Qual Quant (2016) 50:1273–1283
DOI 10.1007/s11135-015-0204-2

Quantifying the coordinated degree of urbanization in Shanghai, China

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Published online: 19 April 2015

Abstract Urbanization involves an array of coupling interactive processes. Consequently, its coordinated development consequently relies on the synchronous advancement of these involved processes. However, seldom studies have quantified the coordinated degree of urbanization by analyzing the coupling interactive relationships among the involved processes. This study assessed the coordinated degree of urbanization by quantifying four involved processes (demographic, social, economic and spatial) in Shanghai City (China) from 1952 to 2012. Results showed that demographic urbanization did not advance discontinuously and roughly presented a U-shaped trend. The social and economic urbanization progressed slowly before 1980 and then accelerated rapidly. The spatial urbanization kept an increasing trend through the 60 years. These four processes interacted with each other with a low coupling degree, and led to the uncoordinated development of urbanization in Shanghai. Specifically, the coupling coordination degree of urbanization increased between 1970 and 2000, but slowed down after the 2000s. To achieve coordinated urbanization development, the social urbanization should be given priorities. This study demonstrated an applicable framework to quantify the coordinated degree of urbanization using the quality and quantity data.

Keywords Urbanization · Coupling coordination degree · Multi-dimensional index system · China

Electronic supplementary material The online version of this article (doi:10.1007/s11135-015-0204-2) contains supplementary material, which is available to authorized users.

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1 Introduction

China has been experiencing an enormous urbanization boom during the last decades. The urban population proportion skyrocketed from 10 % in 1949 to 50 % in 2010 (China Statistical Yearbook 2011). There is no doubt that urbanization will still gain momentum considering the continuous rural–urban migration. For one thing, millions of migrants flowed from rural to urban areas, providing abundant labor force (Du 2006). For another, these new residents, when they pursue a better life, create great opportunities for almost everything, from housing and food to clothes, art collections, and limousines (Ye 2000). This unprecedented urbanization has critical implications for many developing countries in the world (Qin and Zhang 2014). Consequently, recent literature has seen growing efforts devoted to investigating the process and pattern of China's urbanization (Chen and Gao 2011; Chen et al. 2013; Friedmann 2006; Su et al. 2011; Zhang 2008).

Urbanization involves an array of interactive processes (e.g., demographic, social, and economic) and manifest as spatial morphological changes (Mulligan 2013; Gu et al. 2012). Scholars have proposed a variety of indices to describe the level or magnitude of urbanization. The most widely accepted index is the urban population proportion in the total population (Hsieh 2014; Qin and Zhang 2014). Urban land area, population density, and gross domestic product were also popular urbanization indices (Kromroy et al. 2007; Su et al. 2012, 2014a; Tavernia and Reed 2009). Although these indices can describe the urbanization patterns from particular aspects, they are case-specific, and fail to reflect the actual dynamic, integrated process. To address such problems, some scholars developed multi-dimensional index systems to comprehensively reflect the demographic, social, economic, and spatial characteristics of urbanization (Guo et al. 2014; Li et al. 2012; Liu et al. 2011; Srinivasan et al. 2013; Wang et al. 2013). Unfortunately, these developed index systems were generally used to characterize the interactions between urbanization and environment, rather than the process of urbanization itself.

Coordinated urbanization relies on the synchronous development of the involved multiple interactive processes (Cao et al. 2014; Chen and Gao 2011). There exist complex coupling relationships among these interactive processes. For example, rapid economic development can promote social advancement and vice versa. However, when the rate of economic development exceeds that of social advancement to a large extent, the social capitals cannot support the continued economic growth, and the social process would prevent economy from moving forward. Many studies have evidenced that the growth of economic development lags behind urban population proportion (Chen et al. 2013; Zhang 2008). However, seldom studies have characterized the coupling interactions among the demographic, social, economic, and spatial processes.

Concerning the above mentioned limitations, this paper aims to quantify the coordinated degree of urbanization by analyzing the coupling interactive relationships among the involved processes, with a case of Shanghai, the most urbanized city in China. The specific objectives are to: (1) characterize the process of urbanization using a multi-dimensional index system; (2) analyze the coupling interactions among the demographic, social, economic, and spatial processes; and (3) provide some references for urban management.

