

Innovation-based urbanization: Evidence from 270 cities at the prefecture level or above in China

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Abstract: With the rapid development of knowledge economy, a number of important shifts are emerging in urbanization pattern across the world. Traditional urbanization theory has become hard to interpret these changes on a global scale, and “innovation” is a core concept to explain the new changes of the urbanization dynamics. As one of the important contents of urban geography, urbanization dynamic needs to turn from the general population flows between rural and urban areas into emphasizing high skilled migrants flow among cities and regions research. Against this background, we propose a conception of innovation-based urbanization. Using this concept, this study analyzes the spatial distribution characteristics of high skilled migrants and cultural diversity on urban innovation in China, based on the data of the sixth census of 270 cities at the prefecture level or above in China. This study measures the extent to which highly skilled migrants and cultural diversity increase urban innovation, by using spatial Durbin method to construct urban innovation regression model, to support the concept of innovation-based urbanization. The result shows that: first of all, the concept of innovation-based urbanization conforms to the development of knowledge economy, which emphasizes the migration process of highly skilled labor to cities. It helps to promote the changes in urban functions and landscapes and the expansion of urban knowledge activities, which undelines new dynamics of urban development, innovative landscape. Secondly, innovation urbanization based on highly skilled migrants flow is an important driving force for the development of Chinese cities, especially for eastern coastal cities and capital cities. Thirdly, the scale of highly skilled migrants flow and the level of urban cultural diversity in China both have been demonstrated of having positive effect on urban innovation output. With other conditions unchanged, a 10% increase in the number of urban highly skilled migrants and urban cultural diversity will directly result in an increase of 3% and 2% in urban innovation output respectively. This research has deepened our understanding and awareness of the openness and dynamics of the regional innovation system, and it has also provided an important theoretical basis for the formulation of urbanization and urban development policy under knowledge economy.

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1 Introduction

Since the 1980s, with the development of globalization and information technology, “space of flows” has replaced “space of places”, the flow and spatial configurations of production factors such as labor, capital, information, and technology on a global scale have a profound impact on the process of urbanization (Wu *et al.*, 2013). Post-Fordism capitalism is entering a new stage; “knowledge economy”, “information economy”, “creative economy”, “cognitive capitalism” and “cognitive-cultural economy” show that the new institutions are emerging in the world, the capitalist development of cognitive-cultural economy has brought about the third wave of urbanization and spatial development (Scott, 2014). New urbanization phenomena such as “high-tech urbanization” (Castells and Hall, 1994), “creative and knowledge urbanism” (Siemiatycki, 2013) and “entrepreneurial urbanization” (Datta, 2015) are emerging in cities of different countries around the world, which can be divided into two stages (Rossi and Bella, 2017). Firstly, in the early stage of “post-Fordism”, with the capitalist mode of production shifted from Ford’s mass production model to a flexible production, a series of “new industrial zones” and “new industrial spaces” appeared and developed. High-tech urbanization represented by the “Siliconization” model expands on a global scale and shapes new urban spaces. Secondly, since the 21st century, with the development of the new economy, new industries and firm start-ups have a growing impact on economic growth and urban development. Meanwhile, cities in the third wave have shown a high degree of innovative characteristics, which are seen as innovative, creative places and innovation machines (Shearmur, 2012; Florida *et al.*, 2017). However, this kind of changes of urban development and innovation landscape require better theoretical frameworks.

The manifestation of innovation is the dynamic agglomeration and diffusion of innovative elements in cities and regions, forming and shaping the innovative space and landscape of the city (Schoenberger and Walker, 2016). Highly skilled labor force is one of the core elements of innovation and is the foundation of knowledge economy and creative economy development (Scott, 2008). Compared with the general workforce, highly skilled labor has higher mobility characteristics (Storper and Scott, 2009). The movement and migration of highly skilled labor on different spatial scales have different effects on urban innovation: on the one hand, the movement of highly skilled labor among enterprises, universities, scientific research institutions, governments and other organizations constitutes the core mechanism of regional collective learning and knowledge transfer, which is the basis for the dynamic development of high-tech industrial clusters and regional innovation systems (Trippel and Maier, 2010; Asheim *et al.*, 2011). On the other hand, the international and global migration of highly skilled labor has contributed to the development of regional innovation systems in developing countries (Sternberg and Müller, 2010), such as Beijing (Saxenian, 2006) and Shanghai (Sternberg and Müller, 2005). The migration of highly skilled labor has become an important factor in the cross-border linkages and integration of regional, national and international innovation systems (Trippel, 2010; Cooke, 2011). International studies on the relationship between population migration and urban innovation mainly focus on the

