ARTICLE

Dynamic interaction between foreign direct investment and the new urbanization in China

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Abstract
At the macro-national level, foreign direct investment (FDI) can effectively promote the new urbanization in China. However, at the urban level, the interactions between FDI and the new urbanization are still not clear. To answer this question, this study constructs a new urbanization development index system based on a panel data set of 271 cities in China from 2003 to 2014. The weights of 26 secondary indicators are determined by the entropy method, and the spatial and temporal effects between FDI and the new urbanization are analyzed using the Panel Vector Autoregression model. Furthermore, direct–indirect effects of urbanization and that of FDI are respectively studied from short-term and long-term two visual angel. The results show that the FDI inflow is an exogenous motive force for the new urbanization, and the new urbanization provides strong support for attracting foreign capital. However, FDI in the neighboring areas is not conducive to local urbanization, and the urbanization of the surrounding areas will inhibit the local FDI Inflows.

1 Introduction

With the continuous deepening of China's economic globalization and the vigorous implement of "The Belt and Road Initiative",[1] the inflows of foreign direct investment (FDI) in China are growing steadily, and the utilization rate of foreign investments keeps improving. FDI inflows lead to industrial structure upgrading, high-quality human capital, technological spillover, and numerous employment opportunities, which provides considerable direct

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[1] The Belt and Road Initiative refers to China's cooperation initiative to build a "New Silk Road Economic Belt" and a "21st Century Maritime Silk Road". It aims to use the historical symbols of the ancient Silk Road to actively develop economic partnership relationships with the countries along this route.

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support for the new urbanization[2] in China. At the same time, with China's new urbanization moving forward constantly, there is a substantial increase in the local labor quality, and the urban infrastructures are also improving greatly. These achievements will not only help to spawn many new industries and unleash the potential for greater domestic demands, but will also, in turn, create a good external investment environment for all cities to attract FDI and agglomerate the foreign capital. Thus, it is obvious that there is an interaction between FDI and the new urbanization, which are the two major issues in China's current development. Exploring the mechanisms of and interactions between the two can provide empirical evidence and policy recommendations for better utilization of foreign investments and benign development of the new urbanization, thereby achieving positive interactions between them and further promoting sustainable development in China.

At present, it has been confirmed that, at the macro-national level, FDI can effectively promote the development of China's new urbanization. However, at the urban level, several questions arise: What impact will FDI have on the new urbanization? What types of feedback will occur between FDI and the new urbanization? Are there any interactions between the two? If there are interactions, will they change over time? In the process, do any geospatial factors affect the interactions? To answer these questions well in this study, the dynamic interactions between FDI and the new urbanization will be explored, based on the panel data of 271 cities in China from 2003[3] to 2014.

2 Literature review

The literature related to this study can be summarized in two respects: "the mechanisms and effects of FDI on urbanization" and "the mechanisms and effects of urbanization on FDI".

Firstly, with regard to the mechanisms and effects of FDI on urbanization, FDI mainly affects the urbanization of either a country or a region at economic, social, and environmental levels. At the economic level, Lin (2007) found that the international capital flows and the international production activities brought by FDI can promote economic development in the developing countries and, thus, have a positive impact on the urbanization process. Based on content analysis, Seto (2011) payed close attention to 11 countries in Asian and African, and found that FDI could lead to population migration to cities, and then promoted the urbanization. Shi and Gu (2003) discussed the process of urbanization driven by FDI in the Yangtze River Delta of China, and confirmed that FDI improved both industrialization and urbanization by promoting the transformation and upgrading of economic structure and increasing population mobility. Taking Jiangsu Province as an example, Wu and Gu (2005) proved that the positive impact of FDI on economic growth had

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[2] New urbanization is urbanization with Chinese characteristics. It is characterized by urban–rural integration, industrial interaction, intensiveness, ecological livability, and harmonious development.

[3] China' s urbanization was in a high-speed development stage before 2003,the urbanization rate increased from 27.46% in 1992 to 40.53% in 2003. The turning point of China' s urbanization appeared in 2003, the report of 17th National Congress clearly put forward to raise the level of urbanization gradually and persist in the coordinated development of cities along the path to urbanization with Chinese characteristics. Henceforth, China's urbanization began to pursue high "quality". Although the concept of "new urbanization" has not been formally proposed at that time, the characteristics of urbanization have changed, which is the important basis and era background for the emergence of "China's new urbanization". Therefore, the study based on the data from 2003 is in line with Chinese actual conditions.

