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Spatial-temporal characteristics of the coupling coordination of social security and economic development in China during 2002–2018

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Full Length Article

Spatial-temporal characteristics of the coupling coordination of social security and economic development in China during 2002–2018

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ABSTRACT

Clarifying the relationship between social security and economic development is helpful to realize the sustainable social security system and the stable function of sustainable economic development. In this paper, the entropy method, coupling coordination degree, standard deviation ellipse model, and spatial autocorrelation were used to study the spatial-temporal characteristics of coupling coordination of social security and economic development in China from 2002 to 2018. The results indicate that the relationship between social security and economic development in China has been gradually strengthened in the process of mutual adaptation and common development. The benign interaction between the two was unstable, though the coupling coordination degree gradually transitioned to the primary coupling coordination type. Besides, from a spatial perspective, first, the coupling coordination degree of social security and economic development in China contracted in the east-west and north-south directions, and the coupling coordination clustered in the central region in this period; second, the coupling coordination degree generally presented a positive spatial autocorrelation, and regions with similar coupling coordination degrees were in a state of agglomeration; finally, the hot spots clumped together to form a continuous area in the eastern coastal area while the cold spots expanded toward the northwest and northeast. Furthermore, the random distribution areas exhibited a trend of contraction.

1. Introduction

As an essential method of redistribution of national income, the social security system plays an imperative role in regulating the income gap of residents and protecting the rights and interests of citizens. However, China has only established a social security system for urban residents for a long time due to the level of economic development, and the majority of farmers can only rely on their families and lands to handle risks such as diseases and old age. The social security system not only failed to regulate the income gap but also widened the income gap between urban and rural areas. To reduce the income gap between urban and rural areas, the Chinese government attaches great importance to the “Three Rural Issues”, including agriculture, rural areas, and farmers. Apart from several policies benefitting farmers and strengthen agriculture, it also ensures that farmers can share the fruits of national economic development through the arrangements of social security. Furthermore, the gap between the rich and the poor has been gradually reduced with the process of income redistribution. Generally, in the development of China over the past 40 years, the economy and social security have

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made great progress (Lkels, 2002). Triggered by the economic system reform, the social security system has adopted a progressive reform similar to that of the economic system. After 1978, the social security system of China entered a new period of promoting development through reform. China’s reform and opening up started in the early 1980s. It was also a transitional period when the function of the traditional security system was increasingly weakened and the new social security system was not yet developed and established. The decade from the late 1980s to the outbreak of the Asian financial crisis in 1997 was a period of exploratory reform in which China set the goal of establishing a socialist market economy and a new social security system. From August 1997, when the State Council promulgated and established a unified basic old-age insurance system for enterprise employees, to the 18th National Congress of the Communist Party of China in November 2012, the modern social security system of China developed rapidly. After the 18th National Congress of the Communist Party of China, the social security system and public services in China have entered a period of consolidation and improvement. Meanwhile, the Chinese government has made great efforts to promote the equalization of education, deepen the reform of medical and health care, and promote the development of social pension services, contributing to the formation of the world’s largest social security network in China. From the perspective of the relationship between social security and economic development, during 1985–1992, China’s social security matched the reform of state-owned enterprises; during 1993–2004, China’s social security system served the construction and development of the market economy. Since 2004, the social security system has been independently organized to gradually form a system commensurate with the level of economic development. The rapid economic growth provides a solid material foundation for the establishment and improvement of the social security system in China. In turn, the social security system guarantees sustained economic growth and stable development of China owing to its fixed “stabilizer” and “regulator” functions.

Literature on the relationship between social security and economic growth previously focused on the impact of the social security system on economic growth, 

Table 1

<table>
<thead>
<tr>
<th>Target layer</th>
<th>System layer</th>
<th>Criteria layer</th>
<th>Index layer</th>
<th>Weight</th>
<th>Indicator direction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coupling coordination of social security and economic development</td>
<td>Economic development level</td>
<td>Economic growth (0.173)</td>
<td>GDP growth rate (%)</td>
<td>0.068</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Local general revenue growth (%)</td>
<td>0.059</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Retail growth rate of social consumer goods (%)</td>
<td>0.046</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>Industrial structure (0.161)</td>
<td></td>
<td>Ratio of secondary industry value to GDP (%)</td>
<td>0.036</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Ratio of tertiary industry value to GDP (%)</td>
<td>0.125</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>Qualitative efficiency (0.206)</td>
<td></td>
<td>GDP per capita (CNY)</td>
<td>0.151</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Ratio of urban per capita disposable income to rural per capita disposable income (%)</td>
<td>0.055</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Foreign trade (0.460)</td>
<td></td>
<td>Total import and export of goods (1.0 \times 10^6 USD)</td>
<td>0.460</td>
<td>+</td>
</tr>
<tr>
<td>Social security level</td>
<td>Social security expenditure level (0.072)</td>
<td></td>
<td>Proportion of social security expenditure to GDP (%)</td>
<td>0.072</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>Social security fund (0.523)</td>
<td></td>
<td>Accumulated balance of medical insurance fund (1.0 \times 10^8 CNY)</td>
<td>0.102</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Accumulated balance of endowment insurance fund (1.0 \times 10^8 CNY)</td>
<td>0.099</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Accumulated balance of unemployment insurance fund (1.0 \times 10^8 CNY)</td>
<td>0.073</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Accumulated balance of maternity insurance fund (1.0 \times 10^8 CNY)</td>
<td>0.116</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Accumulated balance of work injury insurance fund (1.0 \times 10^8 CNY)</td>
<td>0.133</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>Social insurance coverage rate (0.150)</td>
<td></td>
<td>Coverage rate of medical insurance for urban employees (%)</td>
<td>0.031</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Coverage rate of endowment insurance for urban employees (%)</td>
<td>0.018</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Coverage rate of unemployment insurance (%)</td>
<td>0.022</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Coverage rate of maternity insurance (%)</td>
<td>0.044</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Coverage rate of work injury insurance (%)</td>
<td>0.035</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>Social security treatment (0.255)</td>
<td></td>
<td>Per capita expenditure of basic pension for urban employees (CNY)</td>
<td>0.043</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Technical health personnel per 1000 population (person)</td>
<td>0.057</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Number of beds in medical institutions per 1000 population (bed)</td>
<td>0.058</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Per capita expenditure of rural minimum living security (CNY)</td>
<td>0.097</td>
<td>+</td>
</tr>
</tbody>
</table>

