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Spatio-temporal Dynamic of Quality of Life of Residents, Northeast China

CHENG Yeqing[1], WANG Ying[1], WANG Zheye[2], DU Na[1], SUN Yu[3], ZHAO Zhizhong[1]

(1. *College of Geography and Environmental Sciences*, *Hainan Normal University*, *Haikou* 571158, *China*; 2. *Department of Geography*, *Kent State University*, *Kent* 44242, *United States*; 3. *Northeast Institute of Geography and Agroecology*, *Chinese Academy of Sciences*, *Changchun* 130012, *China*)

Abstract: Quality of life (QOL) is a hotspot issue that has attracted increasing attention from the Chinese Government and scholars, it is also a vital issue that should be addressed during the cause of ′establishing overall well-off society′. Northeast China is one of the most import old industrial bases in China, however, the industrial structure of heavy chemical industry and the development mode of ′production first, living last′ have leaded to series of social problems, which have also become a serious bottleneck to social stability and economic sustainable development. Through applying the methods of BP neural network, exploratory spatial data analysis (ESDA) and spatial regression model, this paper examines the space-time dynamics of QOL of the residents in Northeast China. We first investigate the indexes of QOL of the residents and then use ESDA methods to visualize its space-time relationship. We have found a spatial agglomeration of QOL of the residents in middle-southern Liaoning Province, central Jilin Province and Harbin-Qiqihar-Daqing area of Heilongjiang Province. Two third of the counties are low-low spatial correlation, and the correlative type of about 60% of the prefecture level areas keeps stable, indicating QOL of the residents in Northeast China shows a certain character of path dependence or spatial locked. We have also found that economic strength and development levels of service industry have positive and obvious effect on QOL of the residents, while the effect of such indexes as the social service level and the proportion of the tertiary industries are less.
Keywords: quality of life (QOL); BP neural network; exploratory spatial data analysis (ESDA); spatial regression model; Northeast China

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1 Introduction

Since the 1950s, with the rapid transition of global society and economy, the philosophy of regional development has changed gradually from taking economic growth as the core to the overall development of the society, this ′people-oriented′ development emphasizes that we should take the comprehensive development of human being as the fundamental target (UN, 1995; Peng and Li, 2003), and the most important content is to improve quality of life (QOL) and personal liberation continuously. Therefore, QOL has become one of the hottest issues that have attracted increasing attention from economists, sociologists and geographers over the world, and a series of achievements on the theoretical and practical studies have been made since the Canadian economist Galbraith J K put forth the concept of QOL in 1958 (Feng, 1992).

In general, QOL means the situation that the human demand is satisfied and the degree of gratification that the individual or colony can perceive from many aspects

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Corresponding author: DU Na. E-mail: 673355216@qq.com

in life (Feng, 2007). It is a multi-dimensionality concept (Foreman and Kleinpell, 1990; Ferrans and Powers, 1992; Cimete *et al*., 2003; Hacker, 2003; Kaasa and Loge, 2003). Material level of life is just one dimensionality, while culture and spirit also affect people′s perception of QOL (Jalowiec, 1990; Ferrans and Powers, 1992; Wilson *et al*., 2001). Besides, the subjective well-being, satisfaction with life and local amenities are used to depict QOL frequently (Rosen, 1979; Roback, 1982). Therefore, Diener and Suh (1997) argued that QOL can not be defined well only using social and economic indicators, and the degree of human requirements that is satisfied should be paid more attention (Diener *et al.*, 1999; Hass, 1999; Zhou and Rao, 2001; Easterlin, 2003), and such statuses as material, physiological function, social function and mental health should be taken into account synthetically (The WHOQOL Group, 1995). In fact, QOL is the comprehensive reflection of living conditions of the residents in a certain region, and it is also a symbol that reflects the situation of human living and welfare, including living condition, social culture, education, health, traffic, living service, social climate and social order and so on (Li, 1986; Feng, 2007). From above reviews, we can see that the definitions on QOL are different from diverse perspective of subjects, while the situation that only thinks about objective social indexes or subjective well-being has been changed, and the tendency is obvious that most scholars try to illuminate QOL integrating both of them.

In recent three decades, series of achievements have been made on the index systems of QOL. Diener (1995) selected specific indexes based on basic human values theory of Schwartz, including ten types of values such as self-oriented, irritate, hedonism, achievement, right, safety, obey, tradition and charity, and compared the QOL of 101 counties. Hagerty (1999) selected two or three indexes respectively according to Maslow′s demand hierarchy theory, including such indicators as philosophy, security, social intercourse, respect, and self-realization, which are sententious and explicit and easy to obtain data for temporal analysis of QOL. However, Roback (1982) materialized the concept of QOL, and tried to use some economic indexes to reflect QOL of the residents. Dröge *et al*. (1993) argued that the increasing of meterial possetions can promote human welfare, but meterialism will make people ignore such values as fair and altruism. When we illustrate the urban QOL, employment, education and crime were the important indexes used to represent local amenities (Rosen, 1979). In general, the local amenities can reflect the attraction of one region, but it can not be used to measure and compare the situation of overall welfare of the residents in different region (Rosen, 1979; Roback, 1982). The ′human development index (HDI)′ took income, health and education as major indexes of QOL by establishing the two-dimension connection of social and economic indexes (UNDP, 2010). Besides, enthusiastic discussions were lunched on the index system of subjective well-being and satisfaction with life (Cantril, 1965; Diener and Seligman, 2004; Diener *et al*, 2005; Angner, 2009). However, the Chinese scholars began to pay attention to QOL since the 1980s, which is analogous to the west developed counties. The common scenarios is that the scholars established series of completely different index systems in term of dimensionality, specific indexes, synthesis method and weight matrix (Feng, 2007; BNUG, 2011). The living and consumption, social security, employment, education, medical treatment, reside and environment and safety are usually the most important indexes used to illustrate QOL of the residents (Feng, 1992; Lin and Lu, 1989).

Moreover, with the rapid development of remote sensing and geographical information system, more and more practical researches were done to illustrate the spatial pattern of QOL, especially in the field of urban QOL. For example, Green (1957) extracted a great deal of natural environmental valuables such as housing density, single housing amount, landuse and landcover condition of inside and outside residential district, and calculated the distance between residential district and the central business district, and then measured the suitability of the reside of Birminghan in Abalama State. Mumbower and Donoghue (1967) and Metivier and McCoy (1971) analyzed the spatial pattern of poor using the data of housing density from aeroplane photography. Bederman and Hartshorn (1984) measured QOL of Geogria State at county level based on the data of socioeconomic valuables. In recent years, the space-time dynamic analysis of QOL that combines the socioeconomic census data and remote sensing data became more commonly (Li and Weng, 2007). Weber and Hirsch (1992) established an index system of urban QOL of the Strasbourg in France, and found each index can only reflect a certain respect of urban QOL but cannot reflect the overall situation of a particular unit.

