	0.417	0.448	0.490	0.506	0.533	0.542
Tencho	0.539	0.533	0.537	0.551	0.584	0.589	0.609	0.631	0.620	0.638
Guoyang	0.452	0.390	0.395	0.414	0.511	0.497	0.503	0.525	0.526	0.533
Wuhe	0.416	0.437	0.462	0.468	0.478	0.503	0.522	0.551	0.527	0.541
Xiao	0.391	0.398	0.383	0.415	0.420	0.451	0.437	0.478	0.485	0.496
Yingshang	0.399	0.404	0.421	0.434	0.454	0.473	0.511	0.515	0.522	0.537

The lowest level of coupling coordination occurred between 2009 and 2011 in most regions, and coupling coordination reached its highest level in 2016–2018 after fluctuating growth. Taking Huaibei City as an example, the coupling coordination degree of the three subsystems has increased from 0.503 to 0.600 in the last decade, and it has passed from barely coordinated to primarily coordinated. During 2009–2013, Huaibei City had a mild climate, with sufficient sunshine and moderate precipitation. In the agricultural system, grain production was abundant for four consecutive years, and new business entities such as special industrial bases and leading agriculture-related enterprises expanded rapidly. In the social system, the local government actively promoted ecological demonstration projects, which greatly improved the quality of the urban environment. In 2013–2015, the growth rate of fixed asset investment and total retail sales of social consumer goods in Huaibei City slowed down, and the contradiction between financial revenue and expenditure became prominent. In particular, the production and operation difficulties of coal enterprises intensified, and the development of social systems encountered greater obstacles, which resulted in a decline in the level of coupling and coordination among the three subsystems. From 2015 to 2018, the temperature in Huaibei City was higher than normal, with sufficient heat, the sown area of grain expanded year after year, and the total grain production increased continuously. At the same time, the local government increased the construction of drainage and irrigation infrastructure, which led to the alleviation of the water shortage problem. The three subsystems achieved mutual promotion and orderly coordinated development in this period.

The system coupling coordination degree in some regions reached the highest level during 2012–2015. Taking Lingbi County as an example, the coupling coordination degree increased from 0.3465 to 0.5021 during 2009–2014. This is due to the fact that the local government of Lingbi County took the special agricultural upgrading project as the core, promoted land transfer and rural road transportation system in an orderly manner, which greatly improved the development of the agricultural system. In the social system, the fixed asset investment in Lingbi County grew faster and the consumer market continued to be active. At the same time, the local government's financial expenditure on environmental protection, social security, and housing security increased further. As a result, the county's coupling coordination reached its peak in 2014. However, in 2015, the county experienced extreme weather, such as droughts and floods, and this resulted in severe crop damage. As a result, the development of the agriculture and climate subsystems was hindered, leading to a significant decline in the coupling coordination of the three subsystems. However, in 2016–2018, due to the significant reduction in extreme weather, the farmland soil and water conservation capacity of Lingbi County was effectively improved, the use of chemical fertilizers and pesticides was significantly reduced, and ecological recycling agriculture was developed. Meanwhile, the county's fiscal revenue grew at a considerable rate, education, employment, and social security expenditures continued to grow, and residents' living standards were further improved. Therefore, the coupling coordination of the 3 subsystems increased in this period.

4.2.2. Spatial Evolution Trend of Coupling Coordination

This paper selected the results for 2009, 2013, and 2018, and used the ArcGIS10.8 software to map the evolution of the spatial pattern of the coupling and coordination degree of the APLE system in the HREB (Figure 3). It can be seen that the coupling coordination degree of the APLE system in 34 counties shows a fluctuating upward pattern, and there is significant imbalance between counties.

In 2009, the coupling and coordination degree of each regional system was generally low. Specifically, 20.5% of the counties were low-grade uncoordinated, concentrated in the eastern and western parts of the HREB. Counties clustered around the two major metropolises of Hefei and Nanjing, not only had a good development base, but also benefited from the rapid development of large metropolises. Among them, Huainan City had the highest coupling coordination degree of 0.540. The remaining 61.7% of the counties were slightly uncoordinated.