promoted the process of urbanization. Chen and Wu (2017) found that FDI had a positive impact on urbanization in the coastal region but had no significant impact on urbanization in the inland region, and that, apart from FDI, the economic structure, the level of economic development, the level of fixed assets' investment, and the size of a city's population were important determinants of urbanization in China. Yuan et al. (2017) used provincial panel data from 1985 to 2014 to construct a threshold model and found that there were three apparent thresholds in FDI's influence on the urbanization. It was found that under the low financial threshold value or above the high level financial threshold value, FDI stunted the urbanization; above the low level financial threshold value and under the middle level financial threshold value, FDI significantly propelled the urbanization; above the middle level financial threshold value and under the high level financial threshold value, FDI still propelled the urbanization but with a decreasing trend. At the social level, Foldi and Weesep (2006) opined that the inflows of FDI had brought about a change in people's lifestyles, leading to a change in urban culture and, ultimately, to the development of urbanization. Chen et al. (2009) redefined the connotation of urbanization in China and measured the integrated level of urbanization in China. They found that FDI had a weak influence on urbanization in China, although the degree of impacts had been continuously strengthened over time. Cheng and Duan (2010) measured the urbanization level by the ratio of the urban population to the total population based on time series data and explored FDI and urbanization through cointegration tests and impulse response functions, finding that FDI generated positive effects on urbanization, while urbanization had little effect on FDI. Shen et al. (2000) examined both the spatial diffusion and the determinants of foreign investments, which was the result of the widespread implementation of the open-door policy in the region and significant improvements in the infrastructure. Wu and Radbone (2005) investigated the causes and consequences of different patterns of FDI in Shanghai, confirming that the flow of capital shaped the internal structure of cities. In addition, from an environmental perspective, Liu and Liu (2011) confirmed that FDI had contributed to the international transfer of carbon pollution while promoting the development of urbanization in China, resulting in the non-benign development of urbanization in China. Behera and Dash (2017) found that there was a cointegrating relationship between fossil fuel energy consumption, FDI, urbanization, and CO_2 emission in middle-income countries and that FDI was substantially affecting CO_2 emissions in the SSEA (South and Southeast Asian) region.

Secondly, as regards the impacts of urbanization on FDI, urbanization mainly influences the FDI inflows of either a country or a region at both economic and social levels. From an economic perspective, Cheng and Yan (2003) found that a strong economic system and a high degree of urbanization were prerequisites for FDI to promote a country's economics. Through exploring the FDI inflow issue, Halvorsen (2012) confirmed that changes in the economic structure would have an impact on the scale of FDI. Behname (2013) conducted research based on panel data of countries in Central Europe and confirmed that the economic developments brought about by the developments of urbanization made Central Europe more attractive to FDI. Lu (1997) conducted a regression analysis of the urbanization level, per capita GDP, and preferential policies in China and showed that the level of urbanization played a significant positive role in FDI inflows. Chen et al. (2009) found that the increase in wage costs brought about by the developments of urbanization not only reduced the competitiveness of China's service industry but also weakened the incentive for FDI to flow into China. Kan and Lv (2018) found that the urbanization promoted the growth of FDI both in quantity and quality, by adopting the spatial correction system GMM model. From a social perspective, Sun and Wu (2010) confirmed that the inflow

of FDI required a matching supply of social infrastructure, and the high level of urban infrastructure construction would lay a good foundation for China to improve its attraction and use of FDI better. Cao and Duan (2015) found that FDI was closely correlated with the urbanization rate in Jiangsu and Guangdong province, the industrial structure and the urbanization rate could lead to the growth of FDI. However, the developments of urbanization would also produce "inert" responses to external stimuli from FDI, thus negatively affecting FDI (Peng and Deng 2013).

In summary, much in-depth theoretical and empirical research into FDI and urbanization has been conducted, and many valuable results have been obtained. However, the following problems still need to be solved. First, the existing research on FDI and urbanization is mostly concentrated in single direction, more precisely, the impact of FDI on urbanization or the impact of urbanization on FDI. There are very few studies on the interaction and the dynamic relationship between FDI and urbanization. Second, most of the existing studies on the relationships of FDI and urbanization are based on national and provincial data; only a few of the studies are based on time-series data and employ Granger causality tests and impulse responses. Due to the fact that China has a large area and a wide gap between provinces, it is difficult for these studies to accurately depict the interactions between FDI and urbanization. Third, the frequent occurrence of urban agglomeration and FDI agglomeration has made geospatial factors an important part of the study on FDI and urbanization. However, as of now, no literature has appeared to introduce spatial factors. Fourth, most of the traditional urbanization indicators are based on the proportion of urban population in the total population. This measurement method is too simple to comprehensively measure and reflect China's new urbanization development against the background of its acceleration and the proposal of a new urbanization strategy. In particular, China is a dual household registration system, and not only the free flows of resources between urban and rural areas but also the rational allocation of resources are always hindered. Therefore, the urban–rural coordination level should also be an integral part of the urbanization system, and it is urgent for China to build a city-based unit that covers the comprehensive measures of urbanization in many respects, including economic development, social construction, public facilities' construction, environmental construction, and resource utilization.

To make up for the above insufficiencies, this study first builds a new urbanization system, which includes economic, social, environmental, and urban–rural coordination aspects, based on the panel data from 271 cities in China during 2003–2014, and the weights of the indicators are determined through the entropy method to eliminate the impacts of human subjective factors. Then, a panel-vector autoregressive model (PVAR) is used to incorporate FDI, urbanization, and their lag items into the endogenous systems, exploring the dynamic interactions between FDI and urbanization and examining the correlations between the two. After that, to introduce the geospatial factors, the spatial dynamic panel Durbin model is employed to test the spatial spillover effects, both the direct and indirect effects, in the short- and the long-term, respectively, thus providing a comprehensive and in-depth analysis of the dynamic relationships between FDI and urbanization.

3 Constructing an indicator system of the new urbanization

Based on the panel data (in yearly basis) of 271 cities in China during 2003–2014, 26 indicators are selected from the four aspects of economics, society, environment, and urban–rural coordination to comprehensively measure the level of new urbanization in each

city, and the entropy method is used to determine the weight of each index. The original data[4] used in the study are from the "China Statistical Yearbook", the "China City Statistical Yearbook" and the "China Regional Economic Statistics Yearbook" from 2004 to 2015.

