Chin. Geogra. Sci. 2012 Vol. 22 No. 2 pp. 221–231
doi: 10.1007/s11769-012-0522-4
www.springerlink.com/content/1002-0063

Relationship Between Social Economic Agglomeration and Labor Productivity of Core Cities in Northeast China

ZHANG Peng, YANG Qingshan, ZHAO Yichun
(*School of Urban and Environmental Sciences, Northeast Normal University, Changchun 130024, China*)

Abstract: Dalian, Shenyang, Changchun and Harbin are the four core cities which play an essential role in terms of promoting the economic development in Northeast China. In this paper, the impact of urban agglomeration on labor productivity is explored by making comparisons among these four cities. The model used for analysis is a classical model derived from previous studies. Some indicators, such as population density and economic density, were selected to examine the impact of urban agglomeration on the labor productivity based on the time-series data for the four cities from 1990 to 2007. The four main conclusions are: 1) The promotion from the growth rate of population density on the growth rate of labor productivity is limited. 2) The negative relationship exists between the growth rate of employment density and the growth rate of labor productivity. 3) Agglomeration effect exists in the four cities, the highest one is Dalian, Shenyang takes the second place, followed by Changchun and Harbin, and the predominant promotion exerted on the labor productivity is the output density.

Keywords: social economic agglomeration; labor productivity; population density; economic density; Northeast China

Citation: Zhang peng, Yang Qingshan, Zhao Yichun, 2012. Relationship between social economic agglomeration and labor productivity of core cities in Northeast China. *Chinese Geographical Science*, 22(2): 221–231. doi: 10.1007/s11769-012-0522-4

1 Introduction

It is widely recognized that the regional and urban social economic agglomeration can improve the labor productivity and the externality of agglomeration, according to a number of case analyses in the fields of economic geography and urban economics during recent years (Phelps *et al*., 2001; Pu and Huang, 2008; Meijers and Burger, 2009).

Sveikauskas (1975) firstly proposed a model used to test the relationship between population size or economic scale and labor productivity. He examined the influence of the population size on labor productivity by using data from each industrial sector of American standard metropolitan statistical area in 1967. The results showed that the labor productivity could rise by 5.98% when the city size was doubled. It proved the existence of the agglomeration effectiveness. Most of the case studies (Romer, 1986; Parr, 2002) about the relationship between population size and labor productivity supported the hypotheses that agglomeration effectiveness had positive impact on the labor productivity to some extent. However, some negative conclusions were also made by some scholars when they tried to use the total population or employment to study the relationship between labor productivity and the population or employment. For example, Carlino (1979) came to a conclusion that population size had negative effect on labor productivity. Fugagami and Ohkusa (2003) found that the market scale measured in terms of the number of people had U-type relationship with economic growth rate. However, using the population size or economic size to measure the economic agglomeration level may cause ambiguous analysis outcomes, some scholars attempt to use the economic density (population density or employment density) to measure

Received date: 2011-01-10; accepted date: 2011-04-11
Foundation item: Under the auspices of National Natural Science Foundation of China (No. 41071088), National Social Science Foundation of China (No. 08BJY056)
Corresponding author: YANG Qingshan. E-mail: yangqs027@nenu.edu.cn

the level of economic agglomeration. Ciccone and Hall (1996) firstly developed a test model. They believe that population density or employment density can effectively measure the level of economic agglomeration compared with the population size. By examining the relationship between economic density and labor productivity using the data from counties in America, they found that the economic density was highly associated with the labor productivity. Moreover, Ciccone (2002) found that the elasticity of labor productivity relative to economic density has reached to 4.5% based on the studies of relationship between economic agglomeration density and labor productivity. The result proves the existence of the agglomeration effectiveness. The data set they used were the cross-sectional data at the county level in France, Germany, Italy, Espana and Britain.

The testing model used in the most of domestic empirical researches about the impact of the urban and regional agglomeration on the labor productivity was the model proposed by Ciccone and Hall (1996). By using this model, Fan (2006) examined the impact of non-agricultural employment density on the labor productivity from cross-sectional data of Chinese cities in 2004; Zhang and Liu (2007) used the panel data of Chinese city districts in 1999–2004 to study the impact of non-agricultural population density on the real per capital GDP; Li (2008) used the panel data of Chinese city districts in 1998–2005 to study the impact of the employment density on the labor productivity; Chen *et al*. (2008) employed micro data of Beijing in 2004 to study the impact of economy density on labor productivity (using the average wage level instead). They all concluded that the agglomeration promotes the economic growth.

