Coordination Evaluation of Regional HSER Complex System: An Empirical Analysis Based on 14 Major Cities in China

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Abstract. According to the coordination theory of complex system, this paper establishes a coordination evaluation index system of regional HSER complex system. Taking the Yangtze River Delta, Pearl River Delta, Bohai Rim Region, Northeast China, Central and Western China as study areas, this paper explores a coordination evaluation of regional HSER complex system within 14 major cities in China over the period 2010 to 2018. The empirical evidence suggests that the coordination degrees of the HSER complex system of the Yangtze River Delta, the Pearl River Delta, and the Bohai Rim Region are significantly higher than that of the Northeast, Central, and Western regions in China.

1. Introduction
The analysis and evaluation of the coordinated development of housing industry, society, economy and resources (environment) mainly focus on the interaction between housing industry and urban economy, the coordinated development of housing market and city, the micro-economic analysis and evaluation of housing demand and supply, the evaluation of residents’ affordability and housing price rationality, and the analysis of housing policy [1]. There is still a lack of targeted research framework for the coordinated development of housing industry and society, economy and resources (environment). From the perspective of composite system coordination, the evaluation index system of coordinated development of regional HSER composite system is constructed. The coordination of regional HSER composite system is qualitatively analyzed and quantitatively verified, and then the macro-performance of housing industry is analyzed and evaluated, which provides policy basis for formulating the development planning and industrial regulation of housing industry. It has a very important practical significance to ensure the stability, sustainability and healthy development of housing industry [2].

2. Definition and composition of regional housing industry-social-economic-resource (HSER) composite system
From the perspective of time domain and geography, the development of housing industry system is a gradual process. It has obvious cyclical fluctuation characteristics in time evolution, and has significant spatial non-equilibrium characteristics in geographical distribution. Therefore, combined with the purpose of this paper, based on the composite system theory, a regional housing industry-society-economy-resource (HSER) composite system is constructed to facilitate the study of the macro performance of the
housing industry—the coordination of housing industry and society, economy and resources, and sustainable development problem.

According to the definition of composite system, this paper considers that the regional housing industry-society-economy-resource (HSER) composite system refers to the housing industry, in the process of residential production, circulation, consumption, service and management, at a specific time and region. The social, economic, resource and other systems and the various elements within the systems form an interrelated relationship of mutual adaptation, mutual penetration and mutual restraint. These relationships are intertwined and interacted, and are compounded into open and complex structures and functions [3].

The regional housing industry-society-economy-resource (HSER) composite system is:

\[ S = f(S_1, S_2, S_3, S_4) \]

Where \( S_i \) is a subsystem, \( f \) is a composite factor, \( i = 1, 2, 3, 4 \).

For the regional HSER composite system, there is always the exchange, action and fusion of material flow, energy flow, information flow and value flow between the various subsystems and the internal elements of the system, so that the composite system has complexity, multidimensional features such as synergy, order, openness, and dynamics.

3. The coordination degree model of regional HSER complex system

3.1. The order parameter of the regional HSER composite system subsystem and the order degree of the subsystem

Regional HSER composite system \( S = \{S_1, S_2, ..., S_s\} \), where \( s \) is a number of subsystems that are composited into \( s \), and \( S_j = \{S_{j_1}, S_{j_2}, ..., S_{j_m}\} \), that is, \( S_j \) is composed of several "sub-subsystems" or several basic elements, \( j = 1, 2, 3, 4 \). The interaction of \( S_j \) and their relationship form a complex mechanism of \( S \). In this composite mechanism, there are a number of intrinsically determined stability factors, whether the system's self-organization or external role in the system will not affect such factors [3].

Considering a subsystem \( S_j, j \in [1, 4] \) of the regional HSER complex system, the order parameter variable in its development process is set as \( e_i = (e_{i1}, e_{i2}, ..., e_{in}) \), where \( n \geq 1, \beta_{\mu} \leq e_{i\mu} \leq \alpha_{\mu}, i \in [1, 4] \). Without losing generality, it can be supposed that the larger value of \( e_{i1}, e_{i2}, ..., e_{in} \) will lead to the higher order degree of the system and vice versa. And it also can be supposed that the larger value of \( e_{j(i+1)}, ..., e_{jn} \) will lead to the higher order degree of the system and vice versa. Then we can define the order degree of the order parameter component \( e_{i\mu} \) of subsystem \( S_j \) as follows:

\[
\nu_j(e_i) = \begin{cases} 
\frac{e_{i\mu} - \beta_{\mu}}{\alpha_{\mu} - \beta_{\mu}}, & i \in [1, l] \\
\frac{\alpha_{\mu} - e_{i\mu}}{\alpha_{\mu} - \beta_{\mu}}, & i \in [l+1, n]
\end{cases}
\]

Where \( \alpha_{\mu} \) and \( \beta_{\mu} \) represent respectively the upper and lower limits of the indicator \( i \) of subsystem \( S_j \).

