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Article

Foreign human capital, cultural diversity and urban innovation in China

Cui Zhang

School of economics, Jinan University, China; zzzhangcui@126.com

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Abstract: From the perspective of cross regional flow of human capital, this paper studies the impact and mechanism of foreign human capital on urban innovation in China, and reveals the innovation effect of foreign human capital. The theoretical research shows that the efficient allocation of innovation elements brought by foreign human capital and the diversified externalities associated with it are the source for cities to maintain innovation vitality and competitiveness. The empirical study matching the individual micro data of Chinese census with the urban patent data found that foreign human capital has a significant role in promoting urban innovation, especially in the innovation of invention patents with the highest technological content. Further research on the mechanism reveals that the externality of cultural diversity brought by foreign human capital is an important channel to promote urban innovation. Therefore, the absorption and integration of foreign labor is the key to the city full of innovation and vitality.

Keywords: external human capital; allocation of innovation elements; cultural diversity; creative city innovation

1. Questions raised

Urban innovation is a hot topic in recent years at home and abroad. Scholars study the factors that affect urban innovation from different angles. Among them, [1–3] studied the factors affecting urban innovation in the United States and Europe from the perspective of human capital, [4]. Lobo and Strumsky [5] and Sedgley and Elmslie [6] from the perspective of urban size or population density. Ottaviano and Peri [7] and Lee [8] from the perspective of international migration, [9] from the perspective of industrial structure.

In contrast, the research on the influencing factors of urban innovation in China has just started, and the relevant literature is very few. Cao et al. [10] conducted empirical research on four municipalities directly under the central government in China from 1997 to 2009 and found that urban economic scale and innovation investment have a significant positive impact on their innovation ability. Wang et al. [11] used the panel data of 20 major cities in China from 2007 to 2012 to test the experience and found that human capital, the concentration of employed population and the proportion of government expenditure on science, technology and education significantly promoted urban innovation.

It is worth noting that for China, an emerging market economy in the process of system transformation and rapid urbanization, a prominent phenomenon is the large-scale cross regional labor flow. During the planned economy period, China implemented a strict registered residence system to restrict the interregional mobility and migration of urban and rural residents. Since the 1980s, with the market-oriented transformation of the economic system, the single plan control system of labor factor allocation has been continuously relaxed, and the role of the registered residence

system in restricting population mobility has been greatly weakened. Market forces are playing an increasingly important role in the allocation of labor factors, and the scale of cross regional labor mobility and even broader population migration is growing. According to the national census data of the National Bureau of statistics over the years, the size of China's floating population increased from 6.57 million in 1982 to 12.1 billion in 2000, 22billion in 2010 and 24.7 billion in 2015. Among them, the proportion of highly skilled floating population with college education or above increased rapidly, from 14% in 1982 to 943% in 2000 and 1204% in 2010.

The impact of this large-scale cross regional labor flow on the economy of the inflow region has attracted the attention of many researchers, mainly focusing on the regional income gap [12–16] Employment income of local workers [17–19] and city size [20,21]. There is a relative lack of research on the impact of cross regional labor mobility, especially the cross regional mobility of highly skilled labor, on innovation in the inflow region. A large number of facts about China's urbanization show that cities with concentrated migrant population have stronger innovation ability or innovation level than other regions, which can also be found from news reports and intuitive comparison of urban economy. For example, Beijing, Shenzhen and Shanghai, which have a large number of immigrants, are listed as the cities with the highest innovation level in China, whether it is the "ranking list of China's cities with the highest innovation power" released by the new first tier cities Research Institute of first finance and economics in recent years, the "30 cities with the strongest innovation power in China" released by Forbes, or the "evaluation report on China's innovative cities" released by the China innovative cities evaluation task force.

In view of the above understanding, this paper studies the impact and mechanism of cross regional mobility of highly skilled labor on urban innovation in China from both theoretical and empirical aspects, so as to reveal the innovation effect of foreign human capital. First of all, from the perspective of spatial allocation of innovative production factors, we study the internal influence mechanism and logical connection between external human capital and innovation in the inflow cities. Secondly, the individual micro data of China census is matched with the urban patent data to test whether foreign human capital promotes urban innovation. Finally, with the help of the theory of cultural diversity, we further investigate the mechanism of external human capital on urban innovation.

Our theoretical research shows that urban innovation is an open process, which requires that the input elements of innovation should also flow and open. As an important input factor of innovation, the spatial migration and allocation of human capital affect the innovation ability and efficiency of cities. Based on the actual data of China, this paper finds that foreign human capital has a significant role in promoting urban innovation. This conclusion is still robust after adopting different regression models, different measurement indicators and investigating the endogeneity of instrumental variables (IV). Further research on the mechanism shows that the externality of cultural diversity brought by foreign human capital is an important channel to promote urban innovation.

Compared with the existing research, the innovation of this paper is mainly reflected in: first, although the importance of human capital to innovation has been demonstrated by scholars at home and abroad, the issue of "what kind of human capital

can better promote innovation" has not been specially studied. From the perspective of spatial migration and allocation of human capital, this paper examines the impact of foreign human capital on the innovation of cities in the inflow area, more objectively and carefully combs the innovation effect of human capital flow, and also clarifies an important constraint of decision-making: hindering the free flow of highly skilled labor will lead to resource mismatch in the process of innovation production, which is not conducive to urban innovation and the improvement of its efficiency.

Second, the existing research on the effect of labor mobility in China ignores the regional cultural heterogeneity of migrant labor, and thus ignores the resulting diversity externalities. From the perspective of China's regional cultural diversity, this paper studies the mechanism of foreign human capital promoting the innovation of cities in the inflow region by constructing the index of urban cultural diversity. Under the background that China's urbanization has entered a climax period and the report of the 19th National Congress of the Communist Party of China proposed "stimulating cultural innovation and creativity", this study has important theoretical and practical significance.

Third, at present, the empirical research on China's innovation is mainly limited to the national, provincial and enterprise levels, and the research on the urban level is relatively lacking, and the innovation effect at this level is precisely the expectation of China's urbanization national strategy. Compared with the existing innovation research focused on individual cities, we use the large sample patent database of the State Intellectual Property Office to sort out the city level patent data, covering all prefecture level and above cities in the country. The sample coverage is more comprehensive, which provides data support for the study of urban innovation. The conclusions also provide policy enlightenment on how to build innovative cities and stimulate urban innovation vitality.

