Environ Sci Pollut Res (2017) 24:14163–14175
DOI 10.1007/s11356-017-8980-y

RESEARCH ARTICLE

Empirical research on coordination evaluation and sustainable development mechanism of regional logistics and new-type urbanization: a panel data analysis from 2000 to 2015 for Liaoning Province in China

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Received: 8 January 2017 / Accepted: 3 April 2017 / Published online: 18 April 2017

Abstract As the largest developing country in the world, China has witnessed fast-paced urbanization over the past three decades with rapid economic growth. In fact, urbanization has been not only shown to promote economic growth and improve the livelihood of people but also can increase demands of regional logistics. Therefore, a better understanding of the relationship between urbanization and regional logistics is important for China's future sustainable development. The development of urban residential area and heterogeneous, modern society as well regional logistics are running two abreast. The regional logistics can promote the development of new-type urbanization jointly by promoting industrial concentration and logistics demand, enhancing the residents' quality of life and improving the infrastructure and logistics technology. In this paper, the index system and evaluation model for evaluating the development of regional logistics and the new-type urbanization are constructed. Further, the econometric analysis is utilized such as correlation analysis, co-integration test, and error correction model to explore relationships of the new-type urbanization development and regional logistics development in Liaoning Province. The results showed that there was a long-term stable equilibrium relationship between the new-type urbanization and regional logistics. The findings have important implications for Chinese policymakers that on the path towards a sustainable urbanization and regional reverse, this must be taken into consideration. The paper concludes providing some strategies that might be helpful to the policymakers in formulating development policies for sustainable urbanization.

Keywords Regional logistics · New-type urbanization · Mechanism of action · Indicator system · Econometric analysis · Sustainability

Responsible editor: Philippe Garrigues

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Introduction

Urbanization is the movement of people from rural to urban areas with population growth equal to urban migration, which is shown in two forms: the increasing number of cities and the expanding population of cities (Cohen 2006). Urbanization is the core force of regional economic and social development, the development quality of which determined the regional economic capacity for sustainable development to a large extent (Rana 2011; Wu 2014). The study of Northam (1963)found the urbanization development of all countries generally had an S curve movement. The level of urbanization and the number and size of large cities are unprecedented especially in developing countries (Cohen 2006). According to the United Nations and The World Bank, the world urbanization grew at an average rate of 2.6% per year and more than half (52.1%) of the world population was living in urban areas at the end of 2011 (Mulligan 2013). Urbanization provides benefits that help upgrade market efficiency, jobs, education, and health improvement and provides new opportunities to improve social services and promote economic development (Dyson 2011). Other studies have recognized that the urbanization process helps upgrade industrial structure and increase per capita income. Urbanization is a historical process that accompanies industrialization and concentration of non-agricultural industries and rural population in cities. It is also an important sign of national modernization. Since the implementation of reform and opening-up policy in the late 1970s, China has witnessed, and is still witnessing, fast-paced urban development (Lu et al. 2014; Wang et al. 2014). Over the past three decades, China's urbanization has risen from 17.92% in 1978 to 52.57% in 2012, with an average annual growth rate of 1.02% (Zhao and Wang 2015). Rapid urbanization has been shown to promote economic development and improve people's living standards (Liu et al. 2013). According to China's New Urbanization Plan 2014–2020, China should closely center on improving the quality of urbanization, with city clusters as its major form. The new urbanization initiative should encourage the migration of the population from rural areas into cities in an orderly fashion and stimulate a balanced development of large, medium, and small cities as well as towns to improve sustainability of cities. The potential of urbanization can be tapped through reforms. It should be people-oriented and optimize the arrangement, protect the ecological system, and carry forward cultural traditions. This is expected to promote structural transformation and economic upgrade as well as social harmony and progress, forming a solid foundation for building up a society all around. In the Report to the Eighteenth National Congress of the Communist Party of China, it is pointed out that we must make strategic adjustments to the economic structure with a focus on improving the demand structure and the industrial structure, promoting a balanced development between regions and advancing urbanization. Hence, this new type of urbanization across different regions is the key to the economic transformation of China.

Most literatures on urbanization have focused on the reform of the household registration system, the migration of the rural population into the cities, the correct account of urban population, the relationship between urbanization and the service industry, the welfare distribution problems amid the urban transformation process, and the mode of urban transformation (Guan et al. 2011; Sun 2015; Dai and Chen 2010; Guo 2006; Tang and Cheng 2008; Jantz et al. 2010; Mahiny and Gholamalifard 2007; Dezhkam et al. 2014; Herold et al. 2003; Feng et al. 2012; Akin et al. 2014; Islam et al. 2014; Sakieh et al. 2015; Hens 2015). The others are principles and methods for implementing sustainable urbanization, such as developing indicators to implement urban development towards the mission of sustainable development (Holden 2006; Zhao and Wu 2014; Bannayan and Rezaei 2014; Qiu et al. 2009) and measuring sustainable urbanization performance related to social, economic, environmental, and governance dimensions (Shen et al. 2012; Li et al. 2010). These findings provide new insights and valuable information for optimizing urban development in China.

