Study On The Coupling Relationship Of Urbanization-Social Economy-Ecological Environment In Hohhot-Baotou-Ordos-Ulanqab Urban Agglomeration, China

Zheng Hui[1,2], Zhao Yongfeng [1,2], Zulkhumor Tojiyeva Nazarovna[1]

(1. School of Geography and Natural Resources, National University of Uzbekistan, Tashkent 100174, Uzbekistan;
2. School of Geographic Science and Planning, Jining Normal University, Wulanchabu 012000, People's Republic of China)
Zheng Hui - ORCID code: 0000-0003-2482-4429
Zhao Yongfeng - ORCID code: 0000-0003-0389-2959
Zulkhumor Tojiyeva - ORCID code: 0000-0001-5626-9517
E-mail: 544185476@qq.com

Abstract：Taking Hohhot-Baotou-Ordos-Ulanqab Urban Agglomeration (HBOUUA) as the research object, the spatio-temporal evolution process and pattern of the coupling coordination of urbanization, social economy and ecological environment in HBOUUA from 2003 to 2018 were quantitatively measured by constructing a coupling coordination model of urbanization, social economy and ecological environment. The results indicate that: (1) The comprehensive development level of urbanization, social economy and ecological environment in HBOUUA presents an upward trend, experiencing the process of ecological environment advanced development, social economy advance development and urbanization advance development; (2) The coupling degree of HBOUUA urbanization-social economy-ecological environment system has been improved from high level coupling to high quality coupling, and the coupling coordination degree has undergone moderate coordination and then turned to good coordination. (3) The temporal sequence characteristics of coupling degree and coupling coordination degree of each municipality in HBOUUA display an upward trend, and the spatial characteristics show a spatial pattern of collaborative upgrading evolution. (4) It is recommended to set up the idea of ecological civilization, fully implement the new development concept, promote the green economic development model, preserve people's well-being, actively promote the HBOUUA integration process, continuously upgrade the regional collaborative innovation development capacity, and take the road to high-quality sustainable development.

1. Introduction

With the rapid development of China's social economy in recent years, the urbanization process is expanding year by year and has attained a comparatively high level of development. But the rapid development of urbanization as well as creating more urban problems, the development and utilization of natural resources scale continues to extend, industrial pollution and life pollution swiftly ascending, land resources and ecological environment pressure is growing year by year. Overall, the quality and effectiveness of urbanization highly sabotage the sustainable development of regional economy and ecological environment supporting capacity. Under this background, construction of ecological civilization concept has become an important direction of regional economic construction and social development. The ecological civilization concept into the whole process of urbanization, the realization of urbanization, social coordinated development between economy and ecological environment, ecological priority, green development of a new path of urbanization is the inevitable trend in the new development period in China. Under the guidance of a series of development strategies such as China's new urbanization and urban agglomeration development, the new urbanization development in Inner Mongolia is progressively shifting from the emphasis on speed to the coordinated development direction of speed and quality, and from the development of cities alone to the development of urban clusters. Under the new development concept lead, HBOUUA has now developed into the Yellow River basin of Inner Mongolia ecological protection and the development of high quality natural eco-space important areas, is a new development period of the Inner Mongolia autonomous region key development area core region and economic development, accelerate the HBOUUA integration development, to continuously enhance the regional innovation ability and core competition ability, Improving the degree of economic agglomeration, regional connectivity and policy coordination is of great significance to leading the high-quality development of Inner Mongolia Autonomous Region and promoting the formation of a new pattern of key development of dominant regions in central Inner Mongolia and key protection of ecological function zones.

Based on this, this paper takes HBOUUA as the research object, constructs the evaluation model and quantitative evaluation of the coordinated development of the composite system of urbanization, social economy and ecological environment, identifies the evolution process, pattern and trend of its coordinated development, and analyzes the coupling coordinated development mechanism of HBOUUA urbanization, social economy and ecological environment. To explore and enrich urbanization, social economy and ecological environment system of interactive coupling theory and coupling coordination evolution law, continue to promote the development of new concept led by new pattern of urbanization development, crack how to implement in keeping the ecological environment based on smooth running of the new high quality development of urbanization, and the collaborative process of sustainable development of social economy, It is of great theoretical and practical significance to guide and realize the new-type urbanization construction in Inner Mongolia Autonomous Region and promote the sustainable and stable growth of regional economy and the healthy and orderly coordinated development of the ecological environment.

2. Literature review

At present, urbanization is in a period of rapid development. How to accomplish high-quality sustainable development of urbanization has become a hot topic for scholars at home and abroad. There are few studies on the relationship between urbanization, social economy and the ecological environment. The current research results mostly focus on urbanization and social economy; (2) Urbanization and ecological environment; (3) Research on the relationship between social economy and ecological environment. Foreign studies on urbanization and social economy are earlier. Hollis Chanery (1975) [1], Laumas (1984) [2], Nour E (1989) [3], Henderson (2000) [4], Pacione M (2001) [5], Lewis (2014) [6], Tripathi (2017) [7] et al., through empirical analysis of the data related to urbanization and economic development in many countries, believe that there is a strong positive correlation between urbanization and economic growth. Chinese scholars Zhao Xianzhou (2006) [8], Zhu Konglai (2011) [9] and Zhou Hui (2016) [10] likewise reached the same research conclusion by conducting empirical studies on Chinese cities and towns. Chen Mingxing, Lu Dadao et al. (2010) [11], Huang Muyi (2012) [12], Dong Zhiqing (2019) [13], Zhou Liang (2019) [14], et al., conducted an empirical study on the coordinated development relationship between urbanization and economy. The ecological and environmental problems caused by urbanization in foreign countries have long attracted extensive attention of scholars. At the end of the 19th century, E.Howard tried to deal with the contradiction between urban development and ecology by building agricultural cities, so as to achieve sustainable urban development. Since then, significant studies such as Northam curve [15], PSR model [16], ecological Kuznets hypothesis [17] and decoupling model [18] have appeared successively. Ma Shijun (1984) [19], Liu Yaobin (2005) [20], Fang Chuanglin (2006) [21], Cui Muhua (2015) [22], Liu Menghai (2019) [23],

Deng Zongbing (2019) [24], Du Xia (2020) [25], Zhao Jianji (2020) [26] and other scholars combined with Chinese empirical research Analysis, mainly from measure evaluation, driving factors, spatio-temporal evolution, prediction and simulation, etc. Foreign studies on the relationship between the economy and ecological environment derived from Silent Spring written by Rachel Carson (1962) [27]. Donella H. Meadows et al. (1972) [28] and Mishan (1967) [29] simultaneously held that ecological environment and economic development need to be coordinated and promoted collectively, and one-sided pursuit of economic growth will produce unpredictable negative effects. Gerossman and Kruege (1991) conducted the first empirical analysis on the relationship between environmental quality and per capita income, and the environmental Kuznets curve (EKC) proposed is the most representative research result on the relationship between economic development and ecological environment [30-31]. Chinese scholars Chen Xingpeng et al. (2005) [32], Liu Anxuan et al. (2017) [33], Zhang Xiaodong, Chi Tianhe (2001) [34], Wang Liangjian (2019) [35], et al., took China as an example to conduct verification analysis of ecological Kuznets curve (EKC). At present, there are comparatively few studies on the relationship between urbanization, social economy and the ecological environment. Only li Rui (2019) [36], Hou Langong (2020) [37], Shao Huilin (2020) [38], Wei Yueheng (2021) [39] and other scholars have carried out empirical studies.