Based on environmental valuables from TM data (landuse-landcover, temperature of earth surface, vegetation index) and census data (population density, income per capita, housing price), Lo and Faber (1997) drawn out the map of QOL of the Athens-Clarke County in Georgia state using the method of principal components analysis and spatial summation technology of GIS. Li and Weng (2007) measured QOL of the Indianapolis in Indiana state by combining the data of remote sensing (green converge, impervious surface, temperature of earth surface) and socioeconomic census date (population density, income, employment ratio and educational level) with the help of GIS technology.

From what has been discussed above, it can be found that the studies of QOL have attracted increasing attention from the scholars, and great progress has been made on its conception, measurement and mechanism. Some kept their eyes on the objective factors that impact on the material and spirit of the residents, while some emphasized the subjective felling on amenity and convenience, and the satisfaction of life or happiness was usually used to measure QOL. However, more and more studies tended to use both of objective and subjective indicators to measure QOL, and argued that the QOL is correlated to not only the objective material condition but also the subjective satisfaction of life.

China has achieved rapid development in society and economy since 'reform and opening up', more and more geographers and sociologist keeps the eyes on the studies of QOL of the residents, especially in income, employment, education, medical treatment, housing and social security related to QOL (BNUG, 2011). However, the long-term implementation of uneven development strategy and dual structure of social economy system have led to durative enlarge of regional gap of QOL, which has become one of the most serious issues that should be paid more attention. Therefore, the central government of China has taken the achievement of QOL of the residents as a vital strategic target in current national developmental planning, aiming at social justice and realizing 'overall well-off'.

As one of the most important old industrial bases and commodity grain production bases, Northeast China has made significant contribution for China's economic construction in the past four decades. However, due to the impact of institution and structure, the 'Northeast phenomenon' and 'New northeast phenomenon' arose one after another since the 1990s. The former took place mainly in the urban areas and was characterized as depletion of mineral resource, imbalance of industrial structure, hard enterprises operation, severe decline of efficiency and lacking of alternative industries, while the latter occurred mainly in the vast rural areas and was characterized as large backlog of dominate agricultural products, slow growth of farmers' income, difficult improvement of agricultural economic efficiency and so on. Therefore, regional economic vitality and competetiveness has been declined consistently for a long time, which has also triggered series of livelihood problems such as unemployment, poor and deprived environment (Jin, 2012). Although the Northeast China has achieved significant growth in fixed asset investment and economic aggregate since the central government implemented the strategy of 'revitalizing the northeastern old industrial bases', the livelihood problems can not be addressed fundamentally in a short time due to the capital-intensive and resource-dependent industrial structure (Song, 2007; Yang and Liu, 2008). Moreover, the implementation of heavy industry and urban-oriented regional development strategy has also led to remarkable regional inequality and dual structure of urban-rural areas. Therefore, this paper attempts to select some specific indicators to measure QOL of the resident quantitatively, and examines its space-time dynamic and driving factors, aiming at declining the regional gap of QOL of the residents in Northeast China and providing practical reference for those similar areas in China.

2 Materials and Methods

2.1 Index system and data sources

Although there has not achieved coherent agreement on the concept and index system of QOL, most scholars argued that the subjective indicators can illustrate the micro characteristics and mechanism penetratingly, while the objective indicators can identify macro characteristics and mechanism clearly, and has been applied in most previous practical studies (Feng, 1992; Zhao and Li, 2000; Zhou and Rao, 2001). Therefore, based on the previous studies, and in view of procurability, representation and comparability of the data, we attempt to establish the QOL index (QOLI) to exam the space-time dynamic of QOL of the residents in Northeast China, which includes ten objective indicators such as rural per capital net income (RCNI), urban per capita disposable income (UCNI), collection of public library per hundred people (CPLP), ownership of public car per ten thousand people (OPCP), urban per capita road area (UCRA), greening coverage of built up area (BAGC), hospital number per ten thousand people (HNTP), doctor number per ten thousand people (DNTP), mobile phone users per ten thousand people (MPUP) and internet users per ten thousand people (IUTP). Where, the RCNI and UCNI reflect the economic conditions, the CPLP, OPCP, UCRA and BAGC represent the public service levels, the HNTP and DNTP reflect the medical conditions, and the MPUP and IUTP represent the degree of informatization.

In this paper, the study area consists of three provinces (Liaoning, Jilin and Heilongjiang), which includes 34 prefecture-level cities, 2 prefecture-level regions and 138 counties (county-level city and autonomous county) (Fig.1). Three years of panel data of the units in 2002, 2006 and 2010 are collected to measure QOL of the residents and exam its space-time dynamic and driving factors. All of the original data are from *China City Statistical Yearbook* (NBSC, 2003–2011), *China Civil Affairs' Statistical Yearbook* (MCAC, 2003–2011), *Jilin Statistical Yearbook* (JSB, 2003–2011), *Heilongjiang Statistical Yearbook* (HSB, 2003–2011) and *Liaoning Statistical Yearbook* (LSB, 2003–2011).

2.2 BP neural network model

BP neural network is a supervised learning model (Jiang, 2001), which includes three levels of network, namely, input layer, hidden layer and output layer. The training process of BP neural network includes two phases. The first phase is forward propagation, which is needed to select a sample (X_p, Y_p) from the samples and enter the network, and then calculate the corresponding actual output value (O_p) of network. The second phase is reverse propagation of error, which is needed to calculate the difference between actual output (O_p) and ideal

