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The causal relationship between land urbanization quality and economic growth: evidence from capital cities in China

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Abstract The study of the relationship between economic development and land urbanization is significant not only for China but also for other developing countries. This paper investigates the causal relationship between land urbanization quality and economic growth in China on a regional level in order to explore such relationship. Panel data from 2003 to 2012 of 35 major cities were employed in the analysis. According to the Seventh Five-Year Plan, we divided these cities into three groups, namely, Eastern China, Central China and Western China, based on their geographic position and economic development. By using the VECM methodology, panel fully modified ordinary least square and the Granger method; we intend to highlight the type of causality between land urbanization quality and economic growth. The empirical results show that (1) long-run causality from land urbanization quality to economic growth exists on a national scale, with the largest effects observed in the Western region, followed by the Central region, and the Eastern region, which is ranked last; (2) economic growth positively affects land urbanization quality, although this effect diminishes over time in all three regions; and (3) mutual short-run causality is found in all regions, in addition to Central China. This study placed more emphasis on the quality and efficiency of land use in urban areas. Furthermore, we propose that the transformation of the local government's performance evaluation mechanism, inter-regional coordination, and cross-regional operation can contribute to land urbanization quality and that, more importantly, Central China is the region that requires the greatest policy support from the government.

Keywords Land urbanization quality · Economic growth · Land use · Panel causality

JEL Classification Q24 · Q14 · C33

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1 Introduction

As an essential factor of production, land is an important support for the development of a region's socio-economic resources. Since the mid-1990s, China has experienced rapid land urbanization, with its rate increasing from 30.62 % in 2000 to 54.77 % in 2014, representing an average annual growth of 1.61 %. The process of rapid urbanization not only leads to unrealistically high population urbanization but also to the unceasing expansion of the urban land scale (Hu et al. 2015). From 2000 to 2010, the nationwide urban industrial land per capita increased from 130 square meters to 142 square meters, while urban area population density declined from 7700 to 7000 people per square kilometer. Under the current urban–rural land system, financial system and performance evaluation mechanism, "land finance" and "land to attract investment" serve as the core strategies in bringing in large amounts of "bonus" and promoting economic growth (Yew 2012a, b; Lin and Wu 2014). However, such system also leads to the eviction of people from their lands, severely limiting the development of Chinese cities. In 2010, the non-agricultural population in China accounted for 34.17 % of total household registration. Compared with the sixth nationwide population census data, non-agricultural population differs from the urban population of 205.94 million people, with a difference of 15.51 %. As space urbanization is significantly faster than population urbanization, the accumulated economic and social problems of rapid urbanization have become increasingly prominent. These issues reflect that land urbanization, economy, and population urbanization is not synchronized with the low level of urban land use efficiency or low quality of land urbanization (Lian and Raul 2014; Shen et al. 2015). Under such circumstances, exploring land urbanization quality and its relationship with economic growth presents research and practical significance.

China has experienced unprecedented economic growth and urbanization since 1978. After more than 30 years of development, and by 2012, more than half of the people in China are living in cities; thus, urbanization has become one of the core subjects on the policy agenda of the new leadership of China (Wei and Ye 2014). The process and consequences of rapid urbanization in China have caught the attention of numerous scholars on account of several aspects. First, policymakers and scholars have focused on urbanization quality assessment (Liu and Weng 2013; Zhang et al. 2013; Wang and Wan 2014). A large number of studies have been made by using various qualitative and quantitative methods. Qualitative assessment mainly includes basic theories of urbanization (Chen et al. 2013), urbanization processes (Chen et al. 2014a), and urbanization paths (Zhao 2013). In comparison, quantitative assessment mainly comprises comprehensive assessment of urbanization quality (Li and Li 2014; Yew 2012a, b), development and applications of assessment index systems (Wang et al. 2013), and dynamic coupling of coordination degrees between urbanization and socio-economic and eco-environmental development (de Leon et al. 2014).

Second, abundant literature addressing the special characteristics of "over-urbanization" or "excessive-urbanization," common phenomena and processes of formation, and the new challenges posed by developing countries have been generated (Anderson and Ge 2004). In China, the rate of land acquired for urbanization is growing faster than that of the urban population. Between 2000 and 2011, new town-constructed areas had grown by 76.4 %, while urban residents increased by only 50.5 %. Provincial governments have created urban sprawl at the expense of intensive land use. However, excessive urbanization is incompatible with sustainable development needed by China (Wang et al. 2015). Improving the efficient use of land is commonly recognized as an important consideration in balancing the protection of farmland and the accommodation of socio-economic development, especially for a country like China, which is dealing with intense human-land relationship and rapid urbanization (Choy et al. 2013; Wang et al. 2014). With the expansion of urban land, land use efficiency can increase or decrease depending on the relative rates of change between land consumption and socio-economic output. Existing studies have looked critically at the massive magnitude of urban development by analyzing the dynamics of urban expansion and institutional roots of "losing control" of the urban sprawl in China (Zhou 2006). However, incorporating more land to accommodate a growing population and to support urban economic growth is inherent in the process of urbanization, especially for a country with this magnitude of population and stage of urbanization.