following issues: the measurement of the innovation impact of international migration on national and domestic region, urban or local areas; the impact of international migration on different types of innovation; the in-depth measurement of the impact of different migration groups, especially highly skilled or highly educated migrants on innovation, based on their education level and occupation (Bosetti *et al.*, 2015; Gagliardi, 2015); the exploration of the impact of international migration on regional, urban, and corporate innovation, from the perspective of cultural diversity (Niebuh, 2010; Lee, 2014); the research of the channels and mechanisms through which population migration acts on innovation, such as the study of the relationship between human capital flow, innovation cooperative networks and innovation diffusion (Saxenian, 2005; Miguélez and Moreno, 2013). Chinese scholars have conducted extensive research on the spatial characteristics and reasons of China's population migration (Ding *et al.*, 2005; Pu *et al.*, 2016). Some studies have focused on the economic and social effects of population migration (Yang and Ning, 2015; Li and Miao, 2017). However, at present, these researches have paid limited attention to the innovative effect of population migration, and there is no systematic research result on population migration and urban innovation yet. Scholars simulated the spatial diffusion of technology brought about by labor migration (Gu and Wang, 2014). Xu and Lyu (2016) selected some cities above the prefecture level in China as the research object and analyzed the relationship between urban population migration and urban innovation, but has not effectively distinguished the heterogeneity of the migrating population. Ma (2017) discussed the construction of the relationship between talent migration and urban network. On the whole, the existing researches on population migration and urban innovation still have the following problems: firstly, the research is currently dominated mainly by developed countries, some well-known high-tech areas or cities such as Silicon Valley, and relevant research on developing countries is still limited. Secondly, existing study focuses on the impact of migration on innovation across different countries, and there is a lack of research on the impact of innovation across different cities within one specific country. Thirdly, there is still no systematic research framework on the relationship between population (an important carrier of "flow") and urban innovation.

Since the reform and opening up in 1978, China's urbanization has developed rapidly at an unprecedented speed and scale, and the number and size of cities have increased dramatically (Chen *et al.*, 2009). With the rise of urban agglomerations represented by the three major urban agglomerations of the Yangtze River Delta, the Pearl River Delta, and the Beijing-Tianjin-Hebei, high-tech industries, knowledge-intensive business services, cultural and creative industries and e-commerce are developing rapidly in the above-mentioned urban agglomerations and other developed cities, which have an increasingly significant impact on urban space and development (Ning, 2011; Shen *et al.*, 2015). The third wave of urbanization has gradually emerged in China's major urban agglomerations. The state has implemented a new urbanization strategy and shifted its strategy into "people-focused" urbanization. The driving force of urbanization is also undergoing tremendous changes, which changed from "export-oriented urbanization" (Wu and Gu, 2005; Gu and Wu, 2008) to the development of tertiary industry and modern service industry, and these changes have promoted the development of urbanization (Wang *et al.*, 2013; Wang *et al.*, 2015). Culture has

also become the driving force of urbanization and urban cultural capital has become a new driving force for urban development (Zhang, 2010; Yu, 2012). Innovation with human capital and intellectual capital as the core has become the new motivation of urbanization in China (Lyu, 2010; 2017). Under these circumstances, the perspective of urbanization also needs to change. Friedmann pointed out that traditional research methods from the perspective of township advantages can hardly produce new perspectives, and urbanization research in China needs to be transformed into an “urban perspective” (Friedmann, 2006). By only emphasizing the traditional concept of urbanization of rural population, it is difficult to explain the new changes of urbanization, and it cannot reflect the new driving force and mechanism of contemporary urbanization. Therefore, there is a need to shift the research from the flow of population from rural to urban areas in China to the research of the changes of urban innovation space and landscape brought about by cross-city and cross-regional flows of highly skilled labor.

Based on the above analysis, this paper proposes an innovation-based urbanization concept. Using data from 270 prefecture-level cities or above in China, it analyzes the migration of highly skilled labor and the accompanying multicultural convergence on the development of urban innovation in China, which have validated the theory of innovation-based urbanization.

2 Theoretical framework and research hypothesis

2.1 Defining innovation-based urbanization

Traditional urbanization refers to a complex process in which the population continuously flows from the countryside to cities and towns, which includes three aspects (Pacione, 2001): the increases of the proportion of urban population in the total population; the increase of the population of cities and towns; the expansion of the social and behavioral characteristics of urban life throughout the whole society. Traditional urbanization mainly reflects the migration of rural population to cities, and it takes urbanization rate as the index to measure the urbanization of a region. Obviously, the concept of traditional urbanization has great shortcomings under the knowledge economy. Firstly, the background of modern urbanization is the era of knowledge economy rather than the industrial society, therefore, for developed countries and regions, the population migration is mainly no longer the migration of rural population to the urban population, but it is the migration between cities. Secondly, the urbanization rate in developed countries and regions has reached above 70%, so this concept can no longer explain the new driving forces and new mechanisms for the development of cities and towns in these countries and regions.

