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**Divergence of Human Capital in Cities
in the People's Republic of China:
Exploring Complementarities and
Spatial Agglomeration of the Workforce
with Various Skills**

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Abstract

In cities, complementarity between a low-skilled and a high-skilled workforce can promote each other to improve labor productivity. In this study, we used earlier census data and 1% population survey data to examine the distribution of the skilled workforce in cities in the People's Republic of China (PRC) along with its changes, and drew the following three conclusions. First, a highly skilled workforce is the engine of urban development, increasing urban wages and population. Second, big cities can promote complementarity between skill sets so that there are greater numbers of high-skilled and low-skilled workers in those cities. This explains why both low-skilled and high-skilled workforces agglomerate in big cities. Last, complementarity between the low-skilled and high-skilled workforce is inhibited in the PRC's cities because of the biased household registration system (HRS) toward the high-skilled workforce, resulting in limited supply of low-skilled labor. This policy is not conducive to enhance labor productivity in big cities and to carry out its leading role of economic growth.

JEL Classification: J24; J61; R12

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1. INTRODUCTION

Since the start of the 21st century, the People's Republic of China (PRC) has faced an investment expansion and export-led extensive expansion that have been unsustainable. Economic growth has accumulated serious structural problems such as income and consumption's low share of gross domestic product (GDP), high dependence on foreign trade, and huge trade surplus. At the same time, the PRC is facing environmental degradation and the increasing lack of social stability. In this regard, the consensus has been that the PRC now needs comprehensive reforms, including economic, social, and political systems to sustain its high growth. In the economic restructuring process of the PRC, urbanization and urban development (especially in the service industry) are particularly important. However, the PRC's urbanization seriously lags behind its industrialization. In 2014, the urbanization rate of the population comprising only those with urban household registration (*hukou*) was about 36.7%, while the urbanization rate of the population including rural-to-urban migrants as nonlocal urban residents was about 54.77%;¹ the industry and service rates in the GDP had been over 90% during the same period.

From a different perspective, the lag of urbanization behind industrialization opens an opportunity for economic restructuring in the PRC. Agglomeration of a large population particularly in big cities generates tremendous positive effects in both labor productivity and the efficiency of resources. However, the PRC's current economic policies still limit the expansion of cities and megacities with regard to land supply and the household registration system (HRS).

Using earlier census and a 1% population survey data, we examined the distribution of the skilled workforce in the PRC's cities along with its changes, and drew the following three conclusions. First, a highly skilled workforce is the engine of urban development, increasing urban wages and population. Second, big cities can promote complementarity between skill sets so there are greater numbers of high-skilled and low-skilled workers in those cities. This explains why both the low-skilled and high-skilled workforces agglomerate in big cities. Last, complementarity between the low-skilled and high-skilled workforces is inhibited in the PRC's cities because of the biased HRS toward the high-skilled workforce, resulting in a limited supply of low-skilled labor. This policy is not conducive to enhance labor productivity in big cities and to carry out its leading role of economic growth.

This paper is divided into five sections. Following the introduction in the first section, we demonstrate the effects of high-skilled labor on urban development, especially population increase and wage upgrade in the second section; the third section explains that urban development will promote skill complementarities; the fourth section analyzes the influences of the skill-biased HRS on skill complementarity and spatial distribution of different workforces; and the fifth section summarizes the paper.

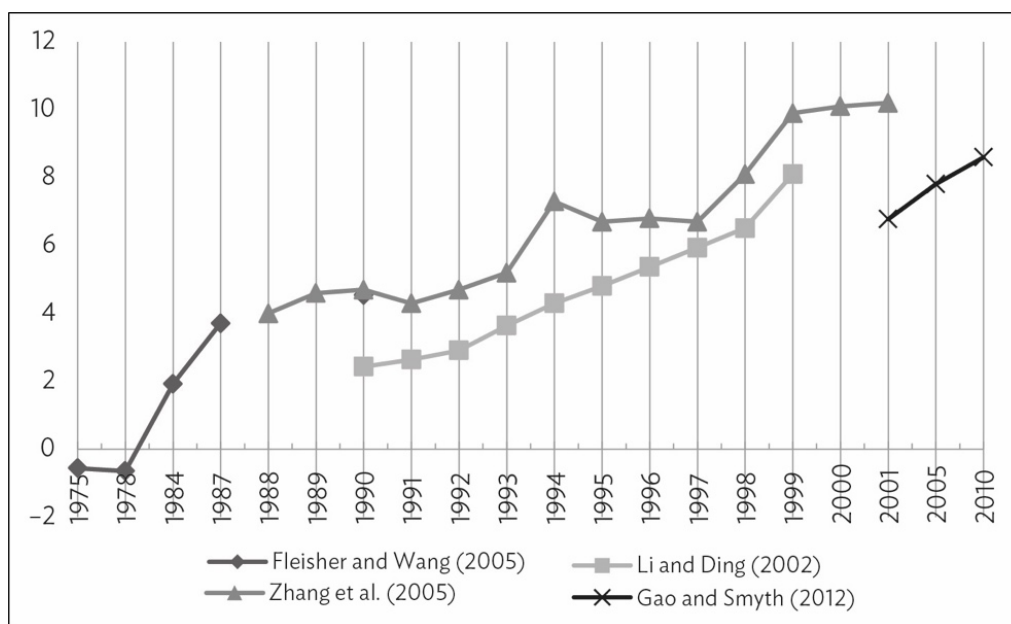
2. HIGH SKILLS IMPROVE URBAN DEVELOPMENT