Logistics industry belongs to service industry, which is a compound service industry composed of transportation, warehousing, freight forwarders, and information, and made great contribution to economic growth for the country. At the same time, the development of logistics industry is also an important symbol for measuring the industrial structure optimization.

The logistics is the service sector of the tertiary industry, and it is an important aspect of the city's comprehensive competitiveness. The improved region-wide logistics can encourage the economic development of the region, and it is a positive correlation between logistics and regional economy (Jara 2000; Juskowiak and Wharton 2004). Modern logistics and the new type are the power factors to promote the development of regional economic. How to promote the benign interaction and coordinated development is one of the important problems for realizing economic sustainable development and is the core issue of regional economic research. The study of Northam (1963)found the urbanization development of all countries generally had an S curve movement. Economic structure and urbanization level had a corresponding relationship on the certain development level of GDP (Chenery 1979).

As can be seen, the existing research mainly focused on two levels: the urbanization and economic development and the logistics and economic development. Few researchers focused on the logistics and new-type urbanization. Only a few studies were done on the relationship between urbanization and region-wide logistics. Most of them focused on quantitative and theoretical analyses (Wang 2014). In practice, the urbanization requires immense human, material, and financial resources, which can be supplied by the logistics industry. Therefore, both urbanization and logistics are main components of social and economic growth. Further analysis found that logistics and new-type urbanization are all important parts of economic and social development, and they could be organic together based on the ties of economic. Therefore, the coordination between logistics and the new-type urbanization will contribute to give a full play on the role in promoting economic development.

Modern logistics is a hybrid service industry that integrates transportation, warehousing, and information industries. Its degree of development is a major measure of comprehensive competitiveness in a country and region. It can promote the coordinated development of urban agglomeration by influencing economic factors such as labor growth, capital, natural resources, technical progress, industrial structure, and infrastructure (Fig. 1). It is the backbone of the service industry and also a new engine of national economy. The concentration of population and industries during urbanization increases the demand for region-wide logistics.

Little attention has, however, been paid to the estimation of the relationship between urbanization and regional logistics. Moreover, studies are limited in regarding urbanization as a shift factor when estimating the interactive relationships between variables (Liu and Xie 2013). This deficiency in contemporary research motivates the present study, which aims to explore the relationship between urbanization and regional logistics. As with the models used in previous studies, correlation analysis and Granger causality tests have been widely used in exploring the relationship between urbanization,

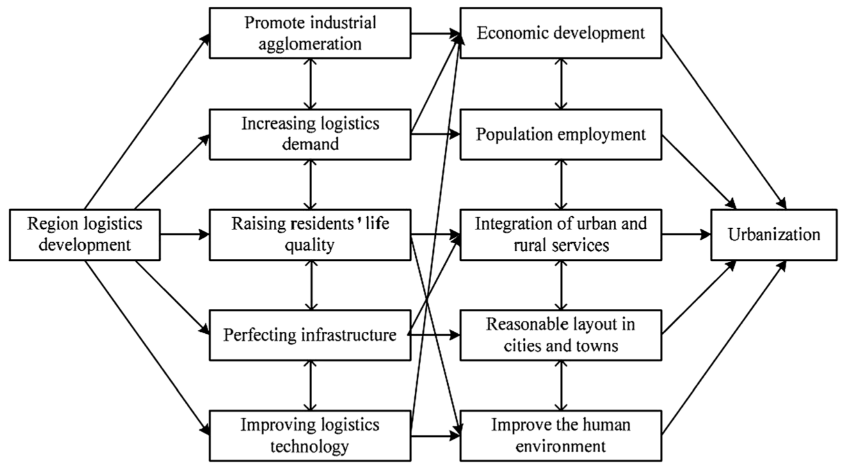

Fig. 1 Influence of regional logistics development on urbanization

economic growth, and energy consumption (Xue et al. 2014; Liu 2005; Zeng et al. 2009; Wu et al. 2013; Du et al. 2009). Little attention has, however, been paid to the utilization of VECM. Although these previous studies have certainly enriched our understanding of the relationship between urbanization and others, they have, as a result, failed to provide adequate and explicit evidence in relation to how urbanization, in fact, affects regional logistics.

How to study the interaction between urbanization and region-wide logistics, finding new insights into urbanization and broadening urbanization research methodology and standpoint are areas of exploration. Modern logistics and urbanization act as stimuli to the coordinated development of regional economy. It is needed to explore the relationship between region-wide logistics and urbanization in order to gain better insights and make informed decisions affecting regional and national development. This paper carries out a quantitative and empirical study on the relationship between region-wide logistics and urbanization in Liaoning, verifies the contribution of region-wide logistics to urbanization, and offers decision-making recommendations for the governmental departments concerned.

