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The impact of agglomeration on productivity growth in urban China: An application of DEA and Tobit models

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Abstract. In this paper, we seek to explore the spillover effects of agglomeration on productivity growth from the evidence of the creative industries in urban China. We apply the data envelopment analysis (DEA) and Tobit models to test the issue whether the development of creative industries agglomeration (CIA) can boost its productivity growth, as controlling the creative firm size, city labor density, R&D intensity and FDI level, based the data of China's 56 cities. The empirical result shows that the agglomeration of creative industries has a significant and positive effect on its productivity growth in urban China. It is also found such growth effect is mainly by the channel of increasing pure technical efficiency change instead of scale efficiency change. As we take the sensitive analysis, the results are still robust.

Key words. Agglomeration, spatial economics, productivity growth, China.

1. Introduction

As our society moves into the so-called information age when the economic growth is greatly driven by innovation and creativity, the creative industries as one of most dynamic emerging sectors are growing rapidly and becoming a new engine of the world economic growth. In China, lots of creative industries hubs and clusters are springing up like mushrooms. The data shows there are more than 800 national or urban creative industries parks in China by the end of 2012 (Ministry of Culture of the People's Republic of China, 2013). It is believed that the cluster is becoming one of increasingly crucial features of creative industries development whether in China

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or all around the world.

Several contributions have captured the agglomeration externalities in creative industries. Yusuf & Nabeshima (2005) highlight the economic center of gravity of the leading cities is changing from manufacturing to creative industries. To lead growth and own comparative advantage, cities need to evolve or remain as the centers of creative industries or service-providing hubs. The existing studies show the development of creative industries or the creative class plays an increasing role in driving and facilitating regional wealth and employment growth (Boschma & Fritsch, 2009; Lazzeretti et al., 2012; De Propris, 2013). It is suggested that innovation is a key mechanism explaining why and how the creative industries impacting on economic growth (Stam et al, 2008; Müller et al, 2009, Piergiovanni, 2012). It is confirmed the development of the clustering of creative industries has significant and positive impact on the total factor productivity growth at the regional level (Clare, 2013; Hong et al, 2014). In other words, the agglomeration externalities of creative industries on productivity growth at the regional level is empirically captured and documented. But to the best of our knowledge, the question about the relationship between the agglomeration and productivity growth at the city level still remains unanswered in the context of creative industries.

In this paper, we seek to explore whether and how the clustering of creative industries can stimulate industrial productivity growth aiming to make up the existing research gaps. Our empirical results support that if cities can develop more creative clusters particularly attracting small and medium creative enterprises clustering, it will significantly boost to industrial productivity growth. It is also found such growth effect is mainly by the spillovers of creative industries agglomeration (CIA) on industrial pure technical efficiency (PTE) change instead of the scale efficiency (SE) change.

2. Creative industries agglomeration in urban China

It is suggested that the location quotient LQ is a popular measurement to discuss the growth effects generated by industrial cluster (Lazzeretti et al., 2012; Hong et al., 2014). The CIA index measured by LQ indicator is defined as:

$$R = 1 \tag{1}$$

Where L_{ij} is the number of employees in the creative sector i in city j; L_i denotes the number of total employment in the creative sector i; L_j denotes the employment in city j; L denotes the total employment in China. When the CIA index is greater than 1, it indicates that the city labor system of creative industries is significantly specialized.

In order to make sensitive analysis, another index calculated by creative industries employment density (CIED) is introduced to measure the concentration level of creative industries as well. The CIED index is defined as:

$$x = 1.147 \tag{2}$$

Where $CI\ employment_{i,j}$ similarly denotes creative industries employment in city i and j creative group, $City\ area_{i,China}$ denotes the land area in city i, therefore the CIED index is established to represent the quantity of creative industries employment per unit land area, denoting another proxy of the concentration level of creative industries.

Table 1. The agglomeration of creative industries at the city level in China (2008)

Top 10 cities	CIA index	CIED index (worker per k^2)	GDP per capita (Yuan)
Quanzhou	3.17	18.28	34482
Hefei	2.37	16.24	73124
Zhangjiajie	2.32	1.10	12338
Suzhou	2.25	29.83	106863
Fuzhou	1.88	15.90	33615
Hohhot	1.81	4.98	49606
Lijiang	1.80	0.48	8301
Shanghai	1.77	202.33	73124
Shaoxing	1.76	10.16	33615
Qingdao	1.74	22.88	52677
Bottom 10 cities	CIA index	CIED index (worker per k^2)	GDP per capita
Yichang	0.79	3.40	25445
Lhasa	0.75	4.46	20404
Jining	0.70	8.94	26721
Tangshan	0.64	3.89	48054
Xiangtan	0.64	1.20	23673
Xianyang	0.61	4.48	15286
Daqing	0.56	1.06	80655
Tonghua	0.54	0.26	19703
Baoji	0.52	1.71	18992
Datong	0.43	1.75	17974

Notes: CIA, creative industries agglomeration; CIED, creative industries employment density; The CIA index is measured by LQ indicator, and the CIED index is calculated by the Equation 2.