Third, extensive research has focused on analyzing the causes of inefficient urban land usage in China. The artificial promotion of urbanization has been criticized as an important institutional reason (Lu 2007; Zhou 2005; Deng et al. 2010). These studies have warned that the speed of urbanization is not "the faster, the better." Land left idle or low-density development is employed as primary evidence in support of this strand of research (Deng and Huang 2004; Chan 2010). Most of these studies, however, fail to present more solid causal evidence to substantiate their claims. Some empirical results show that economic development (particularly non-agricultural economies) and income disparities continue to constitute the main driving forces of land use change (Liu et al. 2011; Rudel et al. 2005).

Finally, the relationship between economic growth and urbanization has recently become a hot research topic in China. Growth can plausibly affect urbanization, but this concept remains a point of contention in the literature. For instance, Zhang and Song (2003) provided certain indirect evidence via Granger causality tests to prove that economic growth Granger causes (positively) rural to urban migration but not vice versa. Meanwhile, in a study of Brazilian cities, (da Mata et al. 2007) found that higher income per capita can lead to larger city population. However, Poelhekke (2011) presented interesting evidence proving that urbanization may occur in the absence of growth, citing sub-Saharan African and several Latin American countries as examples.

Land urbanization was originally proposed in 2007, which calculated by the proportion of a built-up area to the total area (Lu et al. 2007). Exiting researchers mainly start from two perspectives to investigate the connotation of land urbanization. Firstly, from the perspective of land use pattern changes (Hu et al. 2015), where the process of land urbanization serves as the conditions for rural land turn into urban use. Secondly, concerning the change of ownership, where nationalization treated as the most important features of urbanization (Gu and Wu 2010; Xie and Yu 2014). The concept of Land use have to integrate multiple goals such as profit for farmers, biodiversity, natural resource protection, lifestyle and aesthetics (Fohrer et al. 2005).There is some difference between land urbanization quality and existing theory, for example, sustainable land use and smart land use. Sustainable land use lay stress on meeting the needs of contemporary people and future generations (Fröhlich et al. 2013). Meanwhile, smart land use mainly focus on the practice of smart growth theory in urban land use(Edwards and Haines 2007).While Land urbanization quality can be defined as the impact of land use activities on urban areas, including economic benefits, social benefits, ecological environment effects and the appropriateness of urban land use (Xu and Zhang 2016). Therefore, our research objective is twofold: first, we aim to develop a conceptual comprehensive index system for land urbanization quality assessment; and second, we intend to apply this new comprehensive index system to assess the land urbanization quality in China and further explore the causal relationship between economic growth and land urbanization quality. This research presents significance not only for China but for other developing countries dealing with issues related to rapid economic growth and urbanization.

The story of development is a story of urbanization. As a country is modernized, its cities expand and greater numbers of people shift from the countryside to the cities. This process is accompanied by an important change, namely, the conversion of large areas of cultivated land into urban land, a process known as land urbanization. Rapid economic development and urbanization have been the largest contributors to industrial land sprawl and urban land expansion in the developed regions of the world (Thompson and Prokopy 2009). One of the major negative effects of land urbanization for developing countries is the loss of cultivated land, regarding which researchers have expressed various views. One view states that urbanization, especially the expansion of urban land that has experienced rapid economic growth and urban development, leads to the loss of cultivated land (Deng et al. 2009; Liu et al. 2014). At present, a long line of studies has strongly linked with urbanization and economic development (e.g., see Henderson 2002). This relationship is particularly relevant in the developing world, in which economic growth and modernization go hand-in-hand with rapid urbanization (Ding and Lichtenberg 2011; Kasarda and Crenshaw 1991). Meanwhile, less attention has been focused on the relationship between land urbanization and economic development. In particular, considerably fewer research have combined the quality of land urbanization and economic development in developing countries for studying causal relationships.

As mentioned above, the literature has been dominated by analyses of urbanization quality, urban expansion and land use efficiency in China, but few studies have attempted to explain the relationship between land urbanization quality and economic growth. In the current paper, we first develop indicators to measure or monitor land urbanization quality and then present an empirical analysis of the relation between China's economic growth and land urbanization quality in particular. The rest of the paper is divided into sections. Section 2 provides the data and methodology used in this paper. Section 3 offers an evaluation of land urbanization quality. Section 4 explores the causal relationships between economic growth and land urbanization quality. Finally, the conclusion and policy implications are provided in the last section.

2 Data and methodology

2.1 Evaluation system of land urbanization quality

Land urbanization includes not only the process of land from rural to urban transformations in the type, but the total urban land (including land newly turned into urban land), the process that continuously to improve the effectiveness of land use. In this study, we consider the quality of land urbanization at the level of improvement in efficiency of urban land use during the aforementioned process (Xu and Zhang 2016).

In market economies, where land supply is mainly affected by the effects of rural land owners, while land urbanization is mainly affected by the economic and population, the government plays the role of demand regulation in the process. In China, however, land supply mainly affected by local governments, demand of land urbanization is mainly affected by the economic urbanization, population urbanization and local governments, thus, the factors affecting the quality of land urbanization mainly include economic urbanization, population urbanization and local government behavior.