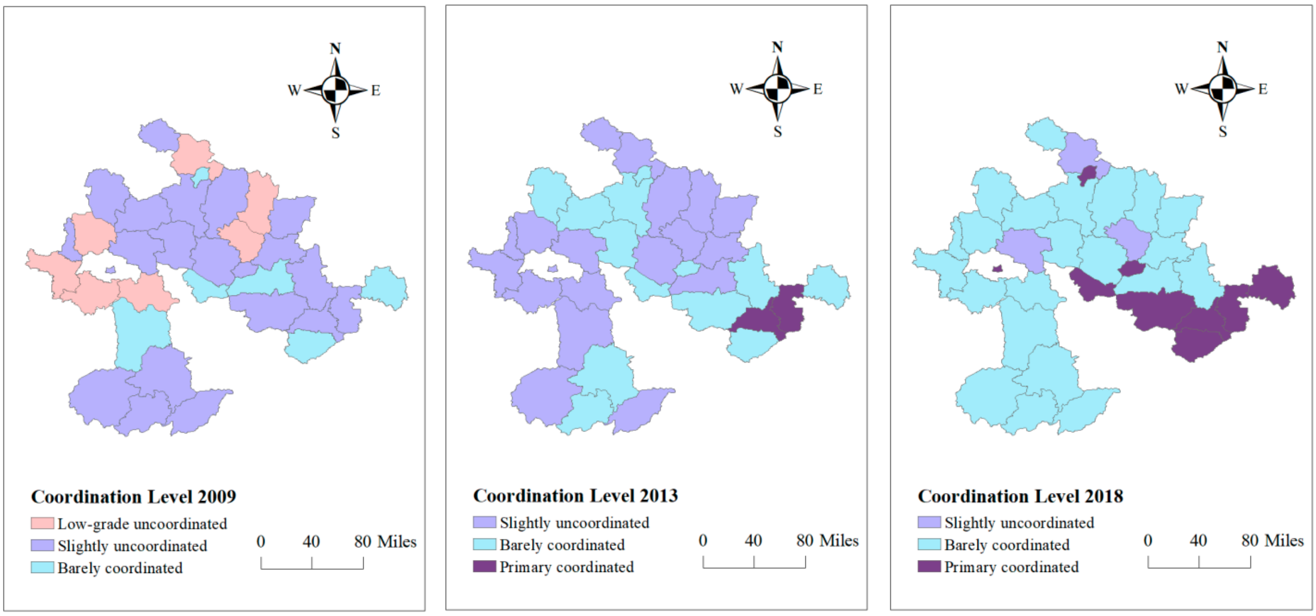

Figure 3. Spatial pattern evolution of coupled coordination degree of APLE system.

In 2013, there was a significant increase in the coupling coordination degree of the APLE system in each region, with no counties considered low-grade uncoordinated. In particular, 55.8% of the counties were slightly uncoordinated and 38.2% were barely coordinated. It is worth noting that from 2009 to 2013, Chuzhou City and Laian County improved from slightly uncoordinated to primary coordinated. This is due to the unique location advantage of the two counties, which are located in the middle of the two metropolises of Hefei and Nanjing and can fully enjoy the dividends of regional synergistic development.

The coupling coordination of the APLE system across counties in 2018 showed a further increase across the regions. Only 11.7% of the counties were slightly uncoordinated, with the lowest value being in Guzhen County at 0.4848. Moreover, 23.5% of the counties were primarily coordinated, with Bengbu, Dingyuan, Huabei, Huainan, Quanjiao, and Tianchang counties being newcomers. The highest value was found in Bengbu, with a high value of 0.668. The ranking of this city's APLE system in terms of the coupling coordination level also improved most significantly during this decade, rising from the ninth to the first. The remaining 64.7% of the counties were barely coordinated.

Overall, from the selected time periods of 2009, 2013, and 2018, the spatial pattern of the coupling coordination degree of the APLE system in the HREB was relatively stable and showed the basic characteristics of being high in the southeast and low in the northwest. In particular, the counties located in the metropolitan areas of Hefei and Nanjing have high potential and a fast growth rate in terms of coupled coordination development.

4.3. An Examination of the Influencing Factors and Driving Mechanisms

4.3.1. Analysis of Influencing Factors

The coupling and coordinated development of the agricultural, climate and social systems in the HREB is affected by many factors. Referring to the existing research results [38,42,47,50], this paper selected the per capita cultivated land area, effective irrigation rate, drought and flood rate, per capita electricity consumption in agriculture, level of urbanization, number of medical beds per 10,000 population, disposable income of urban residents, annual average temperature, and amount of precipitation as the detection factors. The results of risk factor detection (Table 4) showed that there were different influencing factors in different years. In 2009, BHF had the greatest impact, whereas EC had the least. This indicated that improving the level of public health services was more helpful in the early stages of development to promote the coordinated development of the APLE system. In 2013, AP had the greatest impact, whereas EI had the least. This was due to the fact that, around 2013, natural disasters were frequent in the HREB region and caused severe shocks to the agricultural subsystem. Thus, natural conditions played an important role in this phase. In 2018, DIU had the greatest impact, whereas UR had the least. This indicated that with the rapid increase in the urbanization rate, raising the income level of residents becomes an important path for the coupled and coordinated development of the APLE system. In addition, the q-values of CA and UR shrank over time, indicating that their influence on the spatial divergence of the coupled and coordinated development of the APLE system gradually decreased. Moreover, the influence of DFPY showed the opposite results. The influence of EI, BHF, DIU, and AAT showed a V-shaped change of decreasing and then increasing. The influence of EC and AP was on the opposite.

Table 4. Risk factor detection results in 2009, 2013, 2018.

Year	CA	EI	DFPY	EC	UR	BHF	DIU	AAT	AP
2009	0.153	0.169	0.109	0.063	0.072	0.215	0.164	0.135	0.106
2013	0.149	0.007	0.116	0.199	0.045	0.041	0.142	0.060	0.210
2018	0.065	0.128	0.153	0.132	0.044	0.156	0.250	0.244	0.188

Note: CA: Cultivated area per capita (hectare); EI: effective irrigation rate (%); DFPY: drought and flood protection yield (%); EC: per capita electricity consumption in agriculture (degree); UR: level of urbanization (%); BHF: number of beds in healthcare facilities per 10,000 people; DIU: per capita disposable income of urban residents (10,000 yuan); AAT: average annual temperature (°C); and AP: annual precipitation (mm).

Factor interaction detection is mainly used to analyze whether each factor has an interaction with the spatial differentiation of the coupling coordination degree of the 3 subsystems. According to the results from Table 5, the influence of each factor did not exist independently of the others. In 2009, the interactions of CA with EI, DFPY with DIU, and EC with UR all showed a two-way enhancement. In 2013, the interactions of CA with DFPY, EC, DIU, and AP, and EC with BHF and AP, all showed a two-way enhancement. In 2018, the interactions of CA with EI, DFPY with AP, and UR with AP all showed a two-way enhancement. The interactions of other factors were all in the form of nonlinear enhancement. This finding implies that the coupling and coordinated development of the three subsystems of APLE is influenced by the interaction of multiple factors. Therefore, a combination of policies should be introduced to address the combined effects of multiple factors when promoting coupling and coordinated development.

Table 5. Factor interaction detection results in 2009, 2013, 2018.