To sum up, the existing studies are only based on the theoretical and empirical analysis of urbanization, social economy and ecological environment, and the research on the coordinated development of the three is still in its infancy: First, from the perspective of research regions, most of the relevant researches on urbanization, social economy and ecological environment are concentrated in the economically developed eastern regions, and less attention is paid to the Yellow River Basin in the central and western regions. Secondly, from the perspective of research ideas, it is urgent to carry out relevant studies on comprehensively revealing the coordination of urbanization development from a broader three-system dimension from the perspective of high-quality urbanization development in the new development period. Thirdly, the selection of evaluation indicators of existing studies only focuses on the speed or quality of urbanization, and lacks discussion on the connotation of high-quality development of urbanization, which is insufficient in the connotation of high-quality development. Based on this, this paper aims to study the spatio-temporal coupling evolution trend and pattern of urbanization, social economy and ecological environment system from the perspective of high-quality development of new urbanization in HBOUUA. To provide theoretical reference for the new urbanization provides the theory basis for development of high quality, and also provides beneficial reference for other urban sustainable development.

3. Materials and methods
3.1 The study area

HBOUUA is located in central and western Inner Mongolia with an administrative area of 186,200 square kilometers, accounting for 15.7% of the whole region. There are 37 county-level administrative units under the jurisdiction of the urban agglomeration, including 13 administrative districts and 24 administrative banner counties. The city cluster is rich in resources, with proven coal reserves of 265.20 billion tons in 2020, accounting for 51.2 percent of the region. Iron reserves of 2.01 billion tons, accounting for 47.6% of the region. In 2020, there will be 10.015 million permanent residents, accounting for 41.6 percent of the total population of the region. The urbanization rate of permanent residents in urban agglomerations will reach 77.39 percent. The urbanization rate of permanent residents in Hohhot, Baotou, Ordos and Ulanqab will be 79.15 percent, 86.16 percent, 77.45 percent and 59.7 percent, respectively. In 2020, the GDP of the four cities of Hohhot, Baotou, Ordos and Ulanqab reached 994.86 billion yuan, accounting for 57.5% of the whole region.

3.2 Construction of comprehensive evaluation index system

Urbanization, social economy and ecological environment system is a huge system with complex hierarchical structure composed of many elements. The coordinated development degree of the three subsystems is the comprehensive result of the complex interaction among the three subsystems. Establishing a scientific and complete evaluation index system is the basis of grasping the coupled and coordinated development of the assessment of the three subsystems. According to the PSR conceptual model theory and following the principles of validity, scientific and operability of evaluation index selection, the established evaluation index system is rigorously screened by frequency statistics and expert consultation. At the same time, the comprehensive evaluation index system of urbanization, social economy and ecological environment system was constructed by thoroughly merging the characteristics of urban location development in Inner Mongolia Autonomous Region (Table 1).

Table 1. HBOUUA Urbanization-Social Economy-Ecological Environment system evaluation index system and weight calculation results

System layer	Index layer	Index attribute	Entropy weight
Urbanization (UR)	Urbanization rate（%）	+	0.1270
	Natural population growth rate（%）	+	0.0929
	Urban employed persons at the end of the year（Persons）	+	0.1067
	Proportion of the second industry employees（%）	+	0.0978
	Proportion of the number of employees in the tertiary industry （%）	+	0.1017
	Urban construction land area (Square kilometers)	+	0.1105
	Road Area per capita (㎡/ persons)	+	0.1104
	Public transport per 10,000 people (Standard platform)	+	0.1102
	Public toilets per 10,000 people	+	0.1428
Social Economy (SE)	Local financial revenue (Yuan)	+	0.1166
	Gross Regional Product (Yuan)	+	0.1150
	Per capita GROSS Regional Product (Yuan)	+	0.1161
	Per capita disposable income of Urban residents (Yuan)	+	0.1136
	Regional GDP growth rate（%）	+	0.1201
	Total industrial output value above designated size (Yuan)	+	0.1163
	The proportion of the output value of the secondary industry in GDP（%）	+	0.0987
	The proportion of output value of tertiary industry in GDP（%）	+	0.0898
	Total investment in fixed assets of the whole Society (Yuan)	+	0.1137
Ecological Environment (EE)	Total annual precipitation（mm）	+	0.1132
	Per capita Green area of park (㎡)	+	0.1116
	Afforestation Area (Ha)	+	0.1158
	Green coverage rate of urban built-up area（%）	+	0.1220
	Total annual water supply (Ton)	-	0.1152
	otal annual electricity consumption (KWH)	-	0.0983
	Industrial wastewater discharge (Ton)	-	0.1011
	Industrial sulfur dioxide emissions (Ton)	-	0.1207
	Industrial smoke (powder) emissions (Ton)	-	0.1021

3.3 Data Sources

The statistical data are principally from China Urban Statistical Yearbook and Inner Mongolia Statistical Yearbook from 2004 to 2019, and are supplemented by statistical data such as statistical yearbook of various cities and statistical bulletin of national economic and Social Development, which can thoroughly secure the authority, authenticity and reliability of the data.

3.4 Research Methods
3.4.1 Data standardization method
　　The deviation standardized data processing method is used for the standardized processing of the original data. At the same time, in order to exclude the possible zero value, the coordinate translation is added by 0.0001 respectively, so that the data values after the standardized processing are between 0-1, so that the indicators of different units or levels can be compared and weighted.

Forward index formula：$X'_{ij}= （X_{ij}—minX_j）/ （maxX_j—minX_j）$；
Inverse index formula：$X'_{ij}= （maxX_j—X_{ij}）/ （maxX_j—minX_j）$

　　Among them: $maxX_j$ and $minX_j$ are the maximum and minimum values of item j respectively; X_{ij} is the original index value before standardization treatment; X'_{ij} is the index value after standardization treatment.