The paper is based on the secondary data which are collected from different published and unpublished documents. With a simple descriptive analytical approach, the paper is organized as follows: the "Action mechanism of region logistics and urbanization" section discusses the action mechanism of urbanization and regional logistics to indicate their relationship and, necessarily, to promote the economic development; methodology and model are given in the "Methodology and model" section; the development level of urbanization and regional logistics in Liaoning Province are shown in the "Results" section; an empirical analysis using correlation analysis, integration test, co-integration test, error correction model, and the Granger causal relation test is discussed in the "Discussion" section; and the final section concludes and briefly provides some recommendations of the sustainable development of urbanization and regional logistics.

Action mechanism of region logistics and urbanization

Urbanization is featured by integrating urban and rural as well as enhancing ecological habitability and harmonious development. Logistics is a tertiary industry, which can promote spatial distribution of various industries across different regions and encourage coordinated urbanization. The development of regional logistics can cause industrial concentration, which can offer support to the industry and sustain urbanization. Industrial concentration can enhance population migration, optimize industrial structure, and create more jobs in the context of economic development. Furthermore, modern logistics industry can provide necessary systems and infrastructure to optimize the layout of urbanization, improve living standards of urban populations, provide more conveniences, and achieve integration of the public service in rural and urban regions. On the other hand, the development of logistics technologies can be benefited for urban population by paying more attention to environmental protection and service quality.

Urbanization is one of the important conditions to promote the development of logistics. Meanwhile, the development of logistics will also promote the development of urbanization and, in turn, improve the level of social collaboration. The mechanism of interaction between regional logistics and urbanization can be expressed as follows: first, the improvement of urbanization level means the enhancement of economic activities, which can lead to the demand growth for logistics so as to further stimulate the logistics supply and promote the development of logistics industry. Second, the urban had been more developed and advantages of infrastructure and technology are relative to rural areas as an economic growth pole. The improvement of urbanization means the improvement of urban infrastructure construction, which can further strengthen the function economic system and enhance the whole logistics technology level as well as logistics supply capacity. Finally, the development of urbanization raised the share of information, communications, and other high-tech industries in the whole industrial structure, and the layout adjustment of industrial structure will also greatly promote the logistics industry development in the direction of informatization and modernization.

On the contrary, the development of urbanization also needs the strong support of a logistics system. Logistics as a supply chain management can not only promote the development of transportation, information, and other industries but also promote the common development of logistics links such as distribution and processing. As an important support of urbanization, the development of logistics can conveniently realize the resources sharing with the world and meet the needs of resources of the urbanization process. Second, the development of the logistics industry is often accompanied by the construction on large industrial park as well as the quick flow of personnel and material. This is not only conducive to more reasonable resource allocation and provides seed capital for the development of urbanization. Finally, the development of logistics can make economic activities more efficiency and ease the social pressure such as traffic and environment. This can decrease the transaction costs, improve the regional competitiveness, and promote the balanced development of regional economy. With high employment absorption capacity, logistics can solve the problem such as surplus labor force in the process of population, meet the demand of industry transfer, and maintain the social stability. Logistics industry has a high correlation with the first, second, and third industries, which usually are beneficial to the development and enhance the comprehensive competitiveness of urban.

Therefore, the relationship between logistics and new-type urbanization is interaction and common development. They should be coordinated development and benign interaction to jointly promote the economic development.

From the discussions above, it can be seen that the region-wide logistics encourages urbanization by promoting the concentration of industries, increasing the demand for logistics, improving the living standards of people, enhancing the infrastructure, and advancing the logistics technology. Hence, logistics and urbanization together can stimulate economic development.

Methodology and model

Measurement of urbanization

Construction of the set of metrics for urbanization development

Indicators were identified from the following sources:

(1) With a list of 115 sustainable urbanization indicators (Shen et al. 2011), the researchers obtained these indicators after examining indicator systems developed by six different international organizations including the UN, UN-Habitat, The World Bank, and others.

(2) The Economic Forecasting Research Department of State Information Center in China presented 57 indicators with four dimensions including economic and structure, population, resource and environment, public service, and people's livelihood.

(3) The China City Development Academy presented 35 indicators with three dimensions including economic, social, and people's livelihood. The Institute of Urban Environment and Chinese Academy of Sciences presented 12 indicators including economic, social, and environmental.

(4) A list of 259 indicators from 30 different cities in China such as Harbin, Qingdao, and Kunming was obtained by comprehensive redefinition, modification, combination, and deletion.

(5) With the National New Urbanization Plan 2014–2020, Economic Policy Research Laboratory of National Information Center 2009, and China Society of Urban Development (Wang et al. 2014), this paper proposes a new set of metrics for urbanization in Liaoning as shown in Table 1.