Urban development is inseparable from the accumulation of high-skilled labor. High-skilled laborers can promote urban development for the following two reasons:

¹ Reported by China Economic Net. See http://intl.ce.cn/specials/zxxx/201503/13/t20150313_4815599.shtml

- (i) High-skilled labor itself has higher productivity. If skill is determined by education levels, the high productivity of high-skilled labor can be reflected in the rate of returns to education for individuals. This rate varies by country and region, and by the stages of economic development (Card 1999; Heckman et al. 2006). In the PRC, all jobs were arranged by the government during the planned economy era, and returns to education were almost nothing (Cai et al. 2008). Since the Reform and Opening, the rate of individual returns to education has gradually increased.² As shown in Figure 1, the rate of returns to education was only -0.642% in 1978, which rose to 3.707% in 1987 (Fleisher and Wang 2005). Throughout the 1990s, this increased to 8.1% in 1999 from 2.43% in 1990 (Li and Ding 2003)³. After 2000, the rate rose from 6.78% in 2001 to 8.6% in 2010 (Gao and Smyth 2012). After controlling for age, age-squared, gender, ethnicity, and marital status, we found that 1 more year of education will lead to a wage increase of 13.2% on average, using 1% of microdata from the 2005 census. Continuing education results in even more highly skilled workers, who then perform with higher productivity.

Figure 1: Returns to Education in the PRC, 1970–2010



PRC = People's Republic of China.

Source: The data are from Fleisher and Wang (2005), Li and Ding (2002), Zhang et al. (2005), and Gao and Smyth (2012).

- (ii) The agglomeration of a high-skilled workforce can present human capital externalities. Increases in the proportion of a high-skilled workforce promote the mean wage of urban residents. This is not only because high-skilled people received high returns to education, but also because the agglomeration of a high-skilled workforce generates high returns to education for the society based on human capital externalities (Combes and Gobillon 2014; Duranton and Puga 2004; Lange and Topel

² For changes in education and returns to education in the PRC since the Reform and Opening, see reviews by Cai et al. (2008) and Hannum et al. (2008).

³ Similarly, Zhang et al. (2005) found that the rate of returns to education increased from 4.0% in 1988 to 10.2% in 2001.

2006; Moretti 2004a; Rosenthan and Strange 2004), making it a more important reason for a high-skilled workforce to promote urban development.

We further examined the impact of an urban, high-skilled workforce on individual wages in cities, as shown in Table 1. Based on the ordinary least squares (OLS) regression results in column 1, each 1% increase in the proportion of high-skilled labor is seen to result in a rise of 6.41% in urban labor wages. In column 2, we used the number of relocated departments from each city during a "university relocation" campaign over the 1950s as the instrumental variable for the proportion of high-skilled labor in cities (following Glaeser and Lu 2014);⁴ we found that each increase of 1 percentage point in the proportion of high-skilled labor resulted in a rise of 5.56% in urban hourly labor wages. When the number of incoming departments was used as the instrumental variable, the hourly wage for urban labor increased by 5.94%. To compare this with the rate of returns to education, we used the city's average years of schooling to measure the city's human capital in column 4, and found that 1 more year of personal education resulted in an increase of 10.5% in hourly wages, while 1 more year of average schooling led to an increase of 15.5% in personal income. When using the instrumental variable from column 2 in column 5, the rate of returns to education was 10.3% while the rate of returns to education for the society was 19.6%, which was almost twice the rate for individuals. Using the number of incoming departments as the instrumental variable, personal and social rates of returns to education were 10.1% and 22.7% respectively, which were close to the estimates of Glaeser and Lu (2014) using the Chinese Household Income Project Series (CHIPS) data. Therefore, it can be demonstrated that the presence of a high-skilled workforce can improve the average urban wage. In addition, the greater the urban population, the higher the proportion of college students, and the higher rates of returns to education (Xing 2014).

Table 1: Impact of Urban High-Skilled Labor on Individual Wages

Ln Wage	OLS	IV 1	IV 2	OLS	IV 1	IV 2
<i>edu_ind</i>	0.106*** (0.00311)	0.107*** (0.00343)	0.107*** (0.00339)	0.105*** (0.00316)	0.103*** (0.00382)	0.101*** (0.00396)
<i>highskilled_city</i>	0.0641*** (0.00645)	0.0556*** (0.00655)	0.0594*** (0.00826)			
<i>edu_city</i>				0.155*** (0.0212)	0.196*** (0.0229)	0.227*** (0.0355)
Constant	-0.633*** (0.128)	-0.494*** (0.117)	-0.556*** (0.143)	-1.273*** (0.257)	-1.723*** (0.254)	-2.058*** (0.391)
F-value in the first stage		55.277	39.9335		65.1807	37.5911
<i>N</i>	1,084,967	1,084,967	1,084,967	1,084,967	1,084,967	1,084,967
adj. <i>R</i> ²	0.432	0.431	0.432	0.427	0.426	0.423

Notes: The variables are defined as follows: *wage* is hourly wage; *edu_ind* is the individual years of education; *skilled_city* is the proportion of high-skilled workforce (defined as having a college education or higher); and *edu_city* is average years of education. IV1 is the number of outgoing university departments, and IV2 is the number of incoming university departments. In the regression, personal experience, squared experience, gender, marital status, ethnicity, years of education, and province effects have been controlled. Standard errors are shown in parentheses, clustering to the city level.

*** $p < .01$.

Source: Authors.

⁴ Glaeser and Lu (2014) provided evidence that the number of relocated departments was almost random across cities, which is not related to the city's location and its investment in the 1960s and 1970s. One department moved in has increased about 0.03 years of schooling at the city level.