3.4.2 Determination of weight of evaluation index
　　The weight of the index is calculated by the entropy value weighting method, which is widely used in geoscience research. The calculation formula is as follows:

$$P_{ij} = Y_{ij} / \sum_{i=1}^{n} y_{ij}, \quad E_j = -\ln(n)^{-1} \sum_{i=1}^{n} P_{ij} \ln P_{ij},$$

$$w_i = \frac{1 - E_i}{n - \sum E_i}$$

　　Where, P_{ij} is the proportion of indicator j in the i th city, E_j is the information entropy of indicator j, and W_i is the weight of indicator.

3.4.3 Index method
　　The system index evaluation model is adopted, and the comprehensive evaluation value of each subsystem is calculated by linear weighting method. The calculation formula is as follows:

$$B_i = \sum_{j=1}^{m} w_j x_j$$

Where, m represents the number of indicators of each subsystem, B_i is the comprehensive development index of each subsystem, W_i is the weight of indicators, and X_i is the data value after standardized processing.

3.4.4 Coupling degree evaluation model
　　In order to intensely analyze the coupling relationship among urbanization, social economy and ecological environment, a coupling model was recommended by referring to scholars, and the coupling concept was extended to the phenomenon of mutual influence and action among internal elements of the system. The specific calculation formula of coupling coordination was defined as follows:

$$c = \left\{ \frac{f(x) \cdot g(y) \cdot h(z)}{\left[\frac{f(x) + g(y) + h(z)}{3} \right]^3} \right\}^{\frac{1}{3}};$$

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

　　In the formula, the influence intensity of interaction between systems is defined as coupling degree C. The value of C is between 0 and 1, and the value of C is close to 1, indicating that urbanization, economic development and ecological environment systems are more coordinated, and vice versa. The state of system development level was defined as coupling coordination degree D, and the higher the D value was, the higher the coupling coordination development level was. The comprehensive evaluation index T is introduced to reflect the overall benefit of the three subsystems. $α$, $β$, $γ$ is the weight to be determined. Urbanization, social economy and ecological environment construction are equally important in this study, so it is considered to be formulated as $α = β = γ =1/3$。

3.4.5 Classification of coupling degree and coupling coordination degree
　　By referring to the discriminate standard of related coupling degree and incorporating the calculation results of coupling coordination degree, the system coupling degree and coupling coordination degree are set as follows:

Table 2. Classification of coupling coordination degree

Coupling degree C	Coupling stage	Coupling coordination degree D	Coupling coordination level
0.000<C≤0.300	Low level coupling	0.000<D≤0.300	Severe disorder
0.300<C≤0.500	Antagonistic stage	0.300<D≤0.500	Mild disorder
0.500<C≤0.700	Running-in stage	0.500<D≤0.700	Moderate coordination
0.700<C≤0.900	High level coupling	0.700<D≤0.900	Good coordination
0.900<C≤1.00	High quality coupling	0.900<D≤1.00	High quality coordination

4. Results and Analysis
4.1 Comprehensive development level characteristic analysis
4.1.1 Analysis of time series characteristics of comprehensive development level
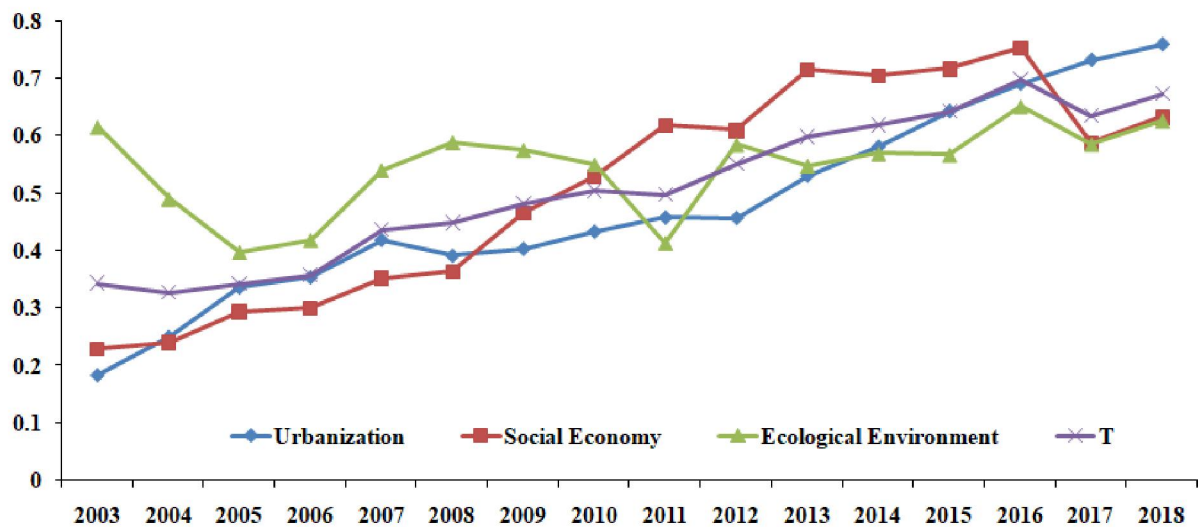

Fig1. Comprehensive index of Urbanization-Social Economy-Ecological Environment subsystem in HBOUUA

Comprehensive analysis by table 3 and figure 1 shows that HBOUUA urbanization, social economy, ecological environment subsystem comprehensive development index sequence evolution trend characterized by interactive wave rise, subsystem of urbanization and social and economic subsystem performance together for greater volatility type, ecological environment subsystem of u-shaped shock wave evolution process. Among them, the urbanization subsystem has the largest growth rate, with an average annual growth rate of 3.59%. After 2017, it has been in the advanced development stage of urbanization and has shown good sustainable growth potential. Before 2010, the ecological environment subsystem was ahead of the development stage of urbanization and social economy subsystem. After 2011, the ecological

environment construction and protection work showed obvious effects, and the subsystem comprehensive evaluation index maintained between 0.55 and 0.65 for a long time. The period from 2011 to 2016 is a stage of advanced social and economic development, which has a strong driving effect on urbanization. The growth trend of social economy and urbanization subsystem is obvious, among which social urbanization grows the fastest, from 0.1843 in 2003 to 0.7592 in 2018, an increase of nearly 4.1 times, with an average annual growth rate of 3.74%. The overall economic aggregate of urban agglomeration grew rapidly. The comprehensive evaluation development index T showed a steady growth trend, increasing from 0.3432 in 2003 to 0.6278 in 2018. Driven by rapid social and economic growth, the growth rate increased