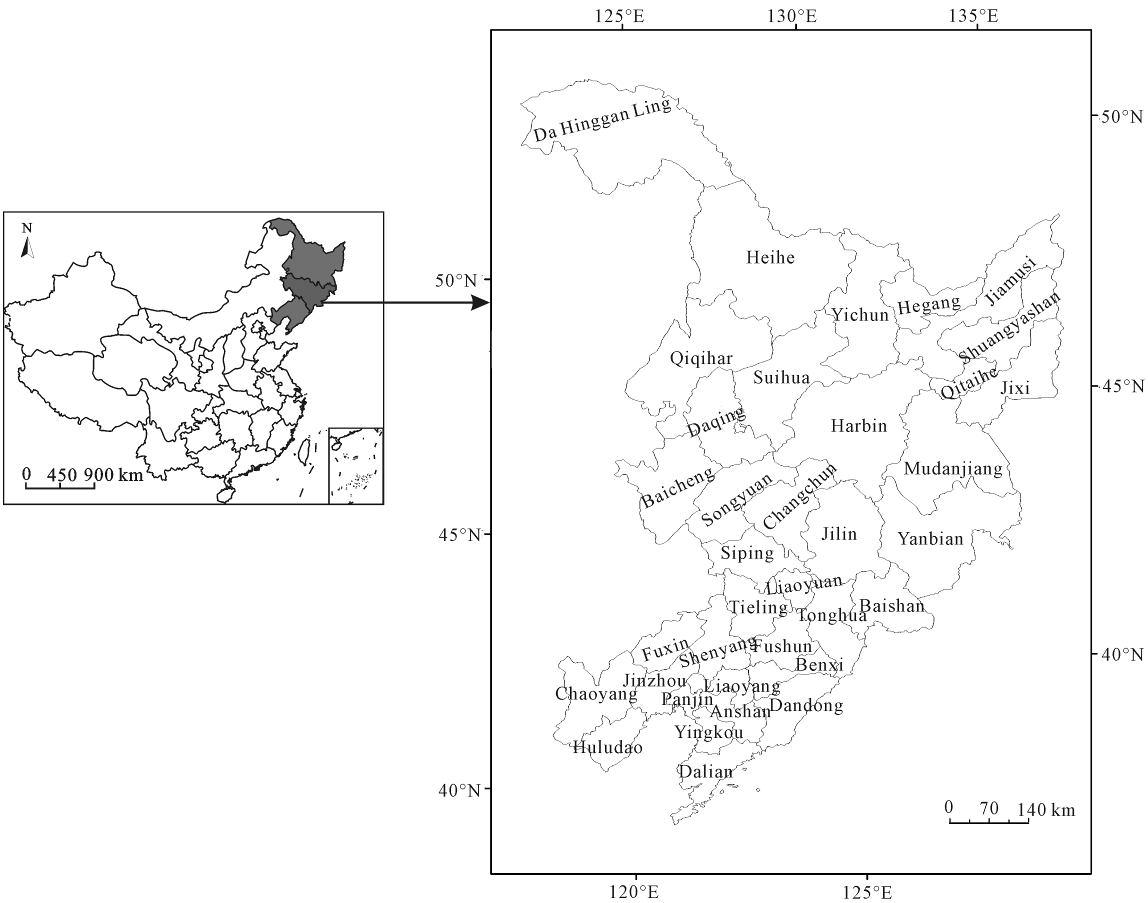

Fig. 1 Location of study area

output (Y_p), when the actual output (O_p) is not in accordance with ideal output (Y_p), then should switch to the stage of anti-propagation of the error, and weight matrix of each level will be amended by way of error gradient descent and then reversed to hidden layer and input layer. These processes of continuous cycle of forward propagation of information and reverse propagation of error is not only the continuous adjustment of weight matrix in each level, but also a training process of neural network, and will not finish until the error of the whole samples decline to the degree that can be accepted or reach the training times that has been set prospectively (Fig. 2). Thus, the network model has a certain ability of self-learning and self-organizing, and we can get more accurate simulated values of the new input samples using this network model (Cheng and Deng, 2010). QOL is a comprehensive concept and is affected by such factors as society, economy and environment, and the traditional static methods are difficult to illustrate the complex relationship exactly. However, the BP neural network model has strong ability of non-linear simulation, as well as the function of self-learning and self-organizing, which can avoid subjective judgment that comes from factitious weighted when measure QOL and make the results of measurement have higher reliability (Jiang, 2001). Therefore, the BP neural network model was used to measure QOL of residents in Northeast China. Firstly, the original data were standardized in order to eliminate the influence of dimension. Secondly, according to the method provided by Le Gallo(2004), the indictors that have been standardized can be classified into five levels such as highest, higher, middle, lower and lowest, which are corresponding to such value as five, four, three, two and one, and then gets the measurement standard of BP neural network (Tables 1–3). Finally, the network training and simulation were conducted based on the samples. The network mode includes ten input neurons, five hidden neurons and one output neurons, thus, the final topological structure of the network is 10 × 5 × 1. The parameters of the network are set as following. The primary weight of the network is a random number between zero and one. Basic learning speed and coefficient of momentum transfer are from the network defaults (Wen *et al.*, 2001), which is 0.01 and 0.90, respectively. The biggest frequency of network training is 1000, and the biggest error is 0.001. All of these processes are realized by the workbox of neural network in Matlab 7. The batch gradient descent with momentum algorithm is used to training of the samples, and the hidden layer transfer function is two-tangent s-shaped transfer function, while output layer transfer function is linear transfer function. After the training network data approaches required precision, the standardized data of the indicators can be input the neural network model and we can conduct the simulation, and then obtain the measurement values of BP neural network of QOL of each spatial unit.

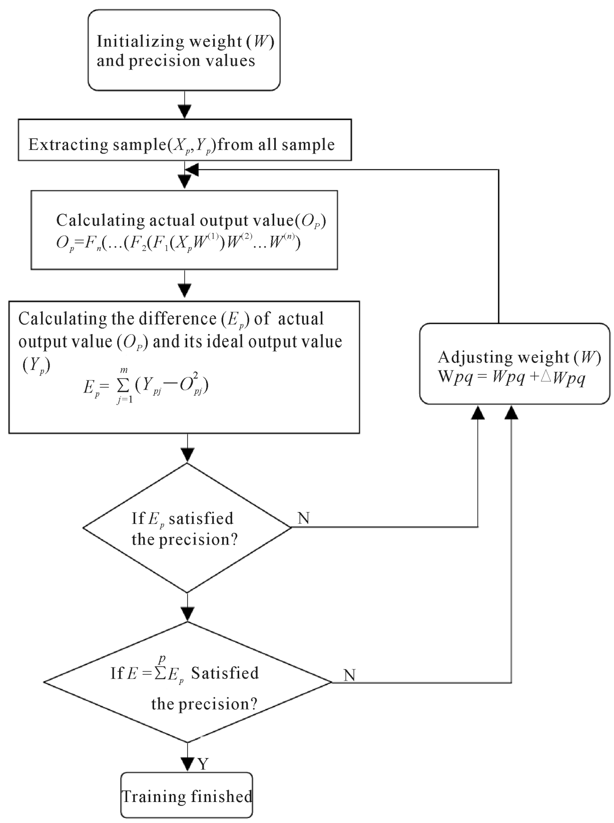

Fig. 2 Flow of BP neural network analysis

Table 1 Evaluation criterion of quality of life (QOL) indicators in 2002 for BP network analysis

P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	Value
1	1	1	1	1	1	1	1	1	1	5
0.6031	0.4286	0.2527	0.4674	0.2749	0.6637	0.1910	0.0881	0.4775	0.3385	4
0.5307	0.3772	0.2224	0.4113	0.2419	0.5840	0.1681	0.0775	0.4202	0.2979	3
0.4583	0.3258	0.1921	0.3552	0.2089	0.5044	0.1451	0.0670	0.3629	0.2573	2
0.3136	0.2229	0.1314	0.2430	0.1430	0.3451	0.0993	0.0458	0.2483	0.1760	1