The entropy method is used to determine the weights of the secondary indicators (B1–B26) in Table 1; this has two main advantages. First, the entropy method is objectively empowering—it determines the indicators' weights based on the relative degree of the index changes and the overall impacts of the system. With high credibility and accuracy, the entropy method can effectively avoid the correlation problems. Second, the entropy method can profoundly reflect the effect value of the index information entropy. This ideology is extremely similar to the sustainable development mechanism of urban economic development, social construction, public facilities' construction, environmental construction, and resource utilization, which is conducive to comprehensively measuring the new urbanization level of 271 cities in China.

Suppose there are m objects and n evaluation indicators, a_{ij} is the j-th indicator of the i-th object. The polarity in Table 1 means that the indicator has either a positive or negative effect on the system, and the secondary indicators can be standardized using Eqs. (1) and (2) respectively.

$$x_{ij} = \frac{a_{ij} - \min\{a_{ij}\}}{\max\{a_{ij}\} - \min\{a_{ij}\}} \quad (i = 1, 2, \ldots, m; j = 1, 2, \ldots, n) \tag{1}$$

$$x_{ij} = \frac{\max\{a_{ij}\} - a_{ij}}{\max\{a_{ij}\} - \min\{a_{ij}\}} \quad (i = 1, 2, \ldots, m; j = 1, 2, \ldots, n) \tag{2}$$

After that, the weight of the i-th sample under the j-th indicator is calculated according to the equation: $p_{ij} = x_{ij} / \sum_{i=1}^{m} x_{ij}$. Based on the above, we can obtain the information entropy of the j-th indicator:

$$e_j = -\frac{1}{\ln m} \sum_{i=1}^{m} (p_{ij} \ln p_{ij}) \tag{3}$$

The information effect value of the j-th indicator depends on the difference between e_j and 1, that is, $h_j = 1 - e_j$. And w_j, the weight of the j-th indicator, can be calculated based on h_j:

$$w_j = \frac{h_j}{\sum_{j=1}^{n} h_j} \tag{4}$$

After the calculation of the weight, f_{ij}, the evaluation value of a_{ij}, is the product of the weight w_j of the j-th indicator and the proximity a'_{ij} of the j-th indicator of the i-th object in the standardization matrix, that is, $f_{ij} = w_j a'_{ij}$. The evaluation value of the i-th object is $Indices_i = \sum_{j=1}^{n} f_{ij}$. The larger the value of $Indices_i$, the higher the urbanization level of the city.

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[4] Because a lot of data for some cities of Xinjiang and Tibet is missing, they have been removed from the sample to ensure the accuracy of this study.

Table 1 The indicator system of the new urbanization

First level indicator layer	Secondary level indicator layer	Weight (%)	Polarity
Economic indicators (A1)	GDP per capita (B1)	2.121	+
	Local fiscal revenue (B2)	4.748	+
	Local fiscal expenditure (B3)	4.751	+
	Per capita disposable income of residents (B4)	2.312	+
	The proportion of the tertiary industry's added value to GDP (B5)	1.058	+
Social indicators (A2)	Permanent resident population (B6)	2.005	+
	Urban registered unemployment rate (B7)	1.980	–
	Proportion of urban population (B8)	2.153	+
	Urban institutions of higher learning (B9)	6.205	+
	Doctors (B10)	6.743	+
	Hospital beds (B11)	1.874	+
	Public library books (B12)	4.458	+
	Railway passenger traffic volume (B13)	5.045	+
	Railway freight (B14)	5.658	+
	Highway passenger traffic volume (B15)	4.914	+
	Road freight (B16)	3.520	+
	Civil aviation passenger traffic volume (B17)	3.481	+
	Civil air cargo traffic volume (B18)	3.914	+
	Annual water use (B19)	5.243	+
	Annual electricity consumption (B20)	5.768	+
	Total telecommunications services (B21)	4.852	+
Environmental indicators (A3)	Industrial wastewater discharge (B22)	6.680	–
	Industrial smoke and dust emissions (B23)	2.075	–
	Green area (B24)	4.804	+
Urban and rural coordination indicators (A4)	Urban–rural income gap (B25)	1.063	–
	The proportion of primary industry added value to GDP (B26)	2.576	–

The weights of 26 secondary indicators are listed in Table 1. According to the ranking of the weights, the top three are industrial wastewater discharge (6.680%), doctors (6.743%), and urban institutions of higher learning (6.205%), which not only reflects that the difference in urban population and economic growth is less than that in environment, health care, and education but also shows that in the comprehensive evaluation indicator system of the new urbanization, the increase in the proportion of the urban population, and the growth of the economy are no longer the main issues of China's urbanization. The environment, medical care, and education have gradually become important factors in the evolution process.

4 Dynamic interactions between FDI and urbanization based on the panel vector autoregression model

The PVAR model regards FDI and urbanization as an endogenous system to be dealt with and considers the lag terms of the two to truly reflect the interactions between them. In addition to the combined advantages of the VAR model and the panel data model, this method can also capture the individual differences and the common shocks in different cross-sections by introducing individual effects and time-effect variables, which can not only solve the problem of variable endogeneity but also effectively describe the shock response and variance decomposition between FDI and urbanization. Since the PVAR model estimation is based on the fixed-effect dynamic panel model, the group mean difference method should be used to remove the time effects before performing a Generalized Method of Moments (GMM) estimation, and the forward mean difference method is then used to eliminate the individual effects.

$$\mathrm{Y}_{it} = \mathrm{Y}_{it-1}\mathrm{A}_1 + \mathrm{Y}_{it-2}\mathrm{A}_2 + \cdots + \mathrm{Y}_{it-p+1}\mathrm{A}_{p-1} + \mathrm{Y}_{it-p}\mathrm{A}_p + f_i + \mu_t + \varepsilon_{it} \tag{5}$$

where Y_{it} is the dependent variable, including $k = 2$ dimensional vectors, which are urbanization and FDI; f_i indicates an unobserved intercept effect,[5] and the fixed-effect can be eliminated by forward-mean-differential Helmert transformation;[6] μ_t is the time effect; ε_{it} is the random error term, and it obeys the following characteristics: E $(\varepsilon_{it}) = 0$, and E $(\varepsilon'_{it}\varepsilon_{it}) = \Sigma$; when $n > m$, E $(\varepsilon'_{im}\varepsilon_{im}) = 0$.

