

## RETRACTED ARTICLE: Does urban spatial structure affect labour income? – research based on 97 cities in China

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# RETRACTED ARTICLE: Does urban spatial structure affect labour income? – research based on 97 cities in China

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## ABSTRACT

The purpose of the research is that: In the context of China's rapid urbanisation in recent 20 years, to discuss about how the spatial structure elements such as the size of city, density, pattern and so on influence the staff's remuneration. Research method: Using American 'Defense Meteorological Satellite Program' nighttime light data and Land-Scan population distribution data, three urban distance indicators are calculated to quantify the city geometric shape and urban sprawl indices are measured in order to illustrate the urban spatial structure. China Household Finance Survey (CHFS) data from household surveys are also used to investigate how the city shape affects individual wages with method Instrument Variable (IV). When individual characteristics are controlled, we find that a larger population size and a higher density are conducive to higher labour income due to agglomeration advantages, while a 'worse' city shape is significantly correlated with lower wages, suggesting that the city shape influences urban agglomeration and the mechanisms through TFP of firms prevails. Further discussion shows that urban density matters less for those working in the secondary sector while the adverse effect of poor urban geometry can be alleviated in cities with a lower density and in those with a large extension of highways per capita.

## ARTICLE HISTORY

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## 1. Introduction

Changes in the wage gap are important issues of global concern. Clarifying the determinants of wage income and understanding the underlying causes of wage differences between different individuals and regions will not only be of reference value in formulating urban development strategies, but also help narrow the gap between the rich and the poor and promote social equity and regional balanced development.

Neoclassical economic theory holds that wages depend on the marginal value of the elements of labour. Increased total factor productivity and rising capital stock per capita will help increase per capita income and real wages. Mincer (1974) proposed

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the classic wage determination equation, emphasising the impact of human capital and work experience on personal wage income from a micro level. Based on the above research Combes et al. (2008) and Qiang (2012) studied the influence of personal factors such as education level, work experience, gender and social capital. Although wage income depends to a large extent on individual factors, individuals cannot be separated from the influence of the local area and social environment, so the wage differences between regions cannot be fully explained by individual reasons (Fleisher & Chen, 1997; Guitian & Zhifeng, 2009; Jianhong et al., 2006; Xuehui & Luodan, 2002). The study uses the characteristics of the city level as explanatory variables of personal wages or regional average wages, such as the proportion of FDI in cities, Investment in fixed assets, local unemployment rate and so on (Xiuyan & Xingmin, 2009).

However, most of the above literatures focus on the workers' own characteristics or the non-spatial characteristics of cities, ignoring the impact of spatial distribution of population and economic activities on wages. New economic geography theories put forward by later researchers remind us: the impact of spatial externalities on economic activities cannot be ignored. In the past few decades, the most obvious and sustainable spatial economic phenomenon in China is the agglomeration of large numbers of population and economic factors into cities. This behaviour has brought rapid urbanisation. As a result, the size of cities has continued to expand, and urban spatial structure and economic characteristics have undergone earth-shaking changes.

### **1.1. Research objectives and methods**

Therefore, the goal of the article is since the economic reform and open up, massive population and economic factors merge in the cities, in the context of the expanding size of city, to discuss about the influences the city's spatial external factors have on economic affairs. More specifically speaking, given that other influence factors stay unchanged, attempt to illustrate how the spatial structure elements, such as the size of city, density, pattern and so on influence the staff's remuneration, there are two different points for the research: first, utilise the relative data in China which could represent other developing countries to expand the academic research in aspect of spatial economics. Second, to provide scientific and sound suggestions to China's 'new-type urbanization'.

Research methods: first, the individual remuneration will be used as explanatory variable, the source of data stems from household finance research project carried out in China, DMSP/OLS Nighttime Light Image is used for quantifying the geometric forms of the sample city in the corresponding year, city density will be reflexed by spread index, geographic tool variables are used for reducing reverse causality or inward matters caused by omitted variables, opt the surface roughness and surface roughness square in the sample cities as the variables for evaluating the city's density index, all those variables will explained in a specific way in the following content; Second, the article will use the corresponding data of hourly salary as the explanatory variable and use the spread index, urban status and size of population as the core explanatory variable. It will specifically view city density as inward variables for least

square mixed cross section in two different phases, to return to the initiative phase of urbanisation and explore its influences on staff's remuneration. Third, to adopt the logarithm of average population density in urban area instead of the spread index of city previously used in order to re-evaluate and re-calculate the index of urban status, to reflex the size of city by using registered population, to use tool variables for testifying the reverse causality and other measures for verifying the robustness of model. In the end, the article adopts split sample and interaction-add item method, to carry out a series of searches regarding the sample's heterogeneity. In order to avoid the biased errors caused by selectivity and inwardness, two measures are used: one is to control the individual characters by utilising China's household finance researches; the other one is to use geographic tool variables for city density, meanwhile to discuss about city status and the inward influences of population size. The result claims that the inward agglomerative economics in China's cities exist in a pervasive way, and the city structure has indispensable influences on the remuneration.

References, Roback (1982) and other scholars consider the general equilibrium idea of space, examine the impact of urban density and residential comfort on wage income, and discuss the impact of urban spatial structure on technological externalities.

## 1.2. Hypothesis and theoretical explanation

### 1.2.1. Consumer preferences and the real estate market

The goal of a representative consumer is to maximise utility, and the personal utility function is homogeneous once:

$$U = \theta C^\alpha H^{1-\alpha} \quad 0 < \alpha < 1 \quad (1)$$

Among them,  $C$  and  $H$ , respectively, represent the consumption of ordinary consumer goods and housing,  $\theta$  is the comfort of living, and  $\alpha$  represents the share of consumer spending on income. Assume that the price of housing in a city is  $P_h$ , the price of consumer goods is standardised to 1 in all cities, and the actual income of workers is derived from wages  $W$ , then housing consumption  $H = [(1-\alpha)W]/P_h$ . The general spatial equilibrium analysis in this article relies on the key assumption that populations can move freely between different cities, which means that in the long-term equilibrium state, representative workers should obtain a retention utility  $\bar{V}_0$  in any city. Otherwise, as long as the utility is below  $\bar{V}_0$ , the worker has an incentive to move to a city where he can obtain more efficient use. The direct utility of the consumer can be expressed as:

$$\ln \bar{V}_0 = \ln \theta + \ln W - (1-\alpha) \ln P_h + k_1 \quad (2)$$

$k_1$  is constant,  $k_1 = (1-\alpha) \ln (1-\alpha) + \alpha \ln \alpha$  (The  $k_n$  appearing below are all constants. In order to make the model concise, the values are not listed one by one). At the same time, the goal of real estate developers is to maximise profits:

$$\max \pi_h = P_h L q - \psi L q^\delta \quad (3)$$

where  $q$  is the average residential building height of the city, and  $L$  is the total area of land used for housing in that city, parameter  $\psi > 0$ ;  $\delta > 1$ . The construction cost representing the unit area monotonically increases with the rise in height, and the growth rate is getting faster and faster (Curci, 2015). At this time, the construction height that can maximise the profit of developers is:

$$q^* = \left( \frac{P_h}{\psi \delta} \right)^{\frac{1}{\delta-1}} \quad (4)$$

Let the total population of the city be  $N$ . According to the quantitative relationship when the housing market reaches equilibrium, the following formula is obtained:

$$[\delta/(\delta-1)] \ln P_h = \ln W + \ln N - \ln L + k_2 \quad (5)$$

The total urban population  $N$  divided by the total area  $L$  can approximate the urban spatial density  $D$ . The above formula can be rewritten as:

$$[\delta/(\delta-1)] \ln P_h = \ln W + \ln D + k_2 \quad (6)$$

When the real estate market and laborer's expenditure income reach equilibrium at the same time, simultaneous Equations (2) and (6) can be obtained:

$$\frac{\alpha(\delta-1)+1}{(1-\alpha)(\delta-1)} \ln W = \ln D + \frac{\alpha}{(1-\alpha)(\delta-1)} [\ln \theta - \ln(\bar{V}_0)] + k_3 \quad (7)$$

$\delta-1 > 0$ ,  $\alpha > 0$  and  $1-\alpha > 0$ , under general equilibrium, real wage income  $W$  is positively related to density and negatively related to living comfort. If the comfort of a city is low, workers need to be compensated with higher wages to ensure that they get the same retention utility without the motivation to migrate. The mechanism of mutual compensation for comfort and wages stems from the movement of workers between different cities. More comfortable cities are flooding with more workers, increasing labour supply and lowering real wages. At the same time, when satisfying the general equilibrium of space:

$$\frac{\alpha(\delta-1)+1}{\delta-1} \ln P_h = \ln D + \ln \bar{V}_0 - \ln \theta + k_4 \quad (8)$$

Since wages are generally positively correlated with urban density in general equilibrium, wages are also positively correlated with housing prices. In other words, as housing prices rise, real wages will increase accordingly as compensation.