Interaction Factor	2009	2013	2018	Interaction Factor	2009	2013	2018
CA ∩ EI	TWE	NLE	TWE	DFPY ∩ DIU	TWE	NLE	NLE
CA ∩ DFPY	NLE	TWE	NLE	DFPY ∩ AAT	NLE	NLE	NLE
CA ∩ EC	NLE	TWE	NLE	DFPY ∩ AP	NLE	NLE	TWE
CA ∩ UR	NLE	NLE	NLE	EC ∩ UR	TWE	NLE	NLE
CA ∩ BHF	NLE	NLE	NLE	EC ∩ BHF	NLE	TWE	NLE
CA ∩ DIU	NLE	TWE	NLE	EC ∩ DIU	NLE	NLE	NLE
CA ∩ AAT	NLE	NLE	NLE	EC ∩ AAT	NLE	NLE	NLE
CA ∩ AP	NLE	TWE	NLE	EC ∩ AP	NLE	TWE	NLE
EI ∩ DFPY	NLE	NLE	NLE	UR ∩ BHF	NLE	NLE	NLE
EI ∩ EC	NLE	NLE	NLE	UR ∩ DIU	NLE	NLE	NLE
EI ∩ UR	NLE	NLE	NLE	UR ∩ AAT	NLE	NLE	NLE
EI ∩ BHF	NLE	NLE	NLE	UR ∩ AP	NLE	NLE	TWE
EI ∩ DIU	NLE	NLE	NLE	BHF ∩ DIU	NLE	NLE	NLE
EI ∩ AAT	NLE	NLE	NLE	BHF ∩ AAT	NLE	NLE	NLE
EI ∩ AP	NLE	NLE	NLE	BHF ∩ AP	NLE	NLE	NLE
DFPY ∩ EC	NLE	NLE	NLE	DIU ∩ AAT	NLE	NLE	NLE
DFPY ∩ UR	NLE	NLE	NLE	DIU ∩ AP	NLE	NLE	NLE
DFPY ∩ BHF	NLE	NLE	NLE	AAT ∩ AP	NLE	NLE	NLE

Note: NLE means nonlinear enhancement; TWE means two-way enhancement. All abbreviations are the same as those listed in Table 4.

4.3.2. Driving Mechanism Analysis

In the process of the coupling and coordinated development of the APLE system, the interaction and comprehensive action of different driving factors release a steady stream of driving forces. Based on the analysis results of the influencing factors, this study divides the driving forces into two parts: internal driving force and external driving force. The internal driving force mainly comes from the system itself, including food security, the consumption level of rural residents, and the urbanization development level. Among them, food security is affected by CA, DFPY, and EI; the consumption level of rural residents is characterized by EC, and the urbanization development level is composed of UR and DIU. External drivers are related to the external environment of the system, including government public welfare and natural conditions. The former is closely related to BHF, and the latter is closely related to AAT and AP.

(1) The internal driving forces

Food security is the foundation of agriculture and the basic point of the development of the "agriculture–meteorology–society" system. Food security is closely related to the nutritional security of the residents, and also represents a country's availability of food [63,64]. Therefore, ensuring food security is the first priority to maintain a balance between supply and demand for social stability. At the same time, food cultivation is also a "contributor" to climate change and a major source of greenhouse gas emissions [65,66]. According to the q value of the factor detection results, the influence of drought and flood protection rates in the selected years increases with the passage of time; the influence of the effective irrigation rate shows a "V"-shaped change with time, which decreases first and then increases. Although the influence of the per capita cultivated area has a downward trend, this factor and other factors, such as the effective irrigation rate (2009 and 2018), drought and flood retention rate (2013), per capita electricity consumption in agriculture (2013), urbanization level (2013), annual precipitation (2013 and 2018), and the number of beds in healthcare facilities per 10,000 people (2013), show a double factor increase. It shows that the interaction between the per capita cultivated land area and other factors acts on the three subsystems and enhances the explanatory power of the spatial differentiation of coupling and coordinated development. Per capita electricity consumption in agriculture is an important manifestation of the rural consumption level. On the one hand, it is an important driving force for social and economic growth. On the other hand, whether rural electricity uses clean energy has a far-reaching impact on the changes in the environment and climate. The detection results show that the influence of this factor increases first and then decreases in an inverted "V" shape over time, but it is always the main driving factor for the coordinated development of the APLE system.

Urbanization construction is an effective way to solve the problems of "agriculture, rural areas, and farmers", and it is also an important measure to coordinate urban and rural development and reshape urban–rural relations [39,43,67]. Urbanization promotes the agglomeration of production factors such as capital, technology, and industry, thus improving the living standards of residents. Furthermore, urbanization stimulates the consumption potential of residents, thus creating new consumer markets and economic growth points. Thus, the rapid progress of urbanization ensures the sustainable development of social subsystems. The influence of the urbanization level has decreased in the selected 3 years, but it has nonlinearly enhanced interaction with factors such as the per capita cultivated area, effective irrigation rate, and drought and flood retention rates, and it has a double-factor enhanced interaction with per capita electricity consumption in agriculture (2009), indicating that the interaction of the urbanization level and other factors jointly affects the coupling and coordinated development of the three subsystems. The influence of the per capita disposable income of urban residents has shown a "V" shape change with the passage of time. It has always been the main driving factor for the coupled and coordinated development of the APLE system. In 2018, the q value of this factor reached 0.25, which is the highest value of all the influencing factors detected.

(2) External driving forces

Governments have always played a crucial role in the development of the APLE system. The public services provided by local governments make an important contribution to the sustainable development of the region [68,69]. According to the results of factor detection, it is clear that the number of beds in healthcare facilities is one of the main external driving forces, with a q value of 0.21 in 2009. This result indicates that the government actively assumes responsibility for public healthcare, optimizes the pattern of healthcare resource allocation, and improves the conditions of healthcare services, can effectively improve the overall quality of production and lives of the population.