Moreover, positive externalities produced by high-skilled labor are reflected in other areas such as the crime rate. Increases in the number of high-skilled workers may contribute to the reduction of urban crime, forming a model effect, bringing down the overall crime rate, and improving the attractiveness of the city (Moretti 2004a).

Human capital externality is generated through face-to-face communication (Fujita and Ogawa 1982; Glaeser 1999; Lucas 1988; Lucas and Rossi-Hansberg 2002); as such, the existence of human capital externalities is confined within a small geographic area (Fu 2007; Rosenthal and Strange 2008), thus causing an agglomeration of more high-skilled laborers in cities (especially the big cities) to enjoy human capital externalities. Hence, we can speculate that cities with a higher proportion of high-skilled laborers will attract more high-skilled workers in subsequent developments, thus leading to divergence of human capital between cities.

Using the 2000 and 2010 census data, and following Berry and Glaeser (2005), we examined human capital situations in the city from the year 2000 and their impact on changes in city human capital from 2000 to 2010 (Table 2). In the first two columns, we used the increase of the proportion of a high-skilled workforce as an explained variable and the initial proportion of a high-skilled workforce as an explanatory variable. It was determined that an increase of 1% in the proportion of high-skilled laborers in the year 2000 caused an increase of 1.3% in the proportion of high-skilled laborers between 2000 and 2010 as shown in column 1. In column 2, even if we controlled the scale of urban population, per capita GDP, and industrial structure for the year 2000, the conclusion remained valid. Taking into account that the changes in the proportion of high-skilled labor may not be normally distributed, we used a logarithmic change for the number of high-skilled workers as the explained variable in column 3, which was equivalent to the growth in the number of high-skilled workers. The results revealed that the higher the proportion of high-skilled laborers in 2000, the lower the growth rate of high-skilled laborers during 2000–2010. The lower growth rate is due to the high proportion base of a high-skilled workforce. It is worth mentioning that the initial high proportion of a high-skilled workforce also influences the follow-up proportion of high-skilled workforce in the United States (US) (Berry and Glaeser 2005).

The regression results in Table 2 demonstrate that the initial high proportion of a high-skilled workforce affects the follow-up proportion. Regarding the proportion of a low-skilled workforce, we added the proportion of a low-skilled workforce based on the regression results in Table 2 and consequently generated Table 3. Table 3 shows that the initial higher proportion of low-skilled laborers will not lead to an increase in the proportion of a high-skilled workforce over a subsequent period, but rather a reduction. Meanwhile, it was verified again that the initial high proportion of a high-skilled workforce results in a significant increase in the follow-up proportion of the high-skilled workforce, which also showed the robustness of the regression results in Table 2.

Table 2: Examination of the Impacts Relating to the Initial Proportion of the High-Skilled Workforce upon the Follow-Up Proportion

Explained Variable	Growth of Proportion of High-Skilled Workers		Growth Rate of the Number of High-Skilled Workers	
	<i>highskilled_2000</i>	1.308*** (0.0676)	1.020*** (0.0917)	-6.147*** (0.925)
<i>Ln pop_2000</i>		0.00221** (0.000935)		-0.00309 (0.0240)
<i>Ln GDP_2000</i>		0.00518*** (0.000829)		0.135*** (0.0277)
<i>industrystructure_2000</i>		0.00131 (0.00174)		0.147*** (0.0294)
Constant	0.00876*** (0.000642)	0.0200 (0.0197)	1.353*** (0.0198)	0.996** (0.413)
<i>N</i>	260	260	260	260
adj. <i>R</i> ²	0.839	0.862	0.107	0.291

GDP = gross domestic product.

Notes: High-skilled workforce is defined as having a bachelor's degree or above, medium-skilled workforce as having a high-school diploma and 3-year college degree, and low-skilled workforce as having a middle-school education or lower. The variables are defined as follows: *highskilled_2000* is proportion of high-skilled workforce in 2000; *pop_2000* is urban population in 2000; *GDP_2000* is GDP per capita in 2000; and *industrystructure_2000* is industry structure in 2000, which refers to the ratio of the output values of the tertiary industry to the secondary industry. Robust standard errors are shown in parentheses.

** p <.05, *** p <.01.

Source: Authors.

Table 3: Examination of Impacts of the Initial Proportion of Low-Skilled Workforce on the Follow-Up Proportion of High-Skilled Workforce

Explained Variable	Growth of Proportion of High-Skilled Workforce			
	<i>Lowskilled_2000</i>	-0.233*** (0.0198)		-0.0288+ (0.0194)
<i>highskilled_2000</i>		1.308*** (0.0676)	1.183*** (0.0741)	1.020*** (0.0917)
<i>Ln pop_2000</i>				0.00221** (0.000935)
<i>Ln GDP_2000</i>				0.00518*** (0.000829)
<i>industrystructure_2000</i>				0.00131 (0.00174)
Constant	0.220*** (0.0170)	0.00876*** (0.000642)	0.0344** (0.0171)	0.0200 (0.0197)
<i>N</i>	260	260	260	260
adj. <i>R</i> ²	0.673	0.839	0.841	0.862

GDP = gross domestic product.

Notes: High-skilled workforce is defined as having a bachelor's degree or above, medium-skilled workforce as having a high-school diploma and 3-year college degree, and low-skilled workforce as having a middle-school education or lower. The variables are defined as follows: *lowskilled_2000* is the proportion of low-skilled workforce in 2000; *highskilled_2000* is the proportion of high-skilled workforce in 2000; *pop_2000* is urban population in 2000; *GDP_2000* is GDP per capita in 2000; *industrystructure_2000* is industry structure in 2000, which refers to the ratio of the output values of the tertiary industry to the secondary industry. Robust standard errors are shown in parentheses.

