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Agglomeration Effects on Regional Labor Productivity Growth: Mechanisms and Evidence in China

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Abstract: This study looks at the effects of agglomeration economies on growth of labor productivity and its components at four specific reasons for this growth: Technological change, technological catch-up, physical and human capital accumulation. These are examined using data for Chinese provincial region-level during 1993-2009. It appears that agglomeration of economic activities of non-agricultural sectors has had beneficial spillover effects in improving regional TFP growth and its four components over the period of the study. Furthermore, empirical tests indicate that the agglomeration of non-agricultural sectors accelerate productivity growth through physical capital accumulation and technological catch-up.

Key words: Agglomeration economies, employment density, total factor productivity

INTRODUCTION

The effect of spatial concentration of economic activities on regional productivity has become a mainstream research area of economics of agglomeration following Marshall (1920), who emphasizes localization which refers as Benefits derived from the agglomeration of a set of activities near a specific facility as key factor of accelerating regional productivity improvement. Arrow (1962) and Romer (1990) formalized Marshall's idea and demonstrated that. Henderson (1986) found that the productivity of firms increases with the size of the industry as measured by industry employment.

A second branch of the literature on agglomeration economies hypothesizes economies of scale internal to cities. Jacobs (1969) was an early contributor, who advocates urbanization that benefits derived from the agglomeration of population, namely common infrastructures (e.g., utilities or public transit), the availability and diversity of labor and market size.

Empirical studies of agglomeration have focused on industry and city size as determinants of productivity as a source of agglomeration economies. On one hand, Henderson (1986), Glaeser *et al*. (1992) and Baldwin *et al*. (2010) found that the productivity of firms increases with the size of the industry as measured by industry employment. On the other hand, Sveikauskas (1975), Segal (1976) and Moomaw (1985) focused the accelerating effects of city size on productivity.

In the last decade, academic focus has turned to the relationship between density of economic activity and regional variations in productivity. Starting with the seminal econometric investigation by Ciccone and Hall (1996), who believe that density rather than size is a more accurate determinant of agglomeration economies, they thus measured spatial density of employment in secondary and tertiary sectors and Using data on labor productivity at state level in the US. They find that a doubling of employment density increases average labor productivity by around 5%. Ciccone (2002) then re-estimated the agglomeration effects by spatial data for Germany, Italy, France, Spain and the UK, in an improved econometric model which takes into externalities across neighboring regions. Empirical results suggest that the estimated elasticity of (average) labor productivity with respect to employment density in these European countries is 4.5%, which is only slightly smaller than agglomeration effects in the US.

The quantitative analysis of agglomeration-related productivity effects in China has been paid a lot of attention in recent years, given that vast and growing regional productivity variations across China. Au and Henderson (2006) verified a significant positive relation between city size and labor productivity by 205 Chinese city level data during 1995-1997. Fan (2004) estimated the employment density elasticity of productivity, which in accordance with the method of Ciccone and Hall (1996), Using data of 261 cities in 2004, found that the estimated elasticity of (average) labor productivity with respect to

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employment density is about 8.8%. Liu (2010) who shows that the agglomeration effects of city on productivity would be up-biased after neglecting the influence of public infrastructure.

There are three drawbacks with the estimation of agglomeration effects: the first is that most quantitative analyses only focus on the magnitude of regional productivity effect of industrial agglomeration, which treat the causal relationship between two variables as a "black box" processing. The second is that empirical work as far estimated the agglomeration effects on aggregate productivity level but with little attention on the components that result in productivity change. The third is that empirical focused on China using cross-section or panel data covering less than five years.

This study overcome the above drawbacks of previous empirical studies of agglomeration economies in three ways: First We use productivity growth that is closer to the theoretical notion of agglomeration externalities and estimate the effects of density of economic activities on regional productivity change. Second, Using Data Envelop Analysis (DEA), We first decompose labor productivity growth into components attributable to technological change (shifts in the world production frontier), technological catch-up (movements toward or away from the frontier) and physical and human capital accumulation (movements along the frontier) and estimate the effects of agglomeration on above four components, respectively. This reveals the possible channels that agglomeration influence productivity change in details. Third, our empirical test is based on a panel data sample composed with 29 provinces across China, during 1993-2009 when the location of Chinese non-agriculture sector experienced the greatest change since the reform and opening in 1980s.