Although many studies explored the impact of the urban and regional agglomeration on the labor productivity, most of the attention in these studies was only focusing on the impact of agglomeration of single element on the labor productivity. Little research focused on the impact of a single city′s agglomeration on the regional economic benefits changing with time. In this paper, four core cities, Dalian, Shenyang, Changchun and Harbin in Northeast China, were selected as sample cities to examine the impact of the city′s agglomeration on the labor productivity by using some indicators, such as population density and economic density, using the time-series data from 1990 to 2007. At the same time, a lateral comparison was made to examine the relationship between social economic agglomeration and labor productivity, which will definitely enrich the theories in terms of agglomeration externalities.

2 Materials and Methods

2.1 Data source

The primary data used in this paper were collected from China City Statistical Yearbook from 1990 to 2007 (National Bureau of Statistics of China, 1991–2008). The original indexes include GDP, total population, total employment, fixed asset investment and urban areas of the four core cities.

Due to some missing data in some years and some adjustments to administrative boundaries of the four cities, we had to analyze the administrative boundaries firstly to keep the consistency and comparability for the data we used. Since there are few and some tiny inner changes to the administrative boundaries of Shenyang and Dalian, respectively, we take the present administrative precincts as the statistical ranges. On the other hand, both Changchun and Harbin have experienced huge adjustments to the administrative areas. For example, Shuangyang used to be a county and was changed into a district of Changchun in 1995. Given the importance of Shuangyang district for Changchun City in terms of social and economic aspects, we kept it in the statistical area. For Harbin, in order to be consistent with other years, the districts of Nangang, Daoli, Daowai, Xiangfang, Songbei, Pingfang were included and the counties of Hulan and Acheng that are relatively isolated from Harbin were excluded in the statistical areas, respectively. Based on the statistical range of the four cities, the missing data of the China City Statistical Yearbook were supplemented in our dataset from other sources. Moreover, in order to guarantee the reliability and comparability of the conclusions, the time-series data were modified using the deflator index, which was set to 100 in the 1990.

2.2 Basic model

The model used in this paper is based on the domestic studies about the impact of the urban agglomeration on labor productivity, which is a spatial externality model generated by the scale density. This model was developed by Ciccone and Hall (1996) and modified by Fan

(2006). Suppose that the coefficient of elasticity produced by the output within unit land area to the externality $(\lambda-1)/\lambda$ is constant and the output coefficient of elasticity generated by the input elements l within unit land area is α, the basic model can be expressed as follows:

$$f(l,\ Q,\ A) = l^{\alpha}\left(\frac{Q}{A}\right)^{(\lambda-1)/\lambda} \tag{1}$$

where $f(l, Q, A)$ is the output which is produced by the l input elements into unit land of area within a geographical unit. The output is affected by the total production of geographical unit Q and the area of land A. It is believed that the externality comes from the intensity of production Q/A.

If we assume that the production within the region is uniformly distributed, Equation (1) can be derived into Equation (2) and Equation (3).

$$Q = Al^{\alpha}\left(\frac{Q}{A}\right)^{(\lambda-1)/\lambda} \tag{2}$$

$$f(l,\ Q,\ A) = l^{\alpha\lambda} \tag{3}$$

where α is the output elasticity-the reaction coefficient of the output in per unit land area to its input. It ranges from 0 to 1. If the capital and the labor input into per unit of land area are very high, it may generate the costs of negative external effects. λ is the external elasticity, measuring the agglomeration effectiveness and its value is generally greater than 1. The area will show the total scale increasing returns when $\alpha\lambda > 1$.

2.3 Empirical model

According to the basic model and actual situations of the four cities, Equation (1) can be simplified as follows:

$$f = \Omega\left((Hn)^{1-\beta}k^{\beta}\right)^{\alpha}\left(\frac{Q}{A}\right)^{(\lambda-1)/\lambda} \tag{4}$$

Normally, the investment element l on per unit of land area can be concreted into labor element Hn and capital k, where H is labor quality; n and k are the amount of labor and capital on per unit of land area, respectively; Ω represents the total factor productivity of city; α reflects the share of return from the capital and labor; β is the distribution coefficient between capital and labor. If the total amount of one city′s capital is expressed as K, the total amount of labor is expressed as L and the total scale of land area A is expressed as T (the population scale and the economy scale), we can get the labor productivity of a city by changing Equation (5):

$$\frac{Q}{L} = \Omega^{\lambda}\left(H^{1-\beta}\left(\frac{K}{L}\right)^{\beta}\right)^{\alpha\lambda}\left(\frac{T}{A}\right)^{\alpha\lambda-1} \tag{5}$$

In Equation (5), the product of $\alpha\lambda$ reflects the impact of the city scale density on the labor productivity. If $\alpha\lambda > 1$, the agglomeration of the population and economy will increase the total scale return of the city.

We can get a simplified Equation (6) from logarithm of both sides of Equation (5):

$$\ln(Q/L) = \mu_0 + \mu_1\ln(K/L) + \mu_2\ln H + \mu_3\ln(T/A) + \varepsilon \tag{6}$$

Equation (6) is the econometric model needed to be estimated. The dependent variable is the urban labor productivity. Explanatory variables are urban capital-labor ratio, labor quality, economic density or population density.