### 1.2.2. Enterprise production and wage income

Assume that the companies producing consumer goods in the same city have the same production technology and constant returns to scale. Both the product market and the factor market are completely competitive. The production function of a representative company is the following Cobb–Douglas (C–D) form:

$$Y = AE^{\rho} N_a^{\beta} K^{\gamma} \bar{Z}^{1-\rho-\beta-\gamma} (\beta > 0; \gamma > 0; \rho > 0; \beta + \gamma + \rho < 1) \quad (9)$$

Among them,  $Y$  is the output of the enterprise.  $A$  is total factor productivity and is the same in the same city.  $N_a$ ,  $E$  and  $K$  are the labour input, human capital input and variable material capital input of the representative enterprises.  $\bar{Z}$  is the fixed capital input that does not change with output. Both variable capital and product prices are 1. In a perfectly competitive market where manufacturers' profits are all 0, after optimising the producers, we obtain the following logarithmic relationship:

$$(1-\gamma) \ln W = \ln A + \rho \ln E + (\beta + \gamma - 1) \ln N_a + (1 - \rho - \beta - \gamma) \ln \bar{Z} + k_5 \quad (10)$$

When the producer, consumer, and real estate markets meet the general equilibrium of the three sectors, each of them is also balanced, and the partial equilibrium relationship in Equation (10) must also be established. Because  $1 - \rho - \gamma > 0$ ,  $1 - \gamma > 0$ ,  $\rho > 0$ , the wage income in general equilibrium is positively related to the total factor productivity and the level of human capital.

### 1.2.3. Impact of urban spatial structure on technical externality and general equilibrium

This section will theoretically explain how the spatial form, density and population size of cities affect wage income by affecting the general equilibrium of workers or production technology of enterprises. First, a high density of the city; its interior will shorten the spatial distance of economic activity and generate positive spatial externalities, facilitating knowledge spillovers, information exchange and efficient combinations of production factors. It can be judged by the superimposed effect of technological externalities and the general equilibrium of space: urban density and wage income have a positive relationship.

Agglomeration economies depend not only on the spatial density of economic activity, but also on the number of factors. It is expected that the size of the population is positively related to productivity, which means that the size of the urban population can promote the wage income of workers. In larger cities, workers will receive a real wage premium.

This article uses the spatial distance  $S$  within a city to quantify the shape of the city. If  $S$  is large, the entire city tends to present what refers to as 'inferior forms'. Residents living in low-quality cities face more commuting hours on daily trips and have lower living comfort (Xiaoping et al., 2015). From the perspective of spatial agglomeration, urban morphology describes the spatial pattern of the distribution of factors, while inferior urban morphologies with large internal distances have weakened the externality of clustering between enterprises and caused urban internal isolation and polycentricity. Therefore it is inferred that the greater the distance indicator within the city, the lower the production efficiency; the partial effect of wages on spatial patterns is  $\frac{\partial W}{\partial S} = \frac{\partial W}{\partial A} \times \frac{\partial A}{\partial S} + \frac{\partial W}{\partial \theta} \times \frac{\partial \theta}{\partial S}$ , and its sign is uncertain, depending on the superposition of the two effects. If the urban form dominates wages through total factor productivity, poor urban forms will reduce workers' wages; if wages are mainly

affected indirectly through compensation comfort, the worse the urban form, the higher the wage income.

If the low-quality city form lowers real wages, it means that this spatial form will force the city to be more centralised due to the increase in the distance within the city and increased congestion, and will cause the spatial isolation of market and economic factors in the same city, thereby weakening the externality of agglomeration. If the spatial structure of the city is already dense and the pressure of congestion will be great, then the inferior city form will be more likely to cause congestion inside the city, and the external loss to economic activities will also be great. We suspect that the negative effects of inferior forms may be more serious in cities with high spatial density. At the same time, if the city's internal transportation infrastructure is improved, such as the increase in per capita road area, it may reduce congestion, speed up the rate of commuting and logistics within the city without changing the original urban form and internal distance. It can be expected that the higher the per capita road area, the lower the negative impact of poor-quality urban forms on wages. Next, this article will use micro survey data from Chinese urban residents to test the above inferences.

## 2. Literature review: agglomeration economy, urban spatial structure and wage decisions

Ciccone and Hall (1993) and Duranton and Puga (2004), and many researchers believe that the impact of spatial externalities on wage income comes from two aspects: first, the technical externalities that are manifested as agglomeration advantages. The gathering of economic elements in the inner space of cities improves productivity through technology spillovers, efficient matching and resource sharing effects. The second is current externalities that manifest as market potential. The expansion of cities and the potential of local markets have helped raise wages (Roback, 1982). However, with the advancement of transportation technology and the continuous improvement of the labour market, the flow of population between different cities or regions has become more frequent, and urban economics has started to analyse the relationship between labor wage income and urban space. It is believed that when the population moves freely, the structure of urban space will affect workers' utility, and the equilibrium wage allows workers to obtain the same utility in each city and the labour market can reach a balance between supply and demand (Combes et al., 2012; Glaeser & Mare, 2001).

The empirical studies of many scholars have confirmed that the size of cities has a positive impact on wages. This is because the labour agglomeration effect in large cities has increased per capita output, but (Guangjie, 2014) a sample of migrant workers did not find that large cities have an advantage in real wages. This is because the degree of advantage generated by agglomeration depends not only on the number of economic factors (such as the size of the urban population) in the region, but also on the distribution pattern of the factors and population in a particular space. From the perspective of industrial layout, it appears as agglomeration level and from urban space.



From a structural perspective, it is mainly the population or employment density of urban areas. For different types of industries, analyse the impact of industrial agglomeration on wages. Ciccone and Hall (1993) and Jianyong (2006) demonstrated the positive impact of high density on per capita output and productivity (Fu & Ross, 2007). U.S. census data proved that employment density and nominal wages are positive related. It was found that employment density and the density changes in different regions before and after immigration did not significantly increase wages (Hering & Poncet, 2010; Liu et al., 2007; Mion, 2004). Urban density and industrial agglomeration have emphasised the impact of spatial patterns on corporate productivity and thus wage income. However, the market potential of a region has the effect of increasing wages. Many scholars affirm (Fingleton & Longhi, 2007; Xiuyan & Xingmin, 2009; Xiaoyi & Jun, 2016) believe that market potential and density (or concentration) have a positive impact on wages, at least without damage (Fallah et al., 2011; Henderson et al., 2012; Meng & Xiuyan, 2015). As the discussion of urbanisation has deepened, scholars' eyes have extended to the inspection of other urban spatial structure indicators, such as urban sprawl, urban compactness and urban polycentricity and so on, and believe that the spreading and polycentric urban spatial structure is not good for GDP growth and production efficiency per capita.