Note: As the data type of the study is panel dataset, the weight of each indicator in the table is the average weight of 17 years. “+” in the indicator direction column indicates that the measurement index is a positive indicator, the larger the better; “–” indicates that the measurement index is a negative indicator, the small the better.
Fig. 1. Spatial distribution of four regions in China in this study. SAR, Special Administrative Region. Note that this map is based on the standard map (No. GS (2019) 1684) of the Map Service System (http://bzdt.ch.mnr.gov.cn/) marked by the Ministry of Natural Resources of the People’s Republic of China, and the base map has not been modified. It should be noted that Hong Kong of China, Macao of China, and Taiwan of China are not included in the research scope of this paper due to the lack of data.
system on savings and investment. Specifically, social security has two effects on savings and investment: crowding in and crowding out. When savings provide social welfare similar to public transfer payments, they may overlap and have a “crowding out” effect. Moreover, the economic well-being remains unchanged because changes in public transfer payments will lead to the corresponding offsetting of savings remittances. Therefore, the expansion of public transfer payment has squeezed the savings remittance and weakened the income distribution impact of social security. Besides, the “crowding out” effect may even cause unnecessary losses due to the administrative cost of government transfer payment projects (Hai, 2017). The influence of social security on investment and savings depends on the comparison of two forces (effects) (Feldstein, 1974), and the substitution effect of the former on the latter is higher than the income

![Fig. 2. Coupling coordination degree of social security and economic development in China and four regions during 2002–2018.](image)

<table>
<thead>
<tr>
<th>Year</th>
<th>Barycentric coordinate</th>
<th>Minor semi-axis length (km)</th>
<th>Major semi-axis length (km)</th>
<th>Measure of area ($\times 10^4$ km²)</th>
<th>Rotation angle (°)</th>
<th>Offset distance (km)</th>
<th>Offset direction</th>
</tr>
</thead>
<tbody>
<tr>
<td>2002</td>
<td>33.397° N, 112.309° E</td>
<td>1073.226</td>
<td>1184.667</td>
<td>399.069</td>
<td>77.99</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>2003</td>
<td>33.425° N, 112.440° E</td>
<td>1054.731</td>
<td>1170.223</td>
<td>387.738</td>
<td>77.58</td>
<td>15.863</td>
<td>Northeast</td>
</tr>
<tr>
<td>2004</td>
<td>33.550° N, 112.543° E</td>
<td>1058.877</td>
<td>1164.339</td>
<td>387.305</td>
<td>76.91</td>
<td>17.378</td>
<td>Northeast</td>
</tr>
<tr>
<td>2006</td>
<td>33.594° N, 112.637° E</td>
<td>1047.846</td>
<td>1169.917</td>
<td>385.106</td>
<td>75.22</td>
<td>11.399</td>
<td>Southeast</td>
</tr>
<tr>
<td>2007</td>
<td>33.542° N, 112.688° E</td>
<td>1046.456</td>
<td>1166.862</td>
<td>383.591</td>
<td>74.67</td>
<td>8.093</td>
<td>Southeast</td>
</tr>
<tr>
<td>2008</td>
<td>33.645° N, 112.612° E</td>
<td>1051.084</td>
<td>1173.074</td>
<td>387.338</td>
<td>74.62</td>
<td>14.223</td>
<td>Northwest</td>
</tr>
<tr>
<td>2009</td>
<td>33.523° N, 112.540° E</td>
<td>1044.905</td>
<td>1177.807</td>
<td>386.615</td>
<td>73.82</td>
<td>15.740</td>
<td>Southwest</td>
</tr>
<tr>
<td>2010</td>
<td>33.494° N, 112.622° E</td>
<td>1039.929</td>
<td>1165.697</td>
<td>380.818</td>
<td>73.55</td>
<td>9.664</td>
<td>Southeast</td>
</tr>
<tr>
<td>2011</td>
<td>33.594° N, 112.309° E</td>
<td>1053.343</td>
<td>1181.947</td>
<td>391.107</td>
<td>76.00</td>
<td>36.509</td>
<td>Northeast</td>
</tr>
<tr>
<td>2012</td>
<td>33.551° N, 112.283° E</td>
<td>1054.604</td>
<td>1182.120</td>
<td>391.632</td>
<td>76.05</td>
<td>5.583</td>
<td>Southwest</td>
</tr>
<tr>
<td>2013</td>
<td>33.467° N, 112.163° E</td>
<td>1057.594</td>
<td>1172.526</td>
<td>389.555</td>
<td>77.03</td>
<td>16.275</td>
<td>Southwest</td>
</tr>
<tr>
<td>2014</td>
<td>33.484° N, 112.362° E</td>
<td>1054.949</td>
<td>1165.320</td>
<td>386.193</td>
<td>76.38</td>
<td>22.191</td>
<td>Northeast</td>
</tr>
<tr>
<td>2015</td>
<td>33.475° N, 112.381° E</td>
<td>1047.115</td>
<td>1167.852</td>
<td>384.158</td>
<td>75.83</td>
<td>2.336</td>
<td>Southeast</td>
</tr>
<tr>
<td>2016</td>
<td>33.291° N, 112.275° E</td>
<td>1045.570</td>
<td>1169.429</td>
<td>384.109</td>
<td>74.96</td>
<td>23.594</td>
<td>Southwest</td>
</tr>
<tr>
<td>2017</td>
<td>33.336° N, 112.333° E</td>
<td>1044.737</td>
<td>1166.020</td>
<td>382.684</td>
<td>75.69</td>
<td>8.157</td>
<td>Northeast</td>
</tr>
<tr>
<td>2018</td>
<td>33.383° N, 112.441° E</td>
<td>1039.648</td>
<td>1152.325</td>
<td>376.347</td>
<td>75.64</td>
<td>13.087</td>
<td>Northeast</td>
</tr>
</tbody>
</table>