AGGLOMERATION AND REGIONAL PRODUCTIVITY GROWTH: THE MECHANISMS

The productivity growth in a region depends on the growth of technical change, physical capital deepening, human capital formation and accumulation, technological progress and technical efficiency catch-up (Henderson and Rusell, 2005), all of that may be affected by agglomeration. A number of authors have verified the positive effects that agglomeration on these aspects, respectively. In this study agglomeration economies are viewed as economies related to the density of economic activity in a region.

Agglomeration and physical capital deepening: Research in this area was originally from the Urbanization economies, Helsley and Strange (1990) set up a model of urban credit market, analyzing the microscopic mechanism of how cities by attracting the issuance of bank credit in order to promote capital accumulation. According to his model, banks are more willing to give the investment project loan in urban areas where industries are highly concentrated. This is because the capital goods in urban areas have more opportunities of recycling. Once the investment project fails, the banks could recover assets with higher recovery value (salvage value). That is, the larger the size of the cities, the greater the value of the collateral.

In recent years, relevant research is extended in line with the New Economic Geography. Martin and Rogers (1995) established footloose capital model (hereinafter referred to as the "FC model"). According to the model, there's a reciprocal relation between capital accumulation and agglomeration with the mobility of capital across regions. That is, in areas with initial industry scale advantage are more able to attract the capital and thus more enterprise. The literatures above suggest that the rate of physical capital deepening will be increased with agglomeration of economic activities.

Agglomeration and human capital accumulation: The strong positive and relation between human capital accumulation and agglomeration of economic activities has been verified by many researches both in theory and in evidence.

Glaeser (1999) constructed a two stage labor model and proved there are more opportunities of contacting and learning from the skilled labor in centralized urban areas, so as to create more opportunities for knowledge sharing and transfering. In addition, Glaeser and Mare (2001) found strong evidence to support the hypothesis of Glaeser. Rotemberg and Saloner (2000) model a region-specific specialization economy where technical workers and entrepreneurs are key factors of production, they shows that there are more potential employer (enterprise) competing for skilled works in areas of industry cluster. For works in these areas, its easier to obtain professional skills because of more opportunities for learning and compensate the cost of learning, so the rate of human capital accumulation is increased with the agglomeration of industry. Brulhart and Mathys (2008) argued there is greater gap in salary between skilled and unskilled works in areas where industries are concentrated, so works in these areas have more incentives to learn for a higher salary in future.

Agglomeration and technology upgrading: The argument that technical progress drives economic growth has been accepted since the seminar work by Romer (1990). In spatial economies, agglomeration of economic activities is of essential importance in knowledge spillovers and thus technology upgrading. Jaffe *et al.* (1993), found strong evidence that knowledge spillovers, are most likely to occur within geographically bounded areas rather than owing freely across regions. This evidence reveals there is strong positive relations between proximity and knowledge diffusion and thus technology upgrading. Bottazzi and Peri (2003) revealed that knowledge spillovers decay rapidly with increasing spatial distance, Meagher and Rogers (2004) stressed that localized social network have positive effect on knowledge spillover and thus technological innovation. They Pointed out that the formation of this local network is due to geographical proximity, which is not only to promote the knowledge, information overflow and pass, but also helpful in constructing technical standards of knowledge, preferences, etc. and thus amplify knowledge spillovers.

Agglomeration and technical efficiency catch-up: Technical efficiency catch-up reflects movements toward (or away from) the frontier, which can be resulted as a economy adopts "best practice" technologies and reduces (or exacerbate) technical and allocative inefficiencies (Kumar and Russell, 2002). Marshall (1920) reveals that productive efficiency in firms improvement can be attributed to a greater degree of specialization on the part of labor, service sector activity and firms in the manufacturing sector. Krugman and Venables (1995) who develop a model of vertical linkage to analyze how the specialization in components suppliers enhanced the productive efficiency in the central agglomerated area of industry.