Table 2 Evaluation criterion of quality of life (QOL) indicators in 2006 for BP network analysis

P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	Value
1	1	1	1	1	1	1	1	1	1	5
0.3728	0.5241	0.3086	0.4461	0.3522	0.8808	0.2817	0.5460	0.5138	0.2597	4
0.3281	0.4612	0.2716	0.3926	0.3100	0.7751	0.2479	0.4805	0.4521	0.2285	3
0.2833	0.3983	0.2346	0.3390	0.2677	0.6694	0.2141	0.4150	0.3905	0.1974	2
0.1939	0.2725	0.1605	0.2320	0.1832	0.4580	0.1465	0.2839	0.2672	0.1350	1

Table 3 Evaluation criterion of QOL indicators in 2010 for BP network analysis

P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	Value
1	1	1	1	1	1	1	1	1	1	5
0.4727	0.6556	0.2318	0.3363	0.3145	0.8610	0.1134	0.2639	0.6743	0.3803	4
0.4160	0.5769	0.2040	0.2960	0.2768	0.7577	0.0998	0.2323	0.5934	0.3346	3
0.3592	0.4982	0.1762	0.2556	0.2390	0.6544	0.0862	0.2006	0.5125	0.2890	2
0.2458	0.3409	0.1205	0.1749	0.1635	0.4477	0.0590	0.1373	0.3506	0.1977	1

2.3 Exploratory spatial data analysis (ESDA)

ESDA is a set of methods aiming at describing and visualizing geographical distributions. ESDA can be utilized to detect spatial outliers or atypical localizations, identify patterns of spatial association and indicate forms of spatial heterogeneity (Haining, 1990; Anselin, 1999; Grubesic and Mack, 2008). ESDA provides measures of global and local spatial autocorrelation to characterize the spatial distribution of a set of values (Ye and Wu, 2011). It is considered as a descriptive step before hypothesis test and regression model implementation (Anselin, 2005). Global autocorrelation is assessed by global Moran′s *I* statistic. A positive and significant Moran′s *I* value indicates a general pattern of spatial clustering of similar values. Local indicator spatial autocorrelation (LISA) considers spatial proximity of each unit/value, which can identify the spatial hot spots of values (Anselin, 1995). The rapid development of ESDA has stimulated a number of research efforts to analyze the spatial inequality and regional dynamics (Rey, 2001; Gallo and Ertur, 2003; Rey, 2004; Pu *et al*., 2005; Goodchild, 2006; Rey and Ye, 2010; Vilalta, 2010; Tu *et al*., 2012). This paper attempts to illustrate the space-time dynamic of QOL from 2002 to 2010.

2.3.1 Global spatial autocorrelation

Global Moran′s *I* is applied to detect the spatial autocorrelation and analyze the spatial relationships among regions (Upton and Fingleton, 1985; Aneslin, 1988; 1995; 1996). An increasing global Moran′s *I* indicates the growing convergence, while a decreasing global Moran′s *I* reveals a more even spatial distribution (Yu and Wei, 2003).

Global Moran′s *I* is given as:

$$I = \frac{n\sum_{i=1}^{n}\sum_{j=1}^{n} W_{ij}\left(y_i - \bar{y}\right)\left(y_j - \bar{y}\right)}{\sum_{i=1}^{n}\sum_{j=1}^{n} W_{ij}\sum_{i=1}^{n}\left(y_j - \bar{y}\right)} \quad (2)$$

where n is the total number of the spatial units; y_i and y_j denote the QOL of i-th and j-th unit, respectively; $\bar{y}$ is the average QOL of the units; W_{ij} is the binary weight matrix of the general cross-product statistic, in which the K-Nearest Neighbor is selected on the basis of the adjacency relations, and K fetches the accepted value of 4 to ensure each unit has one neighbor at least. The z value is used to test the Global Moran′s I, which is given as:

$$z = \left[I - E(I)\right] / \sqrt{\mathrm{Var}(I)} \quad (3)$$

where I is the Moran′s I, $E(I)$ and Var(I) denote the expectation value and the variance of Moran′s I, respectively. Under a given significant level, if z-value is significant and Moran′s I is positive, the units with higher or lower QOL are spatial agglomeration; if z-value is significant but Moran′s I is negative, the difference of QOL of among the unit and its adjacent units are obvious; if z-value is not significant and Moran′s I is closed to 0, the QOL among the units are independent and random distribution.

2.3.2 Local spatial autocorrelation (*LISA*)

Global Moran′s *I* reveals overall spatial associations, but does not illustrate spatial association of individual units. To address this issue, local spatial autocorrelation is applied to undertake a disaggregated analysis of QOL in Northeast China. LISA takes each spatial unit as the inspection object and analyzes its properties of spatial autocorrelation (Anselin, 1999). The equation is given as:

$$I_i = z_i \sum_{j \neq i}^{n} W_{ij} z_j \qquad (4)$$

where I_i is the local autocorrelation index of QOL; z_i and z_j are the standardized values of QOL of spatial unit i and j, respectively and refer the deviation degree of QOL of the units to its average value; W_{ij} is the spatial weight of QOL of unit i and j.

In the map of Moran scatterplot, the four different quadrants divide such two types of spatial association as the positive and negative associations into four different types of local spatial association between individual regions. Namely, High-High (quadrant I, positive associations) indicates high values surrounded by high values; Low-Low (quadrant III, positive associations) indicates low values surrounded by low values; Low-High (quadrant II, negative associations) and High-Low (quadrant IV, negative associations) indicate low values surrounded by high values, and high values surrounded by low values, respectively (Yu and Wei, 2003).

2.4 Spatial regression model

Generally speaking, panel data covers a large amount of information and includes more changes and weaker co-linearity of variable, which can provide a higher freedom degree and improve the reliable estimates of the coefficients (Elhorst, 2003; Ji *et al.*, 2011). Due to the spatial autocorrelation (spatial dependence) of QOL among the units in each time section, the spatial panel econometric model, basing on the common panel data model and blended in spatial and temporal effect, can be applied to illustrate the influence of these selected factors on the space-time dynamic patterns of QOL.