In terms of the natural conditions, the annual average temperature and annual precipitation are both important external driving forces that influence the coupling and coordinated development of the three subsystems. Specifically, the q values of the annual average temperature in 2009, 2013, and 2018 were 0.14, 0.06, and 0.24, respectively. The influence showed a "V"-shaped change with time. With global warming, the rate of warming varies greatly between regions, and the optimal temperature required for the growth of different crops is different. If the temperature is suitable, it will promote the vigorous growth of crops. The q values of the annual amount of precipitation were 0.11, 0.21, and 0.19, respectively. The influence of precipitation increases first and then decreases later with time. The HREB frequently experiences large-scale rainstorms, and the resulting flooding is frequent. A proper amount of precipitation is the basic condition for crop growth. However, heavy rain will delay sowing and the planting process, and even cause rivers to overflow and fertile fields to flood, which poses a great threat to the safety of humans and property.

In summary, the logic of the coupling and coordinated development of the APLE system in the HREB is as follows: Each driving factor is transmitted to the macro level through the micro-influence mechanism, thus forming internal and external driving forces. On this basis, the internal and external drivers both promote each other and restrain each other, thus realizing the coupling and coordinated development of the three subsystems. At different stages of coupling and coordinated development, different driving factors play various roles to the extent, but a multi-driven mechanism of food security, rural residents' consumption level, the urbanization development level, government public welfare, and natural conditions is formed. The driving process is shown in Figure 4.

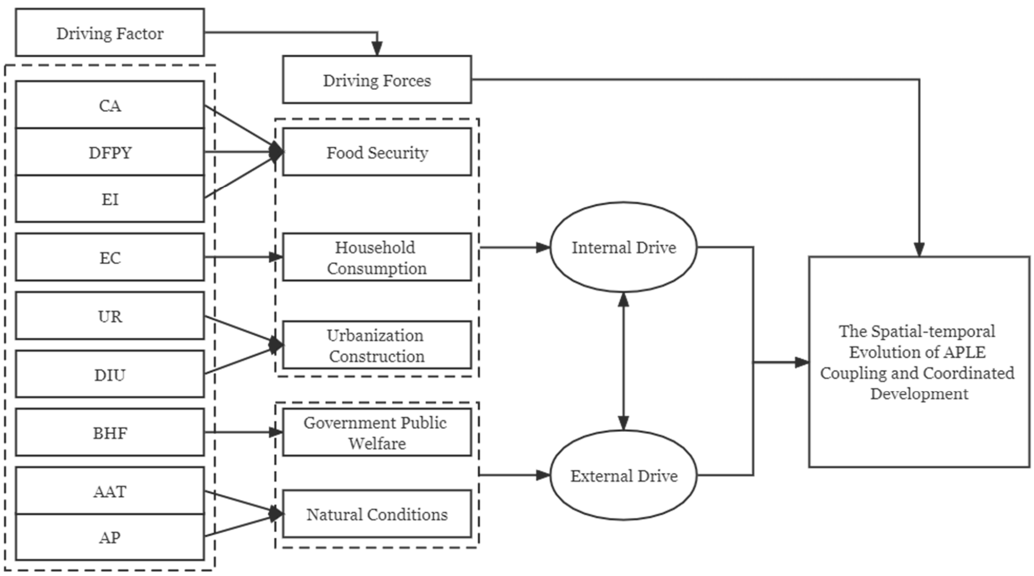

Figure 4. Driving mechanism of coupling and coordinated development of APLE system.

5. Discussion

To achieve the sustainable development goals, it is necessary to address social, economic, and environmental issues in a coordinated manner, so that the economic, social, and environmental aspects can be matched to the production space, the living space, and the ecological space, respectively. The contribution of this paper lies in the following three points:

First, the ecology environment is an important basis for the sustainable development of the agricultural and social subsystems. Therefore, this paper incorporates natural conditions (climate elements) into the APLE analysis framework with Chinese characteristics, which helps to enrich the theoretical basis of regional sustainable development and broaden the research perspective in the field of PLE, and also enriches the theoretical foundation of the field of coupling and coordinated development.

On this basis, this paper quantitatively analyzes the spatial and temporal evolution characteristics of the coupling coordination degree of the APLE system. It is found that the coupling coordination degree in the HREB increased steadily during the study period. This finding is consistent with the trend of coupling coordination in other systems, such as the system of agricultural modernization and regional economic development [40], the system of urban development and ecological environment [34], and the system of population health and economic development [46]. The cross-sectional comparison reveals similar findings in the Yangtze River Economic Belt [41], Tarim River Basin [56], Yellow River Basin [60], and other regions. Therefore, it can be assumed that China's regional sustainable development strategy is steadily advancing under the coupling and coordinated development of multiple systems.

Second, this paper explores the driving forces of the coupled and coordinated development of the APLE system in terms of food security, household consumption, urbanization construction, government public welfare, and natural conditions, which helps to understand the evolution of the coupled and coordinated development of the APLE system more comprehensively and systematically. The coupled and coordinated development of any system is influenced by a combination of multiple factors. Most studies conducted to select drivers from three levels: government, market, and individuals [46,70,71]. However, the results of geographic detectors in this paper indicate that natural conditions are an important driving force of the coupling and coordinated development of the APLE system in the HREB. Meanwhile, natural conditions have a greater impact than themselves alone when they interact with other driving factors. More importantly, compared with the existing studies, this study innovatively explores the coupled coordination characteristics of the APLE system from an agricultural perspective based on the PLE analysis framework. These findings provide richer theoretical support for coordinated regional development and the PLE analysis framework.

Third, this paper takes the HREB as the study area, which will help to provide valuable policy insights for the sustainable development of other areas with important food production tasks and frequent natural disasters.