By refining and classifying existing literatures above, we sort out four major mechanisms of productivity enhancing effects by industrial agglomeration areas, they are physical capital deepening, human capital formation and accumulation, technology upgrading and technical efficiency catch-up.

DATA DESCRIPTIONS AND MODEL

Model: The method used by Ciccone and Hall (1996), which have stated above as pioneer of the study of the agglomeration economies which is measured by employment density is a good starting point for us to choose an appropriate model. The basic form of this model is as follows:

$$\ln lp_{it} = a + \beta_1 \ln agg_{it} + \sum \beta_j \ln x_{it} + \varepsilon_{it} \quad (1)$$

Subscript i and t denote region and year, respectively, the dependent variable, labor productivity, is measured as, the core explanatory variable aggit is measured as the number of employment which exclude the agricultural and the mining sector for per acre in region i. denotes a vector of control variables.

As we focus on agglomeration effects on regional productivity change and it's components, we extended the model as follows:

$$n\, lpg_{it} = a + \beta_1 \ln agg_{it} + \sum \beta_j \ln x_{it} + \varepsilon_{it} \quad (2)$$

$$\ln kc_{it} = a + \beta_1 \ln agg_{it} + \sum \beta_j \ln x_{it} + \varepsilon_{it} \quad (3)$$

$$\ln tc_{it} = a + \beta_1 \ln agg_{it} + \sum \beta_j \ln x_{it} + \varepsilon_{it} \quad (4)$$

$$\ln ec_{it} = a + \beta_1 \ln agg_{it} + \sum \beta_j \ln x_{it} + \varepsilon_{it} \quad (5)$$

$$\ln hc_{it} = a + \beta_1 \ln agg_{it} + \sum \beta_j \ln x_{it} + \varepsilon_{it} \quad (6)$$

Dependent variables of Eq. 2-6 denote regional labor productivity growth, technological change, technological catch-up, physical and human capital accumulation of region i in year t, respectively.

Variable descriptions: The estimation of the model requires data on output, which is measure by value-added of region output, which refers to as GDP. The finest level of geographical detail in the China for which reliable data on GDP have been assembled appears to be the province and municipality level. Thus the observations on output are for the 26 provinces (Xizang is extracted due to data deficiency) and three municipalities (including Beijing Tianjin and Shanghai, the data of Chongqing is combined with that of Sichuan province). The data on employment is measured as total employment in non-agricultural sectors at province level in the end of year t. The land area of every region is measured by square kilometers of land coverage at province and municipality level.

All explanatory variables including other control variables are defined and measured as Table 1.

Table 1: Explanatory variables and measurements

Variables	Measurements
Agg_{it}	Employment of non-agricultural sector/land coverage measured by sq. km
Inf_{it}	Highway mileage for every one hundred peopl
r and d_{it}	The proportion of r and d spending in local GDP
Edu_{it}	The proportion of education spending in local GDP
Fin_{it}	The proportion of total deposits in local GDP
$Open_{it}$	The proportion of total value of exporting in local GDP
ns_{it}	The proportion of output in private-owned enterprises in local total retail sales of consumer goods
$Neigbor_{it}$	$Neigbor_i = \sum_s agg_s \exp(-\rho t_{is})$ according to Broersma (2009), agg_s denotes employment density of neighboring region of t, trs denotes travel timefrom t to s, $\rho = 0.0392$

EMPIRICAL TEST

Empirical test consists consist of two steps: First, we will decompose the regional productivity change into four components, which are dependent variables of Eq. 3-6, we will isolate the capital deepening and technological progress, technical efficiency improvements and the accumulation of human capital contribution to progress on productivity by the decomposition. Second, we will estimate the effects of employment density and other control variables on productivity change and it's components to test four agglomeration-productivity mechanisms.