Note: “–” represents null value.
effect, resulting in a negative impact on savings and economic growth (Hong and Zeng, 2016). If the intergenerational transmission mechanism of parental altruism is considered, social security does not change the family budget constraint and thus has a neutral impact on savings and investment (Imrohoroglu and Kai, 2018). Different from the research conclusions mentioned above, many researchers believed that there is a positive correlation between social security and economic development (Hubbard and Judd, 1987; Justino, 2007; Deng et al., 2019). Through the analysis of China’s statistical data from 2003 to 2012, Deng et al. (2019) revealed that the social security system of China has a positive impact on consumption by narrowing the income gap. Besides, medical insurance and endowment insurance have a positive impact on consumption by reducing residents’ consumption uncertainty, promoting economic development. Hubbard and Judd (1987) investigated the endowment insurance under social security from the perspective of permanent income and discovered that it could significantly reduce the uncertain expectations of residents and thus increase consumption. Justino (2007) used the two-stage least squares model to analyze the impact of social security policies on economic performance in India from 1997 to 1999. The empirical results demonstrate that the social security policy of India is a crucial internal variable for national poverty reduction and economic growth.

The theoretical research on the relationship between social security and economic development started late in China. However, Chinese researchers began to pay attention to this relationship with the advancement of China’s social security system reform. The representative views are detailed as follows. First, there is a long-term positive co-integration relationship and a Granger two-way causality between social security and economic development (Dong and Qiu, 2007; Zhao and Yang, 2011; Zhuang et al., 2017). Second, there is a one-way causal relationship between social security and economic growth (Cui, 2008). Third, the increase in the social security contribution rate reduces the investment of human capital, exhibiting a negative effect on economic growth (Liang and Zhang, 2019). Additionally, some researchers insist that the relationship between economic system reform and social security is complementary, and social security and economic development can develop together. Economic development is the foundation, determining the emergence and development of the social security system. Social security, in turn, plays a dual role in economic development, not only promoting economic development but also hindering economic development. Furthermore, some researchers (Li and Qin, 2020) employed the coupled coordination degree model to measure the coordinated development degree of China’s social security and economic development, and revealed that the relationship between the two gradually became coordinated and adapted to each other from the running-in stage, and the spatial difference in coordination degree was gradually narrowing (Tan, 2011). For such regional differences, researchers generally believed that it is necessary to comprehensively deepen reform, optimize system design, build a unified multi-level security system, and continue to expand the coverage of social security. Besides, Lin (2020) suggested to regulate the raising and expenditure of social security funds, make up for the shortcomings, and build a social security system integrating urban and rural areas by strengthening the agglomeration of human capital elements and improving production efficiency.

Generally, the current research on the relationship between social security and economic growth has made remarkable progress. However, there are great differences in the judgment of the correlation and causal relationship between social security and economic development in the theoretical circle ascribed to the characteristics of social security both in sociology and economics, as well as the different research perspectives, selection of index systems, parameters setting, and research years. Thus, the research on the relationship between social security and economic development continues to be a hot topic of theoretical exploration and academic contention. Simultaneously, with the dynamic changes of social security and economic development in China (Dong and Ye, 2003), the theoretical results on the relationship between social security and economic development are objectively required to be continuously enriched and improved. Given these facts, we adopted the provincial panel data in China (Hong Kong of China, Macao of China, and Taiwan of China are not included in this study due to the lack of data) from 2002 to 2018 in this paper to calculate the coupling coordination degree of social security and economic development in China with the entropy weight method and the coupling coordination model. As an objective weighting method that is more commonly and frequently used, the weight method based on entropy has overcome the influence of human factors in subjective weighting and made the weight and comprehensive score more reasonable. On this basis, we divided the types of coupling coordination and explored the development and evolution rules of coupling coordination at the temporal and spatial levels to provide a scientific basis for seeking action plans beneficial to the coordinated development of social security and economy in China under the new normal.

### Table 3

<table>
<thead>
<tr>
<th>Year</th>
<th>Moran’s I</th>
<th>P value</th>
<th>Year</th>
<th>Moran’s I</th>
<th>P value</th>
</tr>
</thead>
<tbody>
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<td>2002</td>
<td>0.238</td>
<td>0.015</td>
<td>2011</td>
<td>0.228</td>
<td>0.023</td>
</tr>
<tr>
<td>2003</td>
<td>0.294</td>
<td>0.004</td>
<td>2012</td>
<td>0.262</td>
<td>0.010</td>
</tr>
<tr>
<td>2004</td>
<td>0.308</td>
<td>0.003</td>
<td>2013</td>
<td>0.237</td>
<td>0.019</td>
</tr>
<tr>
<td>2005</td>
<td>0.288</td>
<td>0.005</td>
<td>2014</td>
<td>0.280</td>
<td>0.006</td>
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<tr>
<td>2006</td>
<td>0.302</td>
<td>0.003</td>
<td>2015</td>
<td>0.304</td>
<td>0.003</td>
</tr>
<tr>
<td>2007</td>
<td>0.324</td>
<td>0.002</td>
<td>2016</td>
<td>0.087</td>
<td>0.273</td>
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<tr>
<td>2008</td>
<td>0.327</td>
<td>0.002</td>
<td>2017</td>
<td>0.296</td>
<td>0.004</td>
</tr>
<tr>
<td>2009</td>
<td>0.304</td>
<td>0.003</td>
<td>2018</td>
<td>0.295</td>
<td>0.004</td>
</tr>
<tr>
<td>2010</td>
<td>0.329</td>
<td>0.002</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
2. Data and methods