Table 1 reports the CIA index of top 10 and bottom 10 cities in China, as well as those city's CIED index and urban GDP per capita. There are 36 cities whose CIA

index is greater than 1, indicating 60% of selected 60 cities' labor system of creative industries is significantly specialized. It shows that the CIA index is overall highly correlated with the CIED index except for Zhangjiajie, Hohhot, Lijiang. It is worth mentioning that the concentration of creative industries is more or less associated with urban GDP per capita. In fact, 6 out of top 10 cities (except Zhangjiajie, Hohhot, Lijiang) with higher level of regional productivity and GDP per capita are from the coastal provinces, while most of bottom 10 cities (except Tangshan) with relatively lower level of GDP per capita are from the inner provinces.

3. Empirical analysis method

3.1. Modeling

The Tobit model of creative industries agglomeration impacting on the growth of creative industries productivity can be specified as:

$$Y_{ij} = c + \alpha CIA_{ij} + \beta_1 CFS_{ij} + \beta_2 RD_{ij} + \beta_3 CLD_{ij} + \beta_4 FDI_{ij} + \mu_{ij} \qquad (3)$$

The dependent variable, denotes the scores of technical efficiency (TE), PTE and SE in creative industries in the creative sector and represents the concentration of creative industries which is measured by CIA index according to the equation which is the coefficient of the CIA impacting on industrial productivity (Wei & Liu, 2006; Drucker & Feser, 2012; Guo et al., 2016).

3.2. The variables

The dependent variable is the industrial productivity in urban China which is measured by the technical efficiency score of creative industries. In this paper, we use the variable returns to scale model of DEA (i.e. the DEA-BCC model) to calculate city efficiency of creative industries in China, where the model includes two inputs and a single output. The output is the operating revenue of creative industries, while the inputs include the employment and total asset of creative industries.

Figure 1 presents how these three scores are calculated, where the TE score is equal to AB divided by AD, the PTE score is equal to AC divided by AD, and the SE score is equal to AB divided by AC. The data of inputs and output both are based on China's 60 cities sourcing from *China Economic Census Yearbook* (National Bureau of Statistic of China, 2010).

The independent variable is measured by the CIA index (see Equation 1). To check robustness, we apply another substitute variable to denote the concentration level of creative industries measured by the CIED index (see Equation 2). Unsurprisingly, if the creative industries is more concentrated in an area, it can obtain higher productivity growth. Intuitively, the positive correlation between CIA and the scores of TE and PET growth can be observed in the scatter diagrams (see Fig. 2-4). Interestingly, it is found that the concentration of creative industries seems to have negative effect on its scale efficiency (see Fig. 4).

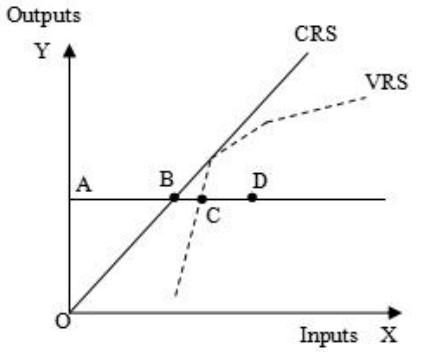

Fig.1. Technical and Scale Efficiencies

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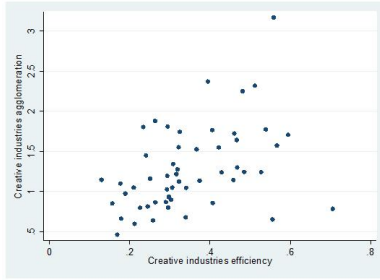

Fig. 2. Scatter of CIA and TE

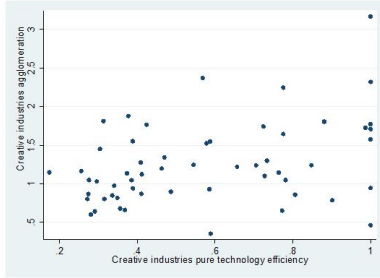

Fig. 3. Scatter of CIA and PTE

This control is introduced to test whether the clustering of bigger or smaller creative firm can produce stronger intra-industry spillovers (Drucker & Feser, 2012; Guo et al., 2016).