Estimations of productivity change and it's components: Using nonparametric, Data Envelop Analysis (DEA), we decompose labor productivity growth into components attributable to technological change (shifts in the world production frontier), technological catch-up (movements toward or away from the frontier) and physical and human capital accumulation (movements along the frontier).

The basic idea of DEA is to envelop the data in the "smallest" "or" "tightest fitting", convex cone and the (upper) boundary of this set then represents the "best practice" production frontier (Kumar and Russell, 2002), By using the DEA which is first proposed by Farrell (1957) and extended by Fare *et al.* (1994), Kumar and Russell (2002) and Henderson and Russell (2005), we estimate four components and then calculate their contributions (percent) to changes of regional productivity for 26 provinces and three municipalities in China during 1993-2009, respectively. The results are presented in Table 2.

Table 2: Contributions of four components on productivity changes in 29 regions of China

Regions	lpg	hc (%)	kc (%)	tc (%)	ec (%)
Beijing	3.891	25.905460	87.2024	64.3	0.5
Tianjin	6.489	10.090640	104.5990	125.2	27.9
Hebei	4.771	31.856650	219.3600	-5.9	20.4
Shanxi	4.625	0.509508	218.2010	19.9	20.6
Neimenggu	7.849	33.385240	289.9500	49.3	1.0
Liaoning	4.596	29.684990	111.4320	62.2	3.3
Jilin	5.238	21.415060	232.3830	25.1	3.7
Heilongjiang	3.765	25.757340	98.3878	23.9	21.9
Shanghai	4.788	31.517480	54.8659	135.1	0.0
Jiangsu	6.488	35.934440	189.1000	36.5	20.9
Zhejiang	5.495	38.113320	234.3220	22.3	-2.7
Anhui	4.247	40.370480	192.9050	-18.3	26.4
Fujian	4.584	49.694820	151.6290	26.2	-3.6
Jiangxi	4.016	41.985520	190.3780	-31.6	42.5
Shandong	4.576	41.186850	130.1690	16.5	20.9
Henan	4.227	33.642790	211.6000	-23.1	32.0
Hubei	4.730	33.635120	192.5160	-11.8	37.2
Hunan	4.386	96.206810	87.5137	-28.3	66.1
Guangdong	4.125	41.491150	140.3710	17.8	3.0
Guangxi	4.124	31.566270	244.4360	-31.0	31.9
Hainan	3.450	28.637860	79.7572	23.5	20.8
Sichuan	5.149	32.200530	284.8680	-12.8	16.1
Guizhou	3.446	54.641500	163.0990	-22.7	9.5
Yunnan	3.471	52.356400	142.3880	-33.4	41.1
Shanxi	4.787	35.434480	148.4020	1.7	39.9
Gansu	4.575	71.596250	131.4350	-42.8	101.3
Qinghai	3.895	61.901660	101.4960	16.1	2.9
Ningxia	3.411	37.304220	109.9730	25.6	-5.8
Xinjiang	3.253	39.082720	86.7981	45.4	-13.9

The results show that there was rapid growth labor productivity in China between 1993 and 2009, with a average growth rate of 4.56 and there's great variations in productivity growth as well as the contributions by it's components across regions. In eastern costal area, the total labor productivity growth rate is 4.8657, which is much more than 4.04 in the southwest areas. Human capital accumulation and technical progress contributed most for the productivity growth in the former, while physical capital accumulation contribute most for the productivity growth in the latter. It's obvious that contributions of human capital accumulation and technical progress to productivity growth is positive correlated with regional economic development.

Empirical findings: Before establishing the regression modeling and carrying out regression analysis of Eq. 2-6, we assess the stationarity of all variables and proceed with the augmented LLC and IPS approaches. The test results suggest that the generating process is stationary. So there's no need to conduct co-integration relation between variables.