Based on the above reasons, combined with the characteristics of the knowledge economy era, we propose the concept of innovation-based urbanization, which refers to the process of migration of highly skilled labor to cities, leading to changes in urban functions and landscapes and expansion of urban knowledge activities and behaviors. Urbanization based on innovation has three connotations: the increase of highly skilled labor force in cities and towns and the increase of its proportion among the total population; the changes of urban landscape caused by innovation and creativity (innovation space); the spread and expansion

of urban knowledge activities and innovation behaviors. Innovation-based urbanization focuses more on the spatial migration of highly skilled labor force and the innovation effects it brings. Its formation mechanism is summarized as follows: highly skilled labor entering into the city; people of different cultural backgrounds gathered and producing different ideas; new norms, ideas, and values are created and tremendous innovation energy is released through fierce conflicts, integration and communication. From this view, we can look at urbanization as an innovation process, and the migration of highly skilled population promotes the continuous formation and development of urban innovation landscape.

Following different social and economic development stages and the flow of urbanization elements, the urbanization process has the characteristics of stage, which can be divided into three stages. The first stage is rural urbanization, the background of which is the establishment and development of the Ford industrial city and population migrate mainly from the rural to cities and towns. The second stage is cross-region urbanization. With the shift of industrial cities to post-Fordism and service-oriented society, population migration occurs in a larger spatial scale cross regions mainly from cities to cities in different regions; The third stage is innovation-based urbanization. With the development of the knowledge economy, the talent inflow from cross-regional, transnational, cross-cultural and even global scale and other multi-scale has become an important driving force for urban innovation and development, and the rise and status of creative cities and innovative cities continue to improve, thus innovation-based urbanization is the advanced stage of urbanization.

There are some differences in the role that highly skilled migrating people play in cities at different stages of development. Under the economic model hypothesis, the developed and developing countries or regions are usually simplified as “North” and “South” (Krugman, 1979). In the developed and innovative “North”, highly skilled migrants are mainly engaged in innovative activities; while in the less developed “Southern” cities, highly skilled migrants are used for imitation activities (Biswas, 2015). Of course, both innovation and imitation activities require specific skills, which are also the driving force behind the migration of highly skilled labor. From a technology-intensive point of view, imitative behavior is very similar to the process of innovation, “authentic imitation process requires the same management talents, scientific and technical talents as other research” (Grossman and Helpman, 1991).

2.2 Research hypothesis

Based on the above theoretical analysis, the following two assumptions are proposed. Before setting up the hypothesis, first we define some of the concepts used in the text.

(1) Migration population. According to the indicator of the sixth national census in 2010, we define migrants by the population of households registered in other provinces and cities.

(2) Low-skilled and highly skilled migrants. Scholars generally divide the migratory population into two types of migratory groups: low-skilled labor and highly skilled labor based on the level of education. In addition to formal education, tacit knowledge and informal knowledge acquired by individuals during their work from experience and vocational training will also enhance individual capabilities, but this informal, specific knowledge or ability is difficult to measure accurately, so the formal level of education is generally used to char-

characterize these hidden abilities (Graversen and Friis-Jensen, 2001). Therefore, according to the classification of Chinese National Education series, this paper defines highly skilled migration population as the ones with a college degree or above (i.e., college specialty, undergraduate, and postgraduate), and the migration group with a degree of college specialty or below are classified as low-skilled migration population.

(3) Urban cultural diversity. Urban culture is a system of interaction between immigrant culture and urban native culture. Immigration culture is an integral part of urban culture and it constantly reshapes urban culture. Urban immigrants have established a new identity and relationship with existing urban population. The geographical relationship plays an important role in the formation of such cultural clusters (Huang, 2015). Although China is not an immigrant country, it has formed a diversified regional cultural system in the course of a long history, and regional cultural diversity is an important feature of Chinese culture (Qu and Meng, 2014). Therefore, using the diversity of the provinces of the migrating population to characterize cultural diversity, and referring to the existing studies, the improved Herfindahl index was used to measure urban cultural diversity (Niebuhr, 2010). The specific calculation formula is:

$$DIV_{it} = 1 - \sum_{k=1}^K S_{ikt}^2 \quad (1)$$

where DIV_{it} represents the cultural diversity index of the year t in i city; S_{ikt} shows the percentage of the number of migrants from k provinces (autonomous regions and municipalities directly under the Central Government) in the year t among the total population in city i , of which $K = 32$ (taking into account the availability of data, not including Hong Kong, Macau, and Taiwan).

Urbanization based on innovation emphasizes the influx of knowledge population or highly skilled population. A considerable number of existing studies have pointed out that highly skilled immigrants have a positive impact on immigration destinations through the promotion of innovation and the creation of new knowledge (Faggian *et al.*, 2017). The theory of endogenous growth points out that economic growth and productivity increase stem from the development of new knowledge, technology and innovation brought about by the enhancement of the human capital base. Many endogenous growth research have analyzed how local and interregional labor migration, especially highly skilled labor migration, supports the development and diffusion of new knowledge and new ideas (Eriksson, 2011). Based on this, the following assumptions are made:

Hypothesis 1: The highly skilled migrant population has a positive effect on urban innovation in China; the more the highly skilled labor inflow, the higher the urban innovation output.