Nonetheless, there are two limitations in this paper. First, due to data limitations, this study could not cover a longer study period, and thus could not provide a more in-depth analysis of the spatial and temporal evolution of the coupling and coordinated development of the HREB. Second, this paper discusses the drivers of the coupling and coordinated development as comprehensively as possible, but there is still room for further refinement. For example, among the government public-welfare drivers, the influence of education service supply and infrastructure construction can be further explored [72]. Among the drivers of urbanization construction, the influence of land urbanization and social urbanization can be further explored [39,45]. Therefore, the data can be further improved in future studies to establish a database with a long time span. Meanwhile, a more diversified index system and analysis framework can be constructed. Based on this, the spatio-temporal evolution pattern of the coupling and coordinated development of the APLE system, the influencing factors, and their driving mechanisms can be analyzed in greater depth.

6. Conclusions and Suggestions

6.1. Conclusions

Based on the analysis of the spatial and temporal characteristics and driving factors of the coupling and coordination degree of the APLE system in the HREB, the main findings include the following:

(1) From 2009 to 2018, the average level of agricultural and social system development quality in the HREB displayed clear stages and volatile change characteristics. The change in the average climate was relatively stable, and the overall trend was "steadily rising". Meanwhile, from 2009 to 2014, the agricultural and social systems formed a "scissor difference", and the quality of the development of the 3 subsystems showed steady and balanced slow growth from 2015 to 2019.

(2) The coupling and coordinated development of the APLE system in the HREB is relatively stable, and the development of the coupling coordination degree shows an upward trend, but there is still large room for improvement. Furthermore, the spatial differences in the coupling coordination degree among counties are obvious and show the basic characteristics of being high in the southeast and low in the northwest. In particular, the counties located in the Hefei and Nanjing metropolitan areas have a higher level of coupled and coordinated development.

(3) The results of the risk factor detection using geographical detectors show that the drought and flood protection yield, effective irrigation rate, per capita electricity consumption in agriculture, number of beds in medical institutions per 10,000 people, per capita disposable income of urban residents, annual average temperature, and annual precipitation are the main influencing factors for the spatial differentiation of the coupling and coordinated development of the three systems. Judging from the detection results of factor interaction, the two-way interaction is stronger than that of the factor alone.

(4) The spatial–temporal evolution of the coupling and coordinated development of the APLE system is the result of the comprehensive effect of internal driving forces, such as food security, the consumption level of rural residents, and the development level of urbanization construction, and external driving forces such as government public welfare and natural conditions.

6.2. Suggestions

Based on the above analysis, the coupling and coordinated development of the APLE system is driven by multiple factors. Therefore, when constructing the coupled and coordinated development path in the HREB, we need to pay attention to the synergistic governance among the policy measures. This paper obtains the following policy implications:

(1) The basic status of agriculture must be consolidated. As an important grain-producing area in China, efforts to develop the agricultural production of Linquan, Fengyang, Huaiyuan, and other grain-producing counties should be made in the HREB, and the main function of it to guarantee China′s food security should be given full play to. (2) Taking the meteorological subsystem as a starting point, on the one hand, we should enhance the research of disaster warning and forecasting technologies to reduce the threat of extreme weather events, such as droughts and floods, to guarantee the safety of human life and the property of residents in the HREB. On the other hand, we need to deepen the ecological precision monitoring work with the help of increasingly abundant digital tools, and solve the "last mile" problem of agricultural weather forecasting in conjunction with crop growth stages. (3) Based on the spatial differentiation of the APLE system among counties, we should increase the construction of road transport and other infrastructure, so as to reduce the cost of production factors flowing between counties and thus narrow the development gap between regions. (4) From the driving mechanism of spatial evolution, it is known that, firstly, the advantages of counties should be fully explored, and county markets should be actively built to promote the consumption level of rural residents. Secondly, we should speed up the construction of new urbanization, and form a new industrial–agricultural–urban–rural integration relationship and a development

pattern of "urban–rural complementarity, mutual promotion of industry and agriculture, and common prosperity". Finally, local governments should improve the supply capacity of public services, especially medical services.