The amount of FDI used by 271 cities in China from 2003 to 2014 (in yearly basis) is selected as an index to measure FDI inflows, and the urbanization level is indicated by the new urbanization scores defined and calculated in the previous text. Since the natural logarithm transformation of the data does not change its original cointegration relationships, the original sequence involved in the study will take the natural logarithm (ln(*indices*) and ln(*fdi*)). On the one hand, they are used to achieve the linearization of the trend, while, on the other hand, they can eliminate the effect of heteroscedastic errors.

Before analyzing the relationships between the new urbanization and FDI inflows in the 271 cities in China, the stationarity test must be conducted, as the non-stationarity of the

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[5] When VAR is applied to the panel data estimation, it is related to the independent variables due to the influence of the dependent variable's lag term, which makes the "mean difference method", traditionally used to eliminate the fixed effects, biased in estimating the coefficient.

[6] The forward differential Helmert transformation method avoids the orthogonality of the lagging regression term and the differential term of the instrumental variable through removing the forward mean, which makes the measurement test result more accurate.

variables often leads to spurious regressions in the regression analysis, making the regression results either biased or even invalid. As shown in Table 2, LLC, HT, and ADF are used to test whether there are unit roots, ensuring the robustness of the test results. The test results reject the assumption that the variables are non-stationary, which can be considered that the two variables are stable and can be analyzed by the PVAR model.

According to the information criteria such as Akaike's (AIC), Schwarz's(BIC) and QIC shown in Table 3, the selection of the lag terms of the PVAR model covering 271 cities in China shows that, when the lag item is 1, the three information criteria reach the minimum value, thereby A PVAR model with a lag order of 1 is established. GMM is used to estimate the PVAR model of urbanization and FDI.

In terms of Eq. 1 in Table 3, the estimation coefficient of the urbanization level in the first lag phase is significantly positive, which shows that the urbanization in the previous period can effectively promote the urbanization in the latter period. The estimation coefficient of FDI in the first lag phase is significantly positive, indicating that FDI in the previous period also plays a positive role in the urbanization in the latter period, but its strength

Table 2 Unit root test of the variables

Variables	Test methods and statistics			LLC test	HT test	ADF test
	LLC	HT	ADF	Conclusion	Conclusion	Conclusion
ln(*indices*)	− 13.4625***	0.2551***	− 7.3524***	Stable	Stable	Stable
ln(*fdi*)	− 13.4054***	0.2573***	− 1.4860*	Stable	Stable	Stable

*, **, and *** indicate statistically significant at the 10%, 5%, and 1% levels respectively

Table 3 Estimation results of the PVAR model and the Granger test

Equation		ln(*indices*) Equation 1		ln(*fdi*) Equation 2
Explanatory variables		Coefficient		Coefficient
$L.\ln(indices)$		0.709*** (0.033)		0.565*** (0.078)
$L.\ln(fdi)$		0.071*** (0.015)		0.663*** (0.039)
Latency selection	AIC criterion		BIC criterion	QIC criterion
Phase 1	− 2.060		− 68.636	− 26.571
Phase 2	0.768		− 43.616	− 15.572
Phase 3	1.222		− 20.970	− 6.949
Granger test	Granger test original hypothesis		χ^2 value	*P* value
ln(*indices*)	The increase of FDI used by governments is not the reason for urbanization development		23.567	0.000
ln(*fdi*)	Urbanization development is not the reason for the increase of FDI used by governments		52.270	0.000

*, **, and *** indicate statistically significant at the 10%, 5%, and 1% levels respectively; the numbers in the parentheses represent the corresponding standard errors of the coefficients

is much smaller than that of the urbanization in the previous period, which shows that the "inertia effect" of urbanization itself is far greater than is the "promoting role" of FDI. Similar to Eq. 1, in Eq. 2, urbanization and FDI in the previous period all play a significant role in promoting FDI in the subsequent period; what differs from the results of Eq. 1 is that FDI and urbanization in the previous period both have stronger effects on FDI in the subsequent period. In addition, Table 3 also lists the Granger causality test results under the framework of the PVAR model, and the results show that the original hypotheses are rejected at a 1% level of significance, indicating that there is a two-way Granger causality between FDI inflows and urbanization in different cities; that is, the two exhibit mutual cause and effect and promote each other.

To characterize the dynamic time-delay relationships between the variables in the system more intuitively, this study applies a standard deviation impact to each variable and carries out 300 simulations using the Monte Carlo method, obtaining the impulse responses to each variable in 0 to 20 periods. Figure 1 shows the impulse responses of the variables. The horizontal axis represents the number of response periods of the impulse responses; the vertical axis represents the response degree of the variable to the impulses; the shaded portion represents the 95% confidence interval; and the middle solid line represents the size of the reaction to the impact during each period.