Urbanization based on innovation points out that cultural diversity is one of the key processes of urban innovation. Empirical evidence from Western economies shows that cities with more cultural diversity have higher levels of innovation. Lee (2014) summarized five main ways of urban cultural diversity to enhance the level of corporate innovation. Florida (2002) also pointed out that the more diverse urban culture brought by highly skilled immigrants may be seen as an attractive urban environment that can attract more highly skilled labor. Based on this, hypothesis 2 is made:

Hypothesis 2: Cultural diversity has a positive effect on urban innovation in China; the

stronger the cultural diversity, the higher the output of urban innovation.

3 Research data and methods

3.1 The model of knowledge production function

Knowledge production function framework is an important tool to study regional knowledge production and innovation and knowledge spillover. Griliche is the first scholar of proposing a theoretical framework for knowledge production function to estimate the impact of R&D related factors on innovation output and linking innovation output to innovation input (Griliches, 1979). Since then, the Griliches-Jaff knowledge production function amended by Jaff has become the basis of such empirical research, and has been widely used (Jaffe, 1989). Knowledge production function believes that R&D is the most important input of knowledge innovation; other input variables include human resource capital, education level and so on (Wu, 2006). Endogenous growth theory also emphasizes the important role of high-quality human capital on the level of R&D (Romer, 1990). In addition, scholars have introduced patent trends into the knowledge production function, arguing that innovative industry has a higher patent density than services and is able to produce more patents (Li *et al.*, 2013). Based on the above empirical analysis of knowledge production function model and regional innovation input, combined with the analysis of the relationship between the size of highly skilled migration population and cultural diversity and urban innovation in the hypothesis, apart from the variables of R&D investment and human capital input, we incorporate the variables of patent, highly skilled migration population and cultural diversity into the knowledge production function. Therefore, the following regression model is preliminarily constructed:

$$\begin{aligned} \text{Log}(P_i) = & \alpha_0 + \alpha_1 \text{Log}(RD_i) + \alpha_2 \text{Log}(HIGH_i) + \alpha_3 \text{Log}(DIV_i) \\ & + \alpha_4 \text{Log}(INDUSTRY_i) + \alpha_5 \text{Log}(HC_i) + \mu_i \end{aligned} \quad (2)$$

where P_i represents the number of patent applications in city i , which is used to characterize the urban innovation output index. Patent data is the most widely used data in the field of innovation research. Despite some limitations, it is being used by a growing number of researchers for innovate research, because of the convenience of data acquisition and detailed information (Wang and Sun, 2017). In addition, regardless of whether the patent application can be approved in the end, the patent application behavior itself can reflect the degree of urban innovation activity (Cheng *et al.*, 2014). Therefore, the number of patent applications is used in the paper as the dependent variable to measure the level of urban innovation output. Considering that the transformation from innovative inputs to innovative outputs requires a certain period of time, based on the existing research, we use the data of innovative input variable indicators with a lag of one year. (2) $R\&D$ represents the investment level in R&D and we use R&D expenditure to measure it. (3) $HIGH$ is the indicator of highly skilled migration population, and we use the migration population who have college degree or above to measure it. The data are derived from the statistics table of ‘population registered in the provinces by place of residence and education level and gender from the sixth census data of the provinces, municipalities and autonomous regions in 2010. The table calculates the number of migrants who now live in different cities (districts and counties) and they

have different education level (no education, primary, lower secondary, upper secondary, and university, undergraduate and postgraduate). Although the former distinguishes the education level of the migrating population, it does not list its source provinces, resulting in the lack of access to the migration network data of the highly skilled population across cities. (4) *DIV* is the cultural diversity of the city. The data of the urban cultural diversity index are derived from the statistical tables of “the population registered in the provinces according to the current residence of the province”, which is from the sixth census data of the provinces, municipalities and autonomous regions in 2010. This table calculated the number of migrants coming from different provinces who are now residing in various cities (districts, counties), but did not distinguish their education level. Therefore, the measurement of cultural diversity index includes the total migration population and does not differentiate between highly skilled and low-skill population. (5) *INDUSTRY* is the industrial-scale level used to characterize patent tendencies, measured by the number of industrial enterprises above scale. (6) *HC* is the level of human capital, measured by the number of college students per million population (Table 1). *u* represents the error term.

Cities at the prefecture level or above in China were selected as the units of analysis. The city with missing data was removed, and the total number of samples was 270 cities. The patent application data for each city in 2010 comes from the statistical data of the municipal intellectual property offices and the patent retrieval system of the State Intellectual Property Office. R&D investment data comes from the 2009 Second National R&D Resource Inventory. All the population data are derived from the 2010 sixth census data of the provinces, municipalities and autonomous regions. The number of industrial enterprises above designated size and the number of university students per 10,000 populations are all from the ‘2010 China City Statistical Yearbook’.