Data standardization

Let the original data have m evaluation objects and n evaluation metrics.

$$A_{ij}=\begin{bmatrix} a_{11} & a_{21} & \cdots & a_{m1}\\ a_{12} & a_{22} & \cdots & a_{m2}\\ \vdots & \vdots & \ddots & \vdots\\ a_{1n} & a_{2n} & \cdots & a_{mn}\end{bmatrix}$$

where a_{ij} is the original data, which is standardized using the following equations:

$$X_{ij}=\begin{cases} X_{ij}=\dfrac{a_{ij}-\min a_{ij}}{\max a_{ij}-\min a_{ij}}, & a_{ij}\ \text{is a positive metric}\\ X_{ij}=\dfrac{\max a_{ij}-a_{ij}}{\max a_{ij}-\min a_{ij}}, & a_{ij}\ \text{is a negative metric}\end{cases}$$

For the metrics bounded by a range, we use the following standardization equation:

$$X_{ij}=\begin{cases} 0 & a_{ij}\notin[a_1,a_2]\\ -\dfrac{a_{ij}^2-2b_1-a_1^2-2a_1b_1}{b_1-a_1^2} & a_{ij}\in[a_1,b_1]\\ 1 & a_{ij}\in[b_1,b_2]\\ -\dfrac{a_{ij}^2-2a_2-b_2^2-2a_2b_2}{a_2^2-b_2} & a_{ij}\in[b_2,a_2]\end{cases}$$

where $[b_1, b_2]$ is the range of a_{ij}, and a_1 and a_2 are the upper and lower boundaries of a_{ij}.

Table 1 Set of metrics for urbanization in Liaoning

Criterion	Metrics	Metrics properties
Economic development (U_1)	Social insurance coverage (%)	Positive
	Urbanization rate (%)	Positive
	Disposable income of urban population	Positive
	Medical staff per 10,000 people	Positive
	Employment rate (%)	Positive
Infrastructure (U_2)	Density of the urban road network	Moderate
	Availability of water supply (%)	Positive
	Availability of natural gas supply (%)	Positive
	Housing area per capita	Moderate
Ecological environment (U_3)	Air quality satisfactory rate (%)	Positive
	Sewage treatment rate (%)	Positive
	Amount of harmless treated waste	Positive
	Green space per capita	Moderate
	Waste recycling rate (%)	Positive
Education (U_4)	Number of college students per 10,000 people	Positive
	Enrollment of middle and primary schools	Positive
	Compulsory education ratio (%)	Positive
	Training and reeducation rate (%)	Positive

Calculation of the weight of metrics

The weight of metrics is computed as follows:

$$w_j = \frac{w_1^j \cdot w_2^j \cdot w_3^j}{\sum_{i=1}^{3} w_1^j \cdot w_2^j \cdot w_3^j}$$

where w_1^j, w_2^j, and w_3^j are the weights computed using the AHP, entropy, and deviation methods.

Measure of development level

$$U = \sum_{j=1}^{n} w_j X_{ij}, \quad i = 1,\ 2, \ldots,\ m$$

Measure of the level of development of region-wide logistics

Construction of metrics

The logistics development level can be evaluated using three aspects: supply of the logistics service, need for the logistics service, and the size of the logistics. Based on the existing research on the logistics industry and the currently available statistical data (Colicchia et al. 2013; Velasquez and Hester 2013; Horenbeek and Pintelon 2014; Akyuz and Erkan 2010; Saaty 2013; Bjorklund and Forslund 2013; Forslund 2012; Gutierrez et al. 2015), the set of metrics for regional logistics is constructed, as shown in Table 2.

Measure of region-wide logistics development level

The original data is standardized using the standardization equation, and the comprehensive weight of the metrics is determined through weight combination. The standardization equation of the original data is

$$Y_{ij} = \frac{a_{ij} - \min a_{ij}}{\max a_{ij} - \min a_{ij}}$$

For the weight, we have

$$w_j = \frac{w_1^j \cdot w_2^j \cdot w_3^j}{\sum_{i=1}^{3} w_1^j \cdot w_2^j \cdot w_3^j}$$

For the logistics development level, we have

$$L = \sum_{j=1}^{n} w_j X_{ij}, \quad i = 1,\ 2, \ldots,\ m$$

Results

Measurement of urbanization in Liaoning

Data for this paper is sourced from the Liaoning Statistical Yearbook 2000–2015, Liaoning Statistical Bulletin on Economic and Social Development 2000–2015, and Liaoning Statistical Bulletin on Environment 2000–2015. Some data comes from the statistical bulletins and official websites of Liaoning Statistical Bureau, Liaoning Bureau on Environmental Protection, Liaoning Bureau on Small- and Medium-Sized Enterprises, Liaoning Bureau on Land Resources, and Liaoning Bureau on Coal Industry

Table 2 Set of metrics for regional logistics

Criterion	Metrics	Metrics properties
Logistics demand (L_1)	Turnover of freight traffic	Positive
	Freight traffic	Positive
	Harbor throughput	Positive
Logistics supply (L_2)	Density of the road network	Positive
	total volume of consumer goods retail sales	Positive
	Total length of the road	Positive
Total amount of logistics (L_3)	Output value of logistics	Positive

Management. Missing data items are compensated using the moving average method to form the final version of original data. To eliminate the influence of price levels, all metrics are computed with the year 2000 as the baseline. The data is standardized using the proposed metrics standardization method.

After standardizing the original data and computing the weights of urbanization metrics through weight combination, the results are shown in Table 3.

The evaluation model is used to determine the development levels of four subsystems (social development, infrastructure, ecological environment, and education) from 2000 to 2015. The results are given in Table 4.