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References

1. Chen, Y.; Wang, G.; Sun, W. Agricultural Status and Agricultural Development in the Rural Revitalization Strategy. *Issues Agric. Econ.* **2018**, *457*, 20–26. [CrossRef]
2. Liu, D.; Zhu, X.; Wang, Y. China′s agricultural green total factor productivity based on carbon emission: An analysis of evolution trend and influencing factors. *J. Clean. Prod.* **2021**, *278*, 123692. [CrossRef]
3. Zhou, Y.; Li, X.; Liu, Y. Rural land system reforms in China: History, issues, measures and prospects. *Land Use Policy* **2020**, *91*, 104330. [CrossRef]
4. Myers, S.S.; Smith, M.R.; Guth, S.; Golden, C.D.; Vaitla, B.; Mueller, N.D.; Dangour, A.D.; Huybers, P. Climate Change and Global Food Systems: Potential Impacts on Food Security and Undernutrition. *Annu. Rev. Public Health* **2017**, *38*, 259–277. [CrossRef]
5. Wijerathna-Yapa, A.; Pathirana, R. Sustainable Agro-Food Systems for Addressing Climate Change and Food Security. *Agriculture* **2022**, *12*, 1554. [CrossRef]
6. Vogel, E.; Donat, M.G.; Alexander, L.V.; Meinshausen, M.; Ray, D.K.; Karoly, D.; Meinshausen, N.; Frieler, K. The effects of climate extremes on global agricultural yields. *Environ. Res. Lett.* **2019**, *14*, 054010. [CrossRef]
7. Ortiz-Bobea, A.; Ault, T.R.; Carrillo, C.M.; Chambers, R.G.; Lobell, D.B. Anthropogenic climate change has slowed global agricultural productivity growth. *Nat. Clim. Change* **2021**, *11*, 306–312. [CrossRef]
8. Hansen, J.; Hellin, J.; Rosenstock, T.; Fisher, E.; Cairns, J.; Stirling, C.; Lamanna, C.; van Etten, J.; Rose, A.; Campbell, B. Climate risk management and rural poverty reduction. *Agric. Syst.* **2019**, *172*, 28–46. [CrossRef]
9. Fu, J.; Bu, Z.; Jiang, D.; Lin, G. Identification and Classification of Urban PLES Spatial Functions Based on Multisource Data and Machine Learning. *Land* **2022**, *11*, 1824. [CrossRef]
10. Zhang, Z.; Xiong, C.; Yang, Y.; Liang, C.; Jiang, S. What Makes the River Chief System in China Viable? Examples from the Huaihe River Basin. *Sustainability* **2022**, *14*, 6329. [CrossRef]
11. Mao, G.; Jin, W.; Zhu, Y.; Mao, Y.; Hsu, W.-L.; Liu, H.-L. Environmental Pollution Effects of Regional Industrial Transfer Illustrated with Jiangsu, China. *Sustainability* **2021**, *13*, 12128. [CrossRef]
12. Pan, Z.; Ruan, X.; Qian, M.; Hua, J.; Shan, N.; Xu, J. Analysis of the Spatial Distribution Characteristics of Livestock and Poultry Farming Pollution and Assessment of the Environmental Pollution Load in Anhui Province. *Hydrol. Res.* **2018**, *49*, 177–193. [CrossRef]
13. Hou, W.; Wu, S.; Yang, L.; Yin, Y.; Gao, J.; Deng, H.; Wu, M.; Li, X.; Liu, L. Production–Living–Ecological Risk Assessment and Corresponding Strategies in China's Provinces under Climate Change Scenario. *Land* **2022**, *11*, 1424. [CrossRef]
14. Lyu, H.-M.; Xu, Y.-S.; Cheng, W.-C.; Arulrajah, A. Flooding Hazards across Southern China and Prospective Sustainability Measures. *Sustainability* **2018**, *10*, 1682. [CrossRef]
15. Liao, R.; Liu, G.; Chen, J.; Zhang, L. Interdecadal Variability of Summer Extreme Rainfall Events over the Huaihe River Basin and Associated Atmospheric Circulation. *Atmosphere* **2022**, *13*, 1189. [CrossRef]
16. Chandio, A.A.; Akram, W.; Sargani, G.R.; Twumasi, M.A.; Ahmad, F. Assessing the impacts of meteorological factors on soybean production in China: What role can agricultural subsidy play? *Ecol. Inform.* **2022**, *71*, 101778. [CrossRef]