As can be seen from Fig. 1, the impact of one standard deviation from FDI has a greater positive impact on FDI in the current period. It decays sharply in the first two periods, and then slowly decreases, gradually converging to zero (the top left of Fig. 1). The impact of FDI does not have an influence on urbanization in the current period, but it will reach maximum positive impact in the second period and then slowly decline, gradually converging (the top right of Fig. 1). The impact of a standard deviation from urbanization on urbanization is similar to the impact of FDI shocks on FDI, both showing a sharp decline
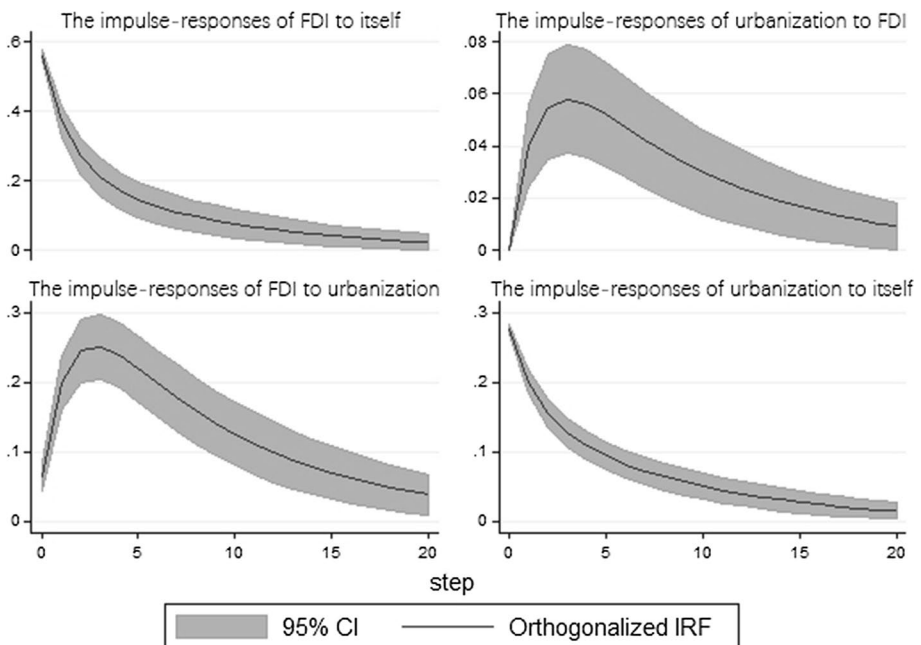

Fig. 1 Impulse-response analysis

followed by a slow decrease and eventually converging to zero (the lower right of Fig. 1). The main reason for this situation is that the government's efforts in urbanization and FDI have a significant driving effect on their own developments in the short-term. The effect is immediate, but the long-term effect it generates is limited. To maintain the steady progress of urbanization development and the sustainable growth of FDI, the government should formulate a long-term development plan. The impact of a standard deviation from urbanization on FDI inflows is similar to the impact of FDI shocks on urbanization (the lower left of Fig. 1). On the whole, although there is a benign cycle between urbanization and FDI, there is a certain lag of the effects from the time of their appearance to the time of their actual functioning. Based on the above results, it can be seen that the impacts of FDI and urbanization all have obvious short-term effects, and there are significant cumulative effects in a certain period. In addition, the positive impact of the shocks from urbanization on urbanization is slightly less than the impact of FDI on FDI, and the positive impact of urbanization on FDI is much smaller than the positive impact of FDI on urbanization.

Variance decomposition is used to further examine the degrees of mutual influences between the variables. We derive the contribution of the shock response of each equation in the PVAR(2) system to the fluctuation of each variable. The error variance decomposition results for each variable during the forecast phase are listed in Table 4.

From Table 4, we can see that the forecast error variance of urbanization in the first phase originates from itself and has nothing to do with FDI. Thereafter, the contribution of urbanization to the error variance increases slowly, and the contribution of FDI to the error variance decreases slowly. In the final period, the contributions of the two are 89.54% and 10.46% respectively, and there is still a large gap, which shows that, in the long run, the main driving force of urbanization comes from the government's strong investment in urbanization, and the role played by FDI is very limited. In addition, the forecast error variance of FDI in the first phase comes both from urbanization and from itself, and the contributions of the two are 1.33% and 98.67%, respectively. Thereafter, the contribution of urbanization construction to the error variance increases sharply, and the contribution of FDI to error variance decreases sharply. In the final phase, the contributions of the two are 39.96% and 60.04%, respectively, and the gap between the two has been greatly reduced, which shows that, in the long term, in addition to the active role played by FDI on itself, the positive impact of the government on urbanization has become more and more obvious. This is mainly due to the increase of the urbanization level, although this effect is not obvious in the short-term, but it can create good conditions for the introduction of the foreign investments in the long term. The higher the urbanization level, the more concentrated the foreign investments. For example, cities such as Beijing, Shanghai, and Shenzhen in China have become China's top places for attracting foreign investments, mainly because of the tremendous achievements these cities have made in terms of urbanization. Furthermore, the results in Table 4 also indicate that FDI inflows have played a minor role in enhancing the level of urbanization, while the improvement of urbanization has played a positive role in the introduction of FDI, which further confirms the estimated results of PVAR and the impulse responses. Overall, the development of the new urbanization has formed a positive interaction with the local FDI inflows. The economic and social developments, the improvements of the living environment, and the integration of urban and rural areas, which are brought about by the new urbanization, have greatly improved the urban investment environment and increased the attractiveness of foreign capital in Chinese cities. Moreover, the inflows of FDI will further promote the optimization of the industrial structure of each city, the economic and social developments, and the improvements of urbanization.