Another problem should be avoided is the circular causalities between agglomeration and productivity growth as well as it's components. Researchers trying to verify empirically whether agglomeration enhances

Table 3: Empirical tests

Variables	$Lnlpg_{it}$	$Lnhc_{it}$	$Lnkc_{it}$	$Lntc_{it}$	$Lnec_{it}$
lnagg	0.0067** (0.0037)	-0.0133 (0.0097)	0.0263** (0.0110)	-0.0315** (0.0078)	(0.00879) 0.0285***
lninf	0.0160** (0.0067)	-0.0537*** (0.0133)	0.0393*** (0.0130)	-0.0333*** (0.0145)	0.0172*** (0.0060)
lnr and d	0.0054* (0.0031)	0.0357*** (0.0136)	-0.0349**]](0.0141)	0.0638*** (0.0122)	0.0047*** (0.0016)
lnedu	0.0043 (0.0110)	0.0207*** (0.0091)	0.0093 (0.0330)	-0.0218 (0.0284)	0.0098*** (0.0051)
lnfin	-0.0278*** (0.0116)	0.0599* (0.0322)	0.0147 (0.0345)	-0.0223*** (0.0073)	0.0380* (0.0232)
lnopen	0.0013 (0.0011)	-0.0011 (0.0025)	0.0028 (0.0034)	0.0032 (0.0022)	-0.0029 (0.0019)
lnins	0.0059 (0.0051)	-0.0054 (0.0117)	0.0283*** (0.0046)	0.0073 (0.0137)	-0.0150 (0.01084)
lnneighbor	0.0030** (0.0016)	-0.0021 (0.0035)	0.0032 (0.0048)	-0.0042** (0.0023)	0.0046*** (0.0010)
Cons	0.1518*** (0.0578)	0.3717** (0.1563)	0.1188 (0.1723)	-0.4832*** (0.0884)	0.3270*** (0.0756)
Regiondum	Controlled	Controlled	Controlled	Controlled	Controlled
Yeardum	Controlled	Controlled	Controlled	Controlled	Controlled
Anderson test	140.783 (0.000)				
Cragg-donald	22.472 (0.000)				
Sargan-test	0.176 (0.6751)	0.301 (0.5830)	0.736 (0.3909)	0.119 (0.7297)	0.390 (0.5253)
F-test	4.9	11.23	21.17	10.90	7.11
Adj R^2	0.1999	0.3295	0.5145	0.2241	0.2982
Obs			406		

***, ** and * indicate significance at 1, 5 and 10% significance levels, respectively, Values in the brackets are stand error values for coefficients

performance inevitably face the major difficulty that causality could run both ways. If a particular location offers some inherent features that improve the profitability of certain economic activities, firms will be attracted to that location (Brulhart and Mathys, 2008). The circular causality will result in biased coefficients by OLS. To avoid such bias, we conduct the regression by using instrumental variables and two-stage least squares (IV-2SLS), which provides a remedy for endogeneity between dependent variables and explanatory variables. We take the two-lagged values of employment density as instrumental variables.

The empirical results about the impact of employment density and other control variables on regional productivity growth and its components are reported in Table 3.

As presented in Table 3, the empirical test shows that the agglomeration effects on productivity growth is positive and significant, one percent increase in regional employment density of non-agricultural sectors results in 0.67% increase in local productivity. While the agglomeration effects on four components of productivity change varied greatly. Agglomeration effects on regional capital accumulation is significantly positive, showing that spatial concentration of economic activities stimulate capital inflows, which promote regional capital deepening and thus the regional labor productivity growth. Similarly, the agglomeration have negative an effect on regional technical efficiency improvement is also significantly positive, indicating that agglomeration promotes regional specialization, which reduces the transaction cost and thus regional labor productivity increase. In contrast, the agglomeration effect on regional technological progress has significantly negative, which implies that agglomeration have some inhibitory effects on the improvement in technology, in addition, the agglomeration effects on human capital accumulation is also negative but not significant.

In sum, the empirical tests indicate that agglomeration accelerate regional productivity growth mainly through capital accumulation and technological catch-up.

DISCUSSION AND CONCLUSION

Despite the limitations, present study with its empirical testing suggests that agglomeration is strongly beneficial to productivity gains. This study attempts to shed some light for future research.

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