Existing literatures are mainly concerned with the index system of urbanization including environmental, social-economic, coordinative development of urban–rural area

Table 1 Evaluation system of land urbanization quality

Layer of target	Layer of factors	Layer of index	Weight	Unit
Land urbanization quality	Moderation of land urbanization	Urban economic expansion coefficient	0.1519	%
		Urban population expansion coefficient	0.1249	%
	Economic benefits of urban land utilization	Secondary and tertiary industry output value per unit area	0.0709	RMB10,000/km^2
		Fixed-asset investment per unit area	0.0805	\$10,000/km^2
		Budgetary revenue of local governments per unit area	0.0675	RMB10,000/km^2
		Total industrial output value per unit area	0.0800	RMB10,000/km^2
	Social benefits of urban land utilization	Population density	0.0378	People/km^2
		Residential land per capita	0.0653	m^2/people
		Transportation land ratio	0.0673	%
		Public facilities ratio	0.0539	%
		Secondary and tertiary industry employer per unit area	0.0159	People/km^2
	Ecological benefits of urban land utilization	Green-covered area as % of the completed area	0.0286	%
		Waste water emissions per unit area	0.0419	ton/km^2
		Industrial waste gas per unit area	0.0468	ton/km^2
		Collection of consumption waste per unit area	0.0337	ton/km^2
		Environmental protection investment per unit area	0.0330	RMB10,000/km^2

and other determinants since 2001 (Zhou et al. 2015; Xu et al. 2016). The common indicators represents land urbanization in existing literatures is the proportion of a built-up area to the total area. There are many researches on evaluation index system on land use, for example, input–output, Ecological-Social-Economic, high efficient and intensified, "pressure-state-response, as well as numerous index system constructed in accordance with various aspects of urban land use (Hubacek and Giljum 2003; Feng et al. 2007). Based on the existing literatures, this study initiatively establishes an evaluation system from four perspectives, moderation and economic-social-ecological benefits of land urbanization. This study finally established evaluation system for land urbanization quality as shown in Table 1 in by screening means of statistical method, and considering the availability and representativeness of the data.

2.2 Data resource and study area

Data at city level in mainland China were collected for this study (given the lack of relevant data in Lhasa, all results in this paper did not include the region). We adopted the annual real GDP per capita to represent economic growth (EG). We mainly analyzed 35 major cities in China, referring to the four municipalities (Beijing, Shanghai, Tianjin, and

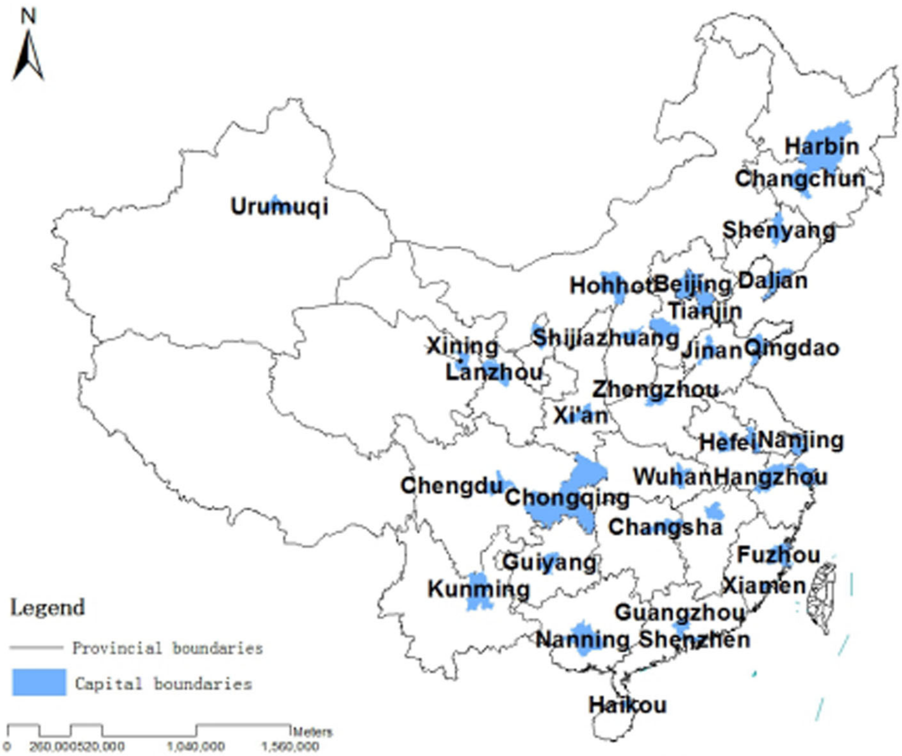

Fig. 1 Spatial distributions of the 35 major cities in China

Chongqing), 15 sub-provincial cities (Harbin, Changchun, Shenyang, Jinan, Hangzhou, Guangzhou, Wuhan, Chengdu, Xi'an, Dalian, Qingdao, Ningbo, Xiamen, and Shenzhen), and 16 other capital cities (Shijiazhuang, Taiyuan, Hohhot, Hefei, Fuzhou, Nanchang, Zhengzhou, Changsha, Nanning, Haikou, Guiyang, Kunming, Lanzhou, Xining, Yinchuan, and Urumqi). The spatial distributions of these areas are shown in Fig. 1. The data included in the model were gathered from the following sources: China's population and employment statistics yearbook 2004–2013, China City Statistical Yearbook 2004–2013, and Statistical Yearbook of China's Urban Construction 2004–2013. Maximum difference normalization method was used for standardization.