+ p <.15, ** p <.05, *** p <.01.

Source: Authors.

At this point, we know that the proportion of a high-skilled workforce will influence the follow-up proportion of a high-skilled workforce. To determine whether this is the result of economic concentration or industrial transfer, we took advantage of a sub-sample of the 1% population survey in 2005 to calculate the following two indicators:

$$\eta_m^{IS} = \sum_i \frac{\sum_m H_{m,i} \cdot L_{m,i}}{\sum_m L_{m,i} \cdot L_m} \quad (1)$$

$$\eta_m^\phi = \sum_i \frac{H_{m,i}}{L_{m,i}} \cdot \frac{\sum_m L_{m,i}}{\sum_m L_m} \quad (2)$$

Assuming that the ratio of high-skilled workforce to low-skilled workforce is the same in each city, η_m^{IS} refers to different skills across industries that are due to different numbers of jobs, where m denotes city and i denotes industry. We regressed city m 's specialization index η_m^{IS} on its ratio between the high-skilled workforce and the low-skilled workforce, $\ln \frac{H_m}{L_m}$. The coefficients represent the differences in skills across industries, which can explain the degree to which skills differ between cities. Assuming the employment ratios of various industries are the same across all cities, η_m^ϕ refers to differences in skills across industries. Through a regression analysis of η_m^ϕ on $\ln \frac{H_m}{L_m}$, the coefficients represent the differences in skills across industries, which can then explain the degree to which differences exist in skills across cities. According to regression results in Table 4, the coefficients of the ratio between an urban high-skilled workforce and a low-skilled workforce under a 1% confidence level are all significantly positive. The regression coefficient for column 1 is 0.164. This is far less than that of column 2, which is 0.791, indicating that human capital differences between cities primarily come with differences within the industry. Similarly, Berry and Glaeser (2005) discovered that in the US, human capital differentiations across cities from 1970 to 2000 were not caused by differences between industries, but mainly differences within industries. Coefficients similar to those used for column 2 in Table 4 were around 0.8 (Hendricks 2011).

Table 4: Study of Sources of Skill Composition in Cities

	$\ln \eta_m^{IS}$	$\ln \eta_m^\phi$
$\ln \frac{H_m}{L_m}$	0.164***	0.791***
	(0.00343)	(0.00725)
Constant	0.197***	-5.787***
	(0.00326)	(0.00689)
N	6,201	6,201
adj. R^2	0.269	0.657

Note: This is a sample of x industry in cities, with a total of 340 cities and 19 major industries. Not all cities include all industries.

*** $p < .01$.

Source: Authors.

Since cities with a higher proportion of high-skilled laborers attract more high-skilled workers in subsequent developments, the level of human capital between cities will gradually diverge. Using data from the 2000 census and 2010 census, we studied human capital differences between cities. The indicators included the mean, standard

deviation, interquartile range, difference index, and isolation index.⁵ Table 5 shows the proportion of college students increasing, on average. At the same time, differences in the proportion of college students between cities are also expanding.

Table 5: Intercity Divergence of Human Capital (2000–2010)

Year	Mean	Standard Deviation	75–25 Quartile Ratio	Difference Index	Isolation Index
2000	0.0121	0.0135	0.00791	1.08e-08	0.0203
2010	0.0368	0.0312	0.0205	3.19e-08	0.0409

Source: Authors.

Finally, we wanted to determine the mechanisms used by high-skilled laborers to promote the intercity divergence of human capital. Among them, entrepreneurship is important. First, urban human capital will promote entrepreneurship (Glaeser et al. 2010). Second, highly educated entrepreneurs and managers tend to hire more high-skilled staff (Berry and Glaeser 2005; Kremer and Maskin 1996). As for the situation in the PRC, the above two hypotheses have yet to be verified as data regarding the education level of corporate representatives or their employees' educational structure are lacking. However, we can still offer two pieces of evidence. One is that urban average education levels in the PRC exhibit negative effects on entrepreneurship (Lu and Ni 2015), which is contrary to the situation in the US (Glaeser et al. 2010). The other is that using a 2-digit occupational code from the microdata from the 2000 census and 2005 census, we calculated the proportion of high-skilled workers among business managers in each city and analyzed its correlation to the city's proportion of high-skilled workers. We found a correlation coefficient of 0.3347 in 2000, which was significant at 5%. It was 0.0299 in 2005, but not significant. Thus, we believe that the intercity divergence in human capital is not because enterprises in the PRC with a greater number of highly educated entrepreneurs and managers may employ more highly-skilled staff. Nevertheless, the situation's details require further study.

Put simply, a high-skilled workforce can promote urban wage increases, population growth, and urban development.

3. URBAN DEVELOPMENT PROMOTES SKILL COMPLEMENTARITIES

Since a high-skilled workforce is the engine of urban development, there is the question of why the low-skilled workforce coexists within the city. This is a result of skill complementarity between these high and low skills. From a productivity perspective, if low-skilled and high-skilled workforces can promote each other's productivity, then skill complementarity exists between them. From an employment perspective, if low-skilled and high-skilled workforces can promote each other's employment, skill complementarity also exists between them.