Moreover, the criterion weight of urbanization in Liaoning from 2000 to 2015 was calculated using the evaluation model established in this paper, which is shown in Table 5.

Finally, the development level of urbanization in Liaoning Province from 2000 to 2015 is figured out in Table 6.

Measurement of logistics development level in Liaoning

The weights for regional logistics development level in Liaoning from 2000 to 2015 are calculated by standardizing the original data and computing the weights of urbanization metrics. The results are shown in Table 7.

The development levels of regional logistics subsystems from 2000 to 2015 are shown in Table 8.

The criterion weight of regional logistics in Liaoning from 2000 to 2015 was calculated using the evaluation model established in this paper, which is shown in Table 9.

Finally, the development level of regional logistics in Liaoning Province from 2000 to 2015 is figured out in Table 10.

Development level of urbanization and regional logistics

According to the calculated results of Tables 6 and 10, the development level figure of urbanization and regional logistics

Table 3 Weights of urbanization metrics

Criterion	Metrics	Code	Weight
Economic development (U_1)	Social insurance coverage (%)	X_1	0.1589
	Urbanization rate (%)	X_2	0.1229
	Disposable income of urban population	X_3	0.1172
	Medical staff per 10,000 people	X_4	0.1449
	Employment rate (%)	X_5	0.1658
Infrastructure (U_2)	Density of the urban road network	X_6	0.1337
	Availability of water supply (%)	X_7	0.1425
	Availability of natural gas supply (%)	X_8	0.1454
	Housing area per capita	X_9	0.1512
Ecological environment (U_3)	Air quality satisfactory rate (%)	X_{10}	0.1559
	Sewage treatment rate (%)	X_{11}	0.1098
	Amount of harmless treated waste	X_{12}	0.1006
	Green space per capita	X_{13}	0.1348
	Waste recycling rate (%)	X_{14}	0.1310
Education (U_4)	Number of college students per 10,000 people	X_{15}	0.1767
	Enrollment of middle and primary schools	X_{16}	0.1428
	Compulsory education ratio (%)	X_{17}	0.1093
	Training and reeducation rate (%)	X_{18}	0.1476

Table 4 Subsystem development level of urbanization from 2000 to 2015

Year	U_1	U_2	U_3	U_4
2000	0.2764	0.0738	0.0745	0.3160
2001	0.2537	0.1655	0.1768	0.2861
2002	0.2440	0.2125	0.2233	0.2604
2003	0.2146	0.2991	0.2779	0.2817
2004	0.2424	0.3284	0.3016	0.2701
2005	0.2263	0.4601	0.3420	0.2451
2006	0.2580	0.5025	0.4134	0.2339
2007	0.3225	0.5519	0.4964	0.2283
2008	0.3493	0.5734	0.5265	0.2496
2009	0.2795	0.6105	0.5516	0.2841
2010	0.4262	0.6518	0.5898	0.3198
2011	0.3944	0.6717	0.6491	0.3710
2012	0.5062	0.7123	0.6967	0.4069
2013	0.5709	0.7384	0.7451	0.4692
2014	0.6119	0.7615	0.7476	0.4836
2015	0.6595	0.7616	0.7573	0.5296

using annual rate as the horizontal axis and development level as the longitudinal axis was mapped. Figure 2 shows the development level of urbanization and regional logistics in Liaoning for 2000–2015.

It can be seen that Liaoning urbanization level increased on an annual basis from 0.1552 for 2000 to 0.6670 for 2015 at a stable annual rate of 3.41%. The region-wide logistics development rate increased from 0.1682 for 2000 to 0.6601 for 2015 at an annual rate of 3.27%. In terms of stability, the urbanization level increased for 2000–2004, decreased for 2004–2007, and fluctuated afterwards. The region-wide logistics followed a similar trend. This implied that there is a strong and consistent link between them.

Discussion

Correlation analysis

Let U be the urbanization development level and L be the region-wide logistics development level. To improve the accuracy of the model and eliminate heteroscedasticity, we perform natural logarithm transformation on the variables while analyzing the time series data and denote them with $\ln U$ and $\ln L$. The correlation coefficient between $\ln U$ and $\ln L$ is computed to be 0.8487 using EViews 7.1. This implies a highly positive correlation and, thus, a dependence relationship between them, qualifying the need for further quantitative analysis.

Table 5 Criterion weights of urbanization

Criterion	Economic development	Infrastructure	Ecological environment	Education
Weight	0.1007	0.2916	0.3527	0.2550

Table 6 Development level of urbanization in Liaoning Province from 2000 to 2015

Year	Development level
2000	0.1552
2001	0.2081
2002	0.2311
2003	0.2748
2004	0.2934
2005	0.3368
2006	0.3771
2007	0.4297
2008	0.4551
2009	0.4708
2010	0.5261
2011	0.5587
2012	0.6086
2013	0.6119
2014	0.6595
2015	0.6670

Regional logistics promotes the development of urbanization by encouraging the concentration of industries, increasing the need for logistics, improving the living standards of people, enhancing the infrastructures, and advancing the logistics technologies. Hence, a correlation test is performed on the metrics for development levels of regional logistics and urbanization. The results are given in Table 11.