The Spatial Lag Model (SLM) emphasizes mainly on the spatial correlation of the variables among the geographical units and inspects its spatial spillover effect. If the spatial interaction effect or spatial autocorrelation comes from the material correlation of regional trade, labor, capital, technology and knowledge flow, it can be analyzed by spatial lag factors that are included dependent variables (Hong *et al.*, 2010). The equation is given as:

$$y_{it} = \delta \sum_{j=1}^{n} w_{ij} y_{jt} + \beta x_{it} + \mu_i + \lambda_t + \varepsilon_{it} \qquad (5)$$

where i is an index of the cross-sectional spatial units, with i =1, …, n, 34 units serve as the cross-sectional spatial units; the index of t represents the temporal periods, with t =1, …, T, and the three years are considered as three time points of temporal dimension (2000, 2006, 2012); δ is the spatial autoregressive coefficient; y_{it} is an observation on the dependent variable (carbon intensity) at spatial unit i and time t; x_{it} is an (1, k) row vector of observed value of independent variable at i and t; β is a matching (k, 1) of fixed but unknown parameters; μ_i denotes a spatial fixed effect, which controls all of the spatial fixing and the variables that will not change with time; λ_t denotes a time fixed effect, which controls all of the time fixing and the variables that will not change with space; w_{ij} is an element of a spatial weights matrix w, and w describes the spatial arrangement of all the spatial units in the sample.

The Spatial Error Model (SEM) inspects mainly the influencing degreed of variable error on observation values. Some independent variables, which are relative to the dependent variable have spatial autocorrelation, may be missed when establishing the spatial regression model, and the random error maybe influence the spatial spillover effect. For example, the elemental fluctuation of a spatial unit will spread to other regions through spatial transmission mechanism, therefore, spatial autocorrelation that ignores the error maybe lead to a bias when establishing the model under some condition (Wu and Li, 2006; Cheng *et al.*, 2014). The equation is given as:

$$y_{it} = \beta x_{it} + \mu_i + \lambda_t + \phi_{it}\ ; \quad \phi_{it} = \rho \sum_{j=1}^{n} w_{ij} \phi_{it} + \varepsilon_{it} \qquad (6)$$

where ϕ_{it} denotes an error item of spatial autocorrelation; ρ is called a spatial autocorrelation coefficient of an error item (Elhorst, 2003).

3 Results and Analyses

3.1 Spatial pattern

In order to illustrate the spatial differentiation of QOL more intuitively in Northeast China, the 34 units can be classified into five grades according to the values of QOLI using the classification criteria established in BP neural network training, namely, highest, higher, middle, lower and lowest region (Fig. 3). It can be seen from Fig. 3 that spatial patterns of QOL in the three time-sections almost have the same characters, that is, the highest and higher QOL areas concentrate mainly in mid-southern Liaoning Province, central Jilin Province and Harbin-Daqing-Qiqihar region of Heilongjiang Province. For example, in 2002, there were 14 units belong to highest and higher QOL region, and 11 of which located in mid-southern Liaoning Province, central Jilin Province and Harbin-Daqing-Qiqihar region. In 2006, the highest and higher QOL units decreased to 10, and 9 units are located in the three regions. In 2010, 10 of 11 highest and higher QOL units are located in the three regions. In summary, the spatial pattern of QOL of the residents in Northeast China takes on obvious hierarchy and regional diversity. The 'Harbin-Dalian' economic belt is not only one of the most important economic development axes in China, but also the agglomeration region of population and economy in Northeast China. It has perfect service system and higher QOL. In provincial scale, the mid-southern Liaoning Province consists of two important regions, namely, the multi-cities of central Liaoning that and the coastal economic belt of Liaoning. It is the most development area of economy and traffic, it is also the portal of opening up and primer region of global process in Northeast China for its concentrative cities, predominate location and higher urbanization level. Harbin-Daqing-Qiqihar region is the center of economy and population and important supporting region of urbanization in Heilongjiang Province, and keeps close relationship of industrial cooperation with others Asian countries. However, lowest and lower QOL units distribute mainly in the fringe regions of Northeast China with worse location, undeveloped economy, less population and lower urbanization level.

3.2 Spatial autocorrelation

Generally speaking, all attribute values on a geographic surface are related to each other, but closer values are more strongly correlation than distant ones (Tobler, 1970; Anselin and Getis, 1992). In order to examine the spatial autocorrelation of QOL of the 34 units in Northeast China, Moran's I of QOL of the units in 2002, 2006 and 2010 are calculated using the method of ESDA with the help of GeoDa. The results show that Moran's I of 2002, 2006 and 2010 are 0.1107, 0.1176 and 0.1955, respectively, indicating that there exists obvious positive spatial autocorrelation of QOL among the units and the correlation tends to increase. Figure 4 illustrates the local spatial autocorrelation of QOL at the