The system order degree \( \nu_j(e_i) \) of subsystem \( S_j \) can be realized by the integration of \( \nu_j(e_{i\mu}) \). The geometric averaging method is adopted for the integration:

\[
\nu_j(e_i) = \sqrt[n]{ \prod_{\mu=1}^{n} \nu_j(e_{i\mu}) } \quad j \in [1, 4]
\]
It can be seen that the larger the value of \( \mu_j(e) \in [0, 1] \) will lead to the higher order degree of the subsystem \( S_j \), and vice versa, the lower \(^{[5]}\).

3.2. Coordination degree of regional HSER composite system

Assuming that the given initial time is \( t_0 \), and the system order degree of subsystem order parameters of regional HSER composite system is \( u_j^0(e_j), j \in [1, 4] \), for the time \( t \), of the whole composite system in the process of development and evolution, if the system order degree of subsystem order parameters is \( u_j^r(e_j), j \in [1, 4] \), and \( XTD(t) \) is defined as the coordination degree of the composite system, then there is:

\[
XTD(t) = \theta \sqrt{\frac{1}{\mu_j(e_j)} \left[ u_j^r(e_j) - u_j^0(e_j) \right]^4}
\]

Where \( \theta = \min \left\{ \frac{u_j^r(e_j) - u_j^0(e_j)}{u_j^r(e_j) - u_j^0(e_j) \neq 0} \right\}, j \in [1, 4] \).

In the formula, \( u_j^r(e_j) - u_j^0(e_j) \) is the change range of system \( S_j \) from \( t_0 \) to \( t \), and \( XTD(t) \in [-1, 1] \). The function of parameter \( \theta \) is that if and only when \( u_j^r(e_j) - u_j^0(e_j) \neq 0, \forall j \in [1, 4] \), the regional HSER composite system adopts positive co-scheduling; if at least one of \( u_j^r(e_j) - u_j^0(e_j) \leq 0, \forall j \in [1, 4] \), the regional HSER composite system adopts non-positive coordination degree, indicating that at least one subsystem of the regional HSER composite system is oriented. The disordered direction evolution indicates that the regional HSER composite system is in the state of non-coordinated development at this time.

According to the definition of coordination degree of composite system, \( XTD(t) \in [-1, 1] \), that is, the regional HSER composite system coordination degree value is between -1 and 1. The greater the coordination value of the composite system, the better the overall coordination of the regional housing industry-society-economy-resource complex system, and the higher the macro performance of the housing industry; on the contrary, the lower. According to the coordination degree of \( XTD(t) \), the coordination of regional HSER composite system is divided into six levels (as shown in Table 1) combined with relevant experts’ opinions \(^{[6]}\).

| Compound system coordination \( XTD(t) \) | [-1.0) | [0.0,2) | [0.2,0.4) | [0.4,0.6) | [0.6,0.8) | [0.8,1.0] |
|-----------------------------------------|-------|--------|----------|----------|----------|---------|
| Coordination level of composite system  | Extremely uncoordinated | Uncoordinated | Weak coordination | General coordination | More coordinated | Coordinated |

4. The coordination evaluation index system of regional HSER complex system

The evaluation of the degree of coordination of the development of the regional HSER composite system involves the multi-dimensional structure of each subsystem and the synergy of each subsystem element. Therefore, the sub-system component parameters of the regional HSER composite system are characterized by large quantity, multiple levels, complex correlations and large differences. The principles to be followed in establishing the regional HSER composite system coordination evaluation
index system are as follows: (1) The principle of purpose; (2) The principle of integrity; (3) The principle of dynamics; (4) The principle of operability [7].

Based on the main contents reflected by the constituent elements of the above subsystems, the basic framework of the evaluation index system for the regional HSER complex system is shown in Table 2:

| Primary indicator | Secondary indicators | Three-level indicators                                                                 | Units          |
|-------------------|----------------------|----------------------------------------------------------------------------------------|----------------|
| Housing industry subsystem evaluation index | Per capita housing construction investment completion | 100 million yuan / person |
|                   | Housing construction investment completion rate growth rate | % |
|                   | Residential investment accounts for the proportion of fixed assets investment in the whole society | m²/person |
|                   | Per capita housing completion area | |
|                   | Per capita residential sales area | |
|                   | Average residential sales price | |
|                   | Residential absorption rate [(sales area / (previous year vacant area + completed area)] | m²/person |
|                   | House price to income ratio | % |
|                   | Number of development companies | number |
|                   | Industry employees account for the proportion of employed persons in the tertiary industry | % |
| Social subsystem evaluation index | Urban population density | person /km |
|                   | Urban population growth rate | % |
|                   | Per capita residential building area of urban residents | m²/person |
|                   | Average wage of employees on the job | yuan/year |
|                   | Per capita disposable income of urban residents | yuan |
|                   | Per capita consumption expenditure of urban residents | yuan |
|                   | Residents’ per capita savings deposit balance | % |
|                   | Engel coefficient of urban households | % |
|                   | Urban consumer price index | |
|                   | Per capita living consumption as a share of consumer spending | |
|                   | The number of buses per 10,000 people in the city | standard number |
| Economic subsystem evaluation index | Gross domestic product gdp | 100 billion yuan |
|                   | Per capita gdp | yuan / person |
|                   | GDP growth rate | % |
|                   | Per capita fiscal revenue | yuan |
|                   | Fiscal revenue growth rate | % |
|                   | Per capita industrial output value | |
|                   | Per capita social investment in fixed assets | 100 billion yuan |
|                   | The growth rate of fixed assets investment in the whole society | % |
|                   | Actual use of foreign investment | 100 billion yuan |
|                   | New fixed assets in the whole society | 10 thousand U.S. dollars |
|                   | The added value of the tertiary industry accounts for the proportion of GDP | % |
5. Coordination Evaluation of Regional HSER Composite Systems: An Empirical Study Based on 14 Major Cities in China

5.1. Selection of evaluation examples and data sources

Considering the strong regional distribution characteristics of housing industry and market, this paper takes the Yangtze River Delta, Pearl River Delta, Bohai Rim, Northeast, Central and Western regions as the research areas, and chooses the main cities with similar geographical location in the region as the basic research object. Shanghai, Hangzhou and Ningbo are representative cities selected from the Yangtze River Delta region, Guangzhou and Shenzhen from the Pearl River Delta region, Beijing and Tianjin from the Bohai Rim region, Harbin, Changchun and Shenyang from the Northeast region, Wuhan and Changsha from the central region, and Chengdu and Chongqing from the western region.

According to the coordinated evaluation index system of regional HSER composite system in Table 2, the relevant historical data needed for the market-oriented development of housing industry from 2010 to 2018 are obtained from China Statistical Yearbooks, the statistical yearbooks of the above cities, the annual data of each city and the statistical bulletin of national economic and social development.

5.2. Calculation of coordination degree of HSER complex system in 14 major urban areas of China

The order parameters of the regional HSER composite system subsystems in each city are the lower limit of the corresponding values of the indicators in 2010, and the corresponding values of the various indicators in 2018 are the upper limit. By substituting the data into the model (2), (3), (4) for calculation, and the order degree of the regional HSER composite system subsystem and the coordination degree of the composite system in 14 major cities from 2010 to 2018 are obtained. (as shown in Table 3 and Figure 1) [8].

Table 3. Regional HSER complex system coordination degree of 14 major cities in China.

| region/city       | 2010   | 2011   | 2012   | 2013   | 2014   | 2015   | 2016   | 2017   | 2018   |
|-------------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| Yangtze River Delta |        |        |        |        |        |        |        |        |        |
| Shanghai         | 0.3640 | 0.5469 | 0.4742 | 0.7354 | 0.8142 | 0.7346 | 0.7061 | 0.7213 | 0.7309 |
| Hangzhou         | 0.2048 | 0.3888 | 0.3662 | 0.3807 | 0.4053 | 0.4669 | 0.5211 | 0.5320 | 0.6035 |
| Ningbo           | 0.1578 | 0.1803 | 0.2124 | 0.2264 | 0.3439 | 0.4245 | 0.4026 | 0.4039 | 0.4173 |
| Pearl River Delta |        |        |        |        |        |        |        |        |        |
| Guangzhou        | 0.2209 | 0.2432 | 0.2155 | 0.3147 | 0.4473 | 0.5102 | 0.3048 | 0.2409 | 0.1892 |
| Shenzhen         | 0.2421 | 0.2336 | 0.2722 | 0.4139 | 0.5563 | 0.4623 | 0.4216 | 0.3855 | 0.3297 |
| Bohai Rim Region |        |        |        |        |        |        |        |        |        |
| Beijing          | 0.2715 | 0.3210 | 0.5339 | 0.5216 | 0.6296 | 0.6189 | 0.6950 | 0.7398 | 0.6421 |
| Tianjin          | 0.0835 | 0.1046 | 0.2371 | 0.2544 | 0.2219 | 0.2919 | 0.2380 | 0.3097 | 0.3602 |
| North-east China |        |        |        |        |        |        |        |        |        |
| Harbin           | 0.0733 | 0.1043 | 0.0814 | 0.0868 | 0.1093 | 0.1416 | 0.2053 | 0.2165 | 0.2414 |
| Changchun        | 0.0382 | 0.0632 | 0.0721 | 0.0582 | 0.1238 | 0.2072 | 0.1660 | 0.2971 | 0.2731 |
Table 1: Regional HSER complex system coordination degree of 14 major cities in China