2.4 Measurement method

This paper estimates the model parameters by using the Ordinary Least Squares (OLS) regression model which is commonly adopted in the empirical researches of geography and economics. In order to test whether or not the fitted model is statistical significant and avoid 'Pseudo-regression', several examination analyses were made as follows:

(1) As the model was obtained by logarithmic transformation of the basic model, the goodness of the fit was used to test the fitting results of regression model.

(2) Hypothetical test was performed by using the F value of the fitted model. The parameters, including the constants, were tested by t value for statistical significance of the fitted models.

(3) There may be instabilities and autocorrelation between the model variables in the time-series data. In order to avoid the pseudo-regression affecting the testing results, ADF method was used to test the stabilities of variables and DW method was used to test the sequence autocorrelation of the model, respectively.

2.5 Variable explanation

According to the empirical model given earlier, the re-

quired data to the model and its specific calculation method are explained as follows:

(1) Labor productivity is calculated by the GDP of urban areas divided by total workforce, with the unit of yuan/person.

(2) Capital-labor ratio can be obtained by the amount of capital investment divided by total workforce, and with the total fixed assets investment as its proxy variable, the unit of capital investment is yuan/person.

(3) Labor quality is represented by the total number of the full-time teachers in the primary, secondary and higher educational systems, with the unit of full-time teachers/10^4 persons.

(4) Population density is the total population of the urban area divided by total urban area, with the unit of person/km^2.

(5) Economic density has output density and employment density. Output density is the GDP of urban area divided by total urban area, with the unit of yuan/km^2; employment density is the total workforce in urban area divided by total urban area, with the unit of person/km^2.

3 Results and Analyses

3.1 Statistical description of major indexes

Table 1 and Table 2 show the descriptive statistics of the variables defined above, from which we can clearly get the overall circumstances of the four cities by investigating the various economic indexes from 1990 to 2007. The employment density is excluded from the statistical description of the variable quantity. The reason is due to the fact that the employed population in those four cities show irregular trend which is embodied by the decreasing employed population after 2000.

The results of simple statistics regarding the major indexes show: 1) The labor productivity of the four cities has been improved obviously and changed significantly, especially during the year 1990–2000. As to the average labor productivity value displayed in Table 1, Dalian has the highest value, Shenyang ranks the second, and the least one is Harbin. Table 2 shows that Chang-

Table 1 Statistical interpretation of primary indicators (1990–2007)

Index	Shenyang		Dalian		Changchun		Harbin	
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
Labor productivity (yuan/person)	85911.3	93886.5	105040.0	89828.4	76256.6	72703.8	42068.0	39203.9
Capital-labor ratio (yuan/person)	43648.4	67411.1	41468.9	54224.3	33078.1	46616.2	16206.3	16835.4
Labor quality (full-time teacher/10^4 person)	99.9	14.6	103.9	15.1	125.9	20.9	125.1	17.2
Population density (person/km^2)	1373.2	41.74	1093.2	64.8	1183.2	485.4	1857.5	130.3
Output density (10^7yuan/km^2)	2.9186	2.1297	3.5480	2.5418	1.8522	1.1609	3.3745	2.7506

Source: National Bureau of Statistics of China (1991–2008)

Table 2 Economic indexes of four cities from 1990 to 2007

		Labor productivity (yuan/person)	Capital-labor ratio (yuan/person)	Labor quality (full-time teacher/10^4 person)	Population density (person/km^2)	Output density (yuan/km^2)
Shenyang	2007	309604	223558	109	1445	82268669
	2000	78457	142839	98	1388	26834930
	1990	70514	1289	62	1299	5293562
Dalian	2007	300731	182524	113	1215	93531677
	2000	100611	134086	98	1109	32716356
	1990	9384	1846	69	992	5619876
Changchun	2007	218065	167527	147	999	43083408
	2000	78516	18900	115	813	17156808
	1990	4818	1144	81	1891	5231183
Harbin	2007	135071	55577	129	2138	99448283
	2000	42667	15466	126	1830	33128313
	1990	5339	849	81	1727	5973122

Source: National Bureau of Statistics of China (1991–2008)