The above literature still has certain shortcomings in the mechanism analysis. First, whether it focuses on the technological externalities of traditional agglomeration economies, or the monetary externalities brought about by market potential, most of them only explain the impact of wages from the perspective of urban spatial layout affecting manufacturers' productivity or labour demand; Second, although quantitatively studies the size or density of cities, it still regards a city as a uniformly distributed and regularly shaped geometry, ignoring the differences in the spatial form of different cities, which has a potential impact on spatial externalities (Zax, 1991) based on Roback (1982) research showing the trade-offs between wages and commuting distance. Quantify the spatial form of different cities instead of treating cities as homogeneous regular shapes, Zhao Jiafeng and Zhou Liang (2015) studies also prove that the scale of agglomeration is conducive to wage increases, but these studies have not fully considered the role of urban spatial structure.

Compared with previous studies on wage income, this article has several major innovations. First, in terms of research content, this article examines the impact of urban spatial characteristics related to agglomeration economies on wage income from a more comprehensive perspective, including the population size, density and spatial form of the city. The urban sprawl index is used to reflect the density of the city, and at the same time, the technology is used to quantify the geometric shape of Chinese cities from the perspective of influencing residents' travel and corporate transportation; Second, in terms of research methods, in order to overcome the self-selection bias, China Household Financial Survey Data (CHFS) was used to capture the wages and personal characteristics of micro-individuals, and to provide micro-level evidence covering multiple income strata from various regions in China, And use two-stage instrumental variable estimation to further weaken the endogenous nature of the core explanatory variables and make the conclusion more rigorous and credible;



Finally, this article also adds a series of interactive terms involving urban form and density, and explores feasible ways to deal with poor urban forms.

### 3. Variables and data

#### 3.1. *Dependent variable: personal salary income*

Wage income in this article includes salaries paid to workers on a monthly, quarterly or annual basis, as well as year-end bonuses, performance wages and other legally relevant bonuses related to the job they are currently engaged in, excluding social security payments, investment income and self-employed profits. We use the logarithmic value  $\ln$  phwage of the actual hourly wage of the worker as the explanatory variable. After data matching, a total of 29,449 sample observation points from 90 sample cities in China in 2010, 2012, 2015 and 2017 were used for mixed cross section regression. Personal sample of nominal wages from Chinese household financial survey data (China household finance survey and research centre, south-western university of finance and economics has carried out the vital researches which include 29 provinces, municipalities and municipalities directly under the central government for 2 years, the statistics cover the personal information, such as the subjects 'vocation, salary, social insurance, demographics, education and so on'. The CHFS statistics used in this article is attained in 2011, 2013 and the sample timeslots are 2010 and 2012. The statistics are not rigid follow-up surveys. For some cities (the individual samples included), due to that the change in the urban division of municipalities are too vast or some data missing, a portion of cities have to be removed from the researches.) divided by labour time is the average hourly nominal wage. Divide the nominal wage by the price level of the province (autonomous region, municipality) in which the sample was interviewed for the current year. With reference to the methods of (Meng & Xiuyan, 2015), the provinces, autonomous regions and municipalities with fixed base periods are used to calculate the price levels of provinces, autonomous regions and municipalities with fixed base periods using the GDP reduction index of each province from the China Statistical Yearbook of the relevant year.

#### 3.2. *City shape indicator*

Urban form is an important aspect of urban spatial structure. This article draws on the research of (Angel et al., 2010), and combines the vector map of China's administrative regions and night light data of Defense Meteorological Satellite Program (DMSP) to quantify the geometric shape of each sample city in the corresponding year. DMSP night light data record the relatively stable lights in cities, towns and villages. The average nightly light data can be obtained by averaging the stable lights in a year. The raster resolution is 30" and the brightness saturation value is 63 (Meng & Xiuyan, 2015). Using night light data to study urban spatial structure and urbanisation issues. The main variables of this article at the city level, including spatial shape, density and city size, are limited to the observation of urbanised areas within the sample cities. Some prefecture-level cities include a large area of non-urbanised areas, so first extract the urbanised areas based on the lighting threshold, and use Arcgis

version 9.2 software<sup>1</sup> to calculate the area of each city (10,000 km<sup>2</sup>). This article has three types of city shapes: road, max and centre, which have the following meanings: Road is the average of the straight-line distance between all grids in a city divided by the square root of the area of the city. If a city contains R grids, then there will be  $[R \times (R - 1)]/2$  distances between grids. After averaging them and dividing by the square root of the area is road. This indicator indicates the average mutual distance between various points in the city, which largely reflects the travel costs (including money, time and physical strength) of the majority of the residents in the city. Max is the maximum of all grid spacings in a city divided by the square root of area. This indicator represents the longest distance that can occur in a city. Compared to road and centre, this indicator can better highlight the geometric characteristics of 'irregular' or 'multi-center' cities. For example, for some cities, a 'protruding' or 'cornering' spatial extension appears in a certain direction, or there is a satellite city far away from the main city, at this time, it will have a higher max value. Centre is the average of the distance of each grid in the city from the surface straight line of the city centre point divided by the square root of area. It reflects the accessibility of the city centre. The larger the value of centre, it means that most residents are farther from the city centre. The city centre provides a large number of jobs for the residents of the city, and it is usually the region with the most active economic activities and the largest population flow. The probability and frequency of residents going to the city centre are often higher than other places in the city. Therefore, centre is very representative, reflecting the daily travel costs and living comfort of residents, and has a significant impact on the performance of urban agglomeration economies.

The three indicators road, max and centre reflect the shape of the city from the perspective of the distance within the city. A high value of the three indicators means that the distance within the city is long, and the accessibility of various parts of the city is poor. The shape of the urban space is irregular, and the urban form is relatively 'poor'. For citizens, poor-quality city forms mean inconvenient travel, the connections between sub-centres in the city are blocked, the scope of daily activities is limited by the shape of the city, and the comfort of living is low; for enterprises, the lengthened spatial distance and higher transportation costs have weakened the original agglomeration externalities within the city. In determining personal wages, if urban form dominates through comfort effects, then actual wages should be positively correlated with these three distance indicators; if urban form dominates through spatial agglomeration economies, then wages should be negative with 3 indicators Related.

### **3.3. Urban density indicators and geographic instrumental variables**

Density is also an important aspect of urban spatial structure. Many studies have calculated the average urban population density (Ciccone & Hall, 1993; Jianyong, 2006), but the average density is a little rough because it considers the urban population as a uniform distribution in the calculation, and it cannot identify the density of different areas in the urban area difference. Borrowing from the research of Fallah et al. (2011) and Meng, Xiuyan, and Songlin (2016), the urban sprawl index sprawl,

which is more accurate and detailed than the population density, is used to reflect the urban density. The formula is:

$$sprawl = \sqrt{\text{land} \times \text{resid}} \quad (11)$$

Urban sprawl refers to the excessive expansion of the urban area beyond the needs of the population. The residents and economic activities that were mainly concentrated in the central area of the city spread to the periphery of the city, and the population density and land use intensity in the urban area have declined (11). The sprawling index of the type (sprawl) represents the degree of spatial spread of a city (city area). Compared with the average population density, this index more comprehensively and accurately reflects the density, looseness and polycentricity of the urban spatial structure. Where  $\text{land} = 0.5 \times (\text{lland} - \text{hland}) + 0.5$ , and  $\text{resid} = 0.5 \times (\text{lresid} - \text{hresid}) + 0.5$ .  $\text{lland}$  and  $\text{hland}$  are the area areas of a city urban area with a population density less than or equal to the national average urban density, and they account for the proportion of the total area of the city;  $\text{lresid}$  and  $\text{hresid}$  are urban areas with a density less than or equal to each city in the country. The proportion of the population with an average population density accounts for the total population of the municipality. An increase in the proportion of low-density population or an increase in the proportion of low-density area in a city represents a decrease in the density of urban spatial structure. The value of the sprawl index is between [0, 1]. The closer to 0, the lower the spread, and the closer to 1, the higher the spread. The calculation of the spreading index requires the use of land use and population distribution data. Screen the high and low density areas in a city based on the population of each grid and calculate the population or area proportion. After obtaining  $\text{lland}$ ,  $\text{hland}$ ,  $\text{lresid}$  and  $\text{hresid}$ , you get  $\text{sprawl}$ . Then add the population and area accumulation of the urbanised area to  $\text{pop}$  and  $\text{area}$  respectively. The difference between the two is the average population density  $\text{dens}$  (person/km<sup>2</sup>). The logarithmic form  $\ln \text{dens}$  is used in the analysis.