⁵ Difference index = $\frac{1}{2} \sum_{city i} \left| \frac{skilled_{city i}}{\sum_{city i} skilled} - \frac{unskilled_{city i}}{\sum_{city i} unskilled} \right|$ is used to calculate the proportion of high-skilled workforce needed to be redistributed for all cities to have the same rate of high-skilled workforce.

Isolation index = $\sum_{city i} \frac{skilled_{city i}}{population} \frac{skilled_{city i}}{\sum_{city i} skilled} - \frac{\sum_{city i} skilled}{\sum_{city i} population}$ is used to calculate the proportion of high-skilled workers around a high-skilled person.

Here, we tested skill complementarity in productivity. As shown in Table 6, we examined the ways in which the proportion of a high-skilled workforce impacted wages of different skilled labor, based on the microdata from the 2005 census. In Table 6, an increase of 1% in the proportion of the high-skilled workforce resulted in an increase of 6.11% in hourly wages for high-skilled laborers and an increase of 7.17% in hourly wages for low-skilled laborers. Thus, the impact on low-skilled labor was slightly larger than that on high-skilled labor. In addition, when we subdivided low-skilled laborers into medium-skilled laborers with a high-school diploma and a 3-year college education, and low-skilled laborers with a junior high-school education and lower, the proportion of the high-skilled workforce had the most significant effect on low-skilled labor wages.

This result is similar to those found in other publications (Glaeser and Lu 2014; Moretti 2004b). Therefore, the existence of skill complementarity between high-skilled and low-skilled workforces can be demonstrated here.

Table 6: Impacts of the Proportion of High-Skilled Labor on Wages of Workers in Cities

Ln Hourly Wage	High Skilled	Low Skilled
<i>highskilled_city</i>	0.0611*** (0.0118)	0.0717*** (0.0111)
Constant	-0.450** (0.189)	-0.523*** (0.0484)
<i>N</i>	35,470	1,049,497
adj. R^2	0.268	0.325

Notes: Personal characteristics, including personal experience, squared experience, gender, marital status, ethnicity, and years of schooling, are controlled for the regression models. A high-skilled workforce is defined as labor possessing a bachelor's degree or higher, and the rest is defined as low-skilled workforce.

** $p < .05$, *** $p < .01$.

Source: Authors.

Second, we explored skill complementarity in changes in employment. If the initial increase in the proportion of high-skilled laborers not only promotes follow-up employment for high-skilled laborers, but also employment for low-skilled laborers, then there is skill complementarity between them. Using data from the 2000 census and the 2010 census, we got Table 7. It was found that a 1% increase in the proportion of high-skilled labor in 2000 resulted in a significant increase of 1.129% in the proportion of high-skilled labor, a significant decrease of 1.479% in the proportion of medium-skilled labor, and a non-significant increase of 0.351% in the proportion of low-skilled labor but t test of the coefficient was greater than 1. Therefore, skill complementarity between high- and low-skilled laborers exists in cities. Similar situations have also occurred in the US: from 1970 to 2000, an initially high proportion of high-skilled laborers led to increases in both the proportions of high-skilled and low-skilled labor over the following 10 years (Berry and Glaeser 2005).

At the firm level, we can also observe the phenomenon of skill complementarity. Skill complementarity affects hiring decisions. Faced with heterogeneous labor during the hiring process, it is necessary for enterprises to consider whether complementarity exists between heterogeneous workforces. Interactions between heterogeneous laborers will generate externalities with the presence of communication costs. Business owners will increase the diversity of staff members when the positive externalities are greater than the cost of communication—in other words, when there is complementarity between heterogeneous staff members (Lazear 1999). In general,

positive externalities generated by the different education levels of employees will exceed communication costs, leading to an increase in productivity. However, heterogeneity in age and race showed reversed effects (Garnero and Rycx 2013; Parrotta et al. 2012). Using the 2008 economic census data, Liang and Lu (2014) found that when a firm is larger than some threshold value, skill complementarity will appear within firms.

Table 7: Heterogeneity of Population Growth

	Proportional Increase of High- Skilled Labor	Proportional Increase of Medium- Skilled Labor	Proportional Increase of Low- Skilled Labor
<i>highskilled_2000</i>	1.129*** (0.0944)	-1.479*** (0.190)	0.351 (0.252)
<i>Lnpop_2000</i>	0.00177+ (0.00118)	0.0109*** (0.00286)	-0.0127*** (0.00340)
<i>GDP_2000</i>	0.00538*** (0.000877)	0.000618 (0.00305)	-0.00600* (0.00320)
<i>Industrystructure_2000</i>	0.00110 (0.00161)	0.00552* (0.00312)	-0.00662* (0.00360)
Constant	0.00131 (0.00376)	-0.00815 (0.0118)	0.00684 (0.0126)
<i>N</i>	260	260	260
<i>adj. R²</i>	0.861	0.295	0.067

GDP = gross domestic product.

Note: Robust standard errors are shown in parentheses.

+ $p < .15$, * $p < .10$, *** $p < .01$.

Source: Authors.

The presence of skill complementarity can explain why low-skilled and high-skilled labor can coexist in cities. However, it is less clear how urban development affects skill complementarity. In big cities, there are more high-skilled workers with more human capital externality, which is bound to promote skill complementarity. At the same time, cities might also affect the level of skill complementarity. The proportion of highly skilled labor is higher, while the average skill level is almost the same as in smaller cities (Bacolod et al. 2009), and skill levels in major cities have greater variance (Gautier and Teulings 2009). Eeckhout et al. (2014) studied skill complementarity from the perspective of urban economics for the first time, and analyzed skill distribution in large and small cities based on US data. They found a higher proportion of high-skilled and low-skilled labor in big cities, and a lower proportion of medium-skilled labor, indicating that big cities promote skill complementarity.