2 Materials and methods

2.1 Index selection and integration

2.1.1 Multi-dimensional index system

Multi-dimensional systems for urbanization typically incorporate four dimensions: demographic, social, economic, and spatial (Guo et al. 2014; Li et al. 2012; Wang et al. 2013, 2014). Following this four-dimensional framework, we first selected 66 relevant indices after literature review and at the same time considering data availability. We then performed Pearson's correlation analysis and principal component analysis to reduce the redundancy of the original data set. Expert panel evaluation was further performed on the remaining indices. The final multi-dimensional index system was shown in Table 1.

2.1.2 Index integration

Data for the selected indices from 1952 to 2012 were obtained from the Shanghai Bureau of Statistics. Since the indices had different dimensions and magnitudes, they were standardized using the following equation.

$$x_{ij} = \frac{X_{ij} - \min \mathrm{X_j}}{\max X_j - \min X_j} \quad (1)$$

Table 1 Multi-dimensional index system of urbanization for Shanghai City, China

Dimension	Index	Unit
Demographic	Urban population proportion	%
	Total population	Persons
	Percentage of persons employed in secondary industry	%
	Percentage of persons employed in tertiary industry	%
	Natural rate of growth	%
Social	Employment rate	%
	Number of books in public libraries per 10,000 people	
	Number of hospital beds per 10,000 people	
	Business volume of post and telecommunications	Billion RMB Yuan
	Expenditure on science, education, and public health care	Billion RMB Yuan
Economic	Gross domestic product	Billion RMB Yuan
	Tertiary industry proportion	%
	Urban–rural income gap ratio	
	Foreign trade	Billion US Dollar
	Investment in fixed assets	Billion RMB Yuan
	Financial budget revenue	Billion RMB Yuan
Spatial	Total road area	ha
	Built-up urban area	ha
	Urban planning area	ha
	Per capita living space	ha

where x_{ij} is the value of index j in year i; min X_j and max X_j are respectively the minimum and maximum value of index j in all years.

We employed the entropy method (Wu and Bai 2011) to integrate the indices into different composite indicators (demographic urbanization index ($D_{em}I$), social urbanization index ($S_{oc}I$), economic urbanization index ($E_{co}I$), and the spatial urbanization index ($S_{pa}I$)). The entropy method was applied, in particular, given the changing contributions of each index in different years and the arbitrariness associated with subjectively assigned weight (Guo et al. 2014). The procedure of weight determination was described as follows.

(1) Calculating the proportion of index

$$r_{ij} = \frac{x_{ij}}{\sum_{i=1}^{n} x_{ij}} \tag{2}$$

where x_{ij} is the standardized value of index j in year i.

(2) Calculating the information entropy

$$h_j = -\sum_{i=1}^{n} r_{ij} Inr_{ij} \tag{3}$$

(3) Standardizing entropy

$$\alpha_j = \max(h_j)/h_j \tag{4}$$

(4) Determining the weight

$$w_j = \alpha_j / \sum_{j=1}^{p} \alpha_j \tag{5}$$

where p is the number of indices.

2.2 Coupling coordination degree model

The coupling coordination degree model [Eq. (6)] (Illingworth 1996), originating from the capacitive coupling coefficient model of physics, has been gradually applied in urban studies (Fang and Wang 2013; Guo et al. 2014; Li et al. 2012; Wang et al. 2014).

$$C_n = \left\{ (u_1 \times u_2 \times \ldots \times u_m) / \left[\Pi (u_i + u_j) \right] \right\}^{1/n} \tag{6}$$

where C is the coupling coordination degree; u_i represents the contribution of certain subsystem i to the total system.

The coupling coordination degree can be divided into four levels: $C < 0.3$ (very low), $0.3 \leq C < 0.5$ (low), $0.5 \leq C < 0.8$ (medium), $C > 0.8$ (high) (Ni et al. 2008). We employed the coupling coordination degree model to determine the coordinated degree of urbanization development. In particular, we calculated two categories of coupling coordination degree: the coupling coordination degree between two processes, and the coupling coordination degree among the four processes. To illustrate the dynamic changes of the coupling coordination degree from 1952 to 2012, the Curve Estimation of SPSS 16.0 (SPSS Inc., Chicago, IL, USA) to draw the fitted curves of the trend.