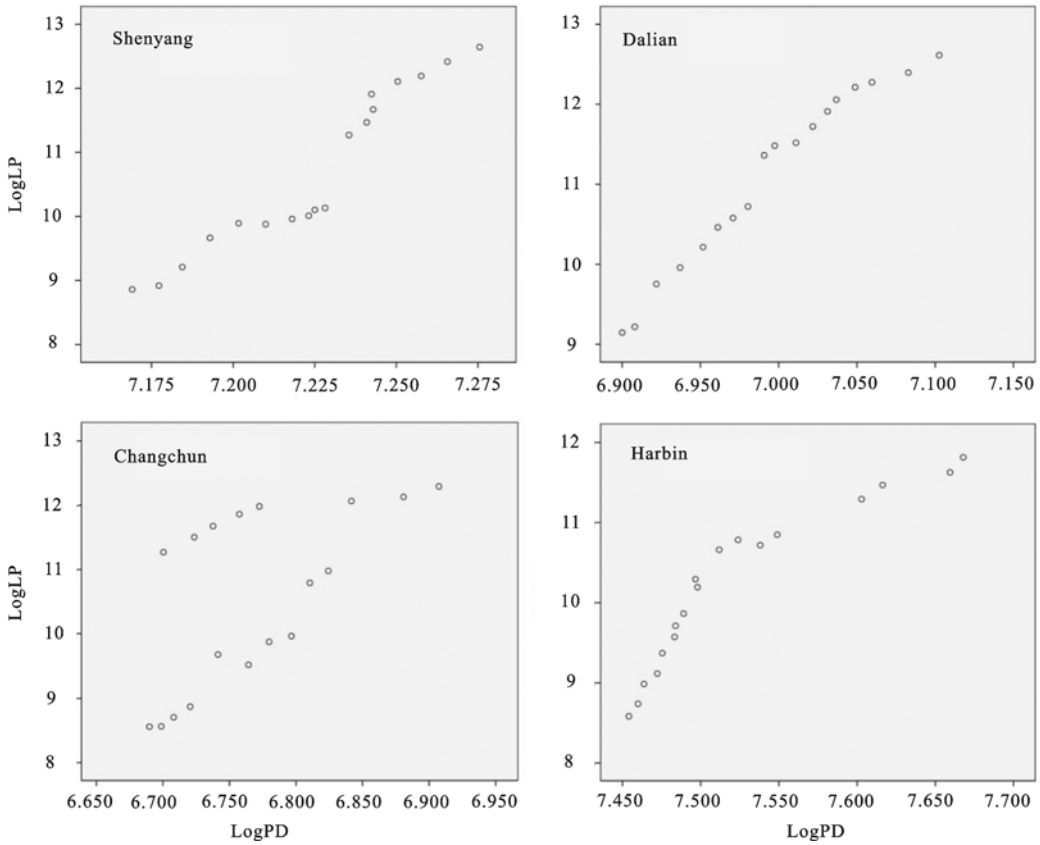
chun has the most significant variation amplitude of labor productivity. On the other hand, Harbin shows the least variational amplitude of labor productivity in the four cities. 2) In view of the capital-labor ratios of the four cities showed in Table 1, all of four cities have more significant change and much bigger variation amplitude than labor productivity, especially for Changchun and Shenyang, which implies that there is a great impact of the investment increase on labor productivity since 1990. It is called capital deepening in economics. 3) In terms of labor quality, as displayed in Table 1 and Table 2, no obvious variation amplitude is found in the four cities. Changchun and Harbin have a little higher average value than the other two cities. 4) Table 2 display that none of the four cities shows a significant change in population density. 5) The four cities show identical variational amplitude of output density as Table 2 displayed. However, Changchun has a small change before 2000.

3.2 Simple correlation between major indexes

In order to test the accuracy of the model used, the paper takes logarithm of labor productivity for the four cities and makes scatter diagram with the logarithms of population density, output density, employment density, respectively (Fig. 1–Fig. 3).