2.1. Index selection and data sources

We selected eight indicators from four dimensions of economic growth, industrial structure, qualitative efficiency, and foreign trade to build an index system reflecting the level of economic development (Table 1) based on theoretical researches (Dong and Qiu, 2007; Tan, 2011; Zhao and Yang, 2011; Liang and Zhang, 2019) and the principles of scientificity and data availability. Further, from the four dimensions of social security expenditure level, social security fund, social insurance coverage rate, and social security treatment, we selected 15 indicators to construct an index system reflecting the level of social security (Table 1). The data in this paper were mainly obtained from the China Statistical Yearbook (National Bureau of Statistics of China, 2003–2019), China Statistical Yearbook on Science and Technology (Department of Social, Science and Technology, and Cultural Statistics National Bureau of Statistics and Department of Strategy and Planning Ministry of Science and Technology, 2003–2019), Almanac of China’s Finance and Banking (Almanac of China’s Finance and Banking Editorial Board, 2003-2019), Finance Yearbook of China (Editorial Board of China Financial Yearbook, 2003–2019), China Labor Statistical Yearbook (Department of Population and Employment Statistics, National Bureau of Statistics and Department of Planning and Finance, Ministry of Human Resources and Social Security of China, 2003–2019), as well as statistical yearbooks of provinces, autonomous regions, and municipalities in China. It should be noted that Hong Kong of China, Macao of China, and Taiwan of China are not included in the research scope of this paper due to the lack of data.

According to several policy documents of the State Council and the report of the 16th National Congress of the Communist Party of China, we divided China into the four major regions in this study. Specifically, the eastern region includes: Beijing, Shanghai, and Tianjin cities, and Guangdong, Zhejiang, Fujian, Hebei, Hainan, Shandong, and Jiangsu provinces; the central region includes: Henan, Jiangxi, Shanxi, Anhui, Hunan, and Hebei provinces; the western region includes: Chongqing City, Inner Mongolia Autonomous Region, Ningxia Hui Autonomous Region, Xinjiang Uygur Autonomous Region, Guangxi Zhuang Autonomous Region, Tibet Autonomous Region, and Shaanxi, Yunnan, Sichuan, Qinghai, Guizhou, and Gansu provinces; and the northeastern region includes: Heilongjiang, Liaoning, and Jilin provinces (Fig. 1).

2.2. Entropy weight method

The entropy weight method is a comprehensive evaluation approach used for multiple objects and multiple indicators. The evaluation results are mainly based on objective data and hardly affected by subjective factors, largely avoiding the intervention of human factors. In this paper, the weight of 8 indicators was determined to measure the comprehensive level of social security, and the weight of 15 indicators was calculated to measure the level of economic development using the entropy weight method. Besides, we calculated the social security index \( U_1 \) and economic development index \( U_2 \) of each region from 2002 to 2018 based on these weights. The entropy weight method was calculated as follows:

If \( X_{ij} \) is a positive indicator, then

\[
x_i = \frac{X_{ij} - \text{Min}(X_i)}{\text{Max}(X_i) - \text{Min}(X_i)}
\]

(1)

If \( X_{ij} \) is a negative indicator, then

\[
x_i = \frac{\text{Max}(X_i) - X_{ij}}{\text{Max}(X_i) - \text{Min}(X_i)}
\]

(2)

Information entropy \( E_j \) of each index was calculated as follows:

\[
E_j = -\frac{1}{\ln(n)} \sum_{i=1}^{n} p_{ij} \ln p_{ij},
\]

(3)

\[
p_{ij} = \frac{x_{ij}}{\sum_{i=1}^{n} x_{ij}}.
\]

(4)

If \( p_{ij} = 0 \), then \( \lim_{p_{ij} \rightarrow 0} p_{ij} \ln p_{ij} = 0 \).

Determination of the weight of each indicator is expressed as:

\[
w_j = \frac{d_j}{\sum_{j=1}^{n} d_j},
\]

(5)

\[
d_j = 1 - E_j.
\]

(6)

The synthesis score of each evaluation system can be determined by:
For the above-mentioned equations, $X_i$ is the raw data; $x_i$ is the standardized data; $E_j$ indicates the information entropy; $p_{ij}$ means the proportion of index value of item $i$ under index $j$; $w_j$ represents the weight of each index; $d_{ij}$ represents the coefficient of difference of the $j$th index; and $U_i$ denotes the synthesis score.

2.3. Coupling coordination degree model

Coupling refers to the degree of interaction and mutual influence between systems, and the coordination model is an evaluation of the degree of mutual influence. In this paper, the model was applied to evaluate the coupling coordination between social security and economic development. Under the combination of the social security index ($U_1$) and the economic development index ($U_2$), the coupling degree ($C$) of each region from 2002 to 2018 was calculated. On this basis, the coupling coordination degree ($D$) of the two systems was calculated. The $D$ value is between 0.000 and 1.000. Specifically, the closer it is to 1.000, the more harmonious and balanced the social security and economic development are; and the closer it is to 0.000, the worse the coordination and unbalanced development are. The calculation formulas are:

\[
C = 2 \left( \frac{(U_1 \times U_2)}{(U_1 + U_2)^2} \right)^\lambda
\]

\[
T = aU_1 + bU_2,
\]

\[
D = \sqrt{C \times T}.
\]

where $T$ is the comprehensive coordination index of social security economic development; $\alpha$ and $\beta$ are the undetermined coefficients ($\alpha + \beta = 1$). Generally, $\alpha$ equals to 0.5 and $\beta$ is the same (0.5). Considering the basic role of social security and economic development, we set $\alpha = 0.6$ and $\beta = 0.4$. Referring to relevant research results (Tan, 2011; Deng et al., 2019), we divided the coupling coordination degree of social security and economic development into six types: extreme imbalance (0.000 $\leq$ $D$ $<$ 0.200), general imbalance (0.200 $\leq$ $D$ $<$ 0.400), barely coupling coordination (0.400 $\leq$ $D$ $<$ 0.500), primary coupling coordination (0.500 $\leq$ $D$ $<$ 0.600), good coupling coordination (0.600 $\leq$ $D$ $<$ 0.800), and high-quality coupling coordination (0.800 $\leq$ $D$ $\leq$ 1.000).