3 Results and discussion

3.1 Urbanization process of Shanghai

Temporal trend of urbanization in Shanghai from 1952 to 2012 was shown in Fig. 1. The $D_{em}I$ roughly presented a U-shaped trend (Fig. 1a), denoting that demographic urbanization in Shanghai did not advance discontinuously. Specifically, it first decreased from 1952 to 1978, then increased steadily from 1978 to 1995, and finally increased rapidly from 1978 on. Such results accorded with the general demographic urbanization process of the whole nation (Chen et al. 2013). Before the economic reform in 1978, China pursued a development mode of anti-urbanization, during which the central government formulated policy and called on people to leave urban city to support rural development (Xie et al. 2008). The urban–rural migration, accompanied by the declines of urban population proportion and its growth, resulted in the decreasing demographic urbanization in Shanghai before 1978. Since the 1980s, China has adopted an urbanization promotion mode (Zhang 2008). Most people came back to the urban city and contributed to the increases in the total population and urban population proportion. Such rural–urban migration process promoted the demographic urbanization in Shanghai. The rural–urban migration process was further accelerated by the market transition started in 1994. As the largest urban city in China, many young labors flowed into Shanghai City, leading to the population boom and increased

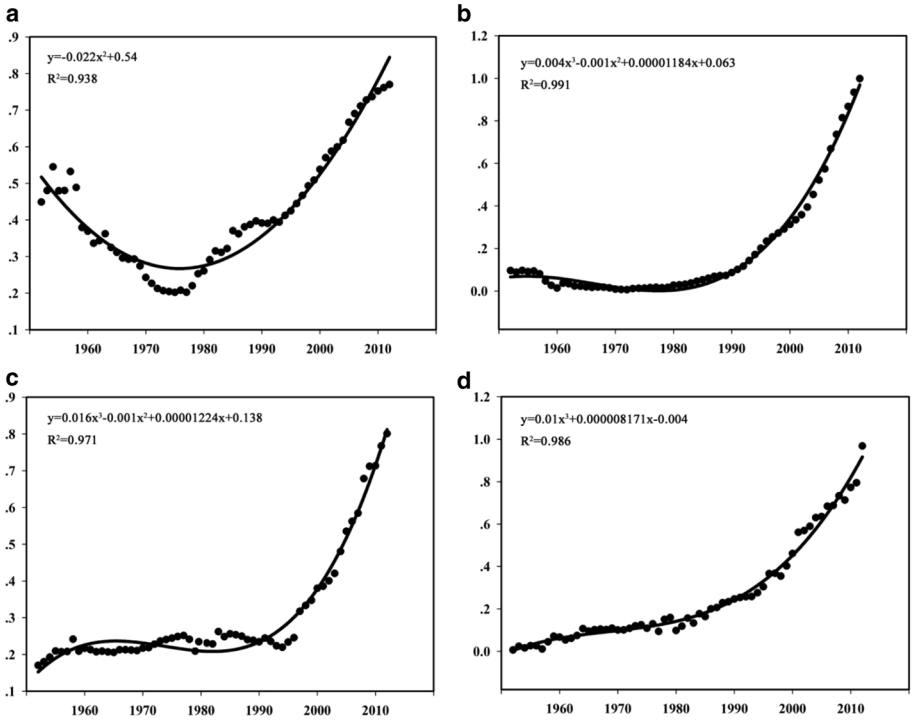

Fig. 1 Temporal trend of demographic urbanization (**a**), social urbanization (**b**), economic urbanization (**c**) and spatial urbanization (**d**) in Shanghai from 1952 and 2012

employees in tertiary industry. All these accounted for the continued rapid demographic urbanization since the 1995s.