significantly from 2011 to 2016, with an average

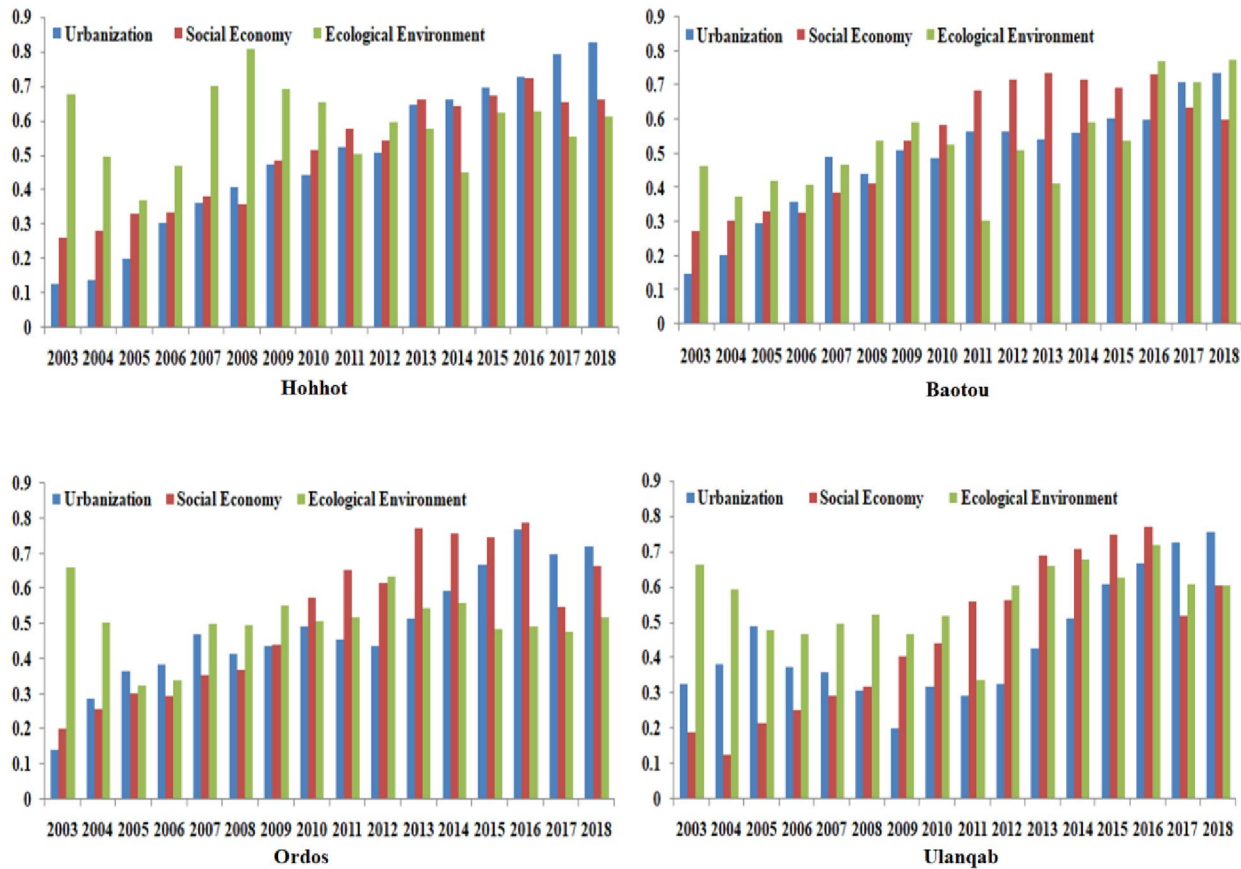annual growth rate of 2.17%.

图 2. Hohhot-Baotou-Ordos-Ulanqab Subsystem composite index

4.1.2 Characteristics of spatial pattern evolution of comprehensive development level

From the comprehensive analysis of Figure 2, it can be seen that the comprehensive development index of urbanization and social economy in Hohhot presents a steady growth trend on the whole, while the comprehensive development index of ecological environment presents a process of shock and fluctuation. The growth trend of the comprehensive development index of urbanization is particularly prominent, increasing from 0.1233 in 2003 to 0.8251 in 2018. The growth rate reached 6.69 times in 2003, and the average annual growth rate of comprehensive development index reached 4.39% during the study period, which highlights the agglomeration function of Hohhot as the capital city of the autonomous Region. Baotou city as a traditional old industrial city, long-term impact on the environment from industrial pollution, ecological environment pressure, the ecological environment comprehensive development index score is low, long-term to maintain between

0.4-0.5, guided by the policy of the industry to capacity since 2016 after better year by year, the overall development of the urbanization and the social economy index show the increasing trend year by year. The comprehensive development index of urbanization and social economy in Ordos city shows a fluctuating growth trend. The comprehensive development index of social economy has been in a strong growth trend since 2010 and reached a peak of 0.7860 in 2016, with an increase of nearly 3.92 times compared with 0.2004 in 2003 and an average annual growth rate of 4.18%. The comprehensive development index of urbanization in Ulanqab showed a fluctuating trend of uptrend, downtrend and rise. After falling to the bottom of 0.1993 in 2009, it showed a strong rebound after being strongly driven by the social economy and ecological environment, and reached 0.754 in 2018. The comprehensive development index of the social economy showed a strong growth trend. The average annual growth rate increased from 0.1253 in 2004 to 0.7708 in 2018, with an average annual growth rate of

4.97%. The comprehensive development index of the ecological environment showed slight fluctuations, and the construction and protection of the ecological environment made good progress, maintaining a good overall condition.

4.2 Analysis of coupling degree evolution characteristics

4.2.1 Overall evolution characteristics of coupling degree

Based on the comprehensive analysis of Table 3 and Figure 3, it can be seen that the coupling degree of HBOUUA has undergone two evolution stages: High level coupling (2003) - High quality coupling (2004-2018). Since 2004, it has entered the stage of high-quality coupling, and the evolution process of coupling degree can be divided into three main stages: The first stage is the ecological environment leading development period (2003-2010), the natural ecological environment background value is good, the overall social and economic development level is low, in the long-term initial development period, the urban social infrastructure supporting construction is not perfect, the overall urbanization level is low. The second stage is