Using a sub-sample of the 1% population survey in 2005, we compared the distribution of skills between different cities to study the level of skill complementarity. We defined a high-skilled workforce as having a bachelor's degree or above; a medium-skilled workforce comprising those with a high-school diploma or a 3-year college degree; and a low-skilled workforce with a middle-school education or lower. Then we directly compared the numbers of these three labor categories between big and small cities in Table 8. In large cities, the average years of education is 9.785 years, while in small cities it is 8.456 years. The difference is 1.32, which is significant at 1% level. Furthermore, we can see a higher proportion of high-skilled and medium-skilled labor in big cities, but the proportion of low-skilled labor is lower. The situation in the US

(in Figure 2) is opposite to what is shown in Table 8: there are high proportions of both high-skilled labor and low-skilled ones in big cities.

Table 8: Comparison of the Numbers of Skilled Laborers in Large and Small Cities

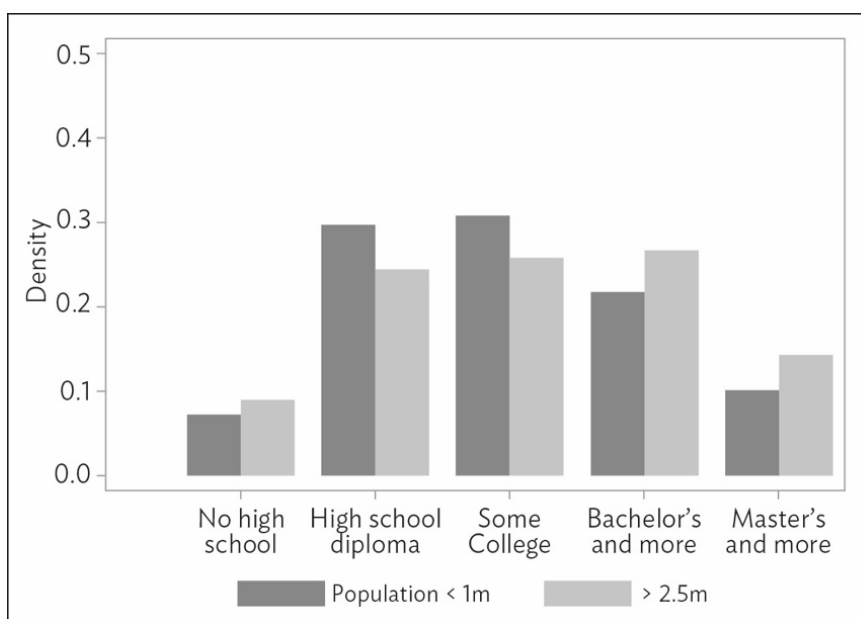
City Size	High Skilled	Medium Skilled	Low Skilled	Average Years of Education
Small city (173)	0.0187	0.179	0.803	8.465
Large city (24)	0.0597	0.276	0.664	9.785
Difference	0.041***	0.097***	-0.139***	1.32***

Note: A small city is defined as a city with a population of less than 1 million, and a large city with a population of more than 2.5 million.

***p<.01.

Source: Authors.

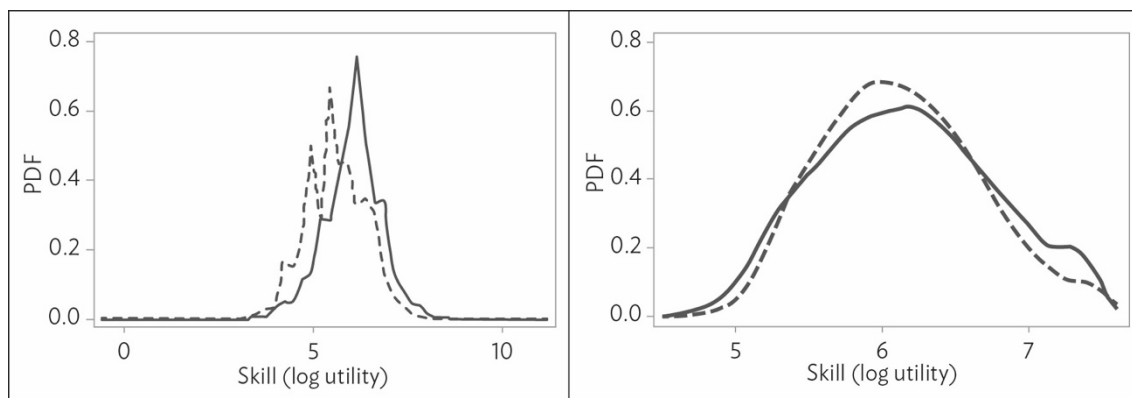
Figure 2: Skill Composition across Different Cities



Source: Eeckhout et al. (2014), Figure 11.

We also used real wages to measure the skill level and to study skill distribution within the city (Figure 3). From the figure on the right, it can be seen that the skill distribution in large US cities present a high proportion of both high-skilled and low-skilled labor, which is similar to the conclusion drawn from Figure 2. However, using the wage information in the survey data in 2005, the skill distribution in the PRC's large cities is skewed toward right—meaning there is a high proportion of high-skilled labor and a low proportion of low-skilled labor. One reason for this might be the bias toward a high-skilled workforce based on the unique household registration system (HRS) in the PRC. We will discuss the situation in more detail in the next section.

**Figure 3: Skill Distribution of Small and Large Cities:
PRC versus the US**



PRC = People's Republic of China, US = United States.