2.4. Exploratory spatial data analysis

The exploratory spatial data analysis was conducted to measure the degree of spatial correlation or dependence between research objects. Currently, global spatial autocorrelation and local spatial autocorrelation are the two most commonly used methods in exploratory spatial data analysis. Among them, global spatial autocorrelation reflects the spatial association pattern of a certain attribute value in the whole research area. Local spatial autocorrelation further reveals the correlation degree and distribution pattern of some attribute values in local space.

Global spatial autocorrelation is often measured by the global Moran index (Moran’s I) with a range from –1 to 1. The value of Moran’s I lower than zero indicates a negative spatial correlation; the smaller the value, the greater the spatial difference. The value of Moran’s I being of zero indicates no spatial correlation, presenting the characteristic of random distribution. The value of Moran’s I higher than zero indicates a positive spatial correlation; the larger the value, the more significant the spatial correlation. The calculation equations are (Huang et al., 2016):

\[
\text{Moran’s I} = \frac{\sum_{i=1}^{n} \sum_{j=1}^{n} W_{ij} (X_i - \bar{X}) (X_j - \bar{X})}{S^2 \sum_{i=1}^{n} \sum_{j=1}^{n} W_{ij}}
\]

\[
S^2 = \frac{1}{n} \sum_{i=1}^{n} (X_i - \bar{X})^2, \quad \bar{X} = \frac{1}{n} \sum_{i=1}^{n} X_i,
\]

where $n$ represents the number of research objects; $S^2$ represents variance; $X_i$ denotes the attribute value of space unit $i$; $X_j$ suggests the attribute value of space unit $j$; $\bar{X}$ represents the mean value; and $W_{ij}$ indicates the space weight matrix.

The local autocorrelation index G-coefficient can accurately detect the location of high-value or low-value elements clustering in space. In this paper, the local G-coefficient was employed to detect the high-value aggregation and low-value aggregation of the coupling coordination degree of social security and economic development in China. The calculation formula of G-coefficient ($G^*$) is (Ord and Getis, 2001):

\[
G^*_i = \frac{\sum_{j=1}^{n} W_{ij} x_j}{\sum_{j=1}^{n} x_j},
\]
where $x_j$ indicates the coupling coordination degree of social security and economic development in the space unit $j$. Generally, $G_i^s$ value is standardized as $Z$ value, and the calculation is expressed as:

$$Z = \frac{G_i^s - E(G_i^s)}{\sqrt{\text{VAR}(G_i^s)}}$$  \hspace{1cm} (14)

where $E(G_i^s)$ represents the mean of $G_i^s$ and $\text{VAR}(G_i^s)$ represents the variance of $G_i^s$.

The larger the $Z$ value, the higher the coupling coordination degree of a neighboring area; the smaller the $Z$ value, the lower the coupling coordination degree of the neighboring area. The $Z$ value close to zero suggests that the coupling coordination degree of neighboring areas is randomly distributed. This paper has some reference for the division of $Z$ value. Specifically, $Z$ value ranging from $-1$ to $1$ represents a random distribution; $Z$ value ranging from $1$ to $2$ means a relatively significant hot spot; $Z$ value greater than $2$ indicates a significant hot spot; $Z$ value ranging from $1$ to $-2$ suggests a relatively significant cold spot; and $Z$ value less than $-2$ represents a significant cold spot. (Chen and Zhang, 2008; Zeng, 2018).

2.5. Standard deviation ellipse

The characteristics of the spatial distribution pattern of geographical elements can be accurately revealed by the standard deviation ellipse. The model parameters are composed of four basic elements: center of gravity coordinates, rotation angle, standard deviation along the long semi-axis, and standard deviation along the short semi-axis. Generally, the spatial and temporal evolution characteristics of geographical elements are expressed by the moving trajectory of the center of gravity and the spreading range of the ellipse. The calculation formulas of relevant parameters are (Jiang et al., 2014):

$$x_i' = x_i - x_{\text{cen}}, \hspace{1cm} y_i' = y_i - y_{\text{cen}},$$  \hspace{1cm} (15)

$$\tan \theta = \frac{\left(\sum_{i=1}^{n} w_i x_i'^2 - \sum_{i=1}^{n} w_i y_i'^2\right) + \sqrt{\left(\sum_{i=1}^{n} w_i x_i'^2 - \sum_{i=1}^{n} w_i y_i'^2\right)^2 + 4\left(\sum_{i=1}^{n} w_i x_i'^2 y_i'^2\right)^2}}{2\sum_{i=1}^{n} w_i x_i y_i},$$  \hspace{1cm} (16)

$$\delta_x = \sqrt{\frac{\sum_{i=1}^{n} (w_i x_i' \cos \theta - w_i y_i' \sin \theta)^2}{\sum_{i=1}^{n} w_i^2}} \hspace{1cm} \delta_y = \sqrt{\frac{\sum_{i=1}^{n} (w_i y_i' \cos \theta - w_i y_i' \sin \theta)^2}{\sum_{i=1}^{n} w_i^2}}$$  \hspace{1cm} (17)

where $(x_i, y_i)$ represents the two-dimensional plane coordinates of the area $i$; $(x_{\text{cen}}, y_{\text{cen}})$ represents the mean center of the spatial distribution; $w_i$ represents the element value of the area $i$; $x_i'$ and $y_i'$ are the relative coordinates; $\tan \theta$ indicates rotation angle ($^\circ$); and $\delta_x$ and $\delta_y$ represent the standard deviation along $x$ axis and $y$ axis, respectively.