The rest of this paper is arranged as follows: the second part is literature review and theoretical analysis; the third part is the description of samples, data and empirical models; the fourth part is regression result analysis and robustness test; the fifth part is the research on the function mechanism from the perspective of cultural diversity; the last part is the conclusion and policy enlightenment.

2. Literature review and theoretical analysis

The innovation effect of external human capital has always been one of the important topics in economic research. Saxenian [22] found in the case study of Silicon Valley that foreign immigrants are conducive to the establishment and innovation of new companies. Ottaviano and Peri [7] conducted a panel data study based on American cities, which showed that the inflow of foreigners to the United States had a positive impact on American productivity, especially on the highly skilled labor force. Peri [23] also found that overseas immigrants promoted the improvement of total factor productivity in American states based on the U.S. census data. In addition, [1] studied the innovation effect of the cross regional flow of British college graduates based on the questionnaire survey of the Bureau of higher education statistics and patent data, and found that London and Scotland, as the main places of inflow of graduates, benefited the most. Hunt and Loiselle [24] conducted a study on

the innovation effect of American immigrants based on state panel data and found that every 1% increase in the proportion of immigrants with college degree or above can promote the increase of per capita patents by 9%–18%. Lee [8] used 2000 small and medium-sized enterprises in the UK to investigate the impact of foreign entrepreneurs on the innovation of their enterprises, and found that enterprises with foreign entrepreneurs or partners are more inclined to develop new products and new production processes. Similarly, Bosetti et al. [25] conducted empirical research on 20 European countries and found that highly skilled immigrants with college degree or above promoted the increase of patent applications in the inflow countries. Fassio et al. [26] also found in their empirical research on Britain, France and Germany that highly skilled immigrants with college degree or above can increase patent innovation by 009 percentage points in the inflow countries.

However, most of the existing studies on the innovation effect of foreign human capital are based on the international migration of developed countries, and lack of studies focusing on the transitional and developing economies such as China. In view of this, this paper takes China, where the labor market is relatively closed to the outside world, as an example to examine the innovative value that the interregional flow of domestic labor brings to the inflow cities. From a new perspective of cultural diversity, this paper studies the mechanism of foreign human capital promoting innovation in inflow areas by constructing relevant indicators to supplement the existing research.

Before carrying out empirical research, it is necessary to make a theoretical analysis on the innovation effect of external human capital. As a key input factor and an important carrier of knowledge in the process of knowledge production, human capital plays an important role in knowledge creation and innovation in a region. Its cross regional flow largely determines the efficiency of resource allocation and innovation results in the process of innovation.

First, external human capital contributes to knowledge spillover and diffusion. An important source of innovation is knowledge spillover, which is essentially a regional and local phenomenon, that is, knowledge spillover decreases with the expansion of geographical scope. As an important carrier of technical knowledge, especially tacit knowledge, cross regional mobility of highly skilled labor force can undoubtedly promote the spatial proximity of human capital, increase face-to-face contact and interaction, reduce the exchange cost of knowledge information, especially tacit knowledge, and promote the diffusion and overflow of knowledge and ideas. As Marshall [27] mentioned in his classic book Principles of economics, "when a person has a new idea, it will soon be absorbed by others and combined with their own experience to generate more new ideas." The interaction between people, knowledge exchange and their previous experience constitute the local knowledge base, which in turn contributes to the generation of new local knowledge.

One of the typical cases in this regard is Silicon Valley in the United States. Saxenian [22] pointed out in his research on Silicon Valley that the flow of highly skilled labor plays an important role in the establishment and innovation of new companies in Silicon Valley. By comparing Silicon Valley and Boston Highway 128, two computer industry clusters, Saxenian found that compared with the isolated internal technology R & D and transformation of enterprises in Boston highway 128 area, the "job hopping" culture in Silicon Valley created conditions for the flow and

diffusion of knowledge and technology among enterprises, which was conducive to industrial expansion and growth, and finally contributed to the innovation boom in Silicon Valley. Moreover, as an international open community, about half of Silicon Valley's high-tech enterprises have immigrants in their innovation teams, which not only promotes the cross-border flow of knowledge, but also expands the scope and ways for enterprises to acquire new knowledge and ideas.

Secondly, external human capital can also increase the supply of human capital in the inflow area and expand the human capital pool, which is conducive to knowledge creation. On the one hand, from the input and output of knowledge production and innovation, the increase of human capital input will undoubtedly improve innovation output. More importantly, knowledge production and innovation is an open process. This openness also requires that the input elements of innovation (such as human capital) flow freely, introducing and applying new ideas and insights from outside to the local market, so as to promote innovation; at the same time, it can avoid duplicating the existing innovations in other regions and improve innovation efficiency. From this point of view, human capital flows connect knowledge production and innovation everywhere, forming an interdependent and interactive network. On the other hand, an interactive mode of two-way learning and co creation can be formed between foreign human capital and local human capital. In fact, as the research problems and technical bottlenecks in the real world become more and more complex, the era of personal invention and creation has been gradually replaced by team creation with different backgrounds and diverse knowledge perspectives. Innovation is no longer a closed process. The diversity of research teams has become a key factor in innovation. When the foreign high skilled labor force and the local high skilled labor force work together, they can gain experience and knowledge from each other and enrich each other's knowledge base. In other words, the knowledge flow between external and local human capital is not one-way, but interactive and two-way, forming a kind of cumulative learning effects emphasized by ACS and Audretsch [28]. Innovation is the result of the interaction between human capital and knowledge spillovers.

Finally, foreign human capital can also help to improve the innovation ability of enterprises in the inflow area, and then promote the innovation of their industries (The author thanks anonymous reviewers for their suggestions.). From the classical labor demand and supply theory, human capital is an important input factor of innovation, and the success of enterprise innovation largely depends on the availability of appropriate labor. The inflow of external human capital can increase the supply of labor factors in the cities where it flows into, expand the local human capital pool, provide more new choices for local market enterprises, better meet the needs of enterprise innovation for talents, and improve the matching quantity and quality between enterprises and human capital, thus contributing to the improvement of enterprise innovation ability. At the same time, foreign human capital is also an important source of local entrepreneurs. The level of entrepreneurs' human capital directly affects enterprise innovation [29], and the improvement of enterprises' innovation ability undoubtedly further promotes the improvement of the innovation level of their industries.

In addition, there is significant skill complementarity between highly skilled labor forces [30]. A large human capital pool facilitates local highly skilled labor forces to find partners with the same skills or at the same level, reduces the search cost of professional skills, and realizes skill complementarity and matching between the two. Since the output of the combination between high skilled labor is usually greater than that between high skilled labor and low skilled labor or between low skilled labor and low skilled labor [31], the innovation output level and efficiency of enterprises with more high skilled labor inflows are correspondingly higher.