Table 4 Variance decomposition of the variables

Variance decomposition		Phase 1 (%)	Phase 5 (%)	Phase 10 (%)	Phase 15 (%)	Phase 20 (%)
Variance decomposition of ln(*indices*)	ln(*indices*)	100	93.83	90.62	89.78	89.54
	ln(*fdi*)	0	6.17	9.38	10.22	10.46
Variance decomposition of ln(*fdi*)	ln(*indices*)	1.33	27.28	36.99	39.31	39.96
	ln(*fdi*)	98.67	72.72	63.01	60.69	60.04

5 Dynamic interactions between FDI and urbanization based on the spatial dynamic panel model

The geospatial factors are introduced in this section, and the dynamic linkages and impacts between FDI, urbanization and their locations are explored after measuring the spatial correlations between FDI and urbanization. The agglomeration of the above two variables' spatial distributions is calculated based on the global space Moran's index, and the calculation method is as follows:

$$Moran's\ I = \frac{\sum_{i=1}^{n} \sum_{j=1}^{n} W_{ij}(g_i - \bar{g})(g_j - \bar{g})}{S^2 \sum_{i=1}^{n} \sum_{j=1}^{n} W_{ij}} \tag{6}$$

where $g = \{indices, fdi\}$, $i = 1, 2, \ldots, 271$, $S^2 = \frac{1}{n} \sum_{i=1}^{n} (g_i - \bar{g})^2$, $\bar{g} = \frac{1}{n} \sum_{i=1}^{n} g_i$, n is the number of the locations; W_{ij} is the matrix element of the first-order geographic adjacency matrix **W** after row normalization, and its calculation formula is $W_{ij} = w_{ij} / \sum_{j=1}^{n} w_{ij}$. When the two regions i and j have a common boundary, W_{ij} is assigned a value of 1, otherwise it is 0.

As shown in Table 5, the Moran's index of urbanization and FDI remain positive from 2003 to 2014, indicating that there is positive spatial autocorrelation[7] between them, with significant spatial spillover effects. Therefore, it is necessary to introduce geospatial factors and employ spatial econometrics methods to further analyze the dynamic relationships and interactions between urbanization and FDI. The spatial dynamic panel Durbin model is chosen in this study, mainly because the model is more comprehensive. Firstly, based on the spatial panel Durbin model, a series of tests are conducted to determine whether it degenerates into either a spatial lag model (SAR) or a spatial error model (SEM) (Elhorst 2014). Secondly, the spatial dynamic panel Durbin model allows the inclusion of the explanatory variables and the controlling variables in the spatial analysis system, which controls the variables that may exhibit either tactical interaction behavior or spatial overflow behavior to the greatest degree and increases the validity and robustness of the estimation (Yu et al. 2013). Thirdly, the spatial dependence of the variables not only reflects the relevant influences of the cities in the current period but also may be affected by the previous corresponding actions from cities (Elhorst 2012). However, due to the fact that the spatial dynamic panel Durbin model cannot be tested on the selection of the fixed effects and random effects models, it is necessary to start from the static models, judge the models according to the results of a series of hypothesis tests, select the optimal model, and extend it to a dynamic model. The spatial panel Durbin model based on a static perspective is as follows:

$$\ln(indices)_{it} = \rho_1^S \mathbf{W} \ln(indices)_{it} + \beta_1^S \ln(fdi)_{it} + \gamma_1^S \mathbf{W} \ln(fdi)_{it} + \mu_i + \nu_t + \varepsilon_{it}$$
$$\ln(fdi)_{it} = \rho_2^S \mathbf{W} \ln(fdi)_{it} + \beta_2^S \ln(indices)_{it} + \gamma_2^S \mathbf{W} \ln(indices)_{it} + \mu_i + \nu_t + \varepsilon_{it} \tag{7}$$

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[7] The Moran's index ranged from -1 to 1. If the measured Moran's I is between 0 and 1, there is a positive spatial autocorrelation, which means that the target variable is positive mutual feedback between different regions; if Moran's I is between -1 and 0, the spatial autocorrelation is negative, and the adjacent regions reflect a certain degree of "competition".

Table 5 Changes of Moran's index from 2003 to 2014

Year	Urbanization			FDI		
	Moran's index	Z value	*P* value	Moran's index	Z value	*P* value
2003	0.102	4.955	0.000	0.283	13.473	0.000
2004	0.105	5.059	0.000	0.254	11.932	0.000
2005	0.079	3.964	0.000	0.230	10.808	0.000
2006	0.124	6.135	0.000	0.241	11.236	0.000
2007	0.149	7.381	0.000	0.232	10.794	0.000
2008	0.129	6.445	0.000	0.199	9.313	0.000
2009	0.101	5.107	0.000	0.181	8.515	0.000
2010	0.089	4.578	0.000	0.146	6.890	0.000
2011	0.152	7.190	0.000	0.119	5.661	0.000
2012	0.143	6.816	0.000	0.113	5.353	0.000
2013	0.132	6.364	0.000	0.097	4.634	0.000
2014	0.097	4.770	0.000	0.091	4.404	0.000

where μ_i and v_t indicate the fixed effects of area and period respectively; ε_{it} is the residual item; superscript S indicates static; and the superscript D that appears later indicates the dynamics.