the social and economic leading development period (2011-2016), economic development entered a period of rapid growth, urban infrastructure construction investment increased year by year, the natural ecological environment pressure began to increase. The third stage is the advanced urbanization leading ecological environment lagging development period (2017-2018), the construction of urban infrastructure and supporting facilities is more perfect, the living standard of urban residents is in a better development period, and the social and economic operation has changed from the past extensive development mode to the green and intensive new urbanization construction goal. HBOUUA overall coupling characteristic performance for more coordinated development evolution process between each subsystem, although the overall coupling is higher, but still belongs to the comprehensive coordinated development process, the low level of development of the development gap between subsystems decreased year by year. At the same time, it also reflects the conform to the system and presents a good coordinated development trend. The future still has a lot of room to grow.
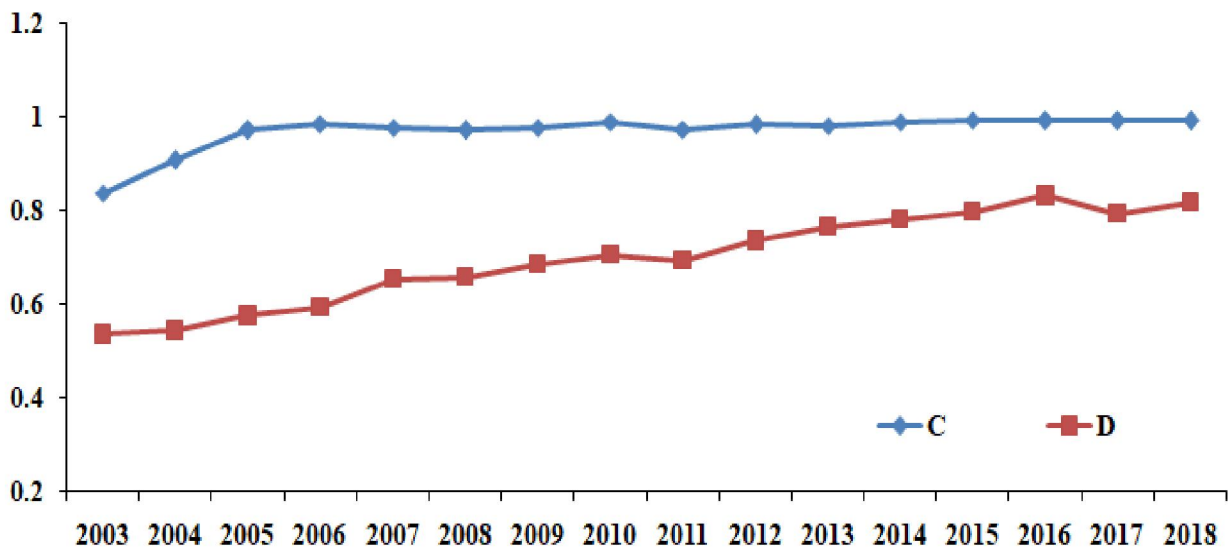

Fig3. Trends of coupling degree and coupling coordination degree of Urbanization-Social Economy-Ecological Environment in HBOUUA

Table3. Coupling degree and coupling coordination degree of Urbanization-Social Economy-Ecological Environment in HBOUUA

Year	Urbanization	Social Economy	Ecological Environment	T	C	D	Contrast relationship	Coupling phase	Coupling type
2003	0.1843	0.2294	0.6160	0.3432	0.8391	0.5356	EE＞SE＞UR	High level coupling	Moderate coordination
2004	0.2510	0.2406	0.4910	0.3275	0.9075	0.5440	EE＞UR＞SE	High quality coupling	Moderate coordination
2005	0.3366	0.2939	0.3982	0.3429	0.9723	0.5764	EE＞UR＞SE	High quality coupling	Moderate coordination
2006	0.3544	0.3005	0.4194	0.3581	0.9852	0.5938	EE＞UR＞SE	High quality coupling	Moderate coordination
2007	0.4194	0.3520	0.5408	0.4374	0.9781	0.6534	EE＞UR＞SE	High quality coupling	Moderate coordination
2008	0.3917	0.3636	0.5894	0.4482	0.9727	0.6589	EE＞UR＞SE	High quality coupling	Moderate coordination
2009	0.4040	0.4657	0.5760	0.4819	0.9788	0.6849	EE＞SE＞UR	High quality coupling	Moderate coordination
2010	0.4337	0.5285	0.5508	0.5043	0.9905	0.7061	EE＞SE＞UR	High quality coupling	Good coordination
2011	0.4581	0.6178	0.4145	0.4968	0.9733	0.6943	SE＞UR＞EE	High quality coupling	Moderate coordination
2012	0.4575	0.6092	0.5855	0.5507	0.9847	0.7361	SE＞EE＞UR	High quality coupling	Good coordination
2013	0.5310	0.7150	0.5483	0.5981	0.9830	0.7667	SE＞EE＞UR	High quality coupling	Good coordination
2014	0.5812	0.7055	0.5697	0.6188	0.9903	0.7827	SE＞UR＞EE	High quality coupling	Good coordination
2015	0.6433	0.7160	0.5677	0.6423	0.9932	0.7986	SE＞UR＞EE	High quality coupling	Good coordination
2016	0.6905	0.7527	0.6516	0.6983	0.9922	0.8323	SE＞UR＞EE	High quality coupling	Good coordination
2017	0.7321	0.5882	0.5860	0.6354	0.9914	0.7933	UR＞SE＞EE	High quality coupling	Good coordination
2018	0.7592	0.6321	0.6270	0.6728	0.9927	0.8170	UR＞SE＞EE	High quality coupling	Good coordination

4.2.2 Spatial evolution characteristics of urban agglomeration coupling degree
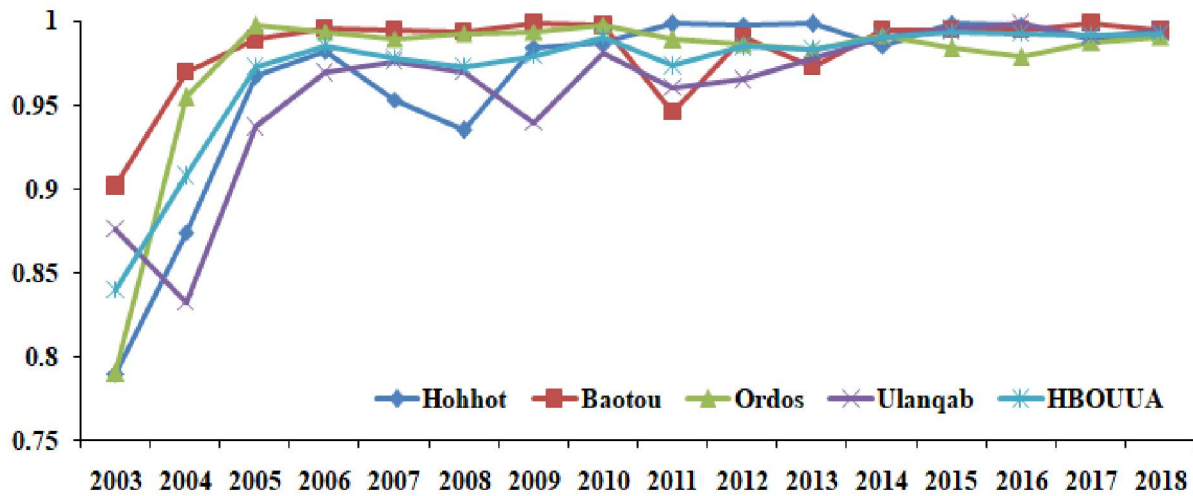

Fig 4. Evolution trend of coupling degree in HBOUUA

Table 4. Coupling degree and coupling coordination degree of Urbanization-Social Economy-Ecological Environment in HBOUUA