Through the above theoretical analysis, it is not difficult to see that the cross regional flow of human capital plays an important role in promoting the innovation of the inflow cities. As an important input factor of innovation, the spatial migration and allocation of human capital affect the innovation ability and efficiency of cities to a great extent. Next, this paper will carry out empirical research on the urban innovation effect of foreign human capital by constructing an econometric model and using China's actual data.

3. Empirical model, variable definition and estimation method

3.1. Model setting, variable definition and data source

In order to further quantify the urban innovation effect of human capital flow, we matched the individual micro data of the Chinese census with the urban patent data to build the following measurement model:

$$\ln P_{ct} = \theta Mhc_{ct} + \boldsymbol{\beta}' \boldsymbol{Controls}_{ct} + \alpha_c + \gamma_t + \varepsilon_{ct} \quad (1)$$

Among P_{ct} them, it represents the innovation output of City C in year t, specifically measured by patent intensity, that is, the number of patent applications per capita, which reflects the innovation efficiency of a Mhc_{ct}city; indicates the level of external human capital that city C has in T, which is measured by the proportion of the external population with college degree or above in the $\alpha_c$total urban population; indicates the unobserved factors related to the specific $\gamma_t$city C; represents the ε_{ct}time effect; is the error interference term. Controlsct represents other control vectors that affect urban innovation output. Specifically, it is consistent with the research of [24,25], including the local human capital level (localhc) of City C in T, which is measured by the proportion of local people with college degree or above in the total urban population, and the total human capital of the city is expressed in HC; the openness of the city is measured by the proportion of the actually used foreign capital in the city's regional GDP (FDI share) and freight volume (freight); number of colleges and universities; *s* & *T* spending; industrial structure (Indus), measured by the proportion of the secondary industry in the city's regional GDP; population density, expressed by the number of people per square kilometer of land area; the level of urban economic development (gdpper) is measured by per capita GDP.

The patent data used to measure urban innovation in this paper comes from the State Intellectual Property Office. The database contains all patents applied by China in 2000 and 2005 (invention patents, utility model patents, and design patents). We use the address of the applicant to calculate the number of patent applications at the city level (According to China's patent law, patent applications are filed according to actual innovation.). The number of migrant populations with college degree or above and the number of local populations are from the micro data of the 2000 and 2005 national population censuses. Consistent with the methods of [24,25], we selected all the workforce in the working age group (16–65 years old).

Since China implements a strict registered residence system to control and restrict the flow and migration of labor, we use the location of registered residence as the judgment standard for the floating population by referring to the practice of the National Bureau of statistics and the existing literature on labor mobility in China [16]. Specifically, the micro data of the 2000 and 2005 national censuses respectively reported the education level and household registration provinces of each person. There were 31 provinces, autonomous regions and municipalities directly under the central government except Hong Kong, Macao and Taiwan, China. If the registered permanent residence of highly skilled workers is not in the province, it is defined as migrant population. The data of other control variables are from China Urban Statistical Yearbook, and the urban statistical caliber is prefecture level and above cities. See **Table 1** for statistical description of main variables.

Table 1. Statistical description of main variables.

Variable	Number of samples	Mean value	Standard deviation	Minimum value	Maximum
ln P	486	049	062	001	470
Mhc (%)	509	017	052	000	730
Localhc (%)	509	591	376	082	2272
HC (%)	509	608	400	119	2786
FDI Share (%)	476	256	374	000	4540
ln Freight	486	828	084	576	1117
ln College	480	136	088	000	438
S&T Spending (%)	507	1675	602	198	4974
Indus (%)	484	4543	1180	1570	8970
ln Density	486	579	079	277	789
ln gdpper	484	918	076	773	1251

3.2. Model identification and estimation methods

Since the proportion of foreign highly skilled labor force (mhcct) in the regression model (1) may be related to the unobserved urban characteristics, its estimation coefficient is biased. To solve this problem, we use panel data, introduce urban fixed effects to control the individual effects that cannot be observed in each city, and use fixed effects regression to estimate formula (1). At the city level, the standard error cluster is used to control the sequence related problems that may exist within the city.

On this basis, we also use the instrumental variable method to further solve the endogenous problem of the proportion of foreign highly skilled labor force (mhcct) caused by missing variables. For the construction of tool variables, the common practice is to adopt the shift share methodology ([7,24,25,32]. Card [33] first applied this method to the study of the economic effects of immigrants. In order to further improve the exogenous nature of instrumental variables, considering that low skilled labor does not directly affect innovation, we use the predicted proportion of foreign low skilled labor as the instrumental variable of the proportion of foreign high skilled labor [25]. We first count the number of people from other provinces with different levels of education in the base period of a city (2000), and then take the population growth rate of other provinces from 2000 to 2005 as the population growth rate of the city from these provinces with different levels of education. On this basis, we predict the proportion of migrant low skilled labor in the city in 2005. The idea behind the construction of this instrumental variable is that the existing floating population from a province in a city will attract more people from that province through the network of hometown relations, which is the phenomenon of migrant enclaves in sociology. Therefore, the tool variable is relevant. Obviously, the predicted proportion of foreign low skilled labor force only uses the proportion of the base period and the overall population growth rate of other provinces at the national level. It does not depend on the actual number of low skilled labor force flowing into the city, and has nothing to do with the unique impact of the city during this period (independent of the error term), so as to meet the exogenous requirements.

4. Empirical results and analysis

4.1. Regression results

The fixed effect regression results based on sample data are shown in **Table 2**. Among them, column (1) is the regression result of the impact of the city's overall human capital (HC) on innovation. The coefficient of human capital is significantly positive, which means that the level of urban human capital has a significant positive impact on innovation, and the level of urban innovation increases with the rise of the level of human capital. This result is consistent with the research conclusions of [24,25], which proves that endogenous growth theory emphasizes that human capital is an important input factor for innovation.

In order to investigate the urban innovation effect of external human capital, we split the overall urban human capital into local and external human capital. Column (2) of **Table 2** covers the regression of these two human capitals to urban innovation. The urban innovation effect of external human capital is significantly positive. Every additional unit of external human capital will increase urban innovation by about 027%. Based on the above theoretical analysis, it can be seen that foreign highly skilled labor not only brings new ideas and skills to the local, but also increases the supply of local human capital, expands the human capital pool, improves the matching efficiency between innovation factors, and then promotes the local innovation output level and efficiency. In contrast, the impact of local human capital on urban innovation is not significant. In fact, [34] also found in their research on Finnish enterprise innovation that human capital hired from other regions plays a very significant role in

enterprise innovation, while human capital recruited locally does not play a significant role in enterprise innovation, thus supporting the classic human capital flow theory proposed by [35]. In addition, it may also be the partial substitution effect of foreign human capital on local human capital, resulting in the insignificant innovation effect of local human capital [36,37].