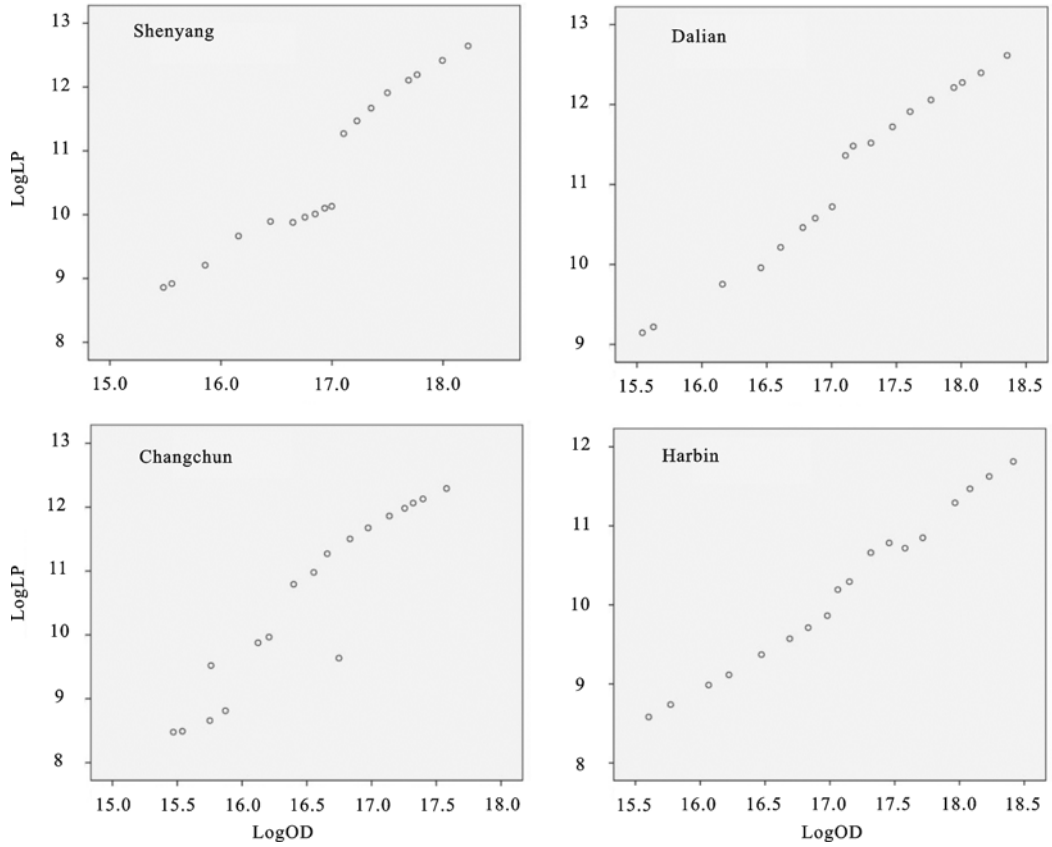
Figure 1 shows that the labor productivity in Shenyang, Dalian, and Harbin is highly correlated with population density. The only exception is labor productivity of Changchun, no strong linear correlation was observed between labor productivity and population density. The main reason may be because that many towns, such as Kalun and Mishazi near to Changchun, became a part of urban area five years ago, which in turn results in the increase in urban area and the decrease in the population density. The labor productivity is affected insignificantly by urban areas. For this reason, there are five outliers obviously appearing on the scatter graph, but a significantly linear correlation could still be observed from the distribution of the outliers.

Figure 2 shows that the labor productivity in those four cities is linearly correlated with output density. It suggests that the model used in this paper can reflects reality in the four cities.



LP, labor productivity; PD, population density

Fig. 1 Scatter diagrams of labor productivity and population density in four cities



LP, labor productivity; OD, output density

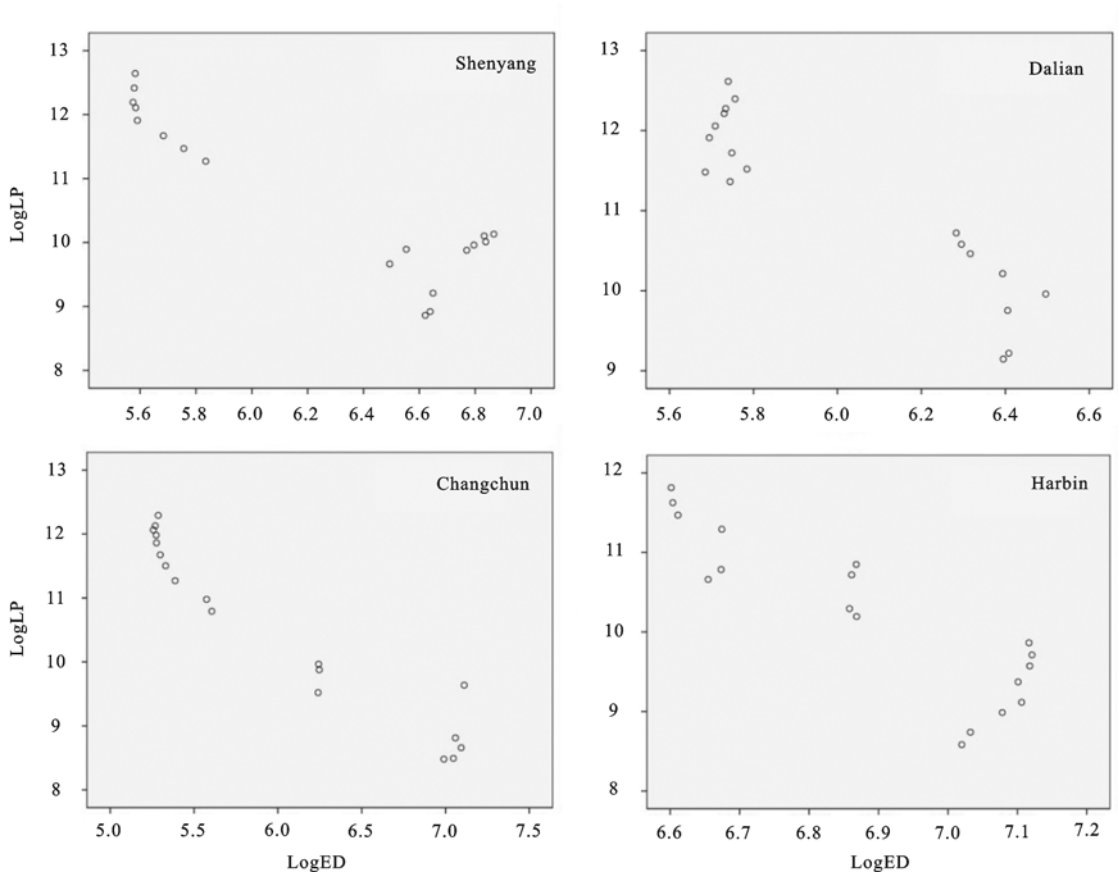
Fig. 2 Scatter diagrams of labor productivity and output density in four cities