City	2003		2008		2013		2018	
	C	D	C	D	C	D	C	D
Hohhot	0.7893	0.5270	0.9346	0.6988	0.9982	0.7906	0.9917	0.8322
Baotou	0.9015	0.5161	0.9935	0.6782	0.9728	0.7409	0.9941	0.8368
Ordos	0.7900	0.5128	0.9927	0.6499	0.9832	0.7749	0.9906	0.7927
Ulanqab	0.8758	0.5865	0.9697	0.6088	0.9776	0.7603	0.9944	0.8065
UrbanAgglomeration	0.8391	0.5356	0.9727	0.6589	0.9830	0.7667	0.9927	0.8170

In order to further analyze the spatial differentiation of the coupling degree of urbanization, social economy and ecological environment in HBOUUA from the municipal scale, four time nodes in 2003, 2008, 2013 and 2018 were selected to plot and sort out the coupling degree of each city (Table 4). As can be seen from Figure 4 and Table 4, the coupling degree of all cities in HBOUUA shows an overall positive development trend, and the spatial evolution shows an obvious trend of convergence and optimization, which is a good foundation for development.

From the perspective of time evolution, in 2003, the coupling degree of Baotou has reached the stage of High quality coupling, Ulanqab, Ordos, Hohhot in the stage of High level coupling, among which, the coupling degree of Hohhot is the lowest 0.7893. From 2008 to 2018, all municipalities in HBOUUA have reached the high quality coupling stage. The above results demonstrate that the subsystems of urbanization, social economy and ecological environment in HBOUUA are closely related and highly dependent on each other, which is reflected in the strong synergistic effect among the subsystems.

4.3. Analysis on evolution characteristics of coupling coordination degree
4.3.1 Overall evolution characteristics of coupling coordination degree

From the comprehensive analysis of Table 3 and Figure 3, it can be seen that the coupling coordination degree of urbanization, social economy and ecological environment in HBOUUA presents a slow and steady upward trend, rising year by year from 0.5356 in 2003 to 0.8170 in 2018, with an average annual growth rate of 1.76%. The evolution process of coupling coordination degree can be divided into: Moderate Coordination (2003-2009), Good Coordination (2010), Moderate Coordination (2011),

Good Coordination (2012-2018) and other four major evolution stages of coupling coordination degree, the score of coupling coordination degree always lags behind the coupling degree for a long time, and presents a smaller trend year by year over time. The synergistic development effect among subsystems of urbanization, social economy and ecological environment gradually emerges. It reflects that the orderly development ability of the system is gradually improving, and the system is moving towards a high-level orderly development trend. However, the coupling coordination degree value is low, and it has been in the stage of good coordination coupling coordination for a long time since 2012, and there is still a big gap to reach the high quality coordination of 0.900. If the current good development trend can be maintained, high quality coordination will be realized soon.

4.3.2 Spatial evolution of coupling coordination degree in urban agglomerations

Due to the significant differences in the development of different cities, in order to further analyze the spatial differentiation of the coupling coordination degree of urbanization, social economy and ecological environment in HBOUUA from the municipal scale (Figure 5), four time nodes in 2003, 2008, 2013 and 2018 were also selected to plot and sort out the coupling coordination degree of each city (Table 4). Can be seen from the figure 5 table 4, HBOUUA urbanization, social economy and ecological environment coordination degree of the ecological environment system are presented for the dynamic fluctuations rise slowly, spatial evolution pattern of performance for each city coupling coordination degree synchronization ascending trend, the coupling coordination degree value gap between cities and minimum are embodied in the urban agglomeration of urban

agglomeration in strong effect, The coordinated development process is reflected among the urban subsystems in urban agglomeration. Nonetheless, there is still a big gap between the

coupling coordination degree of 2018 and high-quality coordination, which also signifies that HBOUUA still has a large room for growth in the future.
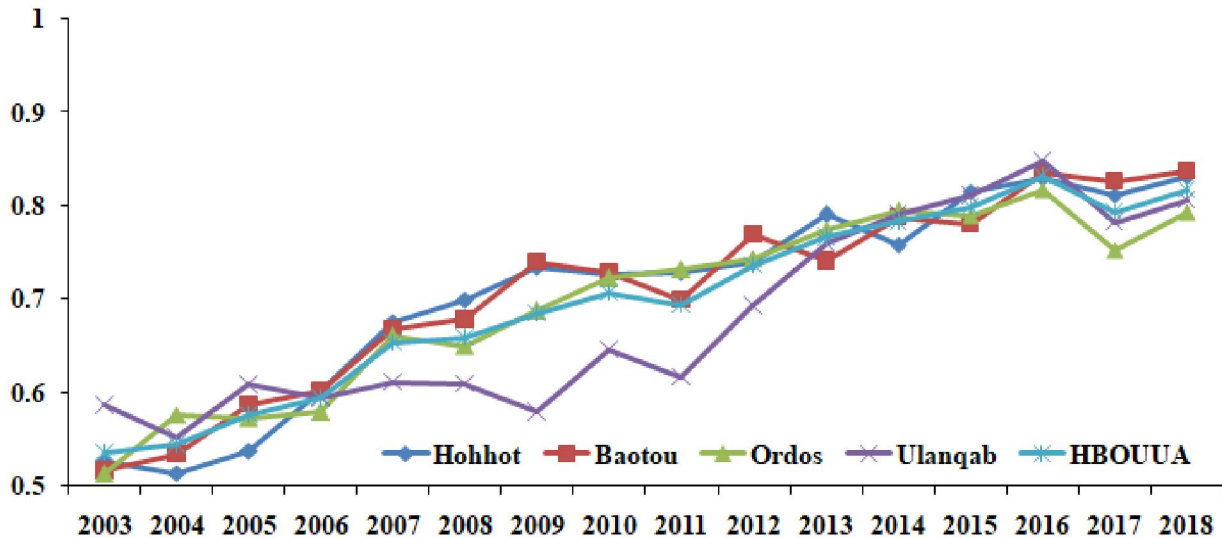

Fig5.Evolution trend of coupling coordination degree in HBOUUA

5. Discussion and Optimal strategies
5.1 Discussion
5.1.1 To sum up, this paper aims to reveal the coupling mechanism, process and pattern of urbanization, social economy and ecological environment system in HBOUUA. First of all, a three-dimensional measurement system of urbanization, social economy and ecological environment is established. Compared with the previous index system [26], it can more truly reflect the comprehensive development level of the coupling system and is more conducive to analyzing the endogenous factors that affect the degree of coupling coordination. Secondly, the comprehensive development index of HBOUUA urbanization, social economy and ecological environment was quantitatively analyzed, and it was found that during the study period, the comprehensive development index of subsystems had significant growth changes, among which the comprehensive development index of urbanization had rapid growth, which was completely consistent with the actual situation of HBOUUA in the new development period [40]. HBOUUA as in Inner Mongolia, the urban population, resources and the core of the most active economic development zone, due to the height of the economic elements together with the innovation and development, during the "13th Five-Year Plan" period of Inner Mongolia Autonomous Region, the annual growth rate of regional GDP was 4.5%, higher than the average growth rate of the whole

region was 0.2%, and the city cluster scale system was in a rising period of growth and development. Accordingly, this study provided an important theoretical support for the high-quality integrated development of HBOUUA.