Table 2. Benchmark regression.

Dependent variable	(1) Number of patent applications per capita	(2) Number of patent applications per capita	(3) Per capita number of invention patent applications	(4) Number of design patent applications per capita	(5) Number of utility model patent applications per capita
HC	0.0290**				
	(0.0132)				
Mhc		0.2666***	0.3750***	0.1608**	0.1889***
		(0.0565)	(0.0627)	(0.0632)	(0.0566)
Localhc		0.0038	0.0086	0.0080	−0.0020
		(0.0132)	(0.0121)	(0.0085)	(0.0087)
FDI Share	−0.0055	−0.0032	−0.0023	−0.0045	−0.0052
	(0.0094)	(0.0083)	(0.0058)	(0.0069)	(0.0077)
Ln College	0.2064***	0.1609***	0.0899***	0.1028***	0.1208***
	(0.0421)	(0.0427)	(0.0264)	(0.0324)	(0.0339)
S&T Spending	0.0021	0.0046	0.0039**	0.0028	0.0034
	(0.0032)	(0.0030)	(0.0020)	(0.0017)	(0.0025)
Ln Density	−0.1786	−0.3375***	0.0750	−0.3840***	−0.0559
	(0.2085)	(0.1313)	(0.1777)	(0.1000)	(0.1010)
Indus	−0.0060	−0.0026	−0.0045	−0.0017	−0.0003
	(0.0042)	(0.0039)	(0.0030)	(0.0027)	(0.0029)
Ln Freight	0.0538	0.0464	−0.0227	0.0625*	0.0372
	(0.0541)	(0.0512)	(0.0323)	(0.0357)	(0.0330)
Ln gdpper	0.2062	0.2090	0.2108**	0.1167	0.1128
	(0.1642)	(0.1495)	(0.1055)	(0.1059)	(0.1076)
Time effect	Control	Control	Control	Control	Control
Urban fixed effect	Control	Control	Control	Control	Control
Observed value	471	471	471	471	471
R2	0.4696	0.5109	0.5998	0.3302	0.4691

Note: the values in brackets are the standard error of the robustness of city level clustering, *, ** and *** indicate the significance level of 10%, 5% and 1% respectively. The following table is the same.

In addition to analyzing the overall innovation of the city, we further divided the overall patent into three categories: invention patent, design patent and utility model patent for regression to investigate the impact of foreign human capital on different types of innovation. The regression results are shown in columns (3)–(5) of **Table 2**. The results show that no matter what form of urban innovation, external human capital plays a positive role in promoting. From the regression coefficient of foreign human capital on different types of innovation, it can be seen that the impact of foreign human capital on urban invention patents is significantly greater than the other two types, which means that foreign human capital has the most obvious impact on the innovation of urban invention patents with the highest technology content, further highlighting the innovation effect of foreign human capital.

4.2. Robustness test

In order to test the robustness of the estimation results, we mainly discuss the following aspects.

First, replace the dependent variable index (P). We use the number of urban patent applications to replace the original number of patent applications per capita for re regression. The results are shown in column (1) of **Table 3**. It can be seen that the coefficient of urban external human capital is still significantly positive, indicating that external human capital can promote urban innovation, and the result is stable.

Table 3. Robustness test.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Number of patent applications	**Fixed effect regression of negative binomial model**	**Proportion of external human capital in total local human capital**	**Remove the immigrant city with the largest proportion of migrant population**	**Remove small cities with a population of less than 500000**	**Remove cities with centralized headquarters**	**Nonlinearity**
Mhc	0.1923***	0.1532**		0.2957***	0.2443***	0.6276***	0.5143***
	(0.0654)	(0.0756)		(0.0964)	(0.0581)	(0.1398)	(0.1188)
Mhc_ alt			0.0214** (0.0092)				
Mhc2							−0.0333** (0.0137)
Control variable	Control	Control	Control	Control	Control	Control	Control
Observed value	471	446	471	467	465	465	471
R^2	0.6401		0.4689	0.4985	0.5238	0.4746	0.5238

Note: other control variables are consistent with column (2) of **Table 2**. The following table is the same. All regressions control the time and city fixed effects.

Second, since the dependent variable number of urban patent applications in column (1) of **Table 3** is a non-negative integer measurement number, which cannot obey the normal distribution required by the ordinary least squares (OLS) method, we use the negative binomial regression model in column (2) for regression [38]. The coefficient and significance of external human capital have not changed significantly, indicating that the benchmark regression results are robust in the estimation method.

Third, replace the external human capital index. Mhc_{ct} Referring to the practice of [25], we adopted the proportion (mhc_alt) of the external population with college degree or above in the total population with college degree or above in City C to replace the original mhcct. The regression results are shown in column (3) of **Table 3**. Since the proportion of local human capital is 1 minus the proportion of foreign human capital, there is a complete collinearity with the proportion of foreign human capital, so regression cannot be added. The results in column (3) show that the impact of external human capital on urban innovation is still significantly positive.

Fourth, Shenzhen and Dongguan, the two cities with the highest proportion of migrant population, are excluded (the proportion of migrant population exceeds 60%), in order to test whether the relationship between migrant human capital and urban innovation is affected by it. The regression results after excluding the two cities are

shown in column (4) of **Table 3**, from which we can see that the coefficient of external human capital is still significantly positive.

Fifthly, referring to the practices of [39], we excluded small cities with small migrant population from the sample to further investigate the robustness of the benchmark regression results. According to the classification standard of the national new urbanization plan (2014–2020), we classify cities with a population of less than 500,000 as small cities and remove them from the sample. From the regression results in column (5) of **Table 3**, we can see that the coefficient sign and significance of foreign human capital have basically not changed. In addition, considering that some R & D may submit patent protection through the headquarters, we also removed Beijing, shanghai and Shenzhen, which have concentrated headquarters. The regression results are shown in column (6) of **Table 3**. The coefficient of external human capital is still significantly positive, indicating that the empirical results of the benchmark regression are relatively robust.