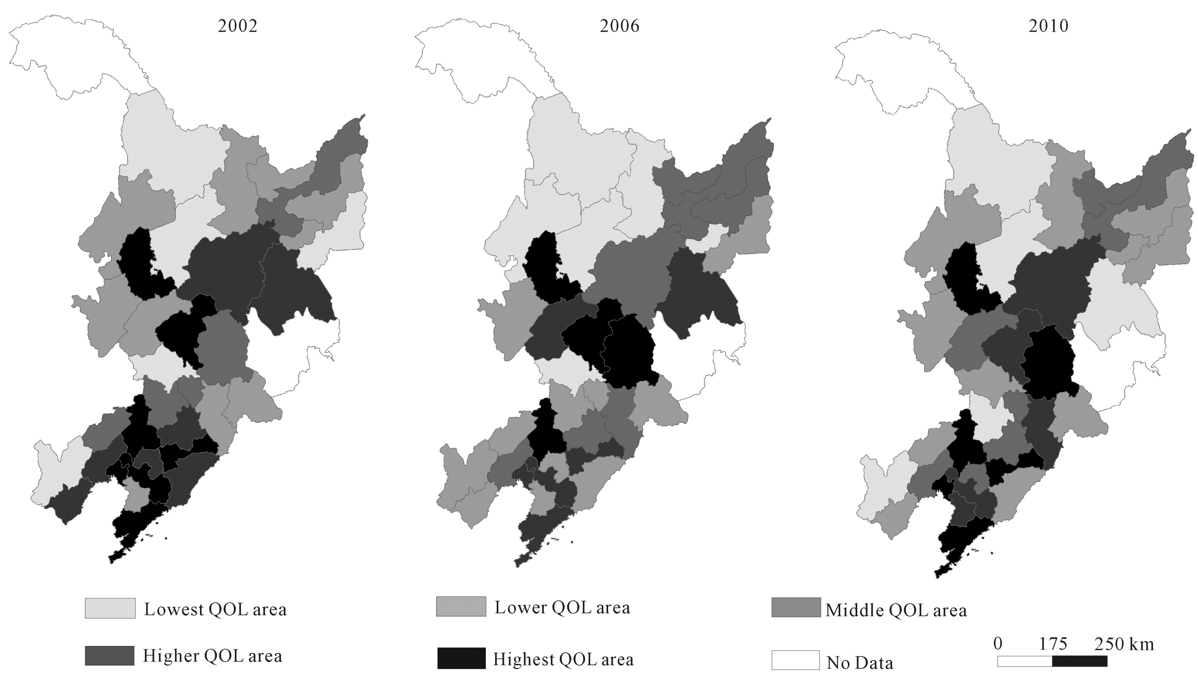

Fig. 3 Spatial patterns of quality of life (QOL) in Northeast China

scale of prefecture-level cities in 2002, 2006 and 2010. As showed in Fig. 4, QOL of Northeast China had obvious characteristics of spatial agglomeration, and 67.0% of unites belonged to the type of High-High (quadrant I) and Low-Low (quadrant III) agglomeration, while the units of High-Low and Low-High agglomeration accounted for 33.0% of the total units only, which indicated that there exists an obvious regional inequality of QOL at scale of prefecture-level. Analyzing the spatial characters, we can see that the units of High-High agglomeration distributed mainly in mid-southern Liaoning Province, central Jilin province and Herbin-Daqing- Qiqihar regions of Heilongjiang Province, while the units of Low-Low agglomeration centralized mainly in the mid-northern regions of Heilongjiang Province. However, the spatial distribution of the units of High- High agglomeration showed more significant changes than that of the units with Low-Low agglomeration from 2002 to 2010. In 2002, seven of eight of units of High-High agglomeration concentrated in mid-southern Liaoning Province. In 2010, the units of High-High agglomeration increased by 10, and its spatial distribution tended to be dispersive and expanded to whole central Jilin Province. The units of High-Low and Low-High agglomeration distributed dispersedly the western and eastern fringe region of Jilin Province and Liaoning Province. It is not difficult to find that spatial pattern of QOL in Northeast China is quite consistent with its spatial association.

3.3 Space-time transition

In order to illustrate changing characteristics of spatial pattern of QOL, the Markov transition matrix of QOL of 2000–2006 and 2006–2010 are calculated respectively to reflect the grade transition of the units of QOL type (Pu *et al*., 2005) (Table 4). As shows in Table 4, *n* denotes the unit number of the grades of initial year, the element of the diagonal denotes the unit number that the grade did not changed, while the element of the diagonal denotes the unit number that changed in different grades. Moreover, the element in upper triangle refers the unit number transited from low grade to high grade, and the element in bellower triangle refers the unit number transited from high grade to low grade. In 2002–2006, the sum of the elements in upper triangle, diagonal and bellower triangle is 8, 11 and 15, respectively, which means 23.5% units transferred from lower grade to higher grade, and 44.1% units transferred from higher grade to lower grade, and 32.4% of units keep stable. However, in 2006–2010, the grade transition of QOL of the units has changed obviously, the sum of the elements in upper triangle, diagonal and bellower triangle is 13, 15 and 6, respectively, which indicates 38.3% of units transferred from lower grade to higher grade, and 17.6% units transferred from higher grade to lower grade, and 44.1% of units keep stable. In summary, QOL of Northeast China took on interim characteristics and come across a process of grade decrease in a large scale and then increase from 2002 to 2010.

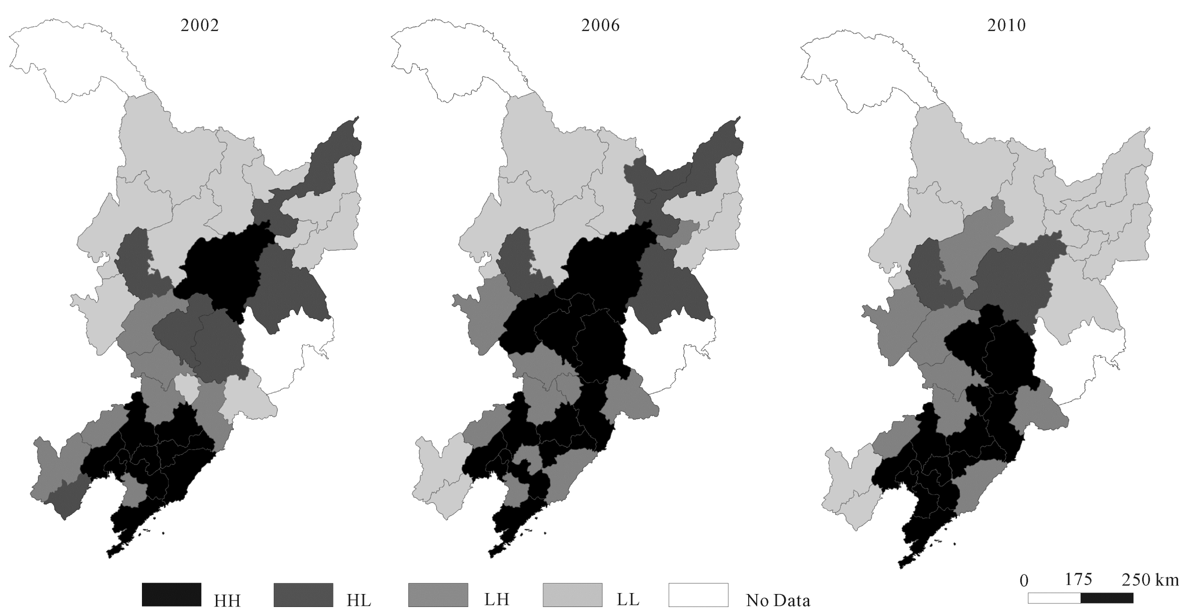

Fig. 4 Spatial Moran′ *I* scatterplot of QOLI of Northeast China in 2002, 2006 and 2010

Furthermore, in order to illustrate the dynamic characteristics of spatial agglomeration of QOL in Northeast China, the 34 units are classified into four types using the method of space-time transition with the aid of the Markov transition matrix, and they are analyzed in term of quantitative change of the units in each type at different stages (Rey, 2001). The definitions of the four types are: Ⅰ denotes the relative transition of one unit; Ⅱ denotes the transition of spatial adjacent units; Ⅲ denotes the transition of both one unit and its adjacent units; and Ⅳ denotes the relative stability of both one unit and its adjacent units. Table 5 shows the dynamic of space-time transition of the units in the stage of 2002–2006 and 2006–2010. The elements in the main diagonal of spatio-temporal transition matrix are the units of Ⅳ transition. In 2002–2006, number of the units belonged to Ⅰ, Ⅱ, Ⅲ and Ⅳ are 6, 7, 0 and 21, respectively, which accounted for 17.6%, 20.6%, 0 and 61.8% of the total units in Northeast China, respectively. In 2006–2010, the number of units belonged to Ⅰ, Ⅱ, Ⅲ and Ⅳ are 7, 4, 0 and 23, respectively, which accounted for 20.6% 11.8%, 0 and 61.8% of the total units in Northeast China, respectively. In summary, we can find that the spatial correlation type of about 60.0% of units did not changed in 2002–2010, only 40.0% of units took place relative transition of itself or the transition of adjacent spatial units, and none unit happened both of the transition, which indicated that QOL of Northeast China has the distributive characteristics of spatial lock or path dependence to some extent.