From Fig. 3, we can see that there is no obviously linear correlation between employment density and labor productivity. Furthermore, the employment density decreases with increase of labor productivity, which is in accordance with other domestic cities. Since the 1980s, Chinese economic development has experienced an extraordinary high speed. However, the phenomenon of low employment growth and increasing unemployment appears in this period, which is so-called ′Increasing-unemployment′ or ′Under-employment Growth′ in theory. Some Chinese scholars have made some explanations to this phenomenon. Most of them believe that the capital deepening generates the crowding-out effect on employment and improves the labor productivity. In other words, the same labor force can create much more products or the equal amounts of goods cost less labor forces. Therefore, with other controlling factors, the capital deepening would exert extruding-effect on employment.

3.3 Ordinary least squares (OLS) regression

First, we used the common ADF (Augmented Dickey-Fuller Test) method to test the variables′ stationary (Table 3). Most variables are non-stationary sequence. The only exceptions are labor quality of Shenyang, Changchun and Harbin as well as population density of Harbin which reject the hypothesis of unit root at 5% level. They are stationary sequences. By testing stationary for first-order difference, population density growth rate of Shenyang and output growth rate, labor quality growth rate of Changchun, as well as population density growth rate of Harbin, are non-stationary sequence. The rest of the cities are stationary sequence and they deny the hypothesis of unit root at 5% significant level. Therefore, we can conduct regression analysis by using the first-order differences of the variables for these cities. The regression results are shown in Table 4.

In Table 4, regression 1 is to examine the influence of population density on the labor productivity rate, regression 2 is to examine the influence of output density on the labor productivity rate, and the regression 3 is to examine the influence of employment density on labor productivity rate. Regression 1 shows that two



LP, labor productivity; ED, employment density

Fig. 3 Scatter diagrams of labor productivity and employment density in four cities

cities, Shenyang and Harbin, have confidence levels above 90%, passing *F* inspection. However, due to the non-stationary in variables and the correlations less than 50% between population density growth rates and labor productivity growth rates of Shenyang, we can not make a confident conclusion in terms of this correlation. In addition, both Dalian and Changchun can not pass the *F* test. No significances in *F* were obtained in the regression results. Therefore, the results of regression 1 can not explain the relationship between the population density and the labor productivity rate.

Regression 2 shows that the confidence level of *F* test reaches to 90%, which indicates that the model we used is reliable. DW statistics ranges from 1.39 to 2.61. Except for Shenyang, no autocorrelation of the sequence is found for these cities. Therefore, we can use the results of regression 2 to explain the relationship between output density and the labor productivity rate.

Regression 3 shows that, except for Changchun, the confidence level for *F* statistics of the rest cities all reach to 95%. DW results indicate no autocorrelation of sequence except Shenyang and Changchun. In addition, because sample numbers we used in the paper are limited, so we can expect a strong correlation if the confidence level reaching to around 70%.

As can be seen from Table 4, agglomeration effect exists in four cities. The predominant promotion exerted on the labor productivity is the output density. Firstly, the elasticity of output density growth rate relative to labor productivity growth rate of Shenyang is 0.820 and the confidence level is about 60%. Because of the rapid economic development in Shenyang, the data we analyzed have great fluctuations, resulting in higher DW statistics than the inspection value. However, the regression result still reflects real situation in Shenyang to some extent. Secondly, the elasticity of output density growth rate relative to labor productivity growth rate of Dalian is 0.848 and the confidence level is above 80%. Thirdly, the elasticity of output density growth rate relative to labor productivity growth rate of