Sixth, although the previous theoretical analysis shows that external human capital can promote urban innovation by bringing complementary skills and ideas to the local, there will also be preference conflicts, mistrust, discrimination and other issues between external human capital and local human capital, which is not conducive to cooperation and innovation [40]. In view of this, we introduce the quadratic term of foreign human capital (mhc2) on the basis of formula (1) and re regress the sample data. The regression results are shown in column (7) of **Table 3**. The coefficient of the primary term of foreign human capital is still significantly positive, and the coefficient of the secondary term is significantly negative, indicating that there is an inverted U-shaped relationship between foreign human capital and urban innovation.

Seventh, considering the endogenous nature of external human capital, in addition to using fixed effect regression to control the unobserved urban characteristics, we also use instrumental variable regression. Column (1) of **Table 4** shows the regression results of two-stage least square method (2SLS) for instrumental variables constructed based on share transfer method. The dummy variables of provinces are introduced into the regression to control the regional fixed effect. Column (2) is the regression result on this basis, excluding Beijing, shanghai and Shenzhen, which have relatively concentrated headquarters. A series of tests on the effectiveness of instrumental variables show that in the first stage regression, the coefficient of instrumental variables is significantly positive, and the statistical value of Cragg Donald Wald f in the correlation test of instrumental variables is much higher than the critical value of 10% significance level 1638, indicating that there is a strong correlation between instrumental variables and endogenous variables, and there is no problem of weak instrumental variables. In the regression results, the coefficient of external human capital is significantly positive, and there is a strong innovation effect of external human capital, which again shows that the benchmark experience results are relatively robust.

Table 4. Instrumental variables and post innovation regression.

	(1) Regression of current innovation instrument variables	(2) Regression of urban instrumental variables with headquarters removed	(3) Fixed effect regression of innovation in the last phase	(4) Regression of innovation instrument variables in the last stage
Mhc	0.5819*** (0.1755)	0.7937*** (0.3014)	0.2344*** (0.0730)	0.7675*** (0.2529)
Stage 1 Tool variables	0.0354*** (0.0103)	0.0245*** (0.0043)		0.0354*** (0.0103)
Phase I f inspection	11.70*** (0.0007)	32.21*** (0.0000)		11.70*** (0.0007)
Cragg Donald Wald F value	79.801	176.612		79.801
Control variable	Control	Control	Control	Control
Time effect	Not controlled	Not controlled	Control	Not controlled
City and province fixed effect	Control	Control	Control	Control
Observed value	229	226	468	229
R^2			0.5690	

Eighth, considering that innovation has a certain periodicity, and in order to avoid the reverse causal relationship between external human capital and urban innovation, we further replaced the number of urban per capita patent applications in 2000 and 2005 with the number of urban per capita patent applications in 2001 and 2006 respectively. The results of the re regression are shown in columns (3) and (4) of **Table 4** (The author thanks anonymous reviewers for their suggestions.). It can be seen that the coefficient of external human capital is significantly positive whether it is fixed effect regression or instrumental variable regression, indicating that external human capital still has a positive effect on urban innovation in the later stage.

Ninth, the micro data of the national census respectively reported the permanent residence of each person five years ago. This paper uses this indicator to replace the registered residence used above as the judgment standard of foreign human capital to test the robustness of two kinds. The first is to use the place of permanent residence five years ago as the measurement and definition standard of foreign human capital. If highly skilled workers lived outside the province five years ago, it is defined as foreign human capital. The second is to define the external human capital by combining the permanent residence and the registered residence location five years ago. At this time, if the highly skilled workers do not have the household registration of the province, they are defined as the external human capital; highly skilled labor who have registered permanent residence in the province but lived outside the province five years ago are also classified as foreign human capital. The regression results based on these two criteria are shown in **Table 5**. It can be seen that no matter what form of migrant population measurement standard is adopted, foreign human capital plays a positive role in promoting the innovation of the cities where it flows in.

Table 5. Instrumental variable regression of different external human capital judgment criteria.

	Standard of permanent residence 5 Years ago		**Combination of registered residence and permanent residence five years ago**	
	(1)	**(2)**	**(3)**	**(4)**
	Current innovation	**Innovation in the next phase**	**Current innovation**	**Innovation in the next phase**
Mhc	0.7424*** (0.2133)	0.9970*** (0.3476)	0.5240*** (0.1484)	0.6870*** (0.2314)
First stage regression instrumental variables	0.0294*** (0.0093)	0.0294*** (0.0093)	0.0400*** (0.0118)	0.0400*** (0.0118)
Phase I F test (P value)	10.06*** (0.0017)	10.06*** (0.0017)	11.57*** (0.0008)	11.57*** (0.0008)
Cragg donaldwaldf value	61.167	61.167	69.959	69.959
Control variable	Control	Control	Control	Control
Provincial fixed effect	Control	Control	Control	Control
Observed value	230	230	232	232

Tenth, as for the definition of external human capital, in addition to taking provinces as the region, we further define the floating population by taking cities as the region. If the registered permanent residence of highly skilled workers is not in this city, it is defined as external human capital. The regression results based on this definition standard are shown in **Table 6**. Column (1) contains the fixed effect regression results of all samples. Column (2) is the fixed effect regression result after removing the two cities with the highest proportion of migrant population (Shenzhen and Dongguan), and columns (3) and (4) are the regression results of corresponding instrumental variables. It is not difficult to see that whether it is fixed effect or instrumental variable regression, the coefficient of foreign human capital defined by the city as a region is still significantly positive, indicating that there is a strong innovation effect of foreign human capital to promote the inflow cities.

Table 6. Return of external human capital defined by cities as regions.

	Fixed effect regression		**Instrumental variable regression**	
	(1)	**(2)**	**(3)**	**(4)**
	Whole	**Remove the largest immigrant city**	**Whole**	**Remove the largest immigrant city**
Mhc	0.1952*** (0.0354)	0.1998*** (0.0500)	0.4883*** (0.1341)	0.8521*** (0.3267)
First stage regression instrumental variables			0.0427*** (0.0122)	0.0310*** (0.0091)
Phase I f inspection (*P* value)			12.17*** (0.0006)	11.68*** (0.0008)
Cragg donaldwaldf value			69.470*	47.264
Control variable	Control	Control	Control	Control
Time effect	Control	Control	Not controlled	Not controlled
Provincial fixed effect	Control	Control	Control	Control
Observed value	471	467	229	227
R^2	0.5067	0.4931		

Finally, we introduce the micro data of the 1990 national census to test the robustness of the regression of the above instrumental variables. Consistent with the share transfer method mentioned above, we first count the number of people from other provinces with different levels of education in the base period of a city in 1990, and then take the population growth rate of other provinces from 1990 to 2000 as the population growth rate of the city from these provinces with different levels of Education, on this basis, we predict the proportion of foreign low skilled labor in the city in 2000. Similarly, we calculate the number of people from other provinces with different levels of education in the base period of 2000, and then take the population growth rate of other provinces from 2000 to 2005 as the population growth rate of the city from these provinces with different levels of education. On this basis, we predict the proportion of migrant low skilled labor in the city in 2005. Through the above two steps, we get the instrument variables of external human capital (mhcct) in 2000 and 2005. The regression results of panel tool variables on this basis are shown in **Table 7** (The sample size decreased due to the lack of data in some cities in 1990.).