The $S_{oc}I$ trend embodied the characteristics of phases for social urbanization in Shanghai (Fig. 1b). It increased rapidly before 1965, slowed down between 1965 and 1980, and finally increased fast after 1980s. When the new China was established in 1949, all the neglected tasks were undertaken and the society progressed gradually, which promoted the social urbanization during the period of 1952–1965. The political movement of the Great Cultural Revolution went against the trend of history, and sets great obstacles to the social development (Xie et al. 2008). Consequently, the social urbanization in Shanghai experienced an extended downturn from 1965 and 1980. The economic reforms in 1978 and

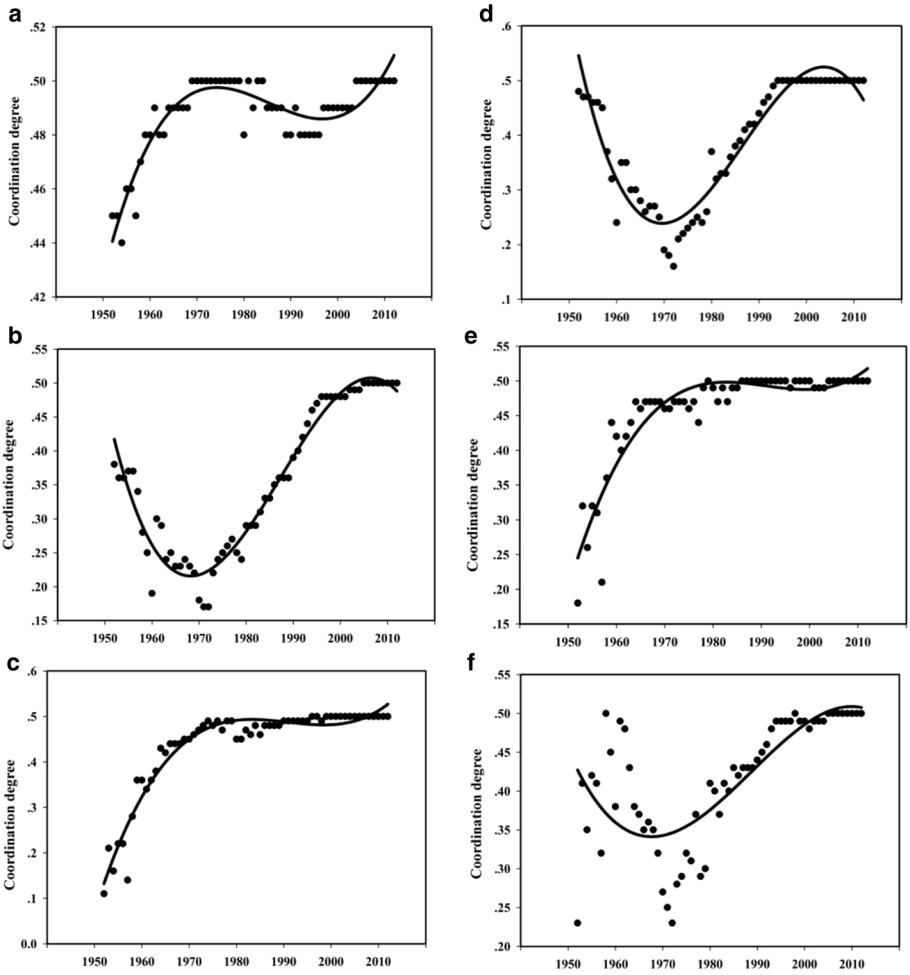

Fig. 2 Temporal dynamics of the coupling coordination degree among the four processes involved in Shanghai from 1952 to 2012: **a** demographic urbanization & social urbanization; **b** demographic urbanization & economic urbanization; **c** demographic urbanization & spatial urbanization; **d** social urbanization & economic urbanization; **e** social urbanization & spatial urbanization; **f** economic urbanization & spatial urbanization

1994 emancipated the productive forces, and the social sectors experienced full recovery. Social urbanization in Shanghai therefore started to grow after 1980, and accelerated after 1995.

The dynamic changes of $E_{co}I$ demonstrated that economic urbanization progressed slowly and even retrogressed slightly before 1980 (Fig. 1c). Economic growth in China relied heavily on industrialization before the reform, and the tertiary industry development was lagged. For example, the tertiary industry proportion of Shanghai decreased from 41.7 % in 1952 to 18.6 % in 1978. The resident income in Shanghai also presented a decreasing trend, declining from 762 in 1952 to 672 Chinese Yuan in 1978. In addition, the foreign trade as well as the investment in fixed assets remained at an extremely low level. All these led to the slowdown in economic urbanization. The reform in 1978 added powers in propelling the full recovery and long-term development of economic urbanization in Shanghai. The total GDP and the shares of the tertiary industry maintained the momentum of growth. Being a port city, Shanghai's foreign trade also experienced a splendid development. All these contributed to the accelerating development of economic urbanization in Shanghai since the 1980s.