Regional logistics is highly correlated with social insurance coverage, urbanization rate, disposable income of urban residents, number of medical staff per 10,000 people, employment rate, density of the road network, housing area per capita, amount of harmless treated waste, sewage treatment rate, enrollment of middle and primary schools, compulsory education rate, and the training and reeducation rate. It is intermediately correlated with air quality satisfactory rate, green

Table 7 Weights of regional logistics metrics

Metrics	Code	Weight
Turnover of freight traffic	Y_1	0.2076
Freight traffic	Y_2	0.1948
Harbor throughput	Y_3	0.1931
Density of the road network	Y_4	0.2038
Retail sales of the total volume of consumer goods	Y_5	0.1991
Total length of the road	Y_6	0.1957
Output value of logistics	Y_7	0.2311

Table 8 Metrics development level of regional logistics from 2000 to 2015

Year	L_1	L_2	L_3
2000	0.3210	0.3852	0.0738
2001	0.3660	0.3954	0.1655
2002	0.3660	0.3901	0.2125
2003	0.4980	0.4069	0.2263
2004	0.4390	0.4137	0.2440
2005	0.4250	0.4145	0.2580
2006	0.3660	0.4215	0.2991
2007	0.4050	0.4095	0.3225
2008	0.4430	0.4082	0.3284
2009	0.3990	0.4019	0.3493
2010	0.3560	0.3810	0.3795
2011	0.3730	0.3873	0.4262
2012	0.3520	0.3711	0.4601
2013	0.3320	0.3671	0.4944
2014	0.3900	0.3807	0.5062
2015	0.4120	0.4054	0.5519

Table 10 Development level of regional logistics in Liaoning Province

Year	Development level
2000	0.1682
2001	0.2778
2002	0.3597
2003	0.4358
2004	0.4924
2005	0.4742
2006	0.4361
2007	0.3352
2008	0.3960
2009	0.4687
2010	0.5514
2011	0.5779
2012	0.4796
2013	0.6606
2014	0.6367
2015	0.6601

space area per capita, and the waste recycling rate. It is poorly correlated with the availability of water supply and natural gas supply. Note that the region-wide logistics is negatively correlated with the air quality satisfactory rate and the amount of harmless treated waste. This implies that logistics development has an influence on the ecological environment during urbanization.

Co-integration test

Co-integration refers to the common random trend. The purpose of co-integration test is to determine whether there is a stable equilibrium relationship between a set of non-stationary series. If a certain linear combination of two or more time series of the same order can obtain a stationary error sequences, these non-stationary time series are regarded to have a long-term equilibrium relationship; i.e., they are co-integrated.

Integration test

The time-varying behavior of the time series in essence implies its non-stationary property. The general method for processing the non-stationary series is to first convert it into a stationary series to carry out research using the stationary series methods. The test on the root of unity for the time series is equivalent to the test on the stationary property of the time series. If the non-stationary time series has a root of unity, it can be eliminated using the difference method to obtain the stationary series. The time series that has a root of unity usually exhibits remarkable memorization ability and continuous fluctuations. Hence, the augmented Dickey-Fuller (ADF) test is the prerequisite of discussions on the co-integration and continuous fluctuations of the series.

Table 9 Criterion weights of regional logistics

Criterion	Logistics demand	Logistics supply	Total amount of logistics
Weight	0.3690	0.4063	0.2247

The co-integration analysis should be preceded by the integration test of the variables. To carry out the co-integration test on urbanization and region-wide logistics, we should first check whether the single variable is co-integrated. Hence, the ADF test is done to determine the stationary property of ln U and ln L. The calculation results are given in Table 12.

It can be seen that all results of the ADF tests are below the threshold of 10%, implying that they are all first-order co-integrated stationary series. Therefore, there exists a stationary and linear combination of urbanization and region-wide logistics in Liaoning.

Co-integration test

Analysis is then performed on the co-integration relationship between urbanization and region-wide logistics. With ln U as the explained variable and ln L as the explaining variable, we construct the regression equation to estimate through OLS

$$\ln U = \alpha + \beta \ln L + \varepsilon$$

The results are given in Table 13.

Based on the regression results, the regression model can be estimated as follows:

$$\ln U = -0.033095 + 1.086436 \ln L + \varepsilon$$

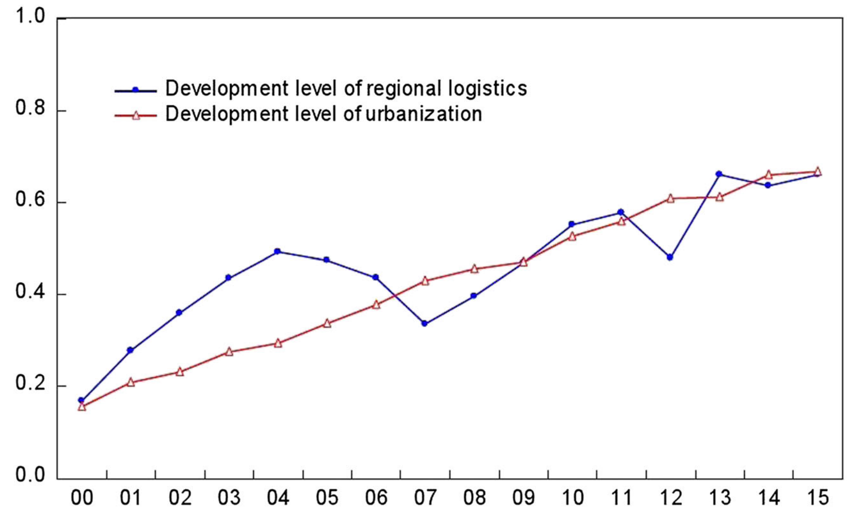

Fig. 2 Development level of urbanization and regional logistics in Liaoning

It can be seen that the value of R^2 for this model is 0.820348, and the adjusted value of R^2 is 0.800373, meaning the equation has a high goodness of fit. The coefficient of determination is 82.0348%. The coefficient of $\ln L$ is positive, and the level of significance is Prob. = 0.0000, passing the significance test at 0.01. The results of *t*-statistic and *F*-statistic are both significant. The model's fitting effect is fairly good.

These results show that the development of urbanization is positively correlated with the development of region-wide logistics in Liaoning for 2000–2015 and that the development of region-wide logistics has a considerable influence on urbanization.

Table 11 Correlation coefficient of regional logistics and urbanization

Metrics	Code	Correlation
Social insurance coverage (%)	X_1	0.8101
Urbanization rate (%)	X_2	0.8195
Disposable income of urban population	X_3	0.8614
Medical staff per 10,000 people	X_4	0.8469
Employment rate (%)	X_5	0.8268
Density of the urban road network	X_6	0.8773
Availability of water supply (%)	X_7	0.3572
Availability of natural gas supply (%)	X_8	0.4441
Housing area per capita	X_9	0.8680
Air quality satisfactory rate (%)	X_{10}	−0.6856
Sewage treatment rate (%)	X_{11}	0.8175
Amount of harmless treated waste	X_{12}	−0.8615
Green space per capita	X_{13}	0.5681
Waste recycling rate (%)	X_{14}	0.7406
Number of college students per 10,000 people	X_{15}	0.8375
Enrollment of middle and primary schools	X_{16}	0.8120
Compulsory education ratio (%)	X_{17}	0.8198
Training and reeducation rate (%)	X_{18}	0.8101

Furthermore, the regression model's residual error is

$$\varepsilon = \ln U + 0.033095 - 1.086436 \ln L$$

The ADF test is done to check whether the residual series is stationary. The results are given in Table 14.

It is found that the ADF value of the first-order difference sequence of the residual series (ε) is below the thresholds 1, 5, and 10%, implying the residual sequence is stationary. This means there is existed a long-term and stable equilibrium relationship between urbanization and region-wide logistics in Liaoning. The coordinated flexibility is 1.086436, meaning when the urbanization level increases by 1%, the region-wide logistics development level will increase by 1.086436%. Thus, the urbanization offers a powerful stimulus to the development of region-wide logistics.

Table 12 ADF test statistic for *ln* U and *ln* L

Variable	Test for unit root in	ADF test statistic		Prob.	Result
ln *U*	Level	*t*-statistic	−3.729518	0.0526	Unsteady
		1% level	−4.728363		
		5% level	−3.759743		
		10% level	−3.324976		
	1st difference	*t*-statistic	−5.461249	0.0044	Steady
		1% level	−4.886426		
		5% level	−3.828975		
		10% level	−3.362984		
ln *L*	Level	*t*-statistic	−0.766820	0.9383	Unsteady
		1% level	−4.992279		
		5% level	−3.875302		
		10% level	−3.388330		
	1st difference	*t*-statistic	−7.157172	0.0003	Steady
		1% level	−4.800080		
		5% level	−3.791172		
		10% level	−3.342253		

Table 13 Regression result of *ln* U and *ln* L

Variable	Coefficient	Std. error	*t*-statistic	Prob.
ln *L*	1.086436	0.180916	6.005181	0.0000
C	−0.033059	0.161001	−0.205338	0.5403
R^2	0.820348			
Adjusted R^2	0.800373			
S.E. of regression	0.248274			
Sum of squared residuals	0.862957			
Log likelihood	0.656816			
F-statistic	36.06220			
Prob. (*F*-statistic)	0.000032			
Mean dependent variable				−0.925161
S.D. dependent variable				0.453565
Akaike information criterion				0.167898
Schwarz criterion				0.264472
Hannan-Quinn criterion				0.172843
Durbin-Watson statistic				0.639104

Error correction model

The co-integration test proves the long-term co-integration relationship between ln *U* and ln *L*, but their short-term relationship is difficult to determine. In order to improve the model's accuracy and check whether there is a short-term relationship between ln *U* and ln *L*, we regard the error correction term as an explaining variable and construct an error correction model that takes into account this explaining variable and the other explaining variables implying short-term fluctuations. That model is

$$\ln U_t = 0.080167 + 0.184762 \ln L_t - 0.115810 \mathrm{ECM}_{t-1}$$

The results are given in Table 15.