Table 7. Regression of panel tool variables based on 1990.

	(1)	(2)	(3)	(4)
	Number of patent applications per capita	**Remove the largest immigrant city**	**Number of patent applications**	**Remove the largest immigrant city**
Mhc	0.9048** (0.4297)	1.2936* (0.6911)	0.9027** (0.4502)	1.3275* (0.7384)
First stage regression instrumental variables	0.0245** (0.0102)	0.0167** (0.0080)	0.0245** (0.0102)	0.0167** (0.0080)
Phase I f inspection (*P* value)	5.82** (0.0170)	4.39** (0.0377)	5.82** (0.0170)	4.39** (0.0377)
Cragg donaldwaldf value	45.777	28.335	45.777	28.335
Control variable	Control	Control	Control	Control
Time effect	Control	Control	Control	Control
Urban fixed effect	Control	Control	Control	Control
Observed value	306	302	306	302

Column (1) of **Table 7** shows the regression results of all samples; column (2) is the regression result after removing the two cities with the highest proportion of migrant population (Shenzhen and Dongguan); column (3) is the regression result of replacing the original dependent variable per capita patent applications with the number of urban patent applications; column (4) is the regression result of removing the two cities with the highest proportion of migrant population on this basis. No matter what form of regression, the coefficient of external human capital is significantly positive, which plays a positive role in promoting the innovation of the inflow cities, and once again shows that the benchmark regression results have strong robustness.

5. Mechanism analysis: from the perspective of cultural diversity

From the previous empirical study, it is not difficult to see that foreign human capital has played a significant role in promoting urban innovation. In this part, we will further investigate the mechanism of the impact of foreign human capital on urban

innovation, that is, through which channels foreign human capital has an impact on urban innovation. We will conduct theoretical and empirical research on this issue from the perspective of cultural diversity.

The innovation effect of diversity has been an important topic in economic research in recent 30 years. Urban economist Jacobs [41] first proposed and systematically investigated this topic. Based on the systematic study of urban economy, she put forward the viewpoint of diversified externality, and believed that the diversity of urban economy is more conducive to stimulating innovation and economic growth.

As another important manifestation of urban diversity, the role of cultural diversity in innovation has been increasingly concerned by scholars, and has been strongly supported by a large number of theoretical and empirical studies. Ottaviano and Peri [7] pointed out that immigrants from countries with different cultural backgrounds constitute the diversity of urban culture in the United States. Due to differences in cultural backgrounds, immigrants from other countries have different skills and abilities compared with the Native American labor force, and promote innovation and economic growth through complementary skills. In fact, people from different regions and cultural backgrounds also have different cognitive abilities, and their views, understanding and solutions to problems are also different. Lazear's [42] empirical research shows that when people from different places interact in the same workplace, their different skills, experiences and problem-solving abilities will produce new ideas of comprehensive innovation.

China is a country with a vast territory and a large population. It is also a country with a long history and rich cultural resources. Previous systematic studies by sociologists Moser [43] and Du [44] have found that people from different provinces in China have different living habits, temperament, values, abilities and skills, and the regional culture of different provinces has left a "birthmark" on every Chinese. This leads to the question: will the flow of human capital promote the agglomeration of highly skilled labor from different provinces and regional cultures in cities, produce cultural diversity externalities, and then promote innovation?

In order to test this mechanism, consistent with the research of [7], we use the origin of labor force as its cultural identity. On this basis, we use the index of fractionalization commonly used in urban economics literature [7] to measure the cultural diversity of Chinese cities. The specific calculation formula is as follows:

$$div_{ct} = 1 - \sum_{i=1}^{I} (e_{it}^{c})^2 \quad (2)$$

where, is $e_{it}^{c}$the proportion of labor force from province I in the total labor force of City C in year t, and the value range of this indicator is between 0 and 1. When all the labor forces in City C come from the same province, the value of this indicator is 0; when no two labor forces in City C come from the same province, the value of this indicator is 1. Therefore, the larger the index value, the higher the degree of cultural diversity of city C. We still use the province where the registered permanent residence of Chinese labor force is located to define its source. We first introduce cultural diversity into formula (1) to examine the impact of cultural diversity on urban innovation in China. The estimated results of fixed effect regression and 2SLS regression including instrumental variables are shown in columns (1) and (2) of **Table**

8. The results show that no matter what form of regression, the coefficient of cultural diversity is significantly positive, which means that cultural diversity promotes urban innovation in China. As the previous theoretical analysis reveals, the labor force with different regional and cultural backgrounds gathered in cities, bringing diverse skills, knowledge and ideas to cities, and promoting urban innovation through the skill complementarity and matching between local and foreign labor forces. This result is consistent with the existing research based on the innovative effect of cultural diversity of international immigrants in developed countries.

Table 8. Functional mechanism test of introducing cultural diversity.

	Introducing cultural diversity		**Basic regression without introducing cultural diversity**	
	(1)	**(2)**	**(3)**	**(4)**
	Fixed effect regression	**Instrumental variable regression**	**Fixed effect regression**	**Instrumental variable regression**
Div	2.4437***	1.9522***		
	(0.4488)	(0.6476)		
Mhc	0.2022***	0.0011	0.2666***	0.5819***
	(0.0527)	(01994)	(0.0565)	(0.1755)
Control variable	Control	Control	Control	Control
Time effect	Control	Not controlled	Control	Not controlled
City and province fixed effect	Control	Control	Control	Control
Observed value	471	229	471	229
R^2	0.5655		0.5109	

We compare the regression results of introducing cultural diversity with the benchmark regression results without cultural diversity (columns (3) and (4) of **Table 8**) and find that the coefficient of foreign human capital in the benchmark regression without cultural diversity decreases significantly after adding cultural diversity variables, indicating that cultural diversity is a mechanism for the impact of foreign human capital (The author thanks anonymous reviewers for their suggestions.).