Table 1 Urban innovation variables declaration

Variable		Variable definitions	Expected symbol
Urban innovation output level	<i>P</i>	Patent applications	+
R&D investment	<i>RD</i>	Research and Experimental Development (R&D) Expenditure	+
High skilled migration population	<i>HIGH</i>	Migration population with college degree or above	+
Cultural diversity	<i>DIV</i>	Cultural diversity index	+
Industrial scale	<i>INDUSTRY</i>	Number of industrial enterprises above designated size	+
Human capital level	<i>HC</i>	The number of university students per 10,000 population	+

3.2 Spatial econometric models

However, non-spatial regression models usually neglect spatial dependence or spatial correlations between variables or error terms (LeSage and Pace, 2009). Global spatial autocorrelation is commonly used to measure the overall spatial correlation of different variables. The commonly used measure indicator is the Moran's I index. The formula is:

$$I = \frac{1}{S^2} \sum_{i=1}^n \sum_{j \neq 1}^n (X_i - \bar{X})(X_j - \bar{X}) / \sum_{i=1}^n \sum_{j \neq 1}^n W_{ij} \quad (3)$$

where n is the total number of regions; \bar{X} is the average value of the samples; X_i is the observation value of the region i ; W_{ij} is the spatial weight matrix, the spatial neighboring value is 1, and the non-adjacent is 0. S^2 is $\sum_{i=1}^n (X_i - \bar{X})^2 / n$. Moran's I ranges from $[-1, 1]$, and the value tends to $+1$, indicating absolute spatial positive correlation, high or low value regions tend to cluster; tending to 0, indicating random spatial distribution; tends to -1 , indicating absolute negative correlation, the high value region is surrounded by the low value region or the low value region is surrounded by the high value region. Using the z test to perform a statistical test on Moran's I results: $Z(I) = \frac{I - E(I)}{\sqrt{\text{var}(I)}}$, where $E(I)$ is the expected value and

$\text{var}(I)$ is the coefficient of variation.

Existing research results have revealed that regional innovation variables have spatial dependence and spatial spillover effects (Elhorst, 2014). Therefore, we need to introduce spatial variables in the regression model (2) to construct a spatial econometric model. Spatial Lag Model (SLM), Spatial Error Model (SEM) and Spatial Durbin Model (SDM) are three commonly used spatial regression models. The SLM and SEM models only consider the interaction effects between the endogenous interaction effects and the interactions between the error terms, and they are non-nested. SDM nests SLM and SEM models and takes into account exogenous interaction effects.

The general equation for SDM is:

$$Y = \rho WY + \alpha \tau_N + X\beta + WX\theta + \varepsilon \quad (4)$$

where Y is an $N \times 1$ vector consisting of unit interpreted variables. X is an $N \times K$ vector consisting of explanatory variables. τ_N is an $N \times 1$ unit vector related to a constant term parameter. θ is the spatial autoregressive coefficient; β and ρ are the vector of $K \times 1$ parameters to be evaluated, WY is the endogenous interaction effect between the explanatory variables, WX is the exogenous interaction effect between the explanatory variables, and W is the $N \times N$ order spatial weight matrix, ε is the error term vector.

Because the spatial regression model incorporates the information of neighboring observations, the regression coefficient cannot be directly used to measure the relationship between the explanatory variables and the interpreted variables in a single region. It needs to be decomposed to report direct and indirect effects or spatial spillover effects. The direct effect is the average influence of the change of a particular independent variable of a spatial unit on the dependent variables of the region; if the change of this explanatory variable also causes the change in explanatory variables of other spatial units, it is called an indirect effect or a spatial spillover effect. In terms of direct effect and indirect effect, the spillover effect in the SEM model is usually zero; the spillover effect and the direct effect ratio of each explanatory variable in the SAR model are the same, and the excessive rigidity leads to the general impracticality of empirical application; the SDM model reflects the heterogeneity of the coefficient of the spatial lag term in a particular explanatory variable, and the direct and indirect effect ratios of each explanatory variable may be different (LeSage and Pace, 2009). This flexibility makes the SDM model more attractive in empirical applications. In addition, SDM is more capable of estimating unbiased coefficients when different spatial measurement models are misconfigured. The advantage of SDM has led researchers to call for shift-

ing the focus of spatial measurement from SAR and SEM, which consider only one type of interaction effect, to SDM. Based on this, the SDM model is selected, and based on formula (4), the following urban spatial regression model is constructed:

$$\begin{aligned} \text{Log}(P_i) = & \rho \sum_{j=1}^n W_{ij} P_j + \alpha_1 \text{Log}(RD_i) + \alpha_2 (\text{Log} HIGH_i) + \alpha_3 \text{Log}(DIV_i) \\ & + \alpha_4 \text{Log}(INDUSTRY_i) + \alpha_5 (\text{Log} HC_i) + \theta \sum_{j=1}^n W_{ij} X_{ij} + \varepsilon_i \end{aligned} \quad (5)$$

Each letter in formula (5) has the same meaning as the previous formulas.

4 Empirical analysis

4.1 Characteristics of spatial distribution of highly skilled migrants and urban cultural diversity

Using the data of the sixth census in 2010, the urban cultural diversity index at or above the prefecture level in China was calculated. The spatial distribution of highly skilled migrants in cities at or above the prefecture level in China (Figure 1) and space for urban cultural diversity were examined respectively (Figure 2).