2.3 Index weight setting and score calculation

Firstly, we used subjective weighting G1 method to calculate the weight of subjective evaluation (w1); and the using entropy method to calculate objective weight of evaluation indexes (w2).We assume that W is the weight of empowerment after the two methods obtained by a linear combination, namely:

$$W = \theta_1 w_1 + (1 - \theta_1) w_2 \tag{1}$$

where θ_1 and $1 - \theta_1$ represent the proportion of w_1 and w_2, respectively.

Based on minimizing the sum of the squares of the deviation of two methods, we build the following objective function (Ye-Jun and Qing-li 2005; Han and Wei 2015):

$$\min z = \left[\sum_{j=1}^{n} (W - w_1)^2 + (W - w_2)^2 \right] \quad (2)$$

Combined with (1) we got

$$\min z = \left[\sum_{j=1}^{n} (\theta_1 w_1 + (1 - \theta_1) w_2 - w_1)^2 + (\theta_1 w_1 + (1 - \theta_1) w_2 - w_2)^2 \right] \quad (3)$$

Make the derivative of (3) zero,we got and finally we got

$$W = 0.5 w_1 + 0.5 w_2$$

Finally,weighted average method was employed to calculate the score of land urbanization quality, which is expressed as

$$L_i = \sum_{i=1}^{n} C_j W_j \quad (4)$$

where L_i represents land urbanization quality of each city, C_j is the standardized value of each i, $W_j$represents the weight of each index, and n is the total index number.

2.4 Analysis of dynamic relationship

We divided 35 cities into three groups: Eastern (Fuzhou, Guangzhou, Haikou, Hangzhou, Jinan, Nanjing, Shanghai, Shenyang, Shijiazhuang, Tianjin, Ningbo, Dalian, Xiamen, Qingdao, Shenzhen, Beijing, and Nanning), Central (Changchun, Changsha, Hefei, Harbin, Hohhot, Nanchang, Taiyuan, Wuhan, and Zhengzhou), and Western China (Chengdu, Chongqing, Guiyang, Kunming, Lanzhou, Urumqi, Xi'an, Xining, and Yinchuan), in accordance with the Seventh Five-Year Plan of the national government.

Impulse response function, panel fully modified ordinary least square (FMOLS), panel unit root analysis, and panel co-integration analysis were employed to further investigate the relationship and causality issue.

3 Land urbanization quality evaluation

According to the aforementioned methods and data sources, the land urbanization quality of 35 major cities in China has been evaluated (Table 2).

The results of land urbanization quality evaluation given in Table 2 are ranked by the 2012 score. Shenzhen is ranked first among 35 cities, indicating a high level of land use. One possible explanation is that Shenzhen has benefited from the implementation of several government policies, namely, its transformation into a special economic zone in 1980, Shenzhen Stock Exchange in 1990, sub-provincial city in 1994, and "green" GDP campaign in 2006 (Chen et al. 2014b). Shenzhen has likewise received considerable amounts of government expenditure. In comparison, Chongqing, which serves as one of the direct-controlled municipalities, is ranked 32nd among 35 cities. This low ranking is mainly due to the relatively low level economic benefits of land use and social development it has received. However, this situation can improved by further economic development and enhancement of infrastructure investment and level of social protection.