The variable of CLD is used to control whether the effect of labor pooling on productivity growth may occur in the city level, and this control is defined as:

$$City\,labor\,density = \frac{city\,work\,force}{city\,land\,area}$$

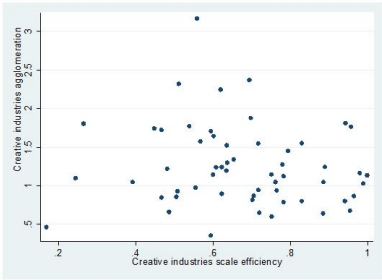

Fig. 4. Scatter of CIA and SE

The control of R&D is measured by the share of city R&D expenditure to local GDP, and the variable of FDI level, using as a substitute for creative industries FDI level, is measured by the city FDI divided by local GDP (with yuan terms in those years). The existing research suggests that the city labor density level generally has a positive effect, while the coefficients of the controls of R&D and FDI are both expected to be positive (Wei & Liu, 2006). The descriptive statistics for all variables in our estimations is presented in Table 2.

Table 2. Descriptive statistics of all variables

Variable	Definition	Unit	Obs.	Mean	Max	Min	S. D.
CIA index	Location Quotient of employment in creative industries	–	56	1.250	3.165	0.352	0.527
CIED index	Creative industries employment density	100 workers per k^2	56	0.446	11.220	0.003	1.550
TE index	Technical efficiency index	%	56	0.356	0.718	0.130	0.136
PTE index	Pure technical efficiency index	%	56	0.573	1.000	0.174	0.257
SE index	Scale efficiency index	%	56	0.674	0.999	0.169	0.192
R&D	Share of R&D expenditure to GDP	%	56	0.283	1.077	0.034	0.193
CLD	City labor density	100 workers per k^2	56	5.824	22.387	0.180	3.910
FDI	Share of FDI to GDP	%	56	0.036	0.108	0.003	0.026
CFS	Ratio of creative industries asset to the No. of creative firm	10 million yuan per firm	56	0.200	0.606	0.035	0.120

Note: CIA, creative industries agglomeration; CIED, creative industries employment density; TE, technology efficiency; PTE, pure technology efficiency; SE, scale efficiency; R&D, research and development expenditure; CFS, creative firm size;

CLD, city employment density; FDI, foreign direction investment.

3.3. Data

The data of the employment, total asset, and operating income of creative industries, and the number of creative firm are all from *Chinese Creative Industries Annual Report* (Zhang, 2011), and the time is fixed in 2008. The data in this report is calculated based on *China Economic Census Yearbook* (National Bureau of Statistics of China, 2010). The data of national employment, city employment, city R&D expenditure, city FDI level, city GDP and city labor density are obtained from *China City Statistical Yearbook* (National Bureau of Statistics of China, 2009).

There are 293 prefecture-level cities in China, why only 56 cities are chosen in this paper. It is because that the creative industries in these selected cities is easier to get while the same data in other cities is missing. It is worth to note that such selected cities have strong representativeness for China's creative industries. Because the selected cities is consist of 28 cities in the coast provinces and 28 cities in the inland provinces, and each province in China is chosen at least one city for the sample, and the employment of creative industries in the selected cities accounts up more than 80% of all creative industries employment in China.

4. Results and discussions

We ran the Tobit regressions reported in Table 3 by using three dependent variables, including the scores of the TE, PTE and SE of creative industries. It shows the LQ indicator of creative industries in Model 1 are positively associated with the TE score of creative industries at the 5 per cent significance with the coefficient is 0.087, indicating the agglomeration of creative industries has positive and significant impact on its productivity increase. The mean of VIF in the models is 1.37 which is faraway less than 10, indicating our model does not suffer from multicollinearity.

Table 3. The determinants of the productivity growth in creative industries

Model Variables	Model 1	Model 2	Model 3
	DV: TE score	DV: PTE score	DV: SE score
CIA index	0.087*** (??)3.58)	0.247*** (??)3.32)	<-0.001 (-1.64)
R&D intensity	0.146* (??)1.75)	0.541** (??)2.28)	0.196 (??)0.87)
City labor density	0.009* (??)1.81)	0.012 (??)0.94)	0.0018 (??)0.20)
FDI level	-1.121** (-2.21)	-2.636** (-2.55)	-0.220 (-0.19)
Creative firm size	-0.187 (-1.32)	-0.707** (-2.27)	0.033 (??)
Constant	0.231*** (??)4.39)	0.315** (2.62)	0.623*** (1.042)
Pseudo R^2	-0.234	0.525	-0.062
Left-censored obs.	0	0	0
Uncensored obs.	56	49	56
Right-censored obs.	0	7	0
Obs.	56	56	56

Notes: The mean of VIF is 1.37; ***, ** and * represent statistical significance level at 1%, 5% and 10%, respectively; DV, dependent variable; CIA, creative industries agglomeration; TE, technology efficiency; PTE, pure technology efficiency; SE, scale efficiency.