It can be seen from Figure 1 that the migration of highly skilled labor force shows two characteristics: first, the eastern coastal cities have become the main inflow area; the second is that they are concentrated in the provincial capital cities. This is mainly because the capital cities are usually the center of economy, culture and innovation in a province, and thus become centers of attracting highly skilled population from other cities and regions.

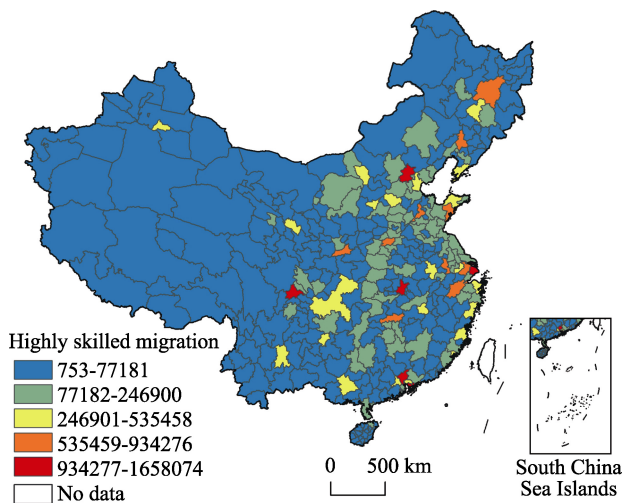


Figure 1 The spatial distribution of intercity highly skilled migration of China in 2010

It can be seen from Figure 2 that the urban cultural diversity presents different spatial distribution characteristics. First, high-cultural and multi-cultural cities are concentrated in the Yangtze River Delta and Pearl River Delta cities. The Yangtze River Delta urban agglomerations have the highest cultural diversity. In Beijing-Tianjin-Hebei urban agglomerations, Beijing, Tianjin, and Langfang also have higher levels of cultural diversity. Second, the level

of cultural diversity in China's border areas such as Inner Mongolia and northern Xinjiang is high due to migration from inland after establishing new China in 1949. Third, similar to the distribution of highly skilled populations, provincial capitals have a high level of cultural diversity.

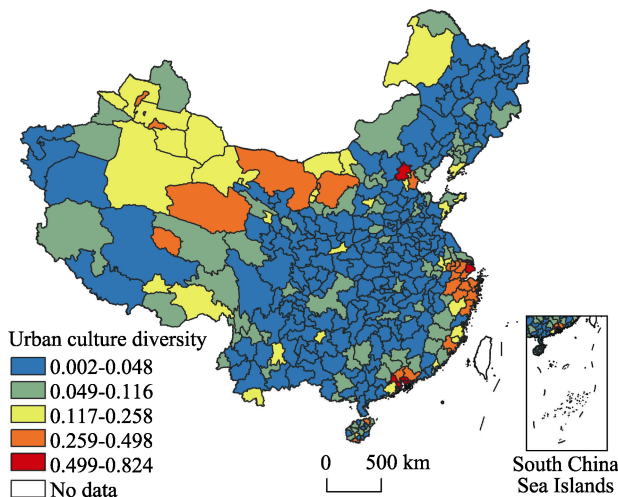


Figure 2 The spatial distribution of cultural diversity of China in 2010

4.2 Analysis of regression results

Prior to model estimation, the global Moran's *I* index for each variable was first calculated to test for the existence of spatial autocorrelation (Table 2). The results show that in addition to the HC variables, the z-statistical test values of the rest of the explained variables (*P*) and the explanatory variables (*RD*, *HIGH*, *DIV*, *INDUSTRY*) Moran's *I* index are greater than the key value of 2.576, and the statistical significance is at the 1% level. This verifies that there is a spatial correlation between innovation variables. Therefore, it is necessary to introduce spatial variables in the non-spatial regression model, that is, to use spatial econometric models.

Table 2 Moran's *I* value

Variable	Moran's <i>I</i>	<i>Z</i> value	<i>P</i> value
<i>P</i>	0.351	9.177	0
<i>RD</i>	0.23	6.048	0
<i>HIGH</i>	0.105	2.829	0.002
<i>DIV</i>	0.572	14.894	0
<i>INDUSTRY</i>	0.437	11.409	0
<i>HC</i>	0.043	1.205	0.114

Matlab (2016a) software was used to estimate the model of urban innovation space regression model. The estimated results are shown in Table 3. The model estimation results show that adjusting the R^2 statistic value is 0.885, which indicates that the regression model has a good overall fitting effect and the overall regression credibility is high.

(1) The spatial lag coefficient value of the explanatory variable *P* is 0.496, and it is significant at the 1% level, which confirms the existence of spatial spillover of innovation out-

put. The change of innovation output in a certain city will bring about the change in the innovation output of neighboring cities. With the other impact factors unchanged, the increase in innovation output per neighboring city will increase by an average of 0.496%. In addition, the spatially lagging terms $W*RD$ and $W*DIV$ of the explanatory variables are significant at the 5% and 1% levels respectively.