Table 2 Evaluation results of land urbanization quality

City	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Shenzhen	9.87	11.39	12.60	12.29	6.61	16.52	17.51	23.42	23.66	22.77
Shanghai	9.87	7.47	8.65	9.23	9.61	9.87	10.18	11.60	12.34	13.90
Guangzhou	5.43	5.78	5.76	5.99	6.01	6.89	7.09	7.31	10.49	12.84
Beijing	5.20	5.60	6.16	5.90	6.18	6.70	6.99	8.00	10.51	11.77
Tianjin	5.67	6.00	6.39	6.84	7.02	7.16	7.79	9.10	9.63	11.72
Hangzhou	6.64	7.54	7.02	7.17	7.88	8.68	8.72	9.58	9.56	10.94
Nanjing	6.33	6.45	6.76	7.25	7.13	7.48	7.87	8.91	9.10	10.78
Ningbo	7.92	8.64	9.03	6.36	7.41	7.63	8.09	8.27	9.59	10.59
Qingdao	5.36	5.54	6.37	7.47	7.69	7.42	6.40	8.07	8.42	10.19
Xiamen	6.51	6.70	7.06	7.91	6.56	7.01	6.90	7.29	9.65	9.68
Shenyang	5.38	6.27	5.71	6.26	6.69	7.18	7.28	8.41	8.21	9.59
Dalian	5.86	5.98	6.58	6.60	7.04	7.98	8.56	7.00	8.07	9.57
Chengdu	4.82	4.88	5.31	5.23	5.29	5.93	6.24	7.04	9.05	9.39
Wuhan	6.90	6.91	7.67	6.92	5.48	6.19	6.79	7.10	13.65	9.29
Changsha	5.47	5.42	6.17	6.00	5.87	6.05	6.75	7.48	8.41	8.74
Xi'an	5.73	5.49	5.72	5.37	3.16	6.59	6.94	7.41	7.03	8.69
Nanchang	6.24	4.59	6.55	6.82	6.86	7.77	5.20	6.78	7.74	8.63
Zhengzhou	5.86	5.39	5.03	5.30	4.93	5.45	5.61	6.63	7.78	8.24
Fuzhou	4.77	5.18	5.46	6.17	6.28	6.21	6.48	6.79	6.62	8.19
Shijiazhuang	6.32	6.34	5.97	6.21	6.07	6.04	5.98	7.38	6.90	8.13
Hefei	4.96	6.73	4.57	4.97	5.54	5.73	5.97	6.52	6.68	8.08
Changchun	6.02	6.27	5.33	5.14	5.29	5.65	5.83	6.70	6.99	7.83
Xining	5.13	5.88	5.21	5.48	5.58	5.82	7.01	6.06	6.21	7.76
Jinan	5.61	5.26	5.95	5.48	5.84	5.96	6.05	7.17	6.73	7.71
Kunming	5.07	15.15	5.74	5.09	5.27	5.28	5.58	6.34	6.32	7.53
Nanning	5.09	5.02	5.08	5.41	5.33	5.69	5.35	6.37	5.76	7.50
Harbin	5.50	5.99	5.34	5.07	5.11	5.42	5.85	6.81	7.21	7.48
Lanzhou	4.57	4.67	4.84	4.75	4.88	5.14	5.22	5.81	5.92	7.38
Taiyuan	5.15	5.28	5.31	5.58	5.19	5.71	5.66	6.70	5.64	7.36
Yinchuan	4.61	4.24	4.64	4.55	4.79	4.97	5.10	5.56	5.71	6.69
Chongqing	5.54	7.12	5.90	5.80	5.67	5.95	6.30	5.91	6.13	6.61
Urumqi	4.71	4.56	4.86	4.59	5.05	4.64	4.41	5.16	5.16	6.42
Haikou	4.35	4.55	4.88	5.26	5.41	5.55	5.80	7.35	7.41	6.35
Hohhot	4.74	4.84	4.99	5.23	5.42	5.48	5.86	4.98	5.81	5.92

At the same time, we can find the different spatial distributions of land urbanization quality in the top ten cities, including Shenzhen, Shanghai, Guangzhou, Beijing, Tianjin, Hangzhou, Nanjing, Ningbo, Qingdao and Xiamen, which are all located in Eastern China. Meanwhile, the majority of the bottom 10 cities, namely, Kunming, Nanning, Harbin, Lanzhou, Taiyuan, Yinchuan, Chongqing, Urumqi, Haikou and Hohhot, are located in Western China. The average of land urbanization quality index of the top ten cities is 12.52, whereas that of the bottom ten cities is 6.92. Hence, a large gap of land urbanization quality index exists between the two groups of cities.

4 Panel causality test between land urbanization quality and economic growth

4.1 Unit root test of panel data

The first step in the investigation of causality involves determining whether the series presents any integration orders. For this purpose, we employed panel unit root tests, which are developed by the groups of Levin, Lin, and Chu (2002, hereafter LLC) and Im, Pesaran, and Shin (2003, hereafter IPS). The LLC (2002) unit root test considers the panel ADF specification given by

$$\Delta y_{i,t} = \rho_i y_{i,t-1} + \sum_{j=1}^{p_i} \delta_{i,j} \Delta y_{i,t-j} + \varepsilon_{i,t} \tag{5}$$

The LLC (2002) test assumes that the persistence parameter, ρ_i, is identical across cross-sections, whereas the lag order, ρ_i, may vary freely. This procedure tests the null hypothesis $\rho_i = 0$ for all i against the alternative hypothesis $\rho_i < 0$ for all i. The rejection of the null hypothesis indicates a possible panel integration process.

The IPS (2003) test, which is also based on Eq. (5), differs from the LLC test by assuming ρ_i to be heterogeneous across cross-sections. The IPS tests the null hypothesis, H_0: $\rho_i = 0$, against the alternative hypothesis, H_1: $\rho_i < 0$ $(i = 1,\ldots,N_1)$; $\rho_i = 0$, $(i = 1,\ldots,N_1)$ for all i. Acceptance of the alternative hypothesis allows the individual series to be integrated (Tugcu 2014; Jackson and Zang 2015).

The LLC and IPS tests were executed on data both in levels and first differences, and results are reported in Table 3. Evidently, all variables are stationary in first difference, whereas level results are mixed. The results indicate that ln (L) and ln (EG) are non-stationary. However, after the first differences are used, both values are stationary. In other words, these results enable us to test the co-integration between economic growth and land urbanization quality in I (1) level.

4.2 Panel co-integration test

As the variable of economic growth and land urbanization quality of 35 Chinese cities is integrated when the first differences are used, the issue of whether a long-run equilibrium relationship exists between the variables arises. In this paper, the Johansen Fisher panel co-integration method is employed in the second step of estimation. The Johansen Fisher panel co-integration test is a panel version of the individual Johansen co-integration test, which offers advantages of flexibility, simplicity of implementation, and intuitive appeal (Storper and Scott 2009). The test results in Table 4 show that the null hypothesis, that is, no co-integration relationship exists between variables, was rejected at 1 % significance level. This result suggests that significant long-run equilibrium relationship exists between economic growth and land urbanization quality.