Table 6 shows that the spatial autocorrelation coefficients ρ_1^S and ρ_2^S pass the 1% significance test, indicating that the spatial econometric model is valid. After that, Wald and LR tests are employed to verify whether the space panel Durbin model can be degenerated to either a SAR or a SEM. The test results reject the original hypothesis at a significance level of 1%, illustrating that the two effects of spatial lag and spatial error exist simultaneously and verifying the rationality of the space panel Durbin model.[8] Furthermore, the Hausman test is used to determine whether to use a fixed effect or a random effect model. The Hausman test results show that the *P* values are all lower than 0.01, indicating that there is a big difference between the fixed effect and the random effect. The selection of a fixed effect model is more accurate and reasonable. The above space panel Durbin model is extended to the spatial dynamic panel Durbin model:

$$
\begin{aligned}
\ln(indices)_{it} &= \psi_1^D \mathbf{W} \ln(indices)_{i,t-1} + \rho_1^D \mathbf{W} \ln(indices)_{it} + \beta_1^D \ln(fdi)_{it} \\
&\quad + \gamma_1^D \mathbf{W} \ln(fdi)_{it} + \mu_i + v_t + \varepsilon_{it} \\
\ln(fdi)_{it} &= \psi_2^D \mathbf{W} \ln(fdi)_{i,t-1} + \rho_2^D \mathbf{W} \ln(fdi)_{it} + \beta_2^D \ln(indices)_{it} \\
&\quad + \gamma_2^D \mathbf{W} \ln(indices)_{it} + \mu_i + v_t + \varepsilon_{it}
\end{aligned}
\tag{8}
$$

The estimation results of Eq. 1 in Table 7 show that, under the spatial–temporal two-dimensional perspective, the current spatial lag coefficient ρ_1^D of urbanization and the

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[8] Using Wald and LR test methods, it can be determined both whether the spatial Durbin model degenerates into a spatial error model through testing $\gamma = -\rho\beta$ and whether it degenerates into a spatial lag model through testing $\gamma = 0$.

spatial lag coefficient ψ_1^D in the previous phase are both significantly positive, indicating that the urbanization of the neighboring cities has a promotional effect on the local towns in both the current and the previous periods. β_1^D is significantly positive, indicating that the city's FDI inflow has a positive effect on the urbanization in the city, and γ_1^D is significantly negative, indicating that FDI in neighboring cities will play a certain role in suppressing the urbanization in the region. When FDI is used as an explanatory variable (Eq. 2), FDI of the neighboring cities in both the current and the previous periods will promote FDI in the region, indicating that an FDI inflow in a city will have spillover effects and benefit the surrounding cities. β_2^D is significantly positive, indicating that the urbanization in the region is conducive to increasing the utilization of the foreign capital in the region, and γ_2^D is significantly negative, indicating that the higher the level of the urbanization in the neighboring cities, the greater the threat to the introduction of FDI in the region, and the less favorable the effect of urbanization on attracting FDI in the region.

Due to the spatial lag terms existing in the spatial dynamic panel Durbin model, the coefficient signs and significance of the lag coefficient estimates are valid, but the magnitudes cannot represent the independent variable's influences on the dependent variables. Therefore, statistics, such as the direct and indirect effects, need to be used to test the spatial effect. There are two direct effects. The one is the impact of local FDI inflow on local urbanization, and this effect includes the spatial feedback effect. The spatial feedback effect means that the neighboring urbanization reacts to the local urbanization, after the local urbanization affects the neighboring urbanization. The other is the impact of local urbanization on local FDI inflow, and this effect includes also the similar spatial feedback effect. The indirect effect is the impact of the change in FDI inflow level (urbanization level) on the level of urbanization (FDI inflow level) in other areas, that is, the spatial spillover effect of the influencing factors. Since it is based on a dynamic perspective, the direct and indirect effects can be divided into long-term effects and short-term effects in the time dimension, reflecting the short-term immediate impact of the independent variable on the dependent variable, and taking the long-term effects of time lag into account. The results in Table 7 show that FDI inflows are beneficial to the local urbanization both in the long-term and the short-term. However, the local FDI inflow can generate a negative effect on the urbanization of neighboring cities, and this indirect effect enhances in the process of evolution from short-term to long- term. This shows that the accumulation of FDI can promote the (negative) indirect effect, which tends to lead to an increase in the urbanization gap between adjacent cities. In addition, urbanization also has a direct spatial effect similar to that of FDI, but its short-term direct effects are greater than the long-term direct effects, indicating that the role of urbanization in FDI inflow has weakened over time, and the foreign investments need to be increased through continuous improvement of the level of urbanization.

In general, the direct effects between FDI and urbanization are consistent with the results of the PVAR model, and they confirm each other: FDI brings forward positive incentives for the improvements of the urbanization level, and the full utilization of FDI contributes to urbanization, while, at the same time, urbanization development has also played a significant role in promoting FDI inflows, and the continuous advancement of urbanization is conducive to attracting more foreign capital. As far as the indirect effects are concerned, this study further confirms that FDI inflows into neighboring cities are not conducive to local urbanization but are beneficial to FDI inflows into the local and neighboring cities. Similarly, urbanization in the neighboring cities will inhibit the local FDI inflows but promote the local urbanization. The reason for the negative indirect effect may be the "reverse flow" of the resources. FDI inflows can easily cause the "reverse flow"

Table 6 Estimation results of the spatial dubin model and the related hypothesis test