### 3.4. Individual characteristics

The wages of different individuals in the same city are very different. Controlling urban spatial structure variables is obviously not enough to explain the wage income of micro individuals. It is also necessary to control variables based on individual characteristics. On the one hand, it can explain which individual factors have a significant effect on wages; on the other hand, it can reduce self-selection bias. These include: (1) Human capital. The individual's years of education  $\text{edu}$  is used to reflect the human capital content of workers and this coefficient is expected to be significantly positive. (2) Empirical variables. Includes the current work experience variable  $\text{exp}$  and potential work experience  $\text{potexp}$ .  $\text{exp}$  is the number of years the worker has been in his current occupation, and  $\text{potexp}$  is the total number of years the worker has participated in the work, specifically the working age from the first job. (3) Industry and job variables. Set dummy variables  $\text{indu}$ ,  $\text{serv}$  and  $\text{zhiwu}$ . If the position or unit of the respondent belongs to the industry (secondary industry) department,

take 1 for indu, otherwise 0; if it belongs to the service industry (tertiary industry), take 1 for serv, otherwise 0; If you are currently holding a mid-level or higher administrative position in your work unit, zhiwu is set to 1, otherwise it is 0. (4) Other dummy variables. Gender variable male, 1 for males and 0 for females; political aspect variable, 1 for CCP members, not 0; marry status variable, 1 for married persons, 0 for unmarried, divorced or widowed persons; urban hukou For Hukou, the value is 1; otherwise, it is 0; for floating population, Liudong is set to 1, otherwise it is 0. The above individual characteristics data are from the CHFS survey.

### 3.5. Urban population size and other city-level variables

The population size is expressed as the logarithm ( $\ln \text{pop}$ ) of the city's resident population. The urban population is the source of the agglomeration economy. It will produce scale effects at the city level and increase wages by increasing corporate productivity. Some literature has proved the positive effect of scale on wages. In addition to urban density, spatial form, and population size, other city-level characteristics also affect wage income. Including: Urban house price level expressed as the logarithm of newly built house price level,  $\ln \text{house}$ , the expected house price level is positively related to actual wages; the provincial capital and coastal dummy variables, if it is a provincial capital, municipality or autonomous region capital, the variable capital is set to 1, otherwise 0; If the city area is close to the ocean and especially has a harbour, the value of the variable port is 1, otherwise it is 0.

The population size ( $\ln \text{pop}$ ) is calculated from the LandScan population distribution database, and the average size of city's dwellings is from the China Regional Economic Statistics Yearbook. Provincial capital cities are judged according to the 'Map of the People's Republic of China' and seaport cities use maps of some provinces and regions in combination with maritime data provided in the 'China City Statistical Yearbook' and 'China Transportation Statistics Yearbook' for comprehensive judgment.

## 4. Regression results and robustness test

### 4.1. Basic regression results

In this article, the logarithmic value of labourer's hourly wage income,  $\ln \text{phwage}$ , is used as the explanatory variable, and the spreading index, urban form and population size are the core explanatory variables. We focus on urban density as an endogenous variable and perform Two-stage least squares (2SLS) mixed-section regression. The estimated results of Two-stage least squares-instrumental (2SLS-IV) variables with the spreading index as an endogenous variable are shown in columns 2–4 of Table 1.

The coefficients of the three urban morphological variables road, max and centre, which appear in turn, are significantly negative at the level of 1%, which indicates that the longer the inner distance of the city and the inferior urban morphology have adversely affected personal wages when the urban area is close. Poor quality urban space (represented by a long distance within the city) reduces living comfort, and real wages may increase modestly to compensate for the loss of comfort and thus stabilise

**Table 1.** Basic regression results.

|                        | Reflecting urban density with a sprawl index | Use average population density <i>In dens</i> |
|------------------------|--|---|
| <i>Road</i>            | -7.48e-04*** (2.02e-04)                      | -0.0021*** (0.0002)                           |
| <i>Max</i>             | -5.5e-04*                                    |   |
| <i>Centre</i>          |  |   |
| <i>Sprawl/ In dens</i> | -2.9490*** (1.4774)                          | 0.68976*** (0.2866)                           |
| <i>Male</i>            | 0.1729*** (0.0264)                           | 0.16850* (0.0860)                             |
| <i>edu</i>             | 0.0840*** (0.0021)                           | 0.0863* (0.0853)                              |
| <i>party</i>           | 0.0414 (0.0274)                              | 0.0743 (0.0639)                               |
| <i>exp</i>             | 0.0106*** (0.0051)                           | 0.0185* (0.0037)                              |
| <i>potexp</i>          | -0.0264*** (0.0014)                          | -0.0138** (0.0074)                            |
| <i>marry</i>           | 0.0473 (0.0063)                              | 0.064 (0.0327)                                |
| <i>zhiwu</i>           | 0.0538 (0.0363)                              | 0.3658* (0.0273)                              |
| <i>indu</i>            | 0.1852*** (0.0742)                           | 0.1818 (0.0607)                               |
| <i>serv</i>            | 0.1836** (0.0637)                            | 0.1020* (0.0596)                              |
| <i>hukou</i>           | 0.0284 (0.0762)                              | 0.0276 (0.0269)                               |
| <i>liudong</i>         | -0.0073 (0.0752)                             | -0.0003 (0.0305)                              |
| <i>In house</i>        | 0.2382*** (0.0748)                           | 0.2399 (0.0387)                               |
| <i>In pop</i>          | 0.1412*** (0.0364)                           | 0.1297 (0.0257)                               |
| <i>capital</i>         | -0.3737*** (0.0752)                          | -0.4277 (0.0596)                              |
| <i>port</i>            | 0.0962** (0.0483)                            | 0.0384 (0.0876)                               |
| Time-fixed effect      | control                                      | control                                       |
| Constant term          | -0.1862 (0.7952)                             | -14.983 (3.7486)                              |
| Instrumental           | <i>F</i> = 77.49                             | <i>F</i> = 117.73                             |
| variable test          |  |   |
| <i>R</i> <sup>2</sup>  | 0.293  | 0.239   |
| Sample size            | 29,449                                       | 29,449  |
|                        |  | <i>F</i> = 138.38                             |

Note: \*, \*\*, and \*\*\* indicate that the estimated coefficients are significant at the levels of 10, 5 and 1%, respectively. The values in parentheses are standard errors.

Source: Authors.

the utility level of workers. However, the more important impact mechanism is that the inferior city form weakens the agglomeration externalities between enterprises, which is not conducive to technology spillovers and productivity increases, and also increases transportation costs and transaction costs of economic activities, hindering the efficient flow of economic factors. As corporate profits in a competitive market are zero, increasing transaction costs will inevitably reduce returns to factors, so wages will fall. On the contrary, a good urban form is like providing a comfortable 'container' for the economic factors inside the city, and it plays a key positive role in the performance of economic activities. The coefficients of road, max and centres reflect that the negative effect of urban form on wages through spatial externalities exceeds (potential) compensation for wages due to reduced comfort. The distance indicator within the city and the actual wage eventually show a negative correlation.

The regression results in Table 1 show that the decline in urban area density has a significant negative impact on wage income. Taking the second column of Table 1 as an example, an increase in the spread index of 0.01 will cause the actual hourly wage to fall by approximately 2.95%, which proves that the dense urban space has a positive effect on wages. It is speculated that the underlying mechanism is: On the one hand, densely populated urban spatial structures bring the physical distance between enterprises closer, promote the use of agglomeration externalities, improve production efficiency and ultimately increase the actual wages of workers; population density will be associated with higher real wages and higher housing prices, so that the real estate market meets the general equilibrium conditions of space.