With the existence of long-run equilibrium relationship between economic growth and land urbanization quality, the long-run equilibrium relationship is bound to be constrained by the co-integration equation. Thus, the panel data co-integration regression is required to specify the form of long-run equilibrium relationship. In the process of empirical analysis, we use the fully-modified OLS (FMOLS) and set ln (L) as the dependent variable. The estimation results are presented below.

Table 3 Panel unit root test results

Region	Variable	LLC				IPS			
		Constant	*P*	Constant + trend	*P*	Constant	*P*	Constant + trend	*P*
Eastern China	ln(L)	4.9195	1.00	−4.1849	0.00	5.7256	1.00	0.3515	0.64
	ln(EG)	−7.5602	0.00	−15.7108	0.00	−0.0888	0.46	−1.5255	0.06
	d(L)	−11.0263	0.00	−18.7274	0.00	−5.8023	0.00	−3.6062	0.00
	d(EG)	−11.4537	0.00	−10.2849	0.00	−5.1975	0.00	−1.5462	0.06
Central China	ln(L)	2.3147	0.99	−3.8138	0.00	2.7487	1.00	−0.1854	0.43
	ln(EG)	−3.0432	0.00	−5.7761	0.00	0.9619	0.83	−1.6817	0.05
	d(L)	−8.0745	0.00	−7.2106	0.00	−4.2146	0.00	−1.5766	0.06
	d(EG)	−6.5405	0.00	−3.8311	0.00	−4.2389	0.00	−1.3904	0.08
Western China	ln(L)	7.1386	1.00	−3.0666	0.00	5.4567	1.00	0.1207	0.55
	ln(EG)	−2.8864	0.00	−8.6606	0.00	1.5935	0.94	−1.1972	0.12
	d(L)	−8.2274	0.00	−9.6795	0.00	−3.9861	0.00	−1.9656	0.02
	d(EG)	−11.5161	0.00	−12.1390	0.00	−5.4108	0.00	−2.3961	0.01

Table 4 Johansen Fisher panel co-integration test

Region	Hypothesized No. of CE(s)	Fisher stat.* (from trace test)	*P*	Fisher stat.* (from max-eigen test)	*P*
Eastern China	None	131.5	0.0000	125.9	0.0000
	At most 1	47.53	0.0616	47.53	0.0616
Central China	None	163.1	0.0000	138.5	0.0000
	At most 1	26.77	0.0834	26.77	0.0834
Western China	None	420.1	0.0000	145.3	0.0000
	At most 1	33.59	0.0142	33.59	0.0142

* Probabilities are computed using asymptotic Chi square distribution

Table 5 Panel fully modified least squares (lnL as independent variable)

Variable	Coefficient	Std. error	*t* statistic	*P*	*R*-squared
Eastern China	0.5341	0.0517	10.3356	0.0000	0.7244
Central China	0.2898	0.0461	6.2896	0.0000	0.5854
Western China	0.3221	0.0411	7.8407	0.0000	0.6121

Table 6 Panel fully modified least squares (lnEG as independent variable)

Variable	Coefficient	Std. Error	*t* statistic	*P*	*R*-squared
Eastern China	1.1653	0.1005	11.5907	0.0000	0.8489
Central China	1.8528	0.2622	7.0650	0.0000	0.4956
Western China	1.9631	0.2303	8.5250	0.0000	0.6121

Tables 5 and 6 show the long-term equilibrium equatiosn of economic growth and land urbanization quality (i.e., co-integration equation), respectively. For the Eastern part, a 1 % increase in GDP per capita could lead to a 0.5341 % increase in land urbanization quality. For the Central region, a 1 % increase in GDP per capita could lead to a 0.2898 % increase in land urbanization quality. For the Western part, a 1 % increase in GDP per capita could lead to a 0.3221 % increase in land urbanization quality. Regression results indicate that economic growth exerts a positive effect on land urbanization quality in all areas. However, such effect significantly varies among regions, with the largest effect recorded in the Eastern region, followed by the Western region, and finally, the Central region.

As can be shown in Table 6, regression results indicate that land urbanization quality positively affect economic growth in all areas, but with regional differences. The largest effect can be found in the Western region, followed by the Central, and the Eastern regions, with coefficients of 1.1653, 1.8528, and 1.9631, respectively. All values are statistically significant at the 1 % level.

4.3 Panel causality test between land urbanization quality and economic growth

Next, we employed the Granger causality method, which originated from the seminal work of Granger (1969). The method is widely used to analyze the causal effects between time series variables. The causal relationship between two variables can be investigated by examining the ways by which the variables interact with each other over time. In that sense, a variable x is said to Granger-cause another variable y if the future values of y can be predicted better by using past values of x and y than by using the past values of y only (Töngüra and Elverenb 2014).