5.1.2 Based on the previous research results, the development of new type of urbanization, the social economy is the important conditionality factors affecting system coupling coordination degree of ascension, the industrial development is the core of effective driving the development of urbanization growth drivers, but at the same time, under the traditional economic development model of energy consumption and the ecological environment resources became evident pressure along with urbanization, This is consistent with existing research results [21,26,39,40]. HBOUUA is an important urban group area for ecological protection and high-quality development along the Yellow River Basin of Inner Mongolia, and a key development area and core area for economic development in the "14th Five-year Plan" of Inner Mongolia Autonomous Region during the new development period. The research results comprehensively reflect the rising trend of system coupling coordination degree. But its ecological environment characteristics for the long-term lagging development since 2014, the ecological environment has become the important influence factors, which

restrict the development of the HBOUUA quality, therefore, to speed up the green development model transformation, urban agglomeration, focusing on the innovation drive shift from elements drive to innovation, relying on resources and environment advantage city form the dislocation differentiation of economic development mode, To enable new-type urbanization to achieve sustainable economic growth within the carrying capacity of ecological, resource and environmental systems.

5.1.3 Limitations and future research directions

There are still some limitations in this study, and some suggestions for future research direction are put forward. Based on previous studies, combined with the composite system perspective analysis and the actual situation of the region, this paper makes a comprehensive evaluation of HBOUUA urbanization, social economy and ecological environment, but there are still some shortcomings. First of all, the town is a complex system complex. Although careful screening has been carried out in the construction process of the comprehensive evaluation index system, its applicability still needs to be verified and improved in subsequent studies. Secondly, due to the limitation of data collection of ecological and environmental indicators, the ecological and environmental indicators in this paper are not comprehensive and complete, which may modify the accuracy of research results to some extent. Thirdly, this research only studies the coupling and coordinated evolution of cities at a comparatively macro level. Future studies should be more detailed to the micro studies of counties, districts and other regions to upgrade the academic nature of the research.

5.2 Optimal strategies

（1）We should promote ecological progress and fully execute the new vision of development. Comprehensive optimization HBOUUA space layout of the productivity, enhance the regional collaborative innovation and development ability, go the way of sustainable development of high quality, through effective policies lead to realize the complementary advantages, differential areas in the urban agglomeration coordinated development strategy, science and technology innovation as stimulate urban agglomeration regional innovation ability to drive and achieving high quality important strategic support for the development of the new path, Speed up the construction of an integrated comprehensive transportation system, improve the connectivity level of modern infrastructure, and actively promote high-quality development of HBOUUA.

（2）Accelerate industrial transformation and upgrading and promote the development model of

green economy. As can be seen from the above calculation results, HBOUUA ecological environment comprehensive assessment index has been in a state of fluctuating development for a long time, and has been in a lagging development mode since 2011. As a key region of HBOUUA's new-type urbanization development, resource consumption and environmental pressure under the traditional economic development model continue to extend, and ecosystem pressure gains year by year. The region should accelerate the transformation to green development mode, so that the new towns can retain the coordinated and consistent development of the economic system within the carrying capacity of the ecological, resource and environmental systems, so as to achieve sustainable economic growth.

（3）Putting people first and ensuring people's well-being .HBOUUA is located in the important area of the Yellow River basin ecological protection is an urgent need to combining with the characteristics of regional ecological environment, moderately reduce the urban agglomeration in the urbanization speed, pay attention to quality and efficiency of urbanization development, reduce the urban agglomeration in the ecological environment pressure, adhere to the "people-oriented" of a new path of urbanization development, enhance citizens' welfare. Strengthen the status of the central city of urban agglomeration, improve the agglomeration effect and scale effect of the region, and at the same time, do a good job of standardized and scientific guidance, avoid the negative impact caused by excessive concentration of various factors, strengthen the support policy for the tertiary industry, give consideration to the economic supply side and social welfare structure, and ensure the welfare level of residents.

6. Conclusion

Taking HBOUUA as an empirical object, this study comprehensively analyzed the comprehensive development level and spatial-temporal evolution process and pattern of coupling coordination of HBOUUA urbanization-social economy-ecological environment system from 2003 to 2018 based on the coupled coordinated development evaluation model. The research results effectively analyzed the coordination mechanism of urbanization, social economy and ecological environment in HBOUUA, expanded the understanding of the evaluation of coupling coordination degree, and provided reference for the sustainable development of HBOUUA urbanization, social economy and ecological environment system. The main conclusions are as follows: (1) The comprehensive development level of urbanization, social economy and ecological environment in HBOUUA shows an upward trend,

experiencing the process of ecological environment advance development, social economy advance development and urbanization advance development; (2) The coupling degree of HBOUUA urbanization-social economy-ecological environment system has been improved from high level coupling to high quality coupling, and the coupling coordination degree has undergone moderate coordination and then turned to good coordination. (3) The temporal sequence characteristics of coupling degree and coupling coordination degree of each city in the urban agglomeration showed an upward trend, and the spatial characteristics showed a synergistic growth and evolution spatial pattern.