Table 3 Parameter estimates of SDM

Variable	Coefficient of elasticity	<i>t</i> value	Variable	Coefficient of elasticity	<i>t</i> value
<i>RD</i>	0.248***	6.985	$W*RD$	-0.137*	-1.944
<i>HIGH</i>	0.283**	4.390	$W*HIGH$	-0.045	-0.666
<i>DIV</i>	0.214***	4.241	$W*DIV$	-0.243***	-4.309
<i>INDUSTRY</i>	0.507***	7.651	$W*INDUSTRY$	-0.074	-0.681
<i>HC</i>	0.094***	2.139	$W*HC$	-0.116	-1.468
Constant term	-1.465	-6.834			
$\rho (W*P)$	0.496***	8.229			
Adjust R^2	0.885				
Log likelihood	132.309				

Note: ***, 1% levels are significant; **, 5% levels are significant; *, 10% levels are significant. Same below

(2) Due to the existence of feedback effect, the valuation of elasticity coefficient is biased, and the estimated values of direct effects and indirect effects (spatial spillover effects) need to be calculated. The estimated results are shown in Table 4. The feedback effect stems from the fact that the impact on a city can be passed on to neighboring cities and the impact of neighboring cities can be returned to the city itself. As can be seen from Table 2, the feedback effect comes from two parts: the estimation of the explanatory variable spatial hysteresis $W \times P$ coefficient and the estimated spatial lag of the explanatory variable. The direct effect of the highly skilled migration population variable is 0.297, and the elasticity coefficient is 0.283. The feedback effect value is 0.014, which is 4.7% of the direct effect. The direct effect of the cultural diversity level variable is 0.196, the elasticity coefficient is 0.214, and the feedback effect value is -0.018, which is -9.1% of the direct effect.

Table 4 Direct and indirect effect estimates of SDM

Variable	Direct effect	<i>t</i> value	Indirect effect	<i>t</i> value	Total effect	<i>t</i> value
<i>RD</i>	0.246***	6.487	-0.030	-0.237	0.215	1.473
<i>HIGH</i>	0.297***	4.475	0.190	1.321	0.487***	2.742
<i>DIV</i>	0.196***	4.211	-0.257***	-3.425	-0.061	-0.877
<i>INDUSTRY</i>	0.530***	8.418	0.333**	2.100	0.863***	5.274
<i>HC</i>	0.084*	1.821	-0.138	-0.932	-0.055	-0.320

(3) From the direct effect point of view, the regression coefficient of explanatory variables is significant and positive, which is in line with the theoretical expectations. Among them, the direct effect of the explanatory variable *HIGH* is 0.297, and it is significant at the level of 1%, confirming that Hypothesis 1 is established, that is, the migration of highly skilled population has a positive effect on urban innovation in China. Under the condition of other

influencing factors unchanged, every 10% increase of urban highly skilled population will directly increase the city's innovation output by 3%. The direct effect of the explanatory variable DIV was 0.196, and it was significant at the level of 1%, confirming that Hypothesis 2 was established, that is, the level of cultural diversity had a positive effect on urban innovation in China. Keeping other influencing factors unchanged, each increase in the level of cultural diversity by 10% will result in the increase of direct urban innovation output by 2%. An interesting phenomenon is that the direct effect of the explanatory variable HIGH is significantly higher than that of HC, which means that the contribution of highly skilled migration population to urban innovation is higher than that of local human capital, but because the university students are used to represent local human capital, this result still needs to be further explored by using more detailed data. The explanatory variable with the greatest direct effect is INDUSTRY, with a value of 0.507, which is significant at the 1% level, showing that the urban industrial size is an important factor for urban innovation output, and it also reveals the existence of patent tendency, that is, the urban innovation output is related to the urban industrial structure to some extent.

(4) From the perspective of indirect effects or spatial spillover effects, only the explanatory variables DIV and INDUSTRY have passed the 5% and 1% significance level tests, respectively, indicating that there are spatial spillover effects in the level of cultural diversity and industrial scale. The level of cultural diversity shows negative spatial spillover effect, that is, the improvement of the level of cultural diversity in a certain city has a negative effect on the innovation output of neighboring cities. The possible explanation is that a city with a high level of cultural diversity may attract innovative elements such as human resources gathering in the city, thus creating a negative effect on the innovation of surrounding cities. The level of industrial scale has a positive spatial spillover effect, which is related to industrial cooperation and transfer in neighboring regions.