This paper adopts the Granger causality test with a dynamic error correction after a long-run steady-state relationship between land urbanization quality and economic growth, which is proven based on the results shown in Tables 3 and 4. The Granger causality model with a dynamic error correction is expressed as

$$\begin{aligned} \Delta \ln S_{it} &= \theta_{1t} + \beta_{1t} \Delta \ln U_{it} + ECM_i \gamma_{i,t-1} + u_{1it} \\ ECM_{t-1} &= \ln S_{t-1} - \vartheta_0 - \beta_{1_t} \ln U_{t-1} \end{aligned} \quad (6)$$

$$\begin{aligned} \Delta \ln U_{it} &= \theta_{2t} + \beta_{2t} \Delta \ln S_{it} + ECM_i \gamma_{i,t-1} + u_{it} \\ ECM_{t-1} &= \ln U_{t-1} - \vartheta_1 - \beta_{1_t} \ln S_{t-1} \end{aligned} \quad (7)$$

where Δ denotes first difference, $\gamma_{i,t-1}$ is panel residual, and ϑ_0 and ϑ_1 are the constants in the panel co-integration equation. Short-run causality could be examined from the estimated parameter β_1 in Eq. (6) and β_2 in Eq. (7).

In Eastern China, mutual short-run causality is found between land urbanization quality and economic growth. Long-run causality is found to run from economic growth to land urbanization quality, but the reverse long-run causality does not exist. Combined with the result of land urbanization quality evaluation shown in Table 2, economic growth and city development in Eastern cities may have have entered the age of high mass consumption according to Rostow's stages of growth. This means that land urbanization quality in Eastern China is in a relatively stable level and can benefit the economies of cities within the region in the long run (Table 7).

In Central China, no short-run causality is found between land urbanization quality and economic growth. Long-run causality is found to run from land urbanization quality to economic growth, but the reverse long-run causality does not exist. One possible explanation is that urban development in Central China is in a stage of rapid growth, which may lead to prompt change in the short term.

In Western China, a non-directional long-run causality running from land urbanization quality to economic growth is found. Meanwhile, mutual short-run causality is found

Table 7 Panel causality test results

Region	Null hypotheses	Coefficient Short-run	Coefficient	Long-run t-statistic ECM (−1)
Eastern China	ln(L) does not cause ln(EG)	0.3449**		−0.7166***
	ln(EG) does not cause ln(L)		0.1328**	0.0575
Central China	ln(L) does not cause ln(EG)	0.0967		−0.5581***
	ln(EG) does not cause ln(L)		0.1189	0.0003
Western China	ln(L) does not cause ln(EG)	0.3441***		−0.5653***
	ln(EG) does not cause ln(L)		0.6096***	0.2121

Notes Lag lengths were selected using Akaike's information criterion. *, **, and *** denote significance at the 10, 5 and 1 % levels, respectively between urbanization quality and economic growth. By combining these findings with the result of land urbanization quality evaluation shown in Table 2, we deduce that gaps exist among the city developments recorded in the Western, Eastern, and Central regions. With the continuous progress of land use, the cities needs more land for economic growth.

4.4 Impulse response function analysis

The impulse response function (IRF) of a dynamic system is the output when presented with a brief input signal (i.e., an impulse). IRF is used to measure the standard deviation of a random disturbance impact on the current value and future trajectory of other variables. Moreover, IRF can visually depict the dynamic interaction and effect between variables. The horizontal axis represents trace periods, which we adopted as 10, whereas the longitudinal axis represents the response of the dependent variable. The solid line shows the response function curves and the two dotted lines represent twice the standard deviation of the confidence belt.

As shown in Fig. 2, in Eastern China, when the impulse is GDP per capita, each response is positive in all response periods, reaching the maximum positive effect at period three. The value fluctuates slightly above the line zero, indicating that economic growth exerts a weak positive effect on the land urbanization quality in the Eastern region and that such effect is relatively lower than that of other regions. Meanwhile, when the impulse is land urbanization quality, the lines reach the maximum positive effect at period three and negative effect at period four, and then diminish every year.

As illustrated in Fig. 3, the extent of land urbanization quality in Central China immediately responds to the change in GDP per capita and reaches the maximum positive effect at period two. Meanwhile, when the impulse is land urbanization quality, GDP per capita responses show an alternation between positive and negative values, subsequently diminishing over time.

As shown in Fig. 4, the extent of land urbanization quality in Western China immediately responds to the change in GDP per capita and approaches to zero afterwards. Moreover, when the impulse is land urbanization quality, each response is positive at all time responsive periods, reaching the maximum effect at period two.

Taken together, these results suggest that economic growth exerts an evidently positive effect on land urbanization quality in all three regions in the first 3 years. When the impulse is land urbanization quality, the response shows mixed results, alternating between positive and negative values in Central China, whereas the effects are all positive in Western and Eastern China.

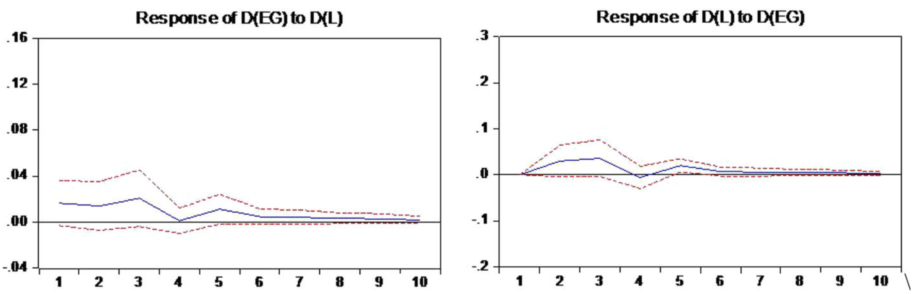

Fig. 2 Impulse response function curve (Eastern China)