Acknowledgment

References:
[1] Chenery H B, Syrquin，M. Patterns of development：1950-1970[M]. London：Oxford University Press，1975.
[2] Laumas P S, Williams M. Urbanization and economic development[J]. Eastern Economic Journal, 1984,10(03): 325-332.
[3] Nour E，Balla A H. The relationship between urbanization and socioeconomic development in the Sudan[J]. Geo Journal, 1989,18(04): 369-377.
[4] Vernon Henderson. How Urban Concentration Affects Economic Growth[J]. Policy Research Working Paper, 2000,42(04): 1-42.
[5] Pacione M. The internal structure of cities in the third world[J]. Geography, 2001,86(03):189-209.
[6] Lewis, Blane D. Urbanization and Economic Growth in Indonesia：Good News，Bad News and （Possible) Local Government Mitigation[J]. Regional Studies, 2014,48(01): 192-207.
[7] Tripathi S, Mahey K. Urbanization and economic growth in Punjab (India): an empirical analysis[J]. Urban Research & Practice, 2016,10(04): 379-402.
[8] Zhao Xianzhou. A Dynamic Analysis of the Interaction between Urbanization and Economic Development in China [J]. China Soft Science, 2006(09): 116-121.
[9]Zhu konglai, Li jingjing, Le feifei. Empirical Analysis on the Relationship between China Urbanization and Economic Growth [J]. Statistical Research, 2011,28(09): 80-87.
[10] Zhou hui. Urbanization, Spatial Spillover and

Economic Growth—Based On Prefecture Level Panel Data Empirical Evidence of The Central Region [J]. Shanghai Journal of Economics, 2016(02): 93-102.
[11] CHEN Mingxing LU Dadao LIU Hui. The Provincial Pattern of the Relationship between China's Urbanization and Economic Development [J]. Acta Geographica Sinica, 2010,65(12): 1443-1453.
[12] HUANG Muyi, CHENG Zhiguang. Analysis on Spatial- temporal Characteristics of the Coordinated Development Degree between Regional Urbanization and Social Economy: A Case Study of Anhui Province [J]. Economic Geography, 2012,32(02):77-81.
[13] DONG Zhiqing, WANG Hui. Urbanization, Economic Agglomeration and Heterogeneity of Regional Economic Growth—Empirical Evidence Based on Spatial Panel Durbin Model [J]. Academic Monthly, 2019,51(10): 54-66.
[14] ZHOU Liang, CHE Lei, SUN Dongqi. The Coupling Coordination Development between Urbanization and Economic Growth and Its Influencing Factors in China [J]. Economic Geography, 2019,39(06): 97107
[15] NORTHAM R. Urban Geography[M]. New York: John Wiley＆Sons, 1979.
[16] KJELLSTROM T，CORVALAN C. Framework for the development of environmental health indicators[J]. World Health Statistics Quarterly, 1995(48).
[17] GROSSMAN G, KRUEGER A. Economic growth and the environment[J]. Quarterly Journal of Economics, 1995(110).
[18] TAPIO P. Towards a theory of decoupling：degrees of decoupling in the EU and the case of road traffic in Fin□land between 1970 and 2001. [J] Transport Policy, 2005,12(2).
[19] Ma Shijun, Wang Rusong. The Social-Economic-Natural Complex Ecosystem [J]. Acta Ecologica Sinica, 1984,4(1).1-9
[20] Liu Yanbin，Song Xuefeng. Coupling Degree Model and Its Forecast} g Model of Urbanization and E co logical Environment [J]. Journal of China University of Mining &Technology, 2005(1).1-9.
[21] FANG Chuang-lin, YANG Yumei. Basic laws of the interactive coupling system of urbanization and ecological environment [J]. Arid Land Geography, 2006,29(1): 1-8.
[22]Cui Muhua. The Relationship of Coupling Coordination between Urbanization and Ecological Environment [J]. Economic Geography, 2015,35(7): 72-78
[23] LIU Haimeng, FANG Chuanglin, LI Yonghong.

The Coupled Human and Natural Cube: Aconceptual framework for analyzing urbanization and eco-environment interactions [J]. Acta Geographica Sinica, 2019,74(8): 1489-1507.

[24] DENG Zongbing, ZONG Shuwei, SU Congwen, CHEN Zheng. Research on Coupling Coordination Development between Ecological Civilization Construction and New Urbanization and Its Driving Forces in the Yangtze River Economic Zone [J]. Economic Geography, 2019,39(10): 78-86.

[25] DU Xia, MENG Yanru, FANG Chuanglin, et al. Spatio-temporal characteristics of coupling coordination development between urbanization and eco-environment in Shandong Peninsula urban agglomeration [J]. Acta Ecologica Sinica, 2020,40(16): 5546-5559

[26] Zhao Jianji, Liu Yan, Zhu Yakun, et al. Spatiotemporal differentiation and influencing factors of the coupling and coordinated development of new urbanization and ecological environment in the Yellow River Basin[J]. Resources Science, 2020, 42(1): 159-171.

[27] Rachel Carson. Silent Spring[M]. Boston：Houghton Mifflin Company, 1962.

[28] Meadows D H，Meadows D L，Randers J，et al. The Limits to Growth[M]. New York：Universe Books, 1972.

[29] E. J. Mishan. The costs of economic growth[M]. London: Stables Press, 1967.

[30] Grossman G，Krueger A B. Environmental Impacts of a North American Free Trade Agreement[J]. National Bureau of Economic Research Working Paper Series，1991, (3914):1-57.

[31] Grossman G，Krueger A B. Economic growth and the environment[J]. Quarterly journal of Economics, 1995, (110): 353-377.

[32] CHEN Xingpeng, FAN Zhenjun, JIANG Xiaojuan, DONG Suocheng. A Research on the Mechanism of Interaction between Economy Development and Ecological Environment of Lanzhou City [J]. Real Research and Development, 2005(01): 92-95.

[33] Liu an xuan, Yang Zhan, Liang xuesh. An Empirical Study on Environmental Kuznets Curve in Heilongjiang [J]. Territory & Natural Resources Study, 2017(02): 58-62.

[34] Zhang setting, Chi the. Analysis on coordination degree of provincial regional economy and environment in China in 1990s [J]. Geographical research, 2001(04): 506-515.

[35] Wang Liang jian, Zou wen, Huang ying et al. An Empirical Study on Environmental Kuznets Curve in Eastern China[J]. Humanities & Social Sciences Journal of Hainan University, 2009,27(01): 57-62.

[36] Li Rui. Study on the coupling relationship between regional urbanization, economic development and ecological environment [D]. North China University of Science and Technology, 2019.

[37] HOU Langong, ZHANG Xiang, ZHAO Chunrong. Study on coordination of urbanization, economy and environment in Chengdu metropolitan area [J]. Hubei Agricultural Sciences, 2020,59(19): 91-98.

[38] Shao Huilin. Study on the Coupled and Coordinated Development between Urbanization, Economic Development and ecological Environment in. Jiangxi Province[D]. Jiangxi University of Finance and Economics, 2020.

[39] Wei YueHeng. Research on coupling and coordination evaluation of eco-environment for urbanization economic development in Beijing-Tianjin-Hebei urban agglomeration [D]. Hebei University, 2021.

[40] Zhao Yongfeng, Zheng Hui. The spatio-temporal interaction and coupling relationship between population, economy, resources and environment in Inner Mongolia [J]. Resource Development＆Market. 2021, 37(06):705-715.

2/22/2022