| City            | 2010   | 2011  | 2012   | 2013  | 2014  | 2015  | 2016  | 2017  | 2018  |
|-----------------|--------|-------|--------|-------|-------|-------|-------|-------|-------|
| Shenyang        | 0.0260 | 0.0469| 0.0536 | 0.0741| 0.0869| 0.0739| 0.1089| 0.3358| 0.1034|
| Wuhan           | 0.0644 | 0.0571| 0.0629 | 0.0771| 0.1105| 0.2139| 0.2607| 0.3045| 0.4702|
| Changsha        | 0.0266 | 0.0523| 0.1307 | 0.0850| 0.1036| 0.2761| 0.5987| 0.2792| 0.5277|
| Chengdu         | 0.0578 | 0.0492| 0.0649 | 0.0722| 0.0828| 0.1505| 0.2884| 0.2734| 0.6529|
| Chongqing       | 0.0117 | 0.0286| 0.0103 | 0.0253| 0.0166| 0.1434| 0.3150| 0.3833| 0.3621|
| Source: China Statistical Yearbook, calendar yearbooks and statistical bulletins of various cities over the years.

Figure 1. Regional HSER complex system coordination degree of 14 major cities in China

5.3. Comparison and analysis of coordination of HSER complex system in 14 major cities of China

Since the rapid development of housing market in 2010, China's housing industry and housing market have made great progress in more than 9 years. Tables 3 and Figure 1 show that the overall coordination of regional housing subsystems, social subsystems, economic subsystems and resource subsystems is tending to improve. Generally speaking, the coordination level of HSER composite system in 14 major urban areas has obvious differences among regions, cities and stages according to the coordination degree of HSER composite system in sample cities [9].

Firstly, the coordination degree of HSER complex system in Yangtze River Delta, Pearl River Delta and Bohai Rim region is significantly higher than that in Northeast, Central and Western regions. Using the mean method to analyze the coordination level among regions, it can be found that the coordination level distribution of regional HSER composite system is in the order of Yangtze River Delta, Bohai Rim, Pearl River Delta, Central, Western and Northeast.

Secondly, from the point of view of coordination degree of regional HSER composite system, the coordination degree of Tianjin, Chongqing, Changchun, Harbin and Shenyang has been less than 0.4 during the 9-year period from 2010 to 2018, the coordination degree of Wuhan and Chengdu for 9 years is less than 0.4, and that of Changsha for 8 years is less than 0.4; only Shanghai and Shenyang for 9 years are the coordination degree of composite system greater than 0.6. Four cities, Beijing, Hangzhou and Chengdu, have six, five, one and one years respectively; Shanghai is the only one city that has a coordination degree greater than 0.6 in 9 years, while Shanghai has a coordination degree of 0.8142 in 2014.

Thirdly, from the stage of coordination level fluctuation during the study period, the coordination level of regional HSER composite system shows a certain degree of fluctuation difference among
sample cities. From 2010 to 2014, the coordination level of most cities fluctuated slightly and improved relatively steadily. During the period from 2015 to 2018, the coordination level of regional HSER composite system in four key cities in eastern China, Shanghai, Beijing, Guangzhou and Shenzhen, showed an obvious fluctuating downward trend, while in the same period, the coordination level of regional HSER composite system in five non-economically developed cities, Chongqing, Chengdu, Wuhan, Shenyang and Changchun, showed an obvious fluctuating upward trend.

According to the coordination analysis of regional HSER composite system in the above 14 major cities, it can be seen that the development time of China's housing industry and housing market is relatively short, the overall level of development is not high, and the coordination level of regional HSER composite system in all regions and cities is generally low. The policy factors of the government's macro-control have exerted a profound impact on the development of China's housing industry since 2014. From the perspective of the coordinated development of the regional HSER complex system, although the degree of marketization of housing in the eastern developed regions is generally higher, the advantages of economy and resources are gradually degraded under the situation of increasing government control measures, while the central and western regions are economically fast. Development, social progress, and industrial resource advantages continue to increase, so the gap between the former and the latter's regional HSER complex system is gradually narrowing.

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