This reveals the short-term relationship between ln *U* and ln *L* and consists of two parts: the part that represents the influence of ln *L* on ln *U* and the part that represents the influence caused due to the long-term deviation from the equilibrium. It can be observed that an increase in ln *L* by 1% brings about an increase in ln *U* by 0.184762%, meaning that the increase in the region-wide logistics development level has a positive influence on the urbanization. The coefficient of ECM_{t-1} represents the degree of adjustment made when ln *U* and ln *L* deviate from the equilibrium on a short-term basis. The value of −0.115810 for this coefficient means that when ln *U* and ln *L* deviate from the equilibrium on a short-term basis, a backward action will be done at an adjustment degree of 0.115810 to restore ln *U* and ln *L* to the equilibrium.

Granger causal relation test

The Granger causal relation test is done on ln *U* and ln *L* with the lag phase set to 1 and 2. The test results are given in Table 16.

It can be seen that when the lag phase is set to 1, urbanization is the Granger cause of region-wide logistics development at a level of 0.15%, but the region-wide logistics is not the Granger cause of urbanization. When the lag phase is set to 2, urbanization is the Granger cause of region-wide logistics development at a level of 0.82%, but the region-wide logistics is not the Granger cause of urbanization. To sum up, there is a unidirectional relationship between urbanization and region-wide logistics in Liaoning. Urbanization plays a dominant role, and region-wide logistics is a result of it.

Conclusions and recommendations

Rapid urbanization has been a pull factor of economic development and regional logistics. The paper tries to emphasize

Table 14 ADF test statistic for ε

Variable	Test for unit root in	ADF test statistic		Prob.	result
ε	Level	*t*-statistic	−2.441868	0.3468	Unsteady
		1% level	−4.728363		
		5% level	−3.759743		
		10% level	−3.324976		
	1st difference	*t*-statistic	−5.304446	0.0055	Steady
		1% level	−4.886426		
		5% level	−3.828975		
		10% level	−3.362984		

Table 15 Result of error correction model

Variable	Coefficient	Std. error	*t*-statistic	Prob.
C	0.080167	0.018673	4.293291	0.0010
D (ln *L*)	0.184762	0.091348	2.022618	0.0660
ECM (−1)	−0.115810	0.072995	−1.586535	0.1386
R^2	0.798079			
Adjusted R^2	0.681092			
S.E. of regression	0.064210			
Sum of squared residuals	0.049475			
Log likelihood	21.57348			
F-statistic	2.547974			
Prob. (*F*-statistic)	0.119599			
Mean dependent variable				0.098197
S.D. dependent variable				0.070955
Akaike information criterion				−2.476464
Schwarz criterion				−2.334854
Hannan-Quinn criterion				−2.477973
Durbin-Watson statistic				1.795563

the issues of urbanization and regional logistics focusing the case of Liaoning Province in China. It is evident that urbanization and regional logistics grow quickly from 2000 to 2015 and there is a close and stable correlation relationship between them during a long-term basis because urbanization has a great influence on regional logistics. Also, regional logistics has a great impact on urbanization by promoting the concentration of industries, increasing the demand for logistics, improving the living standards of people, enhancing the infrastructure, and advancing the logistics technology.

However, based on the urbanization challenges, this paper briefly recommends some steps that need to be considered in urbanization and regional logistics development strategies. The recommendations are as follows: a strong and active logistics infrastructure construction should be expedited. The approach implies adequate road networks and efficient logistics facilities and sites which can meet the urbanization development requirements for regional logistics. Meanwhile, immediate efforts should be made to reform the household registration system by promoting the concentration of population in cities, achieving a harmony between regional logistics and urbanization, as well as reduce the gap between urban and rural areas.

The green development of logistics should be supported and strengthened. Environmental and social issues need to be given more emphasis by using new technical innovation to enhance the technical level of logistics enterprises, minimizing the energy consumption of the logistics industry, improving the environmental protection ability, and avoiding secondary pollution. Recyclable and renewable packing materials should be taken to save costs and reduce the environmental pollution by noise and gas emission.

The central government should provide an overall master plan and guidelines of the urban logistics planning. Logistics planning should be incorporated into urbanization planning. The regional logistics plan should take into account the actual situation of regions and formation of urban logistics systems.

This paper focuses on the influences of urbanization on regional logistics specifically in Liaoning. Analysis of other regions may be the direction for in-depth research in the future.

Table 16 Pairwise Granger causality tests of ln *U* and ln *L*

Null hypothesis	Obs.	*F*-statistic	Prob.
Lags: 1			
Urbanization does not Granger cause logistics	15	16.7521	0.0015
Logistics does not Granger cause urbanization		3.67680	0.0793
Lags: 2			
Urbanization does not Granger cause logistics	14	8.57647	0.0082
Logistics does not Granger cause urbanization		0.78667	0.4843

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