The $S_{pa}I$ kept increasing through the 60 years, and the increasing rate was higher after the 1990s (Fig. 1d). This trend was consistent with most regions in eastern coastal China (Su et al. 2011), and denoted that spatial urbanization had intensified since the 1990s. In Shanghai, the road surface area was 6.2 million m^2 in 1952, increased to 17.9 million m^2 in 1990, and finally reached 269.4 million m^2 in 2012. The intensive spatial urbanization since the 1990s was stimulated by the rapid wealth accumulation and population growth.

3.2 Coupling interactions among the involved processes

Figure 2 showed the temporal changes of the coupling coordination degree among the four processes. For the $D_{em}I$ and $S_{oc}I$, their coupling coordination degree first increased rapidly before the 1970s, decreased slightly from the 1970s to 2000s, and finally increased again after the 2000s (Fig. 2a). The demand for education, health care, and social communication increases as a consequence of population growth. Before the 1970s, the masses responded actively to the call of political movement, and devoted themselves to the socialist construction and industrialization (Chen et al. 2013). The demand for high quality education and health care was low, and the social advancement can meet the residents' needs. However, the demand increased after the economic reforms, and social urbanization lagged behind the demographic urbanization between the 1970s and 2000s. Social advancement increased rapidly after the 2000s. All these factors accounted for the dynamics of the coupling degree between $D_{em}I$ and $S_{oc}I$.

Coupling degree between $D_{em}I$ and $E_{co}I$ presented declining trend before the 1970s, but increasing tendency after the 1970s (Fig. 2b). Economic growth was given priorities by the central government. Before the 1970s, the level of demographic urbanization exceeded that of economic urbanization to a large extent. This factor resulted in the uncoordinated development between these two processes. Though economic urbanization speeded up after the 1970s, its increasing pace lagged behind that of demographic urbanization (Chen and Gao 2011; Zhang 2008). Consequently, the coupling coordination degree between them increased gradually, but its absolute value was still low. Coupling coordination degree between $D_{em}I$ and $E_{sp}I$ rose fast between 1952 and 1980, and increased slowly after the 1980s (Fig. 2c). Such results denoted that coupling coordination degree for interactions of demographic urbanization and spatial urbanization remained low though it gradually increased before the 1980s. Such results should be attributed to it that spatial urbanization

developed faster than the demographic urbanization after 1995 (Chen et al. Chen and Song 2014). The spatial sprawl that the construction of new urban districts, university towns, and development zones in the suburban areas has lost control.

Trend of the coupling coordination degree between $S_{oc}I$ and $E_{co}I$ (Fig. 2d) was similar to that between $D_{em}I$ and $E_{co}I$. The Chinese government overemphasized economic takeoff and ignored the synchronous development of society (e.g., education, health care, and human resources). The development of social urbanization in Shanghai did not grow in step with economic urbanization. Consequently, their coupling coordination degree decreased before the 1970s. The gap between these two processes was narrowed after 1980s, and their coupling coordination degree gradually increased. It should be mentioned that the coupling coordination degree between $S_{oc}I$ and $E_{co}I$, though increased after 1970s, were below 0.5. Such results denoted that the interactions of these two processes were in an uncoordinated status through the 60 years. Coupling coordination degree between social urbanization and spatial urbanization increased steadily before 1980, but became stable after the 1980s (Fig. 2e). Through similar analysis, it can be inferred that the coordination degree between economic urbanization and spatial urbanization first decreased and then increased after the 1970s, but remained at a low level (Fig. 2f). In the initial stage of urbanization in Shanghai, the transportation infrastructure and urban construction were lagged in investment and financing. The pace of spatial urbanization was therefore not equal to that of social and economic urbanization. Therefore, the social and economic urbanization speeded far outpaces growth in spatial urbanization.