17. Chandio, A.A.; Jiang, Y.; Rehman, A.; Rauf, A. Short and long-run impacts of climate change on agriculture: An empirical evidence from China. *Int. J. Clim. Change Strateg. Manag.* **2020**, *12*, 201–221. [CrossRef]
18. Zhang, H.; Chandio, A.A.; Yang, F.; Tang, Y.; Ankrah Twumasi, M.; Sargani, G.R. Modeling the Impact of Climatological Factors and Technological Revolution on Soybean Yield: Evidence from 13-Major Provinces of China. *Int. J. Environ. Res. Public Health* **2022**, *19*, 5708. [CrossRef]
19. Zhang, H.; Tang, Y.; Chandio, A.A.; Sargani, G.R.; Ankrah Twumasi, M. Measuring the Effects of Climate Change on Wheat Production: Evidence from Northern China. *Int. J. Environ. Res. Public Health* **2022**, *19*, 12341. [CrossRef]
20. Huang, X.; Xu, X.; Wang, Q.; Zhang, L.; Gao, X.; Chen, L. Assessment of Agricultural Carbon Emissions and Their Spatiotemporal Changes in China, 1997-2016. *Int. J. Environ. Res. Public Health* **2019**, *16*, 3105. [CrossRef]
21. Mendelsohn, R.; Basist, A.; Kurukulasuriya, P.; Dinar, A. Climate and Rural Income. *Clim. Chang.* **2007**, *81*, 101–118. [CrossRef]
22. Barbier, E.; Hochard, J. Poverty, rural population distribution and climate change. *Environ. Dev. Econ.* **2018**, *23*, 234–256. [CrossRef]
23. Barua, A.; Katyaini, S.; Mili, B.; Gooch, P. Climate change and poverty: Building resilience of rural mountain communities in South Sikkim, Eastern Himalaya, India. *Reg. Environ. Chang.* **2014**, *14*, 267–280. [CrossRef]
24. Sinha, M.; Sendhil, R.; Chandel, B.S.; Malhotra, R.; Singh, A.; Jha, S.K.; Sankhala, G. Are Multidimensional Poor more Vulnerable to Climate change? Evidence from Rural Bihar, India. *Soc. Indic. Res.* **2022**, *162*, 123–149. [CrossRef]
25. Shen, Z.; Balezentis, T.; Chen, X.; Valdmanis, V. Green growth and structural change in Chinese agricultural sector during 1997–2014. *China Econ. Rev.* **2018**, *51*, 83–96. [CrossRef]
26. Tan, R.; Wang, R.; Heerink, N. Liberalizing rural-to-urban construction land transfers in China: Distribution effects. *China Econ. Rev.* **2020**, *60*, 101147. [CrossRef]
27. Shi, Z. Thinking on promoting the high-quality development of Huaihe River Ecological Economic Belt. *Econ. Res. Guide* **2021**, *484*, 38–40.
28. Sun, J.; Yi, S. Research on Ways to Promote the High-quality Development of Huaihe river Ecological Economic belt. *Financ. Trade Res.* **2020**, *31*, 43–48. [CrossRef]
29. Ji, T.; Chen, T.; Mao, G. Assessment of water resources carrying capacity in Huaihe River Ecological Economic Belt based on entropy weight Topsis. *China Agric. Resour. Reg. Plan.* **2018**, *39*, 130–135.
30. Liu, Z.; Wang, H.; Li, N.; Zhu, J.; Pan, Z.; Qin, F. Spatial and Temporal Characteristics and Driving Forces of Vegetation Changes in the Huaihe River Basin from 2003 to 2018. *Sustainability* **2020**, *12*, 2198. [CrossRef]
31. Hsu, W.-L.; Shen, X.; Xu, H.; Zhang, C.; Liu, H.-L.; Shiau, Y.-C. Integrated Evaluations of Resource and Environment Carrying Capacity of the Huaihe River Ecological and Economic Belt in China. *Land* **2021**, *10*, 1168. [CrossRef]
32. Ren, Z.; Zhu, K. Study on the Effect of rural human capital increase and its Spatial characteristics in Huaihe River Ecological Economic Belt. *J. Shanxi Agric. Univ. (Soc. Sci. Ed.)* **2019**, *18*, 54–61. [CrossRef]
33. Liang, J.; Pan, S.; Chen, W.; Li, J.; Zhou, T. Cultivated Land Fragmentation and Its Influencing Factors Detection: A Case Study in Huaihe River Basin, China. *Int. J. Environ. Res. Public Health* **2021**, *19*, 138. [CrossRef]
34. Weng, Q.; Peng, S.; Qiang, Z.; Rui, Y.; Youzhen, W.; Fanrui, B.; Min, X. Temporal and spatial Variation of extreme temperature in the Huaihe River Basin under non-stationary conditions and analysis of teleconferences and circulation characteristics. *Resour. Environ. Yangtze Basin* **2019**, *28*, 2513–2526.
35. Liu, S.; Xie, Y.; Fang, H.; Du, H.; Xu, P. Trend Test for Hydrological and Climatic Time Series Considering the Interaction of Trend and Autocorrelations. *Water* **2022**, *14*, 3006. [CrossRef]
36. Chang, F. Study on Evaluation Index System of Urban Competitiveness in Huaihe River Ecological Economic Belt: An empirical analysis based on dynamic factor model. *Water Econ.* **2021**, *39*, 7–14.
37. Suo, L.; Li, F.; Zhu, X. Analysis of Industrial Undertaking Capacity and Direction in Huaihe River Ecological Economic Belt. *Ecol. Econ.* **2021**, *37*, 64–69.
38. Li, N.; Da Jia, H.; Kim, D.J. Coordinated Development of Agricultural Insurance, Agricultural Loans, and the Agricultural Industry in China. *J. Asian Financ. Econ. Bus.* **2022**, *9*, 205–217. [CrossRef]
39. Deng, F.; Jia, S.; Ye, M.; Li, Z. Coordinated development of high-quality agricultural transformation and technological innovation: A case study of main grain-producing areas, China. *Environ. Sci. Pollut. Res. Int.* **2022**, *29*, 35150–35164. [CrossRef]
40. Wang, Y.; Jin, C.; Peng, Q.; Liu, J.; Wu, X. Systematic Measurement and Evolution Situation of Coupling Coordination Level between Intensive Cultivated Land Utilization and New-Type Urbanization. *Sustainability* **2022**, *14*, 11716. [CrossRef]
41. Chen, K.; Tian, G.; Tian, Z.; Ren, Y.; Liang, W. Evaluation of the Coupled and Coordinated Relationship between Agricultural Modernization and Regional Economic Development under the Rural Revitalization Strategy. *Agronomy* **2022**, *12*, 990. [CrossRef]
42. Yang, M.; Jiao, M.; Zhang, J. Coupling Coordination and Interactive Response Analysis of Ecological Environment and Urban Resilience in the Yangtze River Economic Belt. *Int. J. Environ. Res. Public Health* **2022**, *19*, 11988. [CrossRef] [PubMed]
43. Chen, J.; Liu, Y.; Wang, L. Research on Coupling Coordination Development for Photovoltaic Agriculture System in China. *Sustainability* **2019**, *11*, 1065. [CrossRef]
44. Cai, J.; Li, X.; Liu, L.; Chen, Y.; Wang, X.; Lu, S. Coupling and coordinated development of new urbanization and agro-ecological environment in China. *Sci. Total Environ.* **2021**, *776*, 145837. [CrossRef]
45. Zhang, X.; Xu, Z. Functional Coupling Degree and Human Activity Intensity of Production–Living–Ecological Space in Underdeveloped Regions in China: Case Study of Guizhou Province. *Land* **2021**, *10*, 56. [CrossRef]