4 Driving Factors of Quality of Life

QOL is a multi-dimensionality concept (Foreman and Kleinpell, 1990; Ferrans and Powers, 1992; Cimete *et al*., 2003; Hacker, 2003; Kaasa and Loge, 2003), and is affected by such factors as economic strength, social security, industrial structure and national policies. Economic development can provide material base for improving QOL, which is usually considered as an assignable factor. Diener (1995) argued that the contribution of economic development to QOL reached 62%, which indicates that economic strength has decisive influence on QOL. Social ensure is an important way of meeting basic demand of residents life, which affects QOL of the residents directly. According to the study conducted by Zhang (2010), social ensure level has important positive influence on QOL of the residents in China, and the correlation coefficient is 0.385. The development of service sector has obvious positive sense on QOL. First, service sector is usually labor intensive industry and can provide more employment. Second, service sector provides sorts of service for enriching life way and improving QOL of the residents, especially. With the rapid development of modern service sector,

Table 4 Markov transition matrix of quality of life (QOL) grades

T_i/T_i+1	2002–2006						2006–2010					
	n	Lowest	Lower	Middle	Higher	Highest	*n*	Lowest	Lower	Middle	Higher	Highest
Lowest	5	3	2	0	0	1	6	2	4	0	0	0
Lower	10	3	3	3	1	0	11	2	5	3	1	0
Middle	5	0	3	1	0	1	7	0	1	4	2	0
Higher	7	0	3	3	1	0	6	1	0	1	1	3
Highest	7	0	0	0	4	3	4	0	0	0	1	3

Notes: T_i means the initial time; T_{i+1} means the finish time

Table 5 Markov transition matrix of quality of life (QOL) spatial association types

T_i/T_i+1	2002–2006					2006–2010				
	n	HH	LH	LL	HL	*n*	HH	LH	LL	HL
HH	10	8	2	0	0	12	9	1	0	2
LH	7	2	4	1	0	10	3	6	1	0
LL	11	0	4	6	1	8	0	1	7	0
HL	6	2	0	1	3	4	0	0	3	1

Notes: HH denotes both the unit and its adjacent have higher QOL; HL denotes QOL of the unit is lower than that of its adjacent unit; LL denotes both the unit and its adjacent have lower QOL; LH denotes QOL of the unit is higher than that of its adjacent unit industrialization of service has come down to the whole fields of life, which improves the labor efficiency and QOL. Social investment in fixed asserts is often used to characterize the function of the government. Generally, the government always uses the lever to regulate human settlement, transportation, education, consumption and medical treatment and so on. Therefore, this paper establishes the spatial econometric model to identify the driving factors causing the regional inequality of QOL of the residents in Northeast China. In which, QOLI is the dependence variable, and GDP per capita (GDPPC), proportion of social security expenditure in financial expenditure (SSEF), proportion of tertiary industry in GDP (TIGP) and proportion of investment in fixed assets in GDP (FAIG) are the independence variables.

Previous analysis in this paper showed that QOL of the residents in Northeast China has significant spatial autocorrelation at the scale of prefecture-level cities, which indicates that there exist obvious spatial interaction effects among the factors on QOL. However, these spatial interaction effects have not been nested into traditional regression model (TRM), which may lead to some extent bias on specification and estimative results of the TRM. Meanwhile, spatial panel econometric model (SPM) nests spatial and temporal effects and can identify if the independent variables have spatial spillover effects. Moreover, The SPM can make the spatial regression model fit the practice more exactly and illustrate the spatial influence of the independent variables on the dependent variable more clearly (Anselin, 1988). In general, the TRM, SLM and SEM are relative common methods to analyze the spatial effects of the attributes in geographic surface. However, to be on the safe side, this paper attempts to estimate and test the spatial effects of the selected factors with these three models, respectively, and then chooses the optimal model by comparative analysis the estimative and test results of each model to illustrate the domain factors and their spatial influence on QOL of the residents in Northeast China. Firstly, we use TRM to estimate and test the residual error, and Table 6 shows the results of OLS, Moran′s *I* test on regression error and the spatial dependence of two Lagrange multipliers. Secondly, we conduct a comparative analysis of estimation and test results of SLM and SEM, so as to identify if SLM and SEM are more optimal than TRM (Table 7).

Anselin (1988) suggested the standard of optimizing the SLM and SEM, that is, if LMLAG is more significant than LMERR in the test of spatial dependence, and R-LMLAG is significant while R-LMERR is not significant, the SLM can be considered as the optimizing model. On the other way, if LMERR is more significant than LMLAG in the test of spatial dependence, and R-LMERR is significant while R-LMLAG is not significant, the SEM can be considered as the optimizing model. Besides goodness of fit test (R^2), there are some common used test criterions such as the logarithm likelihood function (logL), Likelihood Ratio (LR), Akaike Information Criterion (AIC) and Schwartz Criterion (SC). In general, the bigger the LogL is and the less LR, AIC and SC are, the better the fit results are. These criterions can also be used to compare TRM, SLM and SEM (Wu and Li, 2006).

Table 6 Estimation and test of OLS in TRM

	Coefficient	SD	*t*	*P*	SDT	MI/DF	Statistic	*P*
Constant	–8.3624	1.2261	–6.8202	0.0000	Moran′s *I* (error)	0.0590	0.9682	0.3329
GDPPC	0.9753	0.1123	8.6822	0.0000	LMLAG	1	0.7636	0.3822
SSEF	0.2331	0.1734	1.3446	0.1892	R-LMLAG	1	1.9828	0.1591
TIGP	0.4776	0.2384	2.0035	0.0546	LMERR	1	0.2184	0.6403
FAIG	–0.0464	0.2809	–0.1650	0.8701	R-LMERR	2	1.4377	0.2305
R^2	0.7334							
logL	–5.4143							
AIC	20.8325							
SC	28.4643							

Notes: QOLI means the quality of life index, GDPPC denotes GDP per capita; SSEF denotes proportion of social security expenditure in financial expenditure; TIGP means proportion of tertiary industry in GDP; FAIG denotes proportion of investment in fixed assets in GDP; logL means Log Likelihood; AIC means Akaike information criterion; SC means schwartz criterion; SD means standard deviation; SDT denotes spatial dependence test; MI/DF denotes multiple imputation/degree of freedom