In terms of individual factors, an extra year of schooling can increase expected wages by more than 8%, echoing the importance of the value of human capital in domestic literature. Men have considerable wage premiums, and other things being equal, men's actual wages are on average nearly 17% higher than women's. This kind of premium comes from some unobserved ability to work and men are stronger in these areas. It is possible that discrimination against women exists in the labour market (Meiyan, 2005). Party members and married people have relatively higher wages, but the coefficients are not significant. Current professional experience has a positive impact on actual hourly wages, while potential experience potexp has a negative impact. The former is well understood, as longer working hours in the same occupation will make you better, and your labour skills will continue to improve. The latter may be because longer potential experience means older workers, which is not good for wages. Compared to being employed in the agricultural sector, working in the industrial and service sectors can earn a higher salary. Employees in administrative positions have significantly higher wages. The wages of the floating population seem to be slightly lower, but the results are not significant. Similarly, having a local urban hukou does not help the salaries of most people substantially.

Finally, look at the role of other urban characteristics. The coefficient of population size  $\ln pop$  is significantly positive. The economy of scale at the city level has a positive effect on personal wages, which is consistent with the previous analysis. In cities with higher housing prices, real wages will also rise. Both the size of the population and housing prices are in logarithmic form, and their coefficients can indicate their elasticity with real wages. Take the second column as an example, the

urban population will increase by 1%, and real wages will rise by about 0.14%; the average residential price in urban areas will increase by 1%, and the local real wages will increase by about 0.23%, and the increase in wages will not be as rapid as changes in house prices. This shows that as housing prices rise, the working-class income-to-income ratio will continue to rise, increasing the pressure on home purchases. It should be noted that, in reality, some provincial capital cities seem to have higher wage levels than small cities. In fact, it is the result of large population, high housing prices and self-selection of highly educated talents. After excluding these factors, the provincial wage advantage will no longer exist. It may even result in higher labour supply due to higher living comfort in the provincial capital, leading to lower equilibrium wages. Coastal cities may pay higher wages, their economies are more open to the outside world, export activities increase market potentials, and at the same time foreign capital entry also generates positive technology spillovers.

#### **4.2. Robustness test: use of average urban population density**

Based on columns 2–4 of [Table 1](#), this article uses the logarithm of the average urban population density to replace the previous urban sprawl index. The results of the second stage of the 2SLS-IV estimation are shown in columns 5–7 of [Table 1](#). Although the average population density is slightly rougher than the spreading index, it can better reflect the tightness of the urban spatial structure when the internal differences in urban population distribution are not so large. The coefficient of  $\ln \text{dens}$  in columns 5–7 is significantly positive at the 1% confidence level, and a 1% increase in density can lead to an increase in wage income from 0.62 to 0.76%, echoing the results previously estimated using the spread index. The coefficients of road form, max and centre of the city form indicator in columns 5–7 of [Table 1](#) are the same as those in columns 2–4, which are significantly negative at the 1% level, while the coefficients of population size  $\ln \text{pop}$  are all at this confidence level. As positive, this shows that the economy of scale of the city is established, and the irregular form of the city hurts wage income. The size, direction and significance of other explanatory variables such as house prices, work experience and job titles did not change much compared to columns 2–4, indicating that the results are more robust.

#### **4.3. Robustness test: recalculation of urban form indicators**

We still design and calculate the shape of the city from the perspective of the distance within the city. The previous road, max and centre are calculated by dividing the corresponding grid distance (or average distance) by the square root of the city area circled by the light. Now, we do the grid spacing calculation of the same content, but divided by the horizontal value of area. Then get the corresponding roadh, maxh and centreh. Previously, dividing the internal distance of a city by the square root of area is a standardised adjustment of the distance index, which can avoid the incomparable distances between cities with different areas. Dividing by area itself has the same effect, and area itself has a larger difference than the square root, which is equivalent to making more severe adjustments to the distance indicators of large cities. More



**Table 2.** Robustness test using other city shape indicators.

| Urban form            | <i>roadh</i>             | <i>maxh</i>             | <i>centreh</i>           | <i>roadl</i>            | <i>maxi</i>               | <i>centrel</i>            |
|-----------------------|--------------------------|-------------------------|--------------------------|-------------------------|---------------------------|---------------------------|
| <i>Shape</i>          | -1.41e-04*<br>(4.25e-05) | -3.16e-05<br>(9.25e-06) | -1.94e-04*<br>(5.94e-05) | -3.15e-06<br>(9.62e-07) | -2.26e-07*<br>(-6.84e-08) | -5.94e-06***<br>(1.94-06) |
| <i>Sprawl</i>         | -2.5763**<br>(1.158)     | -3.0474**<br>(1.184)    | -2.3364**<br>(1.084)     | -2.8749**<br>(1.174)    | -3.3284*<br>(1.138)       | -2.7468**<br>(1.185)      |
| <i>In house</i>       | 0.2585*<br>(0.074)       | 0.2486*<br>(0.084)      | 0.2574*<br>(0.074)       | 0.2238*<br>(0.0454)     | 0.2147***<br>(0.038)      | 0.2284***<br>(0.048)      |
| <i>In pop</i>         | 0.0774*<br>(0.048)       | 0.0974*<br>(0.0275)     | 0.0784*<br>(0.021)       | 0.1153*<br>(0.0283)     | 0.1285*<br>(0.074)        | 0.114**<br>(0.027)        |
| Other variables       | control                  | control                 | control                  | control                 | control                   | control                   |
| <i>R</i> <sup>2</sup> | 0.274                    | 0.274                   | 0.269                    | 0.291                   | 0.225                     | 0.281                     |
| Numbers               | 29,449                   | 29,449                  | 29,449                   | 29,449                  | 29,449                    | 29,449                    |

Note: \*, \*\* and \*\*\* indicate that the estimated coefficients are significant at the levels of 10%, 5%, and 1%, respectively. The values in parentheses are standard errors.

Source: Authors.

powerfully illustrates the negative impact of irregular urban forms on economic performance. Moreover, the *roadh*, *maxh* and *centreh* metrics are *Road*, *max* and *centre* have a high degree of similarity and can be used as 'stand-ins' for road, max and centre indicators in the robustness test. Another idea is to choose the square terms *road2*, *max2* and *centre2* of road, max and centre to replace their horizontal values to measure the pros and cons of the urban space. Compared with road, max and centre, their square terms have a more obvious 'punishment' effect on the inferior urban form, which can highlight the difference between high-quality and inferior urban forms. 2SLS-IV estimation method and other explanatory variables are the same as those in Table 1. The specific results are shown in Table 2.

After readjusting the distance index using the urban area level value, the coefficients of *roadh*, *maxh* and *centreh* are still significantly negative. The significantly negative *sprawl* coefficient illustrates once again the negative impact of falling urban density on wage income. The city size *ln pop* coefficient is still significantly positive, and the absolute value has not changed much from Table 1. In the last 3 columns of Table 2, the coefficients of the square terms of road, max and centre, and the coefficient of urban *sprawl* are all significantly negative, and the impact of urban population size on wages is significantly positive, indicating that dense urban space is conducive to production efficiency and the increase in wage income has the opposite effect of a singular or multi-block urban form. This fully shows that the size of the population lays the foundation for an agglomeration economy within a city, and how the agglomeration performance ultimately exerts depends on whether economic factors can be reasonably organised and arranged in the city's internal space, and whether it can provide economic activity participants convenient. The dense urban spatial structure and well-organised urban form play exactly this role, and have positive effects on improving enterprise efficiency and labour wages.

#### 4.4. Robustness test: using the registered population to reflect the size of the city

In addition to the advantages and disadvantages of urban forms and the intensity of spatial structure, the positive impact of population size on wages needs to be tested

again. We use the logarithmic form  $\ln$  huji of the urban household registration population in the municipal area to replace the previous urban resident population  $\ln$  pop and perform the 2SLS-IV estimation again. The explanatory variable is  $\ln$  phwage, and the sprawl indexes  $\text{sprawl}$  and  $\ln$  dens are the endogenous explanatory variables representing the density of the city, respectively, corresponding to the regression results in columns 2–4 and 5–7 of Table 3. Data on the urban household registration population are from the 2010, 2012, 2015 and 2017 China City Statistical Yearbook.