46. Wang, C.; Ma, Y.; Zhang, A.; Hu, M. Spatio-Temporal Coordination Analysis of Urban Welfare and Tourism Development in the Yangtze River Delta Region. *Systems* **2022**, *10*, 222. [CrossRef]
47. Tang, H.; Chen, Y.; Ao, R.; Shen, X.; Shi, G. Spatial–Temporal Characteristics and Driving Factors of the Coupling Coordination between Population Health and Economic Development in China. *Sustainability* **2022**, *14*, 10513. [CrossRef]
48. Gan, W.; Yao, W.; Huang, S.; Liu, Y. A Study on the Coupled and Coordinated Development of the Logistics Industry, Digitalization, and Ecological Civilization in Chinese Regions. *Sustainability* **2022**, *14*, 16390. [CrossRef]
49. Liu, Y.; Yang, R.; Sun, M.; Zhang, L.; Li, X.; Meng, L.; Wang, Y.; Liu, Q. Regional sustainable development strategy based on the coordination between ecology and economy: A case study of Sichuan Province, China. *Ecol. Indic.* **2022**, *134*, 108445. [CrossRef]
50. Fan, Y.; Fang, C.; Zhang, Q. Coupling coordinated development between social economy and ecological environment in Chinese provincial capital cities-assessment and policy implications. *J. Clean. Prod.* **2019**, *229*, 289–298. [CrossRef]
51. Liu, Q.; Yang, D.; Cao, L. Evolution and Prediction of the Coupling Coordination Degree of Production–Living–Ecological Space Based on Land Use Dynamics in the Daqing River Basin, China. *Sustainability* **2022**, *14*, 10864. [CrossRef]
52. Wang, Y.; Xiang, P. Urban Sprawl Sustainability of Mountainous Cities in the Context of Climate Change Adaptability Using a Coupled Coordination Model: A Case Study of Chongqing, China. *Sustainability* **2018**, *11*, 20. [CrossRef]
53. Paramesh, V.; Kumar, P.; Shamim, M.; Ravisankar, N.; Arunachalam, V.; Nath, A.J.; Mayekar, T.; Singh, R.; Prusty, A.K.; Rajkumar, R.S.; et al. Integrated Farming Systems as an Adaptation Strategy to Climate Change: Case Studies from Diverse Agro-Climatic Zones of India. *Sustainability* **2022**, *14*, 11629. [CrossRef]
54. Liu, T.; Ren, C.; Zhang, S.; Yin, A.; Yue, W. Coupling Coordination Analysis of Urban Development and Ecological Environment in Urban Area of Guilin Based on Multi-Source Data. *Int. J. Environ. Res. Public Health* **2022**, *19*, 12583. [CrossRef]
55. Liu, Z.; Jing, D.; Han, Y.; Yu, J.; Lu, T.; Zhangzhong, L. Spatiotemporal Distribution Characteristics and Influencing Factors Analysis of Reference Evapotranspiration in Beijing–Tianjin–Hebei Region from 1990 to 2019 under Climate Change. *Sustainability* **2022**, *14*, 6277. [CrossRef]
56. Lu, Q.; Yang, Y.; Li, B.; Li, Y.; Wang, D. Coupling Relationship and Influencing Factors of the Water–Energy–Cotton System in Tarim River Basin. *Agronomy* **2022**, *12*, 2333. [CrossRef]
57. Willemen, L.; Hein, L.; van Mensvoort, M.E.F.; Verburg, P.H. Space for people, plants, and livestock? Quantifying interactions among multiple landscape functions in a Dutch rural region. *Ecol. Indic.* **2010**, *10*, 62–73. [CrossRef]
58. Liao, Z. Quantitative evaluation and classification system of the Coordinated development of environment and economy: A case study of the Pearl River Delta urban Agglomeration. *J. Trop. Geogr.* **1999**, *19*, 171–177.
59. Li, J.; Zhou, Q.; Yin, P.; Khan, F. Smart and IoT-Based Coupling and Coordination Development for Financial and Logistics Industries. *Mob. Inf. Syst.* **2021**, *2021*, 3227408. [CrossRef]
60. Li, J.; Sun, W.; Li, M.; Linlin, M. Coupling coordination degree of production, living and ecological spaces and its influencing factors in the Yellow River Basin. *J. Clean. Prod.* **2021**, *298*, 126083. [CrossRef]
61. Wang, J. Geodetector: Principle and prospective. *Acta Geogr. Sin.* **2017**, *72*, 116–134. [CrossRef]
62. Wang, J.F.; Li, X.H.; Christakos, G.; Liao, Y.L.; Zhang, T.; Gu, X.; Zheng, X.Y. Geographical Detectors-Based Health Risk Assessment and its Application in the Neural Tube Defects Study of the Heshun Region, China. *Int. J. Geogr. Inf. Sci.* **2010**, *24*, 107–127. [CrossRef]
63. Thou, Z. Achieving food security in China: Past three decades and beyond. *China Econ. Rev.* **2010**, *2*, 251–275. [CrossRef]
64. Ruiz, Y.D.; Nariño, O.S.; Almonte, J.M.J.; Domínguez, J.A.M. Household Food Security as a Complex System—Contributions to the Social Sciences from the Cuban Perspective during a Pandemic. *Sustainability* **2022**, *14*, 11783. [CrossRef]
65. Zhu, Y.; Huo, C. The Impact of Agricultural Production Efficiency on Agricultural Carbon Emissions in China. *Energies* **2022**, *15*, 4464. [CrossRef]
66. Zang, D.; Hu, Z.; Yang, Y.; He, S. Research on the Relationship between Agricultural Carbon Emission Intensity, Agricultural Economic Development and Agricultural Trade in China. *Sustainability* **2022**, *14*, 11694. [CrossRef]
67. Tao, Z.; Xiang, G. Study on the relationship between the construction of new urban-rural relationship and rural revitalization: A case study of Hunan Province. *China Agric. Resour. Reg. Plan.* **2020**, *41*, 83–90.
68. Wang, L.; Wang, Z.; Ma, Q.; Fang, G.; Yang, J. The development and reform of public health in China from 1949 to 2019. *Glob. Health* **2019**, *15*, 45. [CrossRef] [PubMed]
69. Grigorescu, A.; Lincaru, C.; Pîrciog, S.; Chiţescu, R.-I. Competitiveness and sustainable development in public services. Management & Marketing. *Chall. Knowl. Soc.* **2019**, *14*, 108–129. [CrossRef]
70. Yang, S.; Xu, J.; Yang, R. Research on Coordination and Driving Factors of Sports Industry and Regional Sustainable Development—Empirical Research Based on Panel Data of Provinces and Cities in Eastern China. *Sustainability* **2020**, *12*, 813. [CrossRef]
71. Wei, G.; Sun, P.; Zhang, Z.; Ouyang, X. The Coordinated Relationship between Investment Potential and Economic Development and Its Driving Mechanism: A Case Study of the African Region. *Sustainability* **2020**, *12*, 442. [CrossRef]
72. Liu, D.; Zhang, K. Analysis of Spatial Differences and the Influencing Factors in Eco-Efficiency of Urban Agglomerations in China. *Sustainability* **2022**, *14*, 12611. [CrossRef]