In order to further test this mechanism, we take the urban cultural diversity index as the dependent variable of formula (1) and carry out fixed effect and 2SLS regression with instrumental variables. The estimated results are shown in **Table 9**. Among them, columns (1) and (3) are the regression of the overall sample, and columns (2) and (4) are the regression excluding the two cities with the highest proportion of migrant population (Shenzhen and Dongguan). It is not difficult to see that foreign human capital has played a significant role in promoting urban cultural diversity. It can be seen that gathering highly skilled labor with different regional and cultural backgrounds into cities, bringing diverse skills, knowledge and ideas to cities, and complementing and matching skills between local and foreign highly skilled labor is an important channel for foreign human capital to promote innovation in local cities.

Table 9. Test of action mechanism of cultural diversity as dependent variable.

	Fixed effect regression		Instrumental variable regression	
	(1)	(2)	(3)	(4)
	Whole	Remove the largest immigrant city	Whole	Remove the largest immigrant city
Mhc	0.0263	0.0509***	0.2975***	0.5475***
	(0.0160)	(0.0145)	(0.0817)	(0.1608)
Control variable	Control	Control	Control	Control
Time effect	Control	Control	Not controlled	Not controlled
City and province fixed effect	Control	Control	Control	Control
Observed value	471	467	229	227
R^2	0.1670	0.2431		

In addition, we further defined the floating population by taking the city as the region, and tested the robustness of the above results. If the registered permanent residence of highly skilled workers is not in this city, it is defined as external human capital. Taking the urban cultural diversity index as the dependent variable of formula (1), the fixed effect and 2SLS regression including instrumental variables are carried out (see **Table 10**). Column (1) is the fixed effect regression result including all samples, column (2) is the fixed effect regression result excluding the two cities with the highest proportion of migrant population (Shenzhen and Dongguan), and columns (3) and (4) are the regression results of corresponding instrumental variables. The results show that no matter what form of regression, the coefficient of foreign human capital defined by the city as a region is still significantly positive, which means that foreign human capital promotes urban cultural diversity, indicating that the mechanism of cultural diversity has a strong robustness.

Table 10. Fixed effect regression instrument variable regression for the functional mechanism test of external human capital defined by cities as regions.

	Fixed effect regression		Instrumental variable regression	
	(1)	(2)	(3)	(4)
	Whole	Remove the largest immigrant city	Whole	Remove the largest immigrant city
Mhc	0.0153 (0.0104)	0.0275*** (0.0105)	0.2461*** (0.0658)	0.3534*** (0.1008)
First stage regression instrumental variables			0.0427*** (0.0122)	0.0310*** (0.0091)
Phase I f inspection (*P* value)			12.17*** (0.0006)	11.68*** (0.0008)
Cragg donaldwaldf value			69.470*	47.264
Control variable	Control	Control	Control	Control
Time effect	Control	Control	Not controlled	Not controlled
City and province fixed effect	Control	Control	Control	Control
Observed value	471	467	229	227
R^2	0.3609	0.1969		

6. Conclusions and policy implications

This paper discusses the impact of external human capital on urban innovation from the perspective of cross regional flow of human capital. The main conclusions are as follows: urban innovation is an open process, and this openness requires that its input factors should also flow and open. Our theoretical research shows that, as a key input element and an important carrier of knowledge (especially tacit knowledge) in the innovation process, the spatial migration and allocation of human capital affect the urban innovation ability and efficiency. It not only contributes to knowledge spillover and diffusion, but also introduces and applies foreign new ideas and insights to the local market and promotes innovation in the inflow cities; moreover, it can expand the human capital pool in the inflow area, promote the matching quantity and quality between enterprises and human capital, and improve the efficiency of urban innovation.

We matched the individual micro data of China's census with the urban patent data, and found that human capital has a significant role in promoting urban innovation through empirical research on the urban innovation effect of foreign human capital, which proved that the endogenous growth theory emphasizes that human capital is an important input factor for innovation. The empirical study of dividing the overall urban human capital into local human capital and external human capital also shows that external human capital has a significant role in promoting urban innovation. This conclusion is supported by a series of robustness tests. On this basis, from the perspective of cultural diversity, we further investigated the mechanism of the impact of foreign human capital on urban innovation. The empirical research on the construction of urban cultural diversity indicators shows that the gathering of foreign highly skilled labor with different regional and cultural backgrounds in cities brings diverse skills, knowledge and ideas to cities, which is an important channel for them to promote urban innovation.

This study reveals that if we want our city to be full of innovation vitality, we need to encourage the cross regional flow of human capital and the absorption of diverse talents. The efficient allocation of innovative production factors brought about by the spatial transfer of human capital and the diversified externalities associated with them are the source for cities to maintain innovation vitality and competitiveness. Therefore, how to build a harmonious urban order and an open and inclusive development environment, promote the labor force with different regional and cultural backgrounds to form an organic whole of interaction and cooperation, and improve the city's ability to absorb, gather and integrate foreign labor force undoubtedly plays a vital role in urban sustainable innovation, and is also an area that the government should do in building an innovative city.

Due to the limitation of data, this paper only examines the innovation value brought by the interregional flow of domestic labor force to the inflow city from the urban level, and then verifies the externality of external human capital. Future research can further start from the micro perspective of the enterprises in the inflow area to investigate the impact of foreign human capital on the innovation of their enterprises, so as to provide more direct evidence for this topic.