3.3 Coordination degree of urbanization in Shanghai

Figure 3 exhibited the dynamic coupling coordination degree among the involved four processes through the 60 years. The coordination degree presented an increasing trend, but stayed at a low level (below 0.3). These results implied that urbanization in Shanghai developed in an uncoordinated manner. As mentioned above, there lacked of synchronous development of the involved processes. Besides, the economic urbanization had a low coupling coordination degree with the other three processes, and the demographic urbanization also interacted with social and spatial urbanization with low degree of coupling. Their lowly coupled interactions led to the uncoordinated urbanization in Shanghai. The coupling coordination degree increased between 1970 and 2000, but slowed down after the 2000s. Though social urbanization underwent substantial advancement, its increasing pace was still lagged behind that of economic development after 2000. For example, uncoordinated urban–rural development and urban–rural inequalities in income have increased in

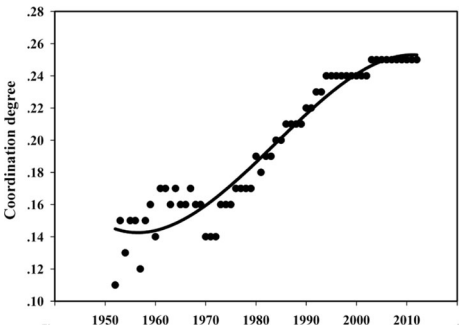

Fig. 3 Dynamic coordination degree of urbanization in Shanghai from 1952 to 2012

more urbanizing places of China (Long et al. 2011, 2012; Liu et al. 2013). Besides, urbanization has become a key national development strategy since the 2000s (Bloom et al. 2008; Chang and Brada 2006; Siciliano 2012). In order to pursue political achievements, policy makers are eager to promote urbanization to achieve GDP growth (Cao et al. 2014). Consequently, the urban expansion was not strictly supervised by the government (Han 2010). New constructions and projects were authorized (Su et al. 2014b), ignoring the actual demand of socioeconomic development. In addition, the former rural population in the suburban areas became to be urban population through administrative adjustment (Guo et al. 2014). It generated superficially increased urban proportion, and further led to inconsistent relations among the four processes. All these factors accounted for the stagnation for the increases in uncoordinated degree of urbanization in Shanghai since the 2000s.

4 Conclusions and prospects

This paper comprehensively analyzed the demographic, social, economic, and spatial characteristics of urbanization in Shanghai using a multi-dimensional index system. Results showed that demographic urbanization did not advance discontinuously and roughly presented a U-shaped trend from 1952 to 2012. The social urbanization increased rapidly before 1965, slowed down between 1965 and 1980, and finally increased fast after 1980s. The economic urbanization progressed slowly and even retrogressed slightly before 1980; and accelerated rapidly after the 1980s. The spatial urbanization kept an increasing trend through the 60 years, and the increasing rate was higher after the 1990s. The economic urbanization had a low coupling coordination degree with the other three processes, and the demographic urbanization also interacted with social and spatial urbanization with low degree of coupling. Their lowly coupled interactions led to the uncoordinated urbanization in Shanghai. Specifically, the coupling coordination degree of urbanization increased between 1970 and 2000, but slowed down after the 2000s. The unbalanced development of the involved processes led to the stagnation in uncoordinated degree of urbanization of Shanghai since the 2000s. To achieve coordinated urbanization development, the policy makers and governors should not overemphasize the growing rate of the urban population proportion and economy, but instead focus primarily on the synchronous development of the involved multiple interactive processes. In particular, the social urbanization should be given priorities, including the education, health care, and other aspects related to life quality. Besides, smart growth, which refers to the sustainable urban expansion, should be adopted and put into practice. The infrastructure facilities should be improved as urban expansion, and the size of city should be in accordance with socioeconomic development.

Although this paper provides some insights into urban study, it still has some limitations. Firstly, further empirical study should be carried to verify the rationality of the multi-dimensional index system. Secondly, we did not analyze the uncertainties of the weight determination method. Further studies should compare different methods and analyze the impacts on numeric analysis of urbanization process. Lastly, I employed a classic approach to analyzing the coupled interactions among different processes. More sophisticated models should be developed and applied. The demonstrated methodology can be applicable to other urbanizing cities and regions. More cases are needed to summarize the universal law for the dynamic changes of urbanization coordinated degree.

Acknowledgments This research received the financial support from the National Natural Science Foundation of China (71403235), the Humanity and Social Science Youth Foundation of Ministry of Education of China (13YJC630208), the Youth Key Projects of Humanity and Social Science for Universities of Zhejiang Province (2013QN002), and the Zhejiang Provincial Natural Science Foundation of China (LQ14G030016).

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