3. Results

3.1. Temporal characteristics of coupling coordination between social security and economic development

We used R software to calculate the coupling coordination degree of social security and economic development in China from 2002 to 2018 according to Equations (1)–(3). The trend chart of the coupling coordination degree of China as well as the four regions (i.e., the eastern region, the central region, the western region, and the northeastern region) is depicted as Fig. 2.

We can draw several conclusions according to the results in Fig. 2. First, in 2002–2018, the coupling coordination degree of social security and economic development in China exhibited a fluctuating and rising trend, increasing from 0.438 to 0.522, which reflected that the coupling coordination level changed from the barely coupling coordination type to the primary coupling coordination type. Thus, China’s social security and economy have gradually adapted to each other and developed together since 2002. Second, from the perspective of different stages, the coupling coordination degree fluctuated and rose in 2002–2014, declined year by year in 2014–2016, rose rapidly in 2016–2017, increased steadily in 2017–2018, and reached the highest value in 2018.

Furthermore, from the perspective of the four regions, the general trend was the same as that of the whole China while there were differences in the change process, fluctuation range, and annual growth rate of each region. During 2002–2018, the coupling coordination degree of the eastern region was much higher than that of the other three regions in the same period, with the index rising from 0.556 to 0.642. From the perspective of different stages, the coupling coordination degree of the eastern region in 2002–2006 ranged from 0.550 to 0.600, belonging to the primary coupling coordination category; in 2008–2018 (with the exceptions of 2015 and 2016), it ranged from 0.600 to 0.650, belonging to the good coupling coordination category, which indicated that social security and economic development in the western region showed better mutual adaptability. The coupling coordination degree in the western region increased from 0.373 to 0.447 in 2002–2018, implying that a positive interaction between social security and economic development in this region was gradually strengthened, with a slight improvement of the coordination situation. The coupling coordination degree in the western region ranked the last among the four regions, and the index in each year was lower than the average level in the whole China. From the perspective of different stages, the coupling coordination degree in the western region fluctuated between 0.200 and 0.400 in 2002–2007, belonging to the general imbalance category. It rose to the barely coupling coordination category during 2008–2018, and
Fig. 3. Spatial evolution trend of the coupling coordination of social security and economic development in China in 2002 (a), 2005 (b), 2008 (c), 2011 (d), 2014 (e), and 2018 (f). Note that this map is based on the standard map (No. GS (2019) 1684) of the Map Service System (http://bzdt.ch.mnr.gov.cn/) marked by the Ministry of Natural Resources of the People’s Republic of China, and the base map has not been modified. It should be noted that Hong Kong of China, Macao of China, and Taiwan of China are not included in the research scope of this paper due to the lack of data.
the coordination index ranged from 0.400 to 0.500. The coordination index in the northeastern region increased from 0.429 to 0.490. Except for the primary coupling coordination category from 2008 to 2012, the coordination index of this region in other years was in the barely coupling coordination category. The coupling coordination degree in the central region from 2002 to 2003 was in the general imbalance category with the value ranging from 0.200 to 0.400, and then it rose to the barely coupling coordination category in 2018 year by year with the value ranging from 0.400 to 0.500.

3.2. Spatial characteristics of coupling coordination between social security and economic development

3.2.1. Spatial evolution process

We calculated a series of elliptical parameters using ArcGIS 10.2, such as the barycentric coordinates, offset distance, rotation angle, and ellipse area of the standard deviation ellipse, according to the coupling coordination degree of social security and economic development in China from 2002 to 2018 (Table 2).

As observed from Table 2, the standard deviation of ellipse gravity center movement path of China’s social security and economic development coupling coordination degree changed irregularly from 2002 to 2018. In addition to Lushan County in Pingdingshan City of Henan in 2005 and 2008, the center of gravity of coupling coordination were always in Nanzhao County in Nanyang City of Henan. The evolution process can be divided into three stages: the stage of moving to the northeast in 2002–2007, the stage of moving to the southwest in 2007–2013, and the stage of moving to the southeast in 2013–2018. Compared to 2002, the gravity center of China’s social security and economic development coupling coordination degree during the study period shifted 10 times to the northeast, 2 times to the southeast, 3 times to the northwest, and 1 time to the southwest, indicating that the coupling coordination of China’s social security and economic development in the eastern region was better than that in the central and western regions. During the study period, the area, axis length, and rotation angle of the standard deviation ellipse of China’s social security and economic development coupling coordination degree all changed. Among them, the area of ellipse decreased by 22.722 × 10^4 km^2 from 399.069 × 10^4 to 376.347 × 10^4 km^2; the minor semi-axis length was shortened by about 33.578 km from 1073.226 to 1039.648 km, the major semi-axis length was shortened by 32.342 km from 1184.667 to 1152.325 km, and the shortened length of the minor semi-axis was greater than that of the major semi-axis; and the rotation angle was reduced by 2.35° from 77.99° to 75.64°. The changes in parameters indicated that during the study period, the coupling coordination of social security and economic development in China contracted in the east-west and north-south directions, and the coupling coordination converged to the central region, consistent with the coupling coordination degree of the central region in this period from general imbalance to barely coupling coordination.

Besides, the center of gravity of social security and economic development coupling coordination degree during the study period shifted significantly to the west in 2008, 2009, 2011, 2013, and 2016, highly consistent with the key points of China’s social security system reform as follows. In 2008, the theory of building a multi-layered, multi-dimensional, and diverse social security system with Chinese characteristics was proposed to “build a social security system covering urban and rural residents”. In 2009, China piloted a new type of rural endowment insurance system. The central government subsidized the insured farmers in the central and western regions from the “import” and “export” ends, contributing to solving the problem of long-term lack of farmers’ endowment insurance. In 2011, the basic endowment insurance system for urban residents was piloted in China, and the insured objects were urban non-employed residents. The central government adopted a differentiated basic pension subsidy standard for different regions to fully subsidize the basic pension of the insured residents in the central and western regions while the eastern region was given a subsidy of 50%. This subsidy policy had a greater incentive effect on residents in the central and western regions, resulting in a higher rate of insurance participation. Additionally, the center of gravity of social security and economic development coupling coordination shifted significantly to the west in 2013 due to the superposition effect of various social security policies. In 2016, China integrated the basic medical insurance for urban residents and the new rural cooperative medical care system, establishing a unified basic medical insurance system for urban and rural residents. This is of great significance for promoting the coordinated social and economic development between urban and rural areas and narrowing the gap between different regions. However, the center of gravity of social security and economic development coupling coordination shifted to the east in the following five years when the center of gravity obviously shifted to the west. It can be observed that the spatial pattern of coupling coordination between social security and economic development is the result of multiple factors, with regional economic strength as the basic reason.