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References

1. Faggian A, McCann P. Human capital, graduate migration and innovation in British regions. Cambridge Journal of Economics. 2008; 33(2): 317-333. doi: 10.1093/cje/ben042
2. Glaeser EL, Resseger MG. The Complementarity Between Cities and Skills. Journal of Regional Science. 2010; 50(1): 221-244. doi: 10.1111/j.1467-9787.2009.00635.x
3. Caragliu A, Del Bo CF, Kourtit K, et al. The winner takes it all: forward-looking cities and urban innovation. The Annals of Regional Science. 2015; 56(3): 617-645. doi: 10.1007/s00168-015-0734-5
4. Carlino GA, Chatterjee S, Hunt RM. Urban density and the rate of invention. Journal of Urban Economics. 2007; 61(3): 389-419. doi: 10.1016/j.jue.2006.08.003
5. Lobo J, Strumsky D. Metropolitan patenting, inventor agglomeration and social networks: A tale of two effects. Journal of Urban Economics. 2008; 63(3): 871-884. doi: 10.1016/j.jue.2007.07.005
6. Sedgley N, Elmslie B. Do We Still Need Cities? Evidence on Rates of Innovation from Count Data Models of Metropolitan Statistical Area Patents. American Journal of Economics and Sociology. 2011; 70(1): 86-108. doi: 10.1111/j.1536-7150.2010.00764.x
7. Ottaviano GIP, Peri G. The economic value of cultural diversity: evidence from US cities. Journal of Economic Geography. 2005; 6(1): 9-44. doi: 10.1093/jeg/lbi002
8. Lee N. Migrant and ethnic diversity, cities and innovation: Firm effects or city effects? Journal of Economic Geography. 2014; 15(4): 769-796. doi: 10.1093/jeg/lbu032
9. Zhu Y, Tu Q. Industrial structure characteristics of global scientific and technological innovation centers-Evidence from 34 metropolitan areas in the United States. Urban development research. 2006; 12.
10. Cao Y, Cao X, Luo C. Comparative Study on Innovation Capability and Its Influencing Factors of China's Four Cities Directly Under the Central Government, China Soft science. 2013; 6.
11. Wang M, Xuan Y, Chen Q. Creative Class agglomeration, knowledge externality and urban innovation-Evidence from 20 big cities. Economic theory and economic management. 2016; 1.
12. Zhong X. Labor mobility and wage gap. China Social Sciences. 2006; 1.
13. Chen Z, and Lu M. From segmentation to integration: political economy of urban and rural economic growth and social harmony. Economic research. 2008; 1.
14. Cai F, Wang M. Why labor mobility has not narrowed the urban-rural income gap. Economic trends. 2009; 8.
15. Meng X. Labor Market Outcomes and Reforms in China. Journal of Economic Perspectives. 2012; 26(4): 75-102. doi: 10.1257/jep.26.4.75
16. Wan H, and Li S. The impact of registered residence discrimination on urban-rural income gap. Economic research. 2013; 9.
17. Yuan Z. Rural-urban labor mobility and urban unemployment in China: an empirical study. Management world. 2006; 8.
18. Liu X, and Zhao Y. The Impact of Labor Mobility on Urban Labor Market. Economics (quarterly). 2009; 2.
19. Shen K, and Yu Ji. The impact of rural labor mobility on the income of Chinese urban residents—A Study Based on the perspective of urban and rural labor division in the process of marketization. Management world. 2011; 3.
20. Liang Q, Chen Q, Wang R. Registered Residence Reform, Labor Mobility and Optimization of Urban Hierarchy System. China Social Sciences. 2013; 12.
21. Du Y, Cai F, Qu X. Continuing China's Miracle: Reaping Dividends from The Reform of The Registered Residence System. Economic Research. 2014; 8.
22. Saxenian A. Silicon Valley's New Immigrant High-Growth Entrepreneurs. Economic Development Quarterly. 2002; 16(1): 20-31. doi: 10.1177/0891242402016001003
23. Peri G. The Effect of Immigration on Productivity: Evidence from US States. Review of Economics and Statistics. 2012; 94(1): 348-358. doi: 10.1162/REST_a_00137
24. Hunt J, Gauthier-Loiselle M. How Much Does Immigration Boost Innovation? American Economic Journal: Macroeconomics. 2010; 2(2): 31-56. doi: 10.1257/mac.2.2.31
25. Bosetti V, Cattaneo C, Verdolini E. Migration of skilled workers and innovation: A European Perspective. Journal of International Economics. 2015; 96(2): 311-322. doi: 10.1016/j.jinteco.2015.04.002
26. Fassio C, Montobbio F, Venturini A. Skilled migration and innovation in European industries. Research Policy. 2019; 48(3): 706-718. doi: 10.1016/j.respol.2018.11.002

27. Marshall A. Principles of Economics. London: Mac-Millan; 1890.
28. Acs ZJ, Audretsch DB. Innovation and Small Firms. Cambridge, Massachusetts: Mit Press; 1990.
29. Gennaioli N, La Porta R, Lopez-de-Silanes F, et al. Human Capital and Regional Development*. The Quarterly Journal of Economics. 2012; 128(1): 105-164. doi: 10.1093/qje/qjs050
30. Eeckhout J, Pinheiro R, Schmidheiny K. Spatial Sorting. Journal of Political Economy. 2014; 122(3): 554-620. doi: 10.1086/676141
31. Venables AJ. Productivity in cities: self-selection and sorting. Journal of Economic Geography. 2010; 11(2): 241-251. doi: 10.1093/jeg/lbq040
32. Zhang C. What kind of city is more conducive to entrepreneurship. Economic research. 2018; 4.
33. Card D. Immigrant Inflows, Native Outflows, and the Local Labor Market Impacts of Higher Immigration. Journal of Labor Economics. 2001; 19(1): 22-64. doi: 10.1086/209979
34. Simonen J, McCann P. Firm innovation: The influence of R&D cooperation and the geography of human capital inputs. Journal of Urban Economics. 2008; 64(1): 146-154. doi: 10.1016/j.jue.2007.10.002
35. Hart RA. Interregional economic migration: some theoretical considerations (PART II). Journal of Regional Science. 1975; 15(3): 289-300. doi: 10.1111/j.1467-9787.1975.tb00932.x
36. Borjas GJ, Doran KB. The Collapse of the Soviet Union and the Productivity of American Mathematicians*. The Quarterly Journal of Economics. 2012; 127(3): 1143-1203. doi: 10.1093/qje/qjs015
37. Kerr WUS. High-Skilled Immigration, Innovation, and Entrepreneurship: Empirical Approaches and Evidence. National Bureau of Economic Research. 2013. doi: 10.3386/w19377
38. Wooldridge JM. Introductory Econometrics: A Modern Approach. England: South-Western Press; 2002. pp. 498-499.
39. Peri G, Shih K, Sparber C. STEM Workers, H-1B Visas, and Productivity in US Cities. Journal of Labor Economics. 2015; 33(S1): S225-S255. doi: 10.1086/679061
40. Ashraf Q, Galor O. The "Out of Africa" Hypothesis, Human Genetic Diversity, and Comparative Economic Development. American Economic Review. 2013; 103(1): 1-46. doi: 10.1257/aer.103.1.1
41. Jacobs J. The Life of Cities. New York: Random House; 1969.
42. Lazear EP. Culture and Language. Journal of Political Economy. 1999; 107(S6): S95-S126. doi: 10.1086/250105
43. Moser LJ. The Chinese Mosaic: The Peoples and Provinces of China. Colorado: Westview Press; 1985. pp. 5-10.
44. Du Y. Chinese personality map, Beijing: Jincheng publishing house; 2010.