Table 3 Stationary test of all variables for four cities

City	Variable	ADF test	Each significant level of critical point		Test results
			1%	5%	
Shenyang	Q/L	–0.214462	–3.886751	–3.052169	non-stationary
	ΔQ/L	–4.098044	–3.920350	–3.065585	stationary
	K/L	0.423652	–3.886751	–3.052169	non-stationary
	ΔK/L	–3.677258	–3.920350	–3.065585	stationary
	H	–3.321383	–3.886751	–3.052169	stationary
	ΔH	–3.712007	–3.920350	–3.065585	stationary
	P/A	–0.135265	–3.886751	–3.052169	non-stationary
	ΔP/A	–2.119893	–4.057910	–3.119910	non-stationary
	O/A	–1.412539	–3.920350	–3.065585	non-stationary
	ΔO/A	–2.254344	–3.920350	–3.065585	non-stationary
	E/A	–0.693780	–3.886751	–3.052169	non-stationary
	ΔE/A	–3.750083	–3.920350	–3.065585	stationary
Dalian	Q/L	–1.467880	–3.886751	–3.052169	non-stationary
	ΔQ/L	–4.542870	–3.920350	–3.065585	stationary
	K/L	–0.240374	–3.886751	–3.052169	non-stationary
	ΔK/L	–4.792740	–3.920350	–3.065585	stationary
	H	–3.088997	–4.004425	–3.098896	non-stationary
	ΔH	–3.664569	–4.057910	–3.119910	stationary
	P/A	–2.336320	–3.886751	–3.052169	non-stationary
	ΔP/A	–3.385801	–3.920350	–3.065585	stationary
	O/A	–1.769457	–3.886751	–3.052169	non-stationary
	ΔO/A	–3.222620	–3.920350	–3.065585	stationary
	E/A	–1.017814	–3.886751	–3.052169	non-stationary
	ΔE/A	–3.709602	–3.920350	–3.065585	stationary
Changchun	Q/L	–1.404854	–3.886751	–3.052169	non-stationary
	ΔQ/L	–5.524680	–3.920350	–3.065585	stationary
	K/L	0.568048	–3.886751	–3.052169	non-stationary
	ΔK/L	–4.849884	–3.920350	–3.065585	stationary
	H	–4.431203	–4.004425	–3.098896	stationary
	ΔH	–2.156852	–4.004425	–3.098896	non-stationary
	P/A	–1.686665	–3.886751	–3.052169	non-stationary
	ΔP/A	–4.049142	–3.920350	–3.065585	stationary
	O/A	–0.744991	–3.920350	–3.065585	non-stationary
	ΔO/A	–5.051482	–4.004425	–3.098896	stationary
	E/A	–1.029465	–3.886751	–3.052169	non-stationary
	ΔE/A	–4.583865	–3.920350	–3.065585	stationary
Harbin	Q/L	–0.265547	–3.886751	–3.052169	non-stationary
	ΔQ/L	–4.310721	–3.959148	–3.081002	stationary
	K/L	–1.450959	–3.886751	–3.052169	non-stationary
	ΔK/L	–4.275632	–3.920350	–3.065585	stationary
	H	–4.252194	–3.920350	–3.065585	stationary
	ΔH	–3.938564	–3.920350	–3.065585	stationary
	P/A	3.311562	–3.959148	–3.081002	stationary
	ΔP/A	–0.860753	–3.959148	–3.081002	non-stationary
	O/A	–1.503479	–3.886751	–3.052169	non-stationary
	ΔO/A	–3.294993	–3.920350	–3.065585	stationary
	E/A	–0.628815	–3.886751	–3.052169	non-stationary
	ΔE/A	–3.571265	–3.920350	–3.065585	stationary

Notes: The Q/L, K/L, H, P/A, O/A, E/A represent the logarithms of labor productivity, capital-labor ratio, labor quality, population density, output density and employment density, respectively; their first-order differences represent labor productivity growth rate, capital-labor growth rate, labor quality growth rate, population density growth rate, output density growth rate and employment density growth rate, respectively, expressed as ΔQ/L, ΔK/L, ΔH, ΔP/A, ΔO/A, ΔE/A