As before, the distance, road, max and centre coefficients in Table 3 are all significantly negative above the 5% level, which again proves that the irregular or fragmented urban form has a negative impact on wages. The coefficient of  $\text{sprawl}$  is significantly negative, and the coefficient of  $\ln$  dens is significantly positive, still indicating that the increase in urban density has a positive effect on real wages. The coefficients for  $\ln$  huji in columns 2–7 are positive at a 1% confidence level. Regardless of the user population or the resident population, the increase in wages is obvious from the size of the city. Nowadays, whether it is the megacities represented by Beishang, Guangshen, or some regional central cities such as Nanjing, Chengde, Jinan and so on, there are more rapid population and economic density growth than surrounding small and medium cities. Job seekers everywhere, especially outstanding talents in various industries, provide a lot of money. The effects of other factors have not changed significantly compared to previous estimates.

## 5. Robustness test for endogenous explanatory variables

The previous explanatory variable  $\text{sprawl}$ , which is suspected of being endogenous, used the surface roughness  $\text{std}$  and its external set of squared instrumental variables because we suspect that there may be a U-shaped or inverted U-shaped quantity relationship between  $\text{sprawl}$  and  $\text{std}$ . Now assume that the relationship between  $\text{sprawl}$  and  $\text{std}$  is linear, and only use  $\text{std}$  as the instrumental variable for the  $\text{sprawl}$  index to re-estimate. The regression results of the second stage are shown in columns 2–4 of Table 4. Only the estimated coefficients of important explanatory variables such as  $\text{city\_shape}$ , density and population size are listed. The remaining explanatory variables and constant terms in Table 1 are listed in Table 4. Controls will no longer be fully listed. After changing the tool variables, the coefficients of road, max, centre and  $\text{sprawl}$  are still significantly negative. The urban population, housing price, and real wages are still positively correlated, and  $\text{std}$  also passes the weak IV test, indicating that the negative impact of urban sprawl on wages does not depend on the specific tool variable setting method.

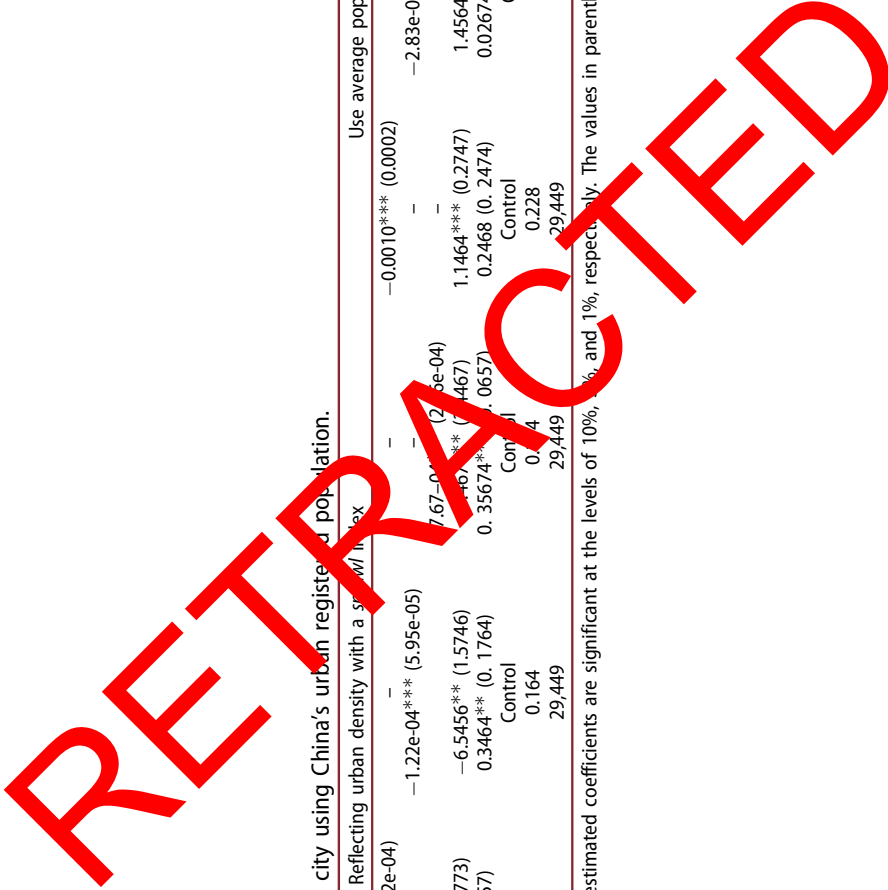
Since urban density ( $\text{spread}$ ) may be adversely affected by wage income, as an important urban spatial structure feature, does urban form also face endogenous problems caused by reverse causality or missing variables? This article uses the instrumental variable method Robustness of urban morphology. With the help of digital surface slope maps and water distribution maps, Arcgis version 9.2 software was used to extract grids with slopes greater than 15 degrees or occupied by rivers, lakes and seas in each city and district. These grids are undeveloped land (Saiz, 2010), their area proportions in the municipal districts can be used as instrumental variables of

**Table 3.** Measuring the size of a city using China's urban registered population.

|                        | Reflecting urban density with a sprawl index | Use average population density <i>ln dens</i> |
|------------------------|--|---|
| Road                   | -4.52e-04*** (2.22e-04)                      | -0.0010*** (0.0002)                           |
| Max                    | -  | -   |
| Centre                 | -  | -   |
| Sprawl/ <i>ln dens</i> | -6.7875*** (2.2773)                          | 1.1464*** (0.2747)                            |
| <i>Ln huji</i>         | 0.3757** (0.1457)                            | 0.2468 (0.2474)                               |
| Other variables        | -1.22e-04*** (5.95e-05)                      | -2.83e-04*** (6.01e-05)                       |
| R <sup>2</sup>         | -6.5456** (1.5746)                           | 1.4564*** (0.2674)                            |
| Sample size            | 0.3464** (0.1764)                            | 0.02674*** (0.0464)                           |
|                        | Control                                      | Control                                       |
|                        | 0.164  | 0.217   |
|                        | 29,449                                       | 29,449  |
|                        | Control                                      | Control                                       |
|                        | 0.4  | 0.249   |
|                        | 29,449                                       | 29,449  |
|                        | Control                                      | Control                                       |
|                        | 0.0657                                       | 0.2673** (0.0473)                             |
|                        | 0.35674*** (0.0657)                          | 1.0674*** (0.2463)                            |
|                        | 0.3674*** (0.1467)                           | -0.0464*** (0.0003)                           |
|                        | 7.67e-04*** (2.06e-04)                       | -   |

Note: \*, \*\*, and \*\*\* indicate that the estimated coefficients are significant at the levels of 10%, 5%, and 1%, respectively. The values in parentheses are standard errors.

Source: Authors.