5 Conclusions and discussion

This paper proposes the concept of innovation-based urbanization and conducts an empirical analysis of it. Using the sixth national census data, the statistical data of highly skilled population migration were excavated, and the spatial Durbin model method was used to construct a spatial regression model for urban innovation, and the influences of highly skilled migrant population and urban diversity levels on urban innovation output were measured. The study draws the following conclusions:

(1) Based on the major changes in the background and dynamics of social and economic development, the concept of traditional urbanization has obvious deficiencies, and it is necessary to put forward the concept of urbanization based on innovation, which conforms to the background of the development of knowledge economy, and can also explain the new impetus, new mechanisms, and new landscape of innovation in urban development. Urbanization based on innovation emphasizes the process of migration of highly skilled labor to cities, promotes changes in urban functions and landscapes and expands urban knowledge activities and behaviors. Urbanization based on innovation is the stage of advanced urbanization. Cross-regional and multinational, cross-cultural, global-scale and other multi-scale talent flow and the "innovation flow" caused by it will become the new features of urbanization in the 21st century, and have great significance for developed regions and countries in

particular. This concept of creation has also deepened the understanding and awareness of the openness and dynamics of regional innovation systems. Building on the innovation elements, the regional innovation system research emphasizes the flow of innovation actors including enterprises, universities, scientific research institutions, government and intermediary institutions across the regional innovation system, which pays less attention to the dynamic flow of innovation elements between regional innovation systems and the external innovation links brought by them. The flow of highly skilled labor not only promotes the effective integration within the main actors of innovation, but more importantly, the mobility of innovative elements, especially the mobility of highly skilled labor force, can promote communication and cooperation between regional or urban innovation system, which contributes to the interactive development of urban innovation systems.

(2) China's innovative urbanization is related to the migration of China's highly skilled population. China's highly skilled migrant population mainly flows into the eastern coastal cities, and another feature is the concentration of highly skilled population in provincial capital cities, which will drive the development of innovative urbanization in the region or city. Urban cultural diversity has a lot to do with population migration. The spatial distribution of urban cultural diversity in China presents three distinct features. First, high-cultural and multi-cultural cities are concentrated in the Yangtze River Delta and Pearl River Delta cities and Beijing, Tianjin, and Langfang also have high cultural diversity. Second, the level of cultural diversity in the border areas of China, such as Inner Mongolia and northern Xinjiang, is relatively high. Third, similar to the distribution of highly skilled populations, provincial capitals have a high level of cultural diversity. The cultural diversity based on the inflow of high-level talents will greatly promote the development of innovative urbanization, thus enhancing the level of development and competitiveness of the city.

(3) Both the highly skilled migration population and the level of urban cultural diversity have a positive effect on China's urban innovation output. With the other conditions remaining unchanged, a 10% increase of the urban highly skilled migrant population will result in 3% increase of the urban innovation output; a 10% increase of the urban cultural diversity level will result in 2% increase of the city's innovation output. This result shows that the inflow of highly skilled labor to cities can promote knowledge activities and innovation in cities. Therefore, in the era of knowledge economy, the urbanization process characterized by the migration of highly skilled labor force in different spatial scales can be regarded as an innovation process, a new driving force and a new mechanism for the new development of cities and towns, that is, urbanization based on innovation. In addition, the empirical results show that the increase of urban cultural diversity brought about by population migration is one of the mechanisms for the promotion of urban innovation by highly skilled migration. However, the improvement of urban innovation level is an integrated system, which requires the coordination and interaction of innovative elements to form a complete urban innovation system.

(4) The concept of urbanization based on innovation has important policy significance. Globally, there is a growing competition on the acquisition of cross-domain intellectual talents and highly skilled talents to make their cities competitive and innovative. Many cities in China have introduced corresponding policies to attract high-level population and promote urbanization based on innovation. Xi'an has launched the goal of "making millions of college students stay in Xi'an" for employment and entrepreneurship, and it has also introduced

and further improved 19 policy initiatives in three areas to attract college students to stay in Xi'an for employment and entrepreneurship. Changsha proposed a subsidy policy for the settlement of college students and high-level talents. Nanjing put forward a policy for high-level talents to settle down in the city. Wuhan has introduced new policies regarding hukou (residence registration), housing and income for university students to settle down, and many cities are adopting similar policies.

Of course, the study also has its limitations. Firstly, due to the difficulty of collecting data on population migration at the municipal level, this study uses the data of the sixth national census which is relatively old, and it fails to analyze the most recent relationship between migration of highly skilled populations and urban innovation. Secondly, Chinese urbanization theory should be multi-mode, multi-dimensional, and multi-scale and urbanization based on innovation is only a dimension of Chinese urbanization development. China has a large geographic area, and each region needs to choose the region's urbanization model, based on their own economic and social development stage and reality. This study will be further explored in the following aspects: firstly, analyzing the formation and changes of urban innovation landscape brought about by the migration of highly skilled labor, based on the theoretical framework of innovative urbanization, and analyzing the accumulation of highly skilled labor and urban innovation space within the city. Secondly, analyzing the global innovation effect of population migration to the entire urban population. The study focused only on the innovative effects of highly skilled labor inflows on cities, and have not yet considered the impact of the outflow of highly skilled population, as well as the combined effects of the highly skilled labor inflow to cities. Thirdly, analyzing the urban innovation mechanism brought about by the migration of highly skilled labor. The above will be an important direction for future research.

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