3.2.2. Global spatial autocorrelation analysis

In this paper, the Moran’s I of the coupling coordination of social security and economic development in 2002–2018 was calculated by ArcGIS 10.2 software to judge whether there are spatial correlation and agglomeration characteristics in the coupling coordination of social security and economic development in China as a whole (Table 3). The results revealed that the Moran’s I of the overall coordination degree of social security and economic development in China was positive. Except for 2016, the global Moran’s I in other years passed the significance test (P < 0.05), indicating that there was a positive spatial autocorrelation relationship between China’s social security and economic development coupling coordination. In other words, the regions with similar coupling coordination degree were clustered in space, and the overall change range was small, suggesting that it had a considerable degree of time inertia and spatial stability.

We visualized the spatial distribution of the coupling coordination degree of social security and economic development in China from 2002 to 2018 using manual analysis method according to the six types of coupling coordination; its spatial pattern was generated as illustrated in Fig. 3. It should be noted that only six years’ visualizations are displayed due to space limitations, i.e., 2002, 2005, 2008, 2011, 2014, and 2018.

As demonstrated in Fig. 3, the coupling coordination of social security and economic development in China had two characteristics of
Fig. 4. Z value of G-coefficient ($G_i^*$) of the coupling coordination degree between social security and economic development in China in 2002 (a), 2005 (b), 2008 (c), 2011 (d), 2014 (e), and 2018 (f). Note that this map is based on the standard map (No. GS (2019) 1684) of the Map Service System (http://bzdt.ch.mnr.gov.cn/) marked by the Ministry of Natural Resources of the People’s Republic of China, and the base map has not been modified. It should be noted that Hong Kong of China, Macao of China, and Taiwan of China are not included in the research scope of this paper due to the lack of data.
solidification and dynamic change in space from 2002 to 2018. The former included barely coupling coordination (Inner Mongolia and Xinjiang), primary coupling coordination (Liaoning), good coupling coordination (Jiangsu and Shanghai), and high-quality coupling coordination (Guangdong) areas. The coupling coordination level of social security and economic development in other areas (provinces, autonomous regions, and municipalities) was in a dynamic change process over time. Specifically, from 2002 to 2005, 29.03% of the areas transferred from general imbalance to barely coupling, and the proportion of the areas in general imbalance decreased from 54.84% to 29.03%. From 2005 to 2008, the coupling coordination level was mainly shifted upwards and supplemented by downwards. Among them, upward shifting areas and downward shifting areas accounted for 25.81% and 6.45% of the total, respectively, and the proportion of areas in general imbalance decreased from 29.03% to 16.13%. From 2008 to 2011, areas with good coupling coordination and high-quality coupling coordination remained unchanged. Among them, Guangdong belonged to high-quality coupling coordination type, while Beijing, Tianjin, Jiangsu, Shanghai, and Zhejiang belonged to good coupling coordination type. The areas in the primary coupling coordination level had both upward and downward shifts, with the number of upward and downward shifts close to each other. Hubei and Sichuan rose from barely coupled coordination to primary coupled coordination, and Jilin dropped from primary coupled coordination to barely coupled coordination. The proportion of areas in general imbalance decreased from 16.13% to 6.45%. Shandong had improved from primary coupling coordination to good coupling coordination. Chongqing and Fujian had improved from barely coupling coordination to primary coupling coordination. Guangxi rose from general imbalance to barely coupling coordination. Yunnan declined from barely coupling coordination to general imbalance. Heilongjiang, Hubei, and Sichuan declined from primary coupling coordination to barely coupled coordination. The total number of areas in general imbalance remained unchanged, accounting for 6.45% of the total. From 2014 to 2018, there were six provinces, autonomous regions, and municipalities with coupling coordination level moving up and down, accounting for 19.35% of the total. During this period, Hainan, Ningxia, Qinghai, and Tibet were the provinces and autonomous regions with general imbalance of coupling coordination, accounting for 12.90% of the total.

As revealed by the above analysis, the coupling coordination degree of social security and economic development in China presented significant dynamic change characteristics in time and space. The heterogeneity among different areas was significant, though the overall coupling coordination level of social security and economic development has been improved to varying degrees. This pattern was driven by many factors, such as economic strength. For example, the per capita GDP of Guangdong, Beijing, Tianjin, Shanghai, Jiangsu, Shandong, Liaoning, and Fujian in 2018 at the level of good coupling coordination reached 86,412, 140,211, 120,711, 134,982, 115,168, 76,267, 58,008, and 91,197 CNY, respectively; however, the per capita GDP of Tibet, which was in general imbalance, was 43,398 CNY. In 2002, 2005, 2011, and 2014, the per capita GDP of Gansu was 4493, 7477, 19,595, and 26,433 CNY, respectively, which were lower than those of other areas (provinces, autonomous regions, and municipalities) in the same period and far lower than those of the areas with good coupling coordination level.

3.2.3. Local spatial autocorrelation analysis

According to the above division of Z value, we divided the spatial agglomeration of social security and economic development coupling coordination degree in 2002–2018 into five categories by the manual method: significant hot spot area, relatively significant hot spot area, randomly distributed area, relatively significant cold spot area, and significant cold spot area. We further analyzed the hot spots and cold spots using ArcGIS12.0 and then obtained the local spatial agglomeration models (Fig. 4).