Explained variable	$\ln(indices)_{it}$		Explained variable	$\ln(fdi)_{it}$	
Model selection	FE	RE	Model selection	FE	RE
β_1^S	0.016**	0.136***	β_2^S	0.079*	0.919***
	(0.007)	(0.009)		(0.041)	(0.035)
γ_1^S	−0.068**	0.232***	γ_2^S	−0.114	−0.617***
	(0.026)	(0.027)		(0.133)	(0.066)
ρ_1^S	0.324***	0.337***	ρ_2^S	0.483***	0.855***
	(0.054)	(0.056)		(0.052)	(0.042)
σ^2	0.081***	0.117***	σ^2	0.453***	0.592***
	(0.002)	(0.003)		(0.011)	(0.016)
Hausman test	Chi2 = 164.83	Hausman test		Chi2 = 212.64	
	Prob >= chi2 = 0.000			Prob >= chi2 = 0.000	
Wald test	Chi2 = 6.63	Chi2 = 72.87	Wald test	Chi2 = 129.5	Chi2 = 74.30
	Prob > chi2	Prob > chi2		Prob > chi2	Prob > chi2
	= 0.010	= 0.000		= 0.000	= 0.000
LR test	Chi2 = 5.86	Chi2 = 152.2	LR test	Chi2 = 179.4	Chi2 = 12.52
	Prob > chi2	Prob > chi2		Prob > chi2	Prob > chi2
	= 0.016	= 0.000		= 0.000	= 0.000

FE indicates a fixed effect model, *RE* indicates a random effect model

*, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively; the numbers in parentheses represent the corresponding standard errors of the coefficients

of all kinds of resources from areas with low levels of urbanization to areas with higher levels, thereby inhibiting the urbanization of neighboring areas, and increasing the urbanization level will induce FDI resources in neighboring cities to "reverse flow" to the local areas, which inhibits FDI inflows into the neighboring cities.

6 Conclusions and policy recommendations

Based on the panel data of 271 cities in China from 2003 to 2014, this study explores the intrinsic links and interactions between foreign direct investment (FDI) and the new urbanization from the dynamic interaction perspective through panel vector autoregression and the spatial dynamic panel Durbin model. The main conclusions of this paper are as follows: (1) From the perspective of new urbanization, the increase in the proportion of the urban population, and the growth of the economy are no longer the main issues of China's urbanization; the environment, medical care, and education have gradually become important factors in the evolution process. (2) From the perspective of dynamic relationship between urbanization and FDI, the development of the new urbanization has formed a positive interaction with the local FDI inflows. The economic and social developments, the improvements of the living environment, and the integration of urban and rural areas, which are brought about by the new urbanization, have greatly improved the urban

Table 7 Dynamic estimation results and direct–indirect effects

Explained variable	ln(*indices*) Equation 1 Coefficient		Explained variable	ln(*fdi*) Equation 2 Coefficient	
Time–space lag variable	ψ_1^D	0.208***	Time–space lag variable	ψ_2^D	0.571***
		(0.069)			(0.075)
Main explanatory variables	β_1^D	0.018**	Main explanatory variables	β_2^D	0.112***
		(0.008)			(0.041)
Spacial lag variable	γ_1^D	−0.107***	Spacial lag variable	γ_2^D	−0.705***
		(0.031)			(0.152)
ρ	ρ_1^D	0.272***	ρ	ρ_2^D	0.228***
		(0.061)			(0.066)
Short term	Direct	0.016**	Short term	Direct	0.103***
		(0.008)			(0.040)
	Indirect	−0.054***		Indirect	−0.353***
		(0.016)			(0.076)
Long term	Direct	0.015**	Long term	Direct	0.082**
		(0.009)			(0.041)
	Indirect	−0.059***		Indirect	−0.485
		(0.018)			(0.538)

*, **, and *** indicate statistically significant at the 10%, 5%, and 1% levels respectively; the numbers in the parentheses represent the corresponding standard errors of the coefficients

investment environment and increased the attractiveness of foreign capital in Chinese cities. Moreover, the inflows of FDI will further promote the optimization of the industrial structure of each city, the economic and social developments, and the improvements of urbanization. (3) From the perspective of urban spatial correlation, FDI inflows into neighboring cities are not conducive to local urbanization but are beneficial to FDI inflows into the local and neighboring cities. Similarly, urbanization in the neighboring cities will inhibit the local FDI inflows but promote the local urbanization. Therefore, according to the conclusions of this study, the following policy recommendations are proposed:

Firstly, in terms of attracting foreign investments, raising the urbanization level should be the work focus of each city. The existence of spatial dependence effects of inter-city FDI indicates that spatial interactions among the neighboring cities will significantly affect the distributions of FDI. When FDI flows into a city, it will not only affect and benefit the influx of FDI in the neighboring cities but will also hinder the urbanization of the neighboring cities, making it difficult to maintain a healthy and sustainable way of attracting foreign investments. Therefore, cities should actively promote cooperation with their neighboring cities and create, through urbanization cooperation, a win–win situation as regards FDI utilization.

Secondly, in terms of advancing the new urbanization, the rational introduction and use of high-quality FDI is the key. Although FDI agglomeration will have a certain positive radiating effect on the FDI inflows in the neighboring areas, it will inhibit the new urbanization developments of the surrounding areas. Therefore, cities should minimize the introduction of FDI with high natural resource consumption, high environmental pollution, and low value-creation. It is necessary for cities to cooperate with their neighboring cities—this can amplify the spillover effects in the whole region and minimize

the negative effects on the new urbanization of the surrounding cities. Against the current background of China's urbanization still lagging behind its industrialization to a certain extent, urbanization cooperation and rational FDI utilization are of great significance in promoting the process of the new urbanization and enhancing the overall strength of the city, thereby maintaining national benign development.

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