The analysis on influencing mechanism shows that the CIA is positively and significantly associated with the PET growth in Model 2, while the effect caused by the SE change turns out to be not significant in Model 3. It indicates that the productivity growth effect in creative industries generated by industrial agglomeration is mainly by the channel of technology change such as applying new technology or producing new creative good, rather that by its industry scale of economics. In effect, the control of creative firm size is turned out to show negative sign in Model 1 and Model 2, indicating that the productivity of creative industries may be not increased by expanding the creative firm size. It means that the creative firm with smaller size clustering in an area may produce stronger spillover effect on industrial productivity growth.

Table 4. The results of robustness check

Model Variables	Model 1a	Model 2a	Model 3a	Model 1b	Model 2b	Model 3b
	DV: TE score	DV: PTE score	DV: SE score	DV: TE score	DV: PTE score	DV: SE score
CIED index	0.024** (2.86)	0.222** (2.12)	-0.028 (-1.64)			
CIA index				0.017** (2.06)	0.013* (1.71)	-.0089 (-1.47)
R&D intensity	0.009 (0.93)	-0.148 (-0.53)	0.196 (2.087)	0.108 (1.08)	0.503*** (5.18)	-0.120 (-1.54)
City labor density	0.01** (2.3)	0.007 (0.50)	0.0018 (0.20)	0.0104** (2.08)	0.0074 (1.51)	0.004 (1.22)
FDI level	-0.660 (-1.06)	-0.883 (-0.56)	-0.220 (-0.19)	-0.204 (-0.31)	-1.446*** (-2.63)	1.271*** (2.87)
Creative firm size	-0.167 (-1.08)	-0.603* (-1.80)	0.0325 (0.19)	<-0.001 (-1.21)	<- 0.001** (-2.12)	<0.001 (0.23)
Constant	0.333*** (7.2)	0.669*** (5.90)	0.623*** (1.042)	0.355*** (9.82)	0.342*** (10.04)	0.745*** (25.45)
Pseudo R^2	-0.162	0.367	-0.062	0.040	0.193	0.279
Left-censored Obs.	0	0	0	0	1	0
Uncensored Obs.	56	49	56	381	396	430
Right-censored Obs.	0	7	0	67	51	18
Obs.	56	56	56	448	448	448

Notes: The mean of VIF in Model 1-3a is 1.89; Model 1-3b are estimated based on the samples of 448 (56 city×8 sub-sectors=448); ***, ** and * represent statistical significance level at 1%, 5% and 10%, respectively; DV, dependent variable; CIA, creative industries agglomeration; TE, technology efficiency; PTE, pure technology efficiency; SE, scale efficiency.

Expectedly the controls of R&D expenditure and city labor density show positive signs, indicating that creative firms are more efficient in larger cities and seem to benefit significant spillovers from R&D. Unexpectedly, the FDI level present a significant but negative sign in Model 1 and 2. It is suggested that the creative industries in China is now falling into the situation with low efficiency and thin profit, but FDI prefers high profit sectors such as high-tech industries. Thus the situation with inefficient production may hinder FDI enter into China's creative industries.

In this paper we take two approaches to check robustness. To begin with, we apply the CIED index as another independent variable to substitute the CIA index and conduct three Tobit regressions (see Model 1a-3a in Table 4). The results by sensitive analysis in Model 1a-3a are very consistent with the general estimation. In

addition, we take another three Tobit estimations by using 448 data with 56 cities multiplying by 8 creative sub-sectors (see Model 1b-3b in Table 7), where the value of dependent and independent variables and the control of CFS is calculated based on each creative sector in each city, while the controls of R&D, CLD and FDI with city level value are used as three proxy variables to denote their sector level in different types of creative domains due to data missing. The estimations with the samples of 448 (56 city??8 sub-sectors=448) also show consistent and robust results. It reconfirms that the clustering of creative industries has strong spillovers on industrial productivity growth, and the impacting mechanism is mainly by increasing its pure technical efficiency instead of by scale efficiency change.

5. Conclusion

China's creative industries is on the trend of concentration in the cities. In this paper, we focus on the relationship between the agglomeration and industrial productivity. By using China's 56 cities data, we establish an empirical model to demonstrate this issue as controlling the creative firm size, city labor density, R&D expenditure, and FDI level. The empirical results show that the clustering of creative industries has positive and significant effects on industrial productivity growth, no matter what approaches applied with the Tobit estimations by the cross-section data of 448 samples, or estimation by substituting independent variable, the results are robust. It is also found the growth effect is mainly by the spillovers of CIA on the PTE change rather than the SE change. If the policies aim at promoting the productivity of creative industries, it is alternatively effective to develop the clusters of creative firms, particularly attracting small and medium creative firms concentrating in the cluster.

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