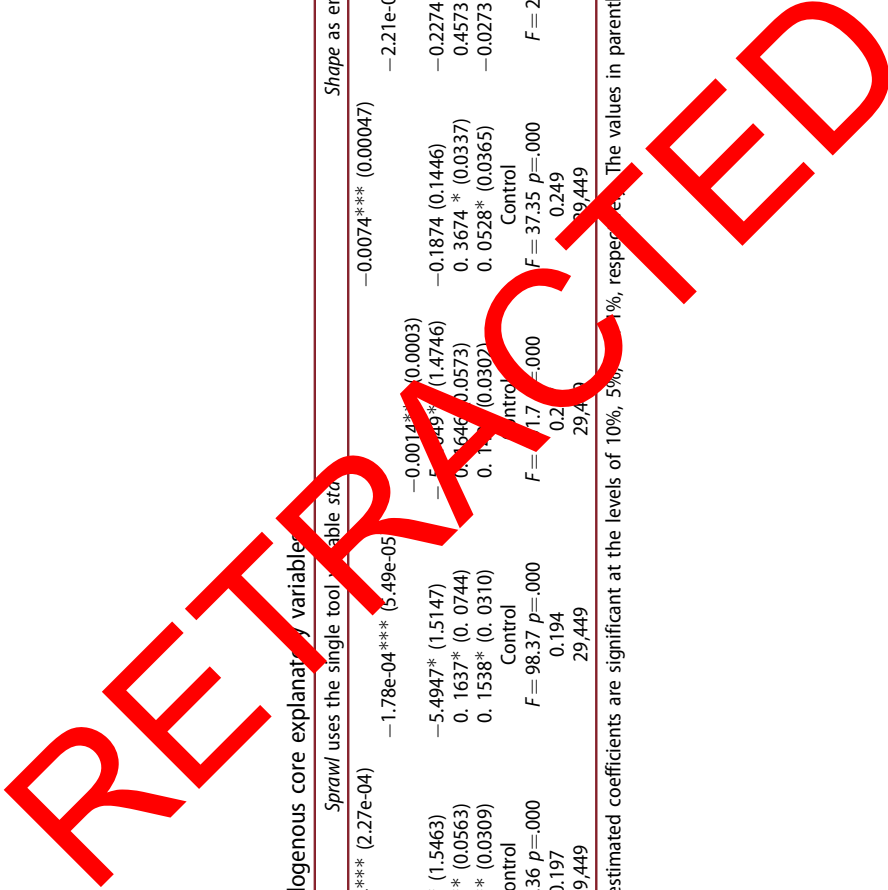


**Table 4.** Robustness test for endogenous core explanatory variables

|                            | Sprawl uses the single tool variable standard |                         | Shape as endogenous variable |                         |
|----------------------------|---|-------------------------|------------------------------|-------------------------|
| Road                       | -6.75e-04*** (2.27e-04)                       | -1.78e-04*** (5.49e-05) | -0.0074*** (0.00047)         | -2.21e-04*** (5.27e-05) |
| Centre                     |   |                         |                              |                         |
| Sprawl                     | -5.3363* (1.5463)                             | -5.4947* (1.5147)       | -0.0014*** (0.0003)          | -0.0074*** (0.00038)    |
| In house                   | 0.1656*** (0.0563)                            | 0.1637* (0.0744)        | 0.3674* (0.14746)            | -0.2274 (0.1536)        |
| In pop                     | 0.1548*** (0.0309)                            | 0.1538* (0.0310)        | 0.3674* (0.0337)             | 0.4573* (0.0737)        |
| Other variables            |   |                         | 0.0528* (0.0365)             | -0.0273 (0.0539)        |
| Instrumental variable test | F = 97.36 p = .000                            | F = 98.37 p = .000      | F = 37.35 p = .000           | F = 21.61 p = .000      |
| R <sup>2</sup>             | 0.197   | 0.194                   | 0.249                        | 0.184                   |
| Sample size                | 29,449  | 29,449                  | 29,449                       | 29,449                  |
|                            | Control                                       | Control                 | Control                      | Control                 |
|                            |   |                         |                              | F = 44.65 p = .000      |
|                            |   |                         |                              | 0.247                   |
|                            |   |                         |                              | 29,449                  |

Note: \*, \*\*, and \*\*\* indicate that the estimated coefficients are significant at the levels of 10%, 5%, and 1%, respectively. The values in parentheses are standard errors.

Source: Authors.



urban form indicators. The undevelop indicator has a high degree of exogenousness, and the company's production and operation activities are rarely in water or on steep slopes, so it is difficult for undevelop itself to directly affect the production efficiency of the enterprise and the wages of workers, mainly by affecting the characteristics of urban space affect economic performance and wage income. The higher the proportion of undeveloped land, the more difficult it is for urban space to expand evenly from all directions. In the direction with more undeveloped landforms, the expansion speed will be slower than other directions, resulting in an irregular city shape, which results in higher road, max and centre values. In columns 5–7 of Table 4, road, max and centre are still significantly negative after using undevelop as the instrumental variable. Undevelop also passed the weak IV test in its first-stage regression. The potential endogenous nature of urban form does not affect the robustness of its relationship with wages.

To exclude the potential endogenous effects of the size of the urban population, we also use the winter average temperature *wintertemp* of the sample cities from 1970 to 2010 as an instrumental variable of population size. The average winter temperature was obtained after processing the raw data provided by China National Climate Centre (website: <http://www.ncc-cma.net/cn>). The temperature before 2010 is hardly affected by the economic and social factors during the sample period of this article, and the exogeneity is high. More importantly, winter temperature can hardly directly affect productivity and wages of workers, but it will affect the population size of a city. Literature that studies the urban population in the United States shows that bitter cold winters can be daunting to many potential immigrants, and that many natives have a tendency to migrate to warmer regions (Black & Henderson, 1999; Rappaport, 2007; Wang et al., 2017). Air temperature was also used as a tool variable for population size or number of migrants in the study. This article expects that winter-temp and  $\ln \text{pop}$  are positively correlated. After using IV for population size, the results in Table 1 have not changed significantly.

## 6. Further discussion: heterogeneity of industry and city

Have the previous discovered laws about the impact of urban density, population size and urban form on wages been established in different cities? What are the different impacts on individual workers engaged in different types of industries? How can the effects of inferior urban forms be avoided? To solve these In doubt, this article still uses  $\ln \text{phwage}$  as the explanatory variable, and uses a method of splitting samples and adding interaction terms to launch a series of investigations on sample heterogeneity.

### 6.1. Sample comparison of workers in the secondary and tertiary industries

Table 5 uses road, max, and centre to reflect the urban form. Columns 2–4 and 5–7 expand the 2SLS-IV regression around a sample of workers engaged in the secondary and tertiary industries. The results show that the impact of urban morphological indicators on the wages of the secondary and tertiary industries is negative, but only in the secondary industry has a significance level of 5%. For tertiary industry wages,

only the centre coefficient is close to a significant level of 10%, and the partial effects of road and max are not significant. Interestingly, the relationship between sprawl and wage income is negative, but only the subsample coefficient of the tertiary industry is significant.

Why do urban forms and urban sprawl have different effects on wages in the secondary and tertiary industries? We think this may be because the locations of secondary industries (mainly industrial and mining) and service industries are different within a city. Spread often implies the flow of population and economic activities from the city centre to the outer urban areas (Meng et al., 2016). While reducing the density of the original old city, the decline in the density of the urban fringe or 'satellite city' is relatively small and local May also have a density increase.

(Although the overall density of the city will decrease as it spreads). In today's China, most industrial and mining companies are near the borders of urban areas, and many service companies are still concentrated in the original old urban areas and city centres. Therefore, the spread will certainly reduce the concentration of the entire city. Location has more influence. In addition, compared with the service industry, which requires customers and enterprises to come face to face, the restrictions on spatial knowledge spillovers and information transfer in industrial industries are becoming smaller, especially as Chinese industries are becoming more standardised and intelligent. Therefore, the negative impact of the spread on workers in the tertiary industry is more significant. Unlike urban sprawl, urban form more affects the density of urban fringe areas than the city as a whole, so the impact on industrial and mining enterprises located in urban fringe areas will be greater. Of course this is just a relatively reasonable guess. What determines the subtle differences between the secondary and tertiary industries, the urban density and the influence of urban morphology, more evidence remains to be answered.