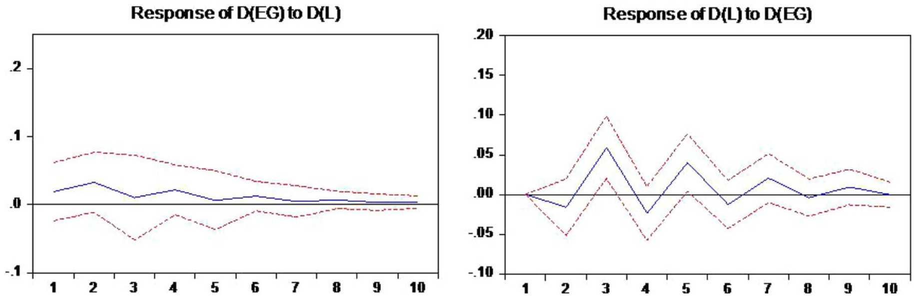

Fig. 3 Impulse response function curve (Central China)

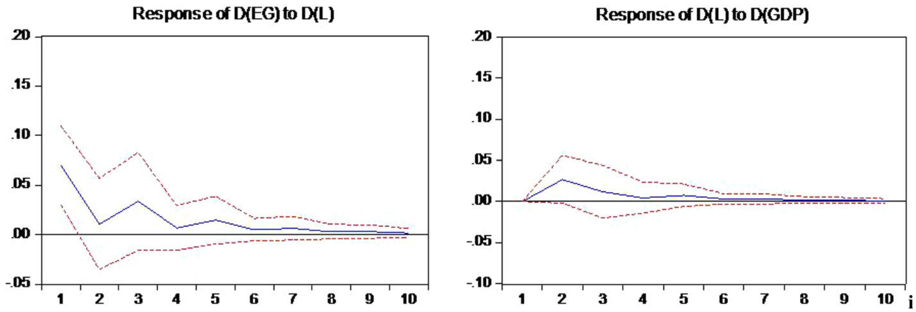

Fig. 4 Impulse response function curve (Western China)

5 Conclusions and discussions

This paper explored the economic, social, and ecological benefits of urban land use, as well as the moderation of urban development. We used panel data of 35 major cities from 2003 to 2012 in the evaluation of land urbanization quality and presented an empirical study of the causality relationship between land urbanization quality and economic growth. The cities studied were divided into three groups, namely, Western, Eastern, and Central China. Regarding research methods, weighted comprehensive evaluation, and impulse response function, panel FMOLS, panel unit root analysis, and panel co-integration analysis were employed.

The results indicate the lack of long-run causality from GDP per capita to land urbanization quality in all three regions. For Eastern China, mutual short-run causality is found between land urbanization quality and economic growth. Long-run causality from economic growth to land urbanization quality has also been found. Economic growth exerts a positive effect on land urbanization quality and diminishes over time. For Central China, no short-run causality is found between land urbanization quality and economic growth. Land urbanization quality alternates between positive and negative values on economic growth and diminishes over time. For Western China, mutual short-run causality is found between urbanization quality and economic growth. Economic growth exerts positive effects on land urbanization quality in the short-run and vice versa.

Based on the empirical results, we identified the following policy implications.

(1) To transform the performance evaluation mechanism of local government to standard government behavior: As shown in the results, economic growth evidently exerts a

positive effect on land urbanization quality in all three regions in the first 3 years. This finding indicates that, under the current GDP assessment system, the land urbanization policy promoted by the government can be inevitably distorted. As urbanization involves population, land, economy and other aspects, land urbanization, the core of urbanization and the key to sustainable development of urbanization, is in question. Land urbanization is not only able to promote fixed-asset investment-led growth and improve short-term economic growth, it can also enable local governments to obtain financial benefits to ease financial pressure. Thus, on the basis of the different circumstances in different regions, we need distinct policies.

For Eastern China to achieve a higher quality of urbanization with a relatively limited space resource, a long-term growth model should be established. One example is to further expand the residence permit system and the household registration system to motivate the surplus labor force to settle down in big cities. In the case of Central China, serving as the engine of next stage of city development, land urbanization alternates between wielding positive and negative effects on the economy; thus, further policy support is required. For Western China, reasonable policies should be formulated to attract the surplus labor force to relocate to these areas. Given that mutual short-run causality exists between land urbanization quality and economic growth, urban scale in these areas can be moderately expanded. The development of these areas is one of the priorities of the national strategy that requires further policy implementation.

(2) To further develop inter-regional coordination and cross-regional operation: As for inter-regional coordination, major national strategies, such the "one belt and one road project" and the coordinated development of Beijing-Tianjin-Hebei region and the Yangtze River economic belt, should be aggressively proposed to further deepen the implementation of the overall strategy for regional development. As for cross-regional operation, the main point is to reduce the economic gap between the Western region and other areas. Based on the results in this paper, land use quality in Western areas remains at a relatively low stage, which is heavily affected by urban expansion in both the short-term and in the long-run. Thus, we need to further deepen cooperation among regions. In addition, promotion of mutual coordination of regional land use level is extremely important and meaningful.

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