Table 4 Regression output of variables for four cities

City	Explanatory variable	Labor productivity growth′ logarithm		
		Regression 1	Regression 2	Regression 3
Shenyang	Constant	0.012 (0.086)	–0.038 (–0.273)	0.150 (5.535)***
	ΔK/L	0.457 (2.806)***	0.461 (2.904)***	0.008 (0.112)
	ΔH	–0.102 (–0.224)	–0.363 (–0.711)	0.322 (1.976)
	ΔP/A	11.965 (0.622)	—	—
	ΔO/A	—	0.820 (1.059)	—
	ΔE/A	—	—	–0.977 (–9.880)***
	R^2	0.391	0.423	0.926
	F	2.782**	3.172**	54.461***
	DW	2.866	2.728	1.249
Dalian	Constant	0.130 (1.125)	0.017 (0.194)	0.134 (5.283)***
	ΔK/L	0.207 (1.436)*	0.190 (1.428)*	0.027 (0.380)
	ΔH	0.589 (1.523)*	–0.171(–0.282)	0.885 (4.918)***
	ΔP/A	0.046 (0.005)	—	—
	ΔO/A	—	0.848 (1.537)*	—
	ΔE/A	—	—	–0.962 (–6.943)***
	R^2	0.254	0.369	0.842
	F	1.477	2.532**	23.02***
	DW	1.638	1.696	2.415
Changchun	Constant	0.285 (2.034)**	0.152 (1.343)	0.252 (1.722)*
	ΔK/L	–0.148 (–0.350)	0.051 (0.154)	–0.102 (–0.229)
	ΔH	–0.099 (–0.188)	–0.115 (–0.278)	–0.192 (–0.347)
	ΔP/A	0.391 (1.243)	—	—
	ΔO/A	—	0.488 (3.240)***	—
	ΔE/A	—	—	–0.080 (–0.296)
	R^2	0.118	0.454	0.020
	F	0.580	3.604***	0.087
	DW	2.215	1.972	2.791
Harbin	Constant	0.054 (1.313)	0.021 (0.152)	0.121 (5.517)***
	ΔK/L	0.400 (3.246)***	0.347 (2.370)***	0.164 (2.045)**
	ΔH	0.091 (0.541)	–0.073 (–0.344)	0.205 (2.133)**
	ΔP/A	2.715 (1.763)*	—	—
	ΔO/A	—	0.578 (1.124)	—
	ΔE/A	—	—	–0.883 (–6.212)***
	R^2	0.535	0.475	0.855
	F	4.987***	3.918***	25.513***
	DW	1.674	1.580	2.264

Notes: the values in bracket are statistical data, and ΔK/L, ΔH, ΔP/A, ΔO/A, ΔE/A represent the first-order difference of the capital-labor ratio, labor quality, population density, output density and employment density respectively; ***, **, * represent for confidence level above 95%, 90% and 80%, respectively

Changchun is 0.488 and the confidence level is above 95%. Lastly, the elasticity of output density growth rate relative to labor productivity growth rate of Changchun is 0.578 and the confidence level is about 70%.

About the growth rate of population density and growth rate of labor productivity, although the previous empirical researches suggested that the population density or economic density has the positive impact on the labor productivity, most of them were based on panel data or cross-sectional data. When we tried to use the

time series data for analysis, we can not get the result that population density growth rate is significantly correlated to the labor productivity growth rate. It indicates that the increase of the population density growth rate does not always promote the growth of labor productivity. The reason may be due to the unstable total variables. The regression analysis does not reflect the relationship between population density and labor productivity but the relationship between their growth rates instead. This is the disadvantage by using the difference of variable quantity to explain the total quantity. Furthermore, the increase of the population density also implies that the urban agglomeration is strengthening during the development of the cities, promoting the growth of the labor productivity. Since the population increase is made up of natural increase and mechanical increase and there is a rarely huge mechanical increase for the four cities in Northeast China, the inherent stability in the increase of the population exerts little impact on the economic growth.

About the growth rate of employment density and growth rate of labor productivity, the description of statistical variables and the analysis of simple correlation obtained above suggest that there is an apparent decreasing trend of employment density with the increase of labor productivity rate in these four cities since 1990, which is consistent with the conclusion of a negative correlation obtained from the regression analysis between the growth rate of employment density and increase of labor productivity. If we calculate the relationship between employment density and labor productivity in a single year among the four cities, the positive correlation will be found, which corresponds with the reality that most cities had chosen the labor-intensive industries as a development model so as to get the densest economic agglomeration. The conclusions indicate that there is a phenomenon of capital deepening in these four cities, leading to the extruding-effect and the decline in the employment density.

4 Conclusions

The present paper conducts the regression analysis by using the first-order difference values of variables to examine the relationships among the growth rates of the corresponding variables. If the growth rate of the population density and the economic density keep increasing, it implies an unceasing growth of the urban population and economics. It also implies that the agglomeration effect keeps strengthening. Following conclusions were obtained from the relationships between urban agglomeration and labor productivity in the four cities.

(1) The promotion from the growth rate of population density on the growth rate of labor productivity is limited.

(2) The negative relationship exists between the growth rate of employment density and the growth rate of labor productivity.

(3) Agglomeration effect exists in four cities. The highest one is Dalian, and Shenyang takes the second place, followed by Changchun and Harbin. The predominant promotion exerted on the labor productivity is the output density.

Theoretically, the productivity of each unit in a city represents its economic development level and capability of economic agglomeration. Hence the output density makes more contributions to the labor productivity. In view of the practical development condition in Northeast China, Dalian and Shenyang have the higher economic development with better development policies, investment environment as well as the infrastructures and so forth which have critical influence on output density. This is consistent with our conclusion of this paper. Therefore, in the future, all of these four cities should actively promote the industrial agglomeration and expand the scale of industrial agglomeration to gain a higher agglomeration effect on the share of labor market, inputs of intermediate products and technology spill-over. In this way, the economic progress of the cities will be greatly promoted by boosting the output density and growth rate.

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