Table 7 Estimation and test of SLM and SEM

Valuable	SLM				SEM			
	Coefficient	SD	*z*	*P*	Coefficient	SD	*z*	*P*
Constant	–8.7830	1.1718	–7.4953	0.0000	–8.5873	1.1742	–7.3131	0.0000
GDPPC	1.0225	0.1112	9.1983	0.0000	1.0018	0.1110	9.0224	0.0000
SSEF	0.2500	0.1598	1.5641	0.1178	0.2417	0.1625	1.4874	0.1369
TIGP	0.4882	0.2181	2.2382	0.0252	0.5134	0.2136	2.4032	0.0163
FAIG	0.0704	0.2749	0.2561	0.7979	–0.0325	0.2658	–0.1224	0.9026
Statistic test	DF	Statistic	*P*		DF	Statistic	*P*	
R^2	0.7409				0.7365			
logL		–4.9583				–5.2604		
LR	1	0.9159	0.3386		1	0.3116	0.5767	
AIC		21.9166				20.5209		
SC		31.0748				28.1527		

Notes: QOLI means the quality of life index, GDPPC denotes GDP per capita; SSEF denotes proportion of social security expenditure in financial expenditure; TIGP means proportion of tertiary industry in GDP; FAIG denotes proportion of investment in fixed assets in GDP; logL means Log Likelihood; LR means Likelihood Ratio; AIC means Akaike information criterion; SC means Schwartz Criterion; SD means standard deviation; SDT denotes spatial dependence test; MI/DF denotes multiple imputation/degree of freedom

Analyzing the results of Moran′ *I* test and spatial dependence of Lagrange multipliers in Table 6, it can be seen that the spatial dependence of the TRM is not significant (33.29% significant level). Moreover, in order to differentiate endogenous spatial lag or autocorrelation of spatial error, we conduct the test of error, lag and robustness of the Lagrange multipliers. The results show that almost all of criterion such as LMLAG, R-LMLAG, LMERR and R-LMERR did not pass though the significant test of 10% level, thus, the TRM can`t identify the dominate factors impacting on QOL of the residents clearly. At the same time, we also compared the value of logL, LR, AIC and SC of the SLM and SEM in Table 7, it is difficult to decide which model should be selected. Therefore, we should analyze the influence factors of QOL according to the estimated results of these two models. From Table 7, we can find that the coefficients of GDPPC, SSEF and TIGP in SLM and SEM are positive, and the order of the coefficient from big to small is GDPC, TIGP and SSEF. The coefficients of GDPC and TIGP passed though the significant test of 1% level and 5% level, which indicates that economic strength and service sector development have more significant impact than social security level on QOL of the residents. It should be pointed out that the coefficient of FAIG are much less than that of GDPPC, SSEF and TIGP in the SLM and SEM, which indicates that this variable has little impact on QOL of the residents. On one hand, investment in public service facility can not play its real role. On the other hand, the proportion of investment has small relative directly to the life of the residents in the investment structure of fixed asserts. The policies sense of this paper is that economic growth can improve QOL of the residents to a greater extent, but it can not explain the whole causes of QOL, and improvement of social security level, optimizing of industrial structure and increasing of the investment can also contribute to the improvement of QOL of the residents in Northeast China.

5 Discussion and Conclusions

Aiming at providing scientific basis for making differential policies and strategies of QOL of the residents in Northeast China, this paper examines the space-time patterns and identifies the driving factors of QOL of the residents in Northeast China using spatial autocorrelation analysis and spatial panel model. The conclusions are summarized as follows.

Firstly, the units with highest and higher QOL concentrate mainly in mid-southern Liaoning Province, central Jilin Province and Harbin-Daqing-Qiqihar region of Heilongjiang Province, where have the highest developed level of economy and intensive cities in Northeast China. The units with lowest and lower QOL distributes mainly in the fringe regions of Jilin and Laioning and Heilongjiang, where have worse location, undeveloped economy, less population and lower urbanization ratio. Secondly, Moran′s *I* of QOL of the residents in 2002, 2006 and 2010 are 0.1107, 0.1176 and 0.1955, respectively, indicating that there exists obvious positive spatial autocorrelation of QOL in Northeast China, and 67.0% of unites belonged to the type of High-High and Low-Low agglomeration, while the units of High-Low and Low-High agglomeration accounted for 33.0% of the total units only. Moreover, the units of High-High agglomeration distributed mainly in mid-southern Liaoning Province, central Jilin province and Herbin-Daqing-Qiqihar regions of Heilongjiang Province. The units of Low-Low agglomeration centralized mainly in the mid-northern regions of Heilongjiang Province, while the units of High-Low and Low-High agglomeration distributed dispersedly to the western and eastern fringe regions of Jilin Province and Liaoning Province. Thirdly, spatial econometric analysis showed that the coefficients of GDPPC, SSEF and TIGP in SLM and SEM are positive. The coefficients of GDPC and TIGP passed though the significant test of 1% level and 5% level, which indicates that economic strength and service sector development have more significant impact than social security level on QOL of the residents in Northeast China. The coefficient of FAIG is much less than that of GDPPC, SSEF and TIGP in the SLM and SEM, indicating that this variable has little impact on QOL of the residents in Northeast China.

Without double, the method of spatial autocorrelation and spatial econometric model can examine the space-time dynamic of QOL properly. Comparing with traditional statistics methods or qualitative analysis methods, they can illustrate the space-time change of pattern and connection type more obviously, and identify the main influence factors more charily. However, as we all know, the QOL is an intricate concept, and the indicators and influence factor that can be used to depict the QOL are also diversity. In this paper, due to the restriction of data, we selected some important indicators that represent the economic condition, public service level, medical condition and informatization level to depict the QOL of the residents. However, they can not reflect the essence of QOL completely. Therefore, the indicators needs to be further investigated in the subsequent studies. Besides, the evaluation criteria and the applicability of suggested methodological procedures also warrant follow-up perfection, and the calculation of spatial weight matrix in this paper depended mainly on the author's experiences and existing literatures, and ignored the frictional coefficient of distance, and such elements as trade, labor and capital should be took into account.

As one of the most important old industrial bases and commodity grain production bases in China, Northeast China has accumulated serious issues of QOL in such fields as social security, education, housing, employment and medical treat. However, due to the long-time influence of planned economic system, the system-mechanic reformation of enterprise, construction of public service facility, economic transition and adjustment of industrial structure can not achieve effective propulsion in a short time, which may aggravate the worsening of QOL of the residents. Therefore, the QOL of the residents in Northeast China has become one of the most important and urgent issues that should be addressed under the macro conditions of sustainable development. In-depth studies need to be conducted on the mechanism of space-time change of QOL, especially the influence of capacity of resources and environment, industrial location and leading process of population on QOL, so as to provide theoretical support and scientific basis for improving the QOL of the residents and decreasing its difference in Northeast China. In addition, the central and local government should make series policies to address the issues of QOL, including the transition of ways of economic growth, balancing urban and rural development, strengthening construction of public service facilities and accelerating the system-mechanic reformation of social security.

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