As illustrated in Fig. 4, the hot spots and cold spots of the coupling coordination degree of social security and economic development in China during the study period showed significant spatial evolution characteristics, in which the significant and relatively significant hot spots spread along the eastern coast and radiated to some central areas, the relatively significant cold spots spread to the northwest and northeast, and the random distribution areas exhibited a trend of contraction. Specifically, in 2002, there were 17 areas (provinces, autonomous regions, and municipalities) with the randomly distributed coupling coordination degree, 10 areas in cold spots, and 4 areas in hot spots. In 2005, the number of randomly distributed areas decreased to 14, the number of cold spots remained at 10, and the number of hot spots increased to 7. In 2008, there were 13 randomly distributed areas, 11 cold spots, and 7 hot spots. From 2011 to 2018, the coupling coordination degree of China’s social security and economic development presented the largest number of cold spots, with randomly distributed areas converging to the central region and hot spots clustering to form an interconnected region. During the research period, Jiangsu and Shanghai had always been significant hot spots. The local autocorrelation analysis demonstrated that the coupling coordination degree of social security and economic development in China is becoming more closely related in space, and the relationship between social security and economic development in neighboring areas has mutual influence and infiltration. Neighboring areas with good coupling coordination relationship between social security and economic development have good coupling coordination relationship; on the contrary, neighboring areas with poor coupling coordination relationship between social security and economic development exhibit poor coupling coordination relationship. Therefore, narrowing regional gaps and coordinating regional economic and social development are essential issues that China should be addressed to achieve its two centenary goals in the future.

4. Discussion and conclusions

In this paper, the entropy method, coupling coordination degree, standard deviation ellipse model, and spatial autocorrelation were used to study the spatial-temporal characteristics of coupling coordination of social security and economic development in China from 2002 to 2018.

In terms of time, the relationship between social security and economic development in China was gradually getting closer in mutual adaptation and common development, and the coupling coordination type gradually transitioned to the primary coupling coordination type in 2018. Among the four regions, only the northeastern region has been in the mode of barely coupling coordination, and the other three regions had significant coupling coordination grade transition. This is embodied in the following aspects. The coupling
coordination degree of the eastern region has increased from primary coupling coordination to good coupling coordination; the central and western regions had increased from general imbalance to forced coupling coordination; on the whole, the coupling coordination degree presented the phenomenon of “the eastern region > the northeastern region > the central region > the western region”. Besides, the coupling and benign interaction between China’s social security and economic development was unstable, and the task of promoting the long-term and benign interactive development of the two remained difficult.

In terms of space, first, the coupling coordination degree of social security and economic development in China contracted in the east-west and north-south directions, and the coupling coordination clustered in the central region in this period. Second, the coupling coordination degree had a positive spatial autocorrelation as a whole and regions with similar coupling coordination degree were in a state of agglomeration. Finally, the hot spots clumped to form a continuous region in the eastern coastal area while the cold spots expanded toward the northwest and northeast, and the random distribution areas exhibited a trend of contraction. The coupling coordination degree of social security and economic development in China was increasingly closely linked in the spatial level, and the relationship between social security and economic development in neighboring areas influenced and penetrated each other.

Therefore, we proposed two suggested countermeasures in this paper. Specifically, first, China should adapt to the new normal and maintain moderate economic growth. The rapid economic growth will undoubtedly promote the development of social security, increasing the profits of enterprises, residents’ income, and fiscal revenue. This is not only conducive to expanding the coverage of the social security system but also conducive to residents to choose a higher level of contribution, so as to expand the scale of the social security fund. With the rapid growth of China’s economy for more than 30 years, the social security system has been continuously improved. However, China’s economy entered the new normal in 2014. Instead of the high growth rate of around 10% in the past years, China’s economy entered a medium growth rate, affecting the revenue of the social security fund. Therefore, China should actively adapt to the new normal, upgrade and optimize the economic structure, drive the economic development through innovation, keep the economic operation within a reasonable range, and consolidate the material foundation needed for the sustainable development of its social security system. Second, China should improve and build a sustainable and multi-level social security system that coordinates urban and rural areas. The construction of a multi-level social security system aims to realize the multi-level of major projects, such as pension insurance, medical security, pension services, and social assistance. At present, in the multi-level social security system, China still presents the statutory basic security system led by the government, namely, the first level dominant pattern. It not only undermines the enthusiasm of market subjects and social forces to participate, but also continuously intensifies the financial burden of local governments, affecting the sound development of China’s social security system. Social pension insurance, which accounts for the largest proportion in social security, covers multi-level and multi-type insurance, such as basic pension insurance for urban employees, basic pension insurance for urban and rural residents, enterprise annuity, and personal commercial insurance. Thus, it is necessary to recognize that the development of enterprise annuity as the second pillar is insufficient, and the personal commercial pension as the third pillar is unable to accurately identify its customer groups, though the current basic pension system covers 9.87 × 10^8 people in China, basically achieving full coverage of the system. While the development of basic pension insurance is guaranteed, the reform of the pension insurance system in the second and third pillars also needs to be promoted, enabling the market to play a decisive role in the allocation of pension resources in the second and third levels. Due to the long-term dual economic development model between urban and rural areas, the differences in social security between urban and rural areas and between regions are rather large, and the coupling coordination of social security and economic development in the eastern, central, and western regions are significantly heterogeneous, even though China's social security system has achieved full coverage, and the level of national social security treatment has generally improved. Therefore, China should adhere to the strategy of the overall planning of urban and rural development, establish a national basic pension and medical insurance system for the whole urban and rural areas, realize the national overall planning of basic pension, expand the financing channels of social security funds, establish a social security treatment and adjustment mechanism that covers all types of personnel, promote the overall planning of social insurance across the country based on accelerating the overall planning at the provincial level, and reasonably balance the financial burden of social security between different regions, so as to truly establish a “Full Coverage, Basically Guaranteed, Multi-level, and Sustainable” social security system and then realize the stabilizing function of economic sustainable development.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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