Notes: The figure on the left is skill distribution in the PRC's cities. On the right is skill distribution in US cities, which is from Eeckhout et al. (2014). The skill level is the adjusted results of the annual wage on the housing price, and the expression is $U = \alpha^\alpha (1 - \alpha)^{(1-\alpha)} w/p^\alpha$, where $\alpha = 0.24$ in the US (Eeckhout et al. 2014) and $\alpha = 0.3$ in the PRC. The conclusion is robust to change in α . The dashed lines denote the small cities with a population smaller than 1 million; the solid lines denote the major cities with a population larger than 2.5 million.

Source: The figure on the left is from author's calculation; the figure on the right is from Eeckhout et al. (2014), Figure 1.

We have demonstrated that big cities promote skill complementarity, enabling a greater number of high-skilled laborers, as well as low-skilled laborers, to coexist in cities. Why do big cities promote skill complementarity? The reasons might be as follows:

- (i) Division of labor. When the market capacity increases, division of labor is more refined, different skilled labor is more closely related, and the situation is more prone to skill complementarity.
- (ii) Human capital externalities. The presence of human capital externality improves the labor productivity of people around high-skilled labor. Big cities have higher population density, which enhances social interaction and knowledge spillover.

Combining the above two points, it can be seen that division of labor can engage people with various skills in occupations consistent with their comparative advantages. In the presence of externalities, increases in high-skilled labor will improve the productivity of high-skilled labor while also promoting the productivity of low-skilled labor. Therefore, big cities promote skill complementarity. We found that skill complementarity between high-skilled and low-skilled laborers can appear within an enterprise. However, the effects of promoting complementarity in big cities are not significantly stronger than those in medium-sized or small cities. Nevertheless, big cities might promote skill complementarity by promoting externalities between enterprises and between industries (Liang and Lu 2014).

- (iii) Consumption externalities. Rising wages will increase the opportunity cost in housework. For the high-skilled workforce, high opportunity costs in housework will result in housework being outsourced to low-skilled laborers for work involving housekeeping, catering, and other consumer services. Meanwhile, increasing wages will lift the demands for other services, including health care, arts, and legal services, where the workforce is largely high-skilled. Big cities will increase wages for high-skilled labor, thus promoting high-skilled laborers to outsource their housework, increasing the demand for consumer services,

and further improving employment for consumer services. Each high-skilled job has been estimated to lead to an increase of five job vacancies in consumer service, two of which are for high-skilled occupations such as health care, art, and law; while the rest is for low-skilled labor such as food services and cashiers (Moretti 2012).

4. THE HOUSEHOLD REGISTRATION SYSTEM SUPPRESSES SKILL COMPLEMENTARITIES

Through sharing, matching, and learning mechanisms, incomes in big cities improve while living costs increase. By trading off income and corresponding living costs, workforces select among different cities to maximize utility. When labor is freely mobile, skilled labor receives the same utility between different cities, thus achieving a spatial equilibrium. When free mobility of laborers is impeded, labor could not flow to the cities to achieve higher utility, which would result in the loss of utility. On the other hand, labor may flow to or remain in a particular city for some city-specific interests that are only provided to local *hukou* residents,⁶ leading to distortion in the labor market.

As shown in Figure 3, it is already known that large cities in the US have agglomerated higher proportions of high-skilled labor and low-skilled labor while skill distribution in the PRC's metropolitan cities has shifted to the right, indicating that big cities in the PRC have gathered a higher proportion of high-skilled labor instead of low-skilled labor. When comparing the situation between the US and the PRC, the reason behind this outcome could be the HRS, which increases the cost for low-skilled labor to flow to big cities and settle down.

Formed during the planned-economy era, the HRS still profoundly impacts all aspects of the lives of affected residents (Chan and Buckingham 2008). Without local household registration, people could face all kinds of discrimination with regard to employment, social security, and public services (Lu and Wan 2014). The HRS favors high-skilled labor in two ways. First, the HRS barely obstructs the free flow of skilled labor. What occurs more often is that high-skilled laborers would prefer to sacrifice a part of their salary to enjoy the public services that come with the local urban registration, as opposed to moving to another city for a better job. This spatial mismatch of human capital is bound to undermine the country's welfare. Second, the HRS hinders the free flow of low-skilled labor into cities with better opportunities and higher incomes, resulting in no improvement in personal welfare and suppressing skill complementarity, which further decreases the productivity of high-skilled laborers.

Above all, the HRS leads to changes in skill distribution in different cities. Compared with small cities, big cities do not attract a higher proportion of low-skilled laborers. However, to what extent this is caused by the HRS remains to be seen. Following Firpo et al. (2009), we decomposed factors influencing skill distribution in Table 9. The settlement index in the table is conducted by Wu and Zhang (2010). The higher the index, the harder the settlement, and the stricter the HRS. The results showed that for low-skilled labor, such as labor ranked at the 10th percentile in the skill distribution, the index was significantly negative, revealing a higher index, which indicates a lower proportion of low-skilled labor at the 10th percentile in big cities. For high-skilled labor, such as labor ranked at the 90th percentile in the skill distribution, the index was significantly positive, revealing that the higher the index, the higher the proportion of

⁶ In the PRC, better public service and greater chances to enter universities are such city-specific interests related to one's local *hukou* identity.

high-skilled labor ranked at 90 in big cities. Therefore, the HRS indeed leads to a greater number of high-skilled laborers and fewer low-skilled laborers in cities.⁷

Table 9: Hukou Affects Skill Distribution in Cities

Skill Level	10th Percentile	90th Percentile
<i>Hukou index</i>	-0.0862*** (0.00434)	0.0659*** (0.00616)
<i>High-skilled share</i>	7.926*** (0.125)	-3.229*** (0.144)
<i>Ln per capita GDP</i>	0.335*** (0.00523)	0.328*** (0.00785)
<i>Indus. Struc. (tertiary-secondary)</i>	-0.416*** (0.00759)	0.163*** (0.00850)
Constant	2.985*** (0.0260)	4.081*** (0.0238)
<i>N</i>	268,850	268,850
<i>adj. R2</i>	0.164	0.179

GDP = gross domestic product.