## **6.2. Interaction between urban form and urban density**

Individual differences will lead to different effects of urban morphology and density on actual wages. So does the heterogeneity of cities have similar effects? According to the foregoing analysis, differences in urban density may have heterogeneous effects on urban morphology. In the regression, the interaction terms of the sprawl index and urban form indicators road, max, and centre are introduced one by one. The other variables and the 2SLS-IV estimation method are exactly the same as those in columns 2–4 of Table 1. The coefficients of sprawl and the shape indicator of the city are both significantly negative, which is consistent with previous conclusions. It is intriguing that the coefficients of the interaction terms of sprawl and shape are significantly positive. As the spread increases and the density of urban areas decreases, the negative impact of poor urban forms on wages will be alleviated to a certain extent. This is because in cities with poor spatial forms, even if there is a dense urban structure, the positive role of the agglomeration economy will be compromised. Dense spatial structures, on the other hand, are more likely to form congestion and isolation within the city, and 'agglomeration diseconomy' will occur earlier than cities with regular shapes. Therefore, for cities with poor shapes, appropriately reducing the

**Table 5. Heterogeneity impact on secondary and tertiary industries.**

|                   | Impact on wages of secondary industry workers |                        | Impact on wages of workers in the tertiary industry |                      |
|-------------------|---|------------------------|---|----------------------|
| <i>Road</i>       | -0.0017** (0.0001)                            | -4.47e-05** (2.11e-04) | -2.67e-04 (2.47e-04)                                | -4.37e-05 (6.58e-05) |
| <i>Max</i>        |   |                        |   |                      |
| <i>Centre</i>     |   |                        |   |                      |
| <i>Sprawl</i>     | -4.5385 (4.0446)                              | -6.5947 (4.8286)       | -2.5637 (1.2673)                                    | -2.6836** (1.2637)   |
| <i>Male</i>       | 0.1884* (0.04337)                             | 0.1747** (0.0447)      | 0.1437* (0.0284)                                    | 0.1473* (0.0273)     |
| <i>edu</i>        | 0.0564 (0.0047)                               | 0.074 (0.017)          | 0.0884* (0.0372)                                    | 0.0884* (0.0027)     |
| <i>party</i>      | 0.0547 (0.0742)                               | 0.0537 (0.0636)        | 0.0730 (0.0379)                                     | 0.0273 (0.0337)      |
| <i>exp</i>        | 0.0037* (0.0074)                              | 0.0037 (0.0074)        | 0.0127* (0.0374)                                    | 0.0173 (0.0037)      |
| <i>potexp</i>     | -0.0137* (0.0074)                             | -0.017* (0.0377)       | -0.0734* (0.0375)                                   | -0.0137* (0.0083)    |
| <i>marry</i>      | -0.0236 (0.0884)                              | -0.0374 (0.0734)       | 0.0770* (0.0272)                                    | 0.0674* (0.0733)     |
| <i>zhiwu</i>      | 0.4736 (0.05237)                              | 0.4374 (0.0374)        | 0.3226* (0.0273)                                    | 0.3237* (0.0737)     |
| <i>hukou</i>      | 0.0474 (0.0837)                               | 0.0376 (0.0730)        | 0.0373 (0.0361)                                     | 0.0379 (0.0734)      |
| <i>liudong</i>    | -0.0379 (0.0847)                              | -0.0379 (0.0739)       | 0.0037 (0.0347)                                     | 0.0735 (0.0735)      |
| <i>In house</i>   | 0.2371 (0.1830)                               | 0.1579 (0.1831)        | 0.2557 (0.0478)                                     | 0.2437* (0.0838)     |
| <i>In pop</i>     | 0.1337** (0.0830)                             | 0.1537** (0.0743)      | 0.0837* (0.0305)                                    | 0.0937* (0.0305)     |
| <i>Capital</i>    | -0.5134* (0.1746)                             | -0.5997* (0.2066)      | -0.3345* (0.0773)                                   | -0.374 (0.0736)      |
| <i>port</i>       | 0.0378 (0.0769)                               | -0.0137 (0.0942)       | 0.1156** (0.0526)                                   | 0.1136** (0.0369)    |
| Time-fixed effect | Control                                       | Control                | Control   | Control              |
| Constant term     | Control                                       | Control                | Control   | Control              |
| R <sup>2</sup>    | 0.187   | 0.093                  | 0.294   | 0.287                |
| Sample size       | 10,227  | 10,227                 | 19,222  | 19,222               |

Note: \*, \*\* and \*\*\* indicate that the estimated coefficients are significant at the levels of 10%, 5%, and 1%, respectively. The values in parentheses are standard errors. Source: Authors.



population density and encouraging a polycentric spatial structure will, on the contrary, enable some enterprises to get rid of the constraints of urban spatial form and slightly alleviate the negative impact of inferior urban forms on efficiency.

## 7. Conclusion and suggestion

As China's urbanisation rate continues to rise, the rise of many large cities (clusters), and the steady advancement of new urbanisation strategies, the impact of urban size and spatial structure on wage income has become a 'common' rather than 'old-born' topic. We refer to the general space equilibrium framework. Considering that the city itself is not a 'mass point' but a geometry with various shapes, and the density of the city also plays an important role in the effect of spatial agglomeration, we selected three cities. The distance indicator uses the DMSP night light data to calculate the spatial form of each city in China (in the municipal jurisdiction only), and uses the spread index to reflect the urban spatial density. In order to avoid self-selection and endogenous bias, we adopt two measures: one is to control individual characteristics with the help of CHFS survey data; the other is to use geographical tool variables for urban density, including surface roughness and its square, and also discuss the urban form and endogenous effects of population size. The main findings of this article are as follows: (1) When the city area is constant, the form of urban space with a long internal distance is not conducive to increasing wages; (2) The decline in urban density is not conducive to increasing wage income; (3) The size of the urban population and wage levels are positive relevant; (4) Urban form and population density have an interactive effect on wages. Decreasing density or polycentric development can reduce the negative effects of poor urban form; (5) the improvement of urban transport infrastructure, such as increasing per capita road area, can quickly mitigate the negative impact of poor-quality city forms. The conclusion of this article shows that the agglomeration economy in China's cities exists widely, so the urban spatial structure has an important impact on wage income.

This research could lead to some feasible suggestions. First, the urbanisation process of developing countries represented by China is far from being over, the authorities need to pay attentions to a high extent of density in city structure in order to avoid the excessively land development and city spread, otherwise it could reduce the advantages of city's inward agglomeration and habitants 'salary'. Second, the population size of city means a lot for the increase of economics and salary, it is the guarantee of marketing's smooth and positive running. Agglomerative economies are based on the population. In the context of China's specific residence registration system, big cities should gradually eliminate the barricades like the restriction on residence registration which hinders the increasing of population, the intermediate-size and small-size should be devoted to creating habitant-friendly environments. In the end, as to the cities which have poor quality in the spacial status and have long distance inwards, they need to optimise the road infrastructures including freeway, dead end road, it could facilitate the residents' journey, reduce the loss of social well-being, reduce the negative influences caused by the original city status. Hence, to optimise the services for public transportation and develop the tram system are feasible solution too.

At present, the developing countries represented by China are still in the process of rapid urbanisation and city vast expanding, however, a great deal of literatures are still in their tentative phrase in the aspect of exploring the relationship between city spacial structure and region's economic development, especially the ones which use China as the subject. In combination of the contemporary theories, the author believes that there are couple of matters which is worth attentions.

1. To enhance the researches regarding how the city spacial structure prompts the region's development, by means of optimising the economics policy in the regions and improving the city spacial structure in order to boost up the region's smooth and harmonious running. Such as, how to use the industry chain as the core power, to prompt the industry agglomeration and form value chain, and eventually form city chain, to drive the development of city agglomeration and region economics by using city chain.
2. To increase the researches in the coordinated development mechanics in between different regions, especially to increase the researches in the mechanics which coordinate the cooperation and benefit conflicts of different cities in the process of region's integration, adequately utilise the central city's functions in regional cooperation and competitions, such as how to explore the cross-region cooperation and industry agglomeration among developed cities and under-developed cities, to achieve win-win goal.

## Note

1. This software was developed by Environmental Systems Research Institute, Inc., headquartered in BaiRed Lanes, California, is the world's largest geographic information system technology provider.

## Disclosure statement

No potential conflict of interest was reported by the author(s).

## Data availability

The data used to support the findings of this study are available from the corresponding author upon request.

All variables are part of the Application Demonstration numerical variables, these data can be obtained from the official website or contact the corresponding author of the article:

China Household Finance Survey, CHFS: <https://chfs.swufe.edu.cn/>

Statistical Yearbook of the Statistics Bureau of the People's Republic of China: <http://www.stats.gov.cn/tjsj/ndsj/2019/indexch.htm>

LandScan Demographics: <https://landscan.ornl.gov/landscan-datasets>

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