Notes : Robust standard errors are in parentheses. The regressions have controlled for individual experience, squared experience, ethnicity, sex, and years of schooling. The skill level is the adjusted result of the annual wage on the housing price, and the expression is $U = \alpha^\alpha (1 - \alpha)^{(1-\alpha)} w/p^\alpha$, where $\alpha = 0.3$. The conclusion is robust to change in α . Considering that Wu and Zhang (2010) only constructed the settlement index for 45 cities, mainly big cities such as provincial capitals, we defined 18 small cities as those with a population under 2 million, and 14 big cities as those with a population of more than 3 million.

*** $p < .01$.

Source: Authors.

The HRS also affects skill distribution in cities, which in turn suppresses skill complementarity. Liang and Lu (2014) studied the impact of the HRS on skill complementarity within the firm. Employees of state-owned enterprises can obtain the household registration more easily than employees of non-state-owned enterprises. Thus, in cities where the HRS is stricter, state-owned enterprises are more inclined to hire low-skilled local labor to replace nonlocal high-skilled labor, which inevitably results in a higher proportion of low-skilled labor in state-owned enterprises. It was empirically discovered that skill complementarity in state-owned enterprises is lower compared with non-state-owned enterprises, and even fewer in larger metropolises. Once the settlement index has been controlled, the differences in skill complementarity between state-owned enterprises and non-state-owned enterprises will lessen, and the skill complementarity within firms in big cities will greatly increase. The conclusions have shown that the HRS will indeed suppress skill complementarity within firms.

⁷ We also found from Table 9 that the coefficient of the index of the proportion of high-skilled labor was significantly positive, ranking at the 10th percentile for labor distribution, while it was significantly negative at the 90th percentile for labor distribution. This partly indicates that when the effect of the household registration system was under control, the agglomeration of a high-skilled workforce led to an increase in the demand for a low-skilled workforce, while the increase in the proportion of the high-skilled workforce caused competition between high-skilled workers. The industry structure index (the ratio of tertiary industries to secondary industries) was significantly negative at the 10th percentile for labor distribution, but significantly positive at the 90th percentile for labor distribution. This indicates that when compared with the development of the secondary industry, the development of the tertiary industry is less likely to promote the employment of low-skilled workers. Likely, this is because the tertiary industry in the PRC's cities focuses more on business services, while consumer services, which use low-skilled workforce, are suppressed.

In addition, when household registration is restricted, migrants (especially low-skilled laborers) can neither easily settle down in cities nor enjoy public services such as health care or education. Consequently, the elderly and children remain in their hometowns and a greater number of women stay in their hometown to take care of them. Family separation will negatively influence children's growth and education and the health of the elderly, and will lead to more migrants sending home remittances, thereby reducing local consumer demand. Using the sample of CHIPS 2002, we calculated the average remittances sent home by each migrant, and multiplied that by the number of migrants based on microdata of the 2005 population survey in each city; we obtained the total amount of money and estimated its impact on the wages of local residents. The results revealed that a 1% increase of the remittance amount depresses the wage of local workers by 0.088%. The reason for this is that the more remittances migrants sent home, the lower consumer consumption was in the city, which is not conducive to the growth of job vacancies, thus leading to decreases in employment and local wages. Considering that urban migrants frequently comprise the low-skilled labor pool, we believe that the HRS can suppress skill complementarity by reducing consumption externalities.

5. CONCLUSIONS

In this paper, we studied the spatial distribution of skills and the corresponding changes in the PRC's cities using earlier census data and reached the following three conclusions:

- (i) A high-skilled workforce is the engine of urban development, promoting urban wages and population size. This is because high-skilled laborers not only have high productivity but also generate substantial human capital externalities, improving the labor productivity of other residents.
- (ii) However, high-skilled labor is not wholly responsible for urban development; it is also inseparable from low-skilled labor—there is skill complementarity between the two. Big cities can likewise promote skill complementarity, meaning that there can be a greater number of both high-skilled and low-skilled laborers in cities at the same time.
- (iii) We revealed that the HRS, which favors high-skilled laborers, will result in more high-skilled labor but less low-skilled labor. This system suppresses the supply of low-skilled labor and skill complementarity, which is not conducive to urban development or a city's economic growth.

This work has demonstrated that addressing high-skilled labor while ignoring low-skilled labor to upgrade industries during the urbanization process would be harmful to healthy urban development. In post-industrialization cities, consumer service is the key to developing large cities, and the low-skilled workforce is the primary provider of consumer services. Excluding low-skilled labor from a city negatively impacts economic development and urban competitiveness.

The attractiveness of a city lies in its freedom and diversity. Obstructing the free mobility of labor is not helpful in improving the quality of life in cities, thereby harming economic growth and urban competitiveness. In the process of urban development, the PRC's cities should not only create conditions for accumulating high-skilled labor but also gradually eliminate the institutional discrimination of low-skilled labor.

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* The Asian Development Bank refers to “China” as the People’s Republic of China.

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