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Transport improvement, agglomeration effect and urban productivity: The case of Chinese cities.

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ABSTRACT: Improvement in the transport sector will increase accessibility to economic activities, which in turn benefit urban productivity by enabling agglomeration economies. This paper aims to establish the link between agglomeration effect and wider economic benefits of transport, and test the magnitude of city-level agglomeration elasticity in China. Based on the measure of effective employment density, this paper finds that a doubling of effective density will improve the productivity in urban areas by 10.9 percent. Agglomeration elasticities vary across different regions. With improvements in transport conditions, the agglomeration elasticity on productivity will increase, but will reach a threshold value of around 17.010.

KEY WORDS: ***Agglomeration Elasticity, Transport, Wider Economic Benefits, Urban Productivity, China.***

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1. Introduction

New investments in transport can make a larger scale of activity more accessible by reducing travel times and the costs of travel, giving rise to positive user benefits. Transport improvement could lead to higher density employment clusters and larger, more diverse cities. These changes could, in turn, increase productivity and enhance consumer welfare by enabling agglomeration economies. The positive relationship between productivity and agglomeration (employment or employment density) had been proven by numerous studies (see Rosenthal and Strange (2004) and Melo et al. (2009) for review). Meanwhile, there is a significantly growing interest in the externalities of the transport sector, otherwise known as the Wider Economic Benefits (WEBs), which is focused on evaluating the effect of transport investment under the environment of externality. This paper aims to build the logical relationship of transport-agglomeration-productivity, and tests the existence and magnitude of agglomeration elasticity of transport on productivity of cities in China.

Because of positive externalities and public good nature, marginal social benefits of transport projects may exceed their marginal costs. Therefore, the size of transport improvement may be smaller than the social optimum. In some cases, wider economic benefits, which can't be measured by the traditional Cost-Benefit Analysis (CBA), are quite large. As such, it is hard to calculate the wider economic benefits, which are usually indirect and long-term. As Geurs and van Wee (2004) defined, wider economic benefits are "not directly related to the project but causally linked to the direct impacts." Despite its difficulty, some methods are being developed to estimate the wider benefits of transport investment, like spatial computable general equilibrium (SCGE) model.

The agglomeration effect is a major contributor to the wider economic benefits caused by transport improvement. According to Rognlien (2010), agglomeration benefits account for more than 50% of wider economic benefits of transport projects. Current researches on wider economic benefits mainly focus on the relationship between transport and agglomeration (Shefer and Aviram 2005; Graham 2007; DfT 2010). Due to the development of monopolistic competition models, the theoretical foundations of the agglomeration economies are being built.

The transport infrastructure construction was viewed as the driving force for China's economic growth. Large amounts of government investment are being input into the transport area continuously. Although transport related problems, such as traffic congestion and pollution, exist in many cities in China, It can't be denied that the accessibility to different cities and across different regions have been improved massively, which in turn expanded the market firms can cover and increased the employment firms can access, compared to decades ago. According to the micro-foundation of agglomeration economies, the improvement of effective employment will bring lots of benefits, such as skilled workers, the employment pool effect, learning and matching mechanism. Therefore, this paper chooses panel data from Chinese prefectural cities to examine the agglomeration effect of transport improvement. Moreover, China has hundreds of differently sized cities and detailed record of economic data, which are ideal to test the agglomeration effect of transport.

This paper is structured as follows. The next section reviews the related literatures and theories on the agglomeration effect and wider economic benefits of transport sector. Section 3 presents the methodology, variable description and regression issues of the paper. Section 4 reports and analyses the regress results of agglomeration elasticity of transport on productivity. Section 5 simulates the change of agglomeration elasticity under different assumption of transport condition. The penultimate section presents the conclusion and future research direction.

2. Literature review

2.1 The externalities of transport and wider economic benefits

Improvements in transport can provide cost and time savings, greater accessibility, more flexible routes, and more travel choices. Basically, decisions on the transport infrastructure investments are based on outcomes of cost benefit analysis, in which users' benefits are the primary consideration. In typical highway appraisals, the contribution of time savings to the estimate of economic benefits is 70-90 percent (Welch and Williams 1997). However, the impacts of transport are potentially diverse. Not only transport sector, the wider economy will also benefit from the transport investment.

Since external economies exist in transport market, the real size or scale of transport projects may be smaller than the social optimum (as shown in Figure 1). The wider economic impacts of transport improvement are complex, including but not limited to economic growth, productivity, employment, location, competition and investment. This paper will focus on productivity effect of transport improvement.

The agglomeration effect is a major part of wider economic benefits of transport improvement. Venables (2007) used a SCGE model to demonstrate that including agglomeration effects on productivity could give rise to 85 percent to 147 percent additional benefits for commuting journeys, compared to CBA. Graham (2007) indicated that initial calculations of agglomeration externalities are typically added to conventional user benefits of 10-20 percent arising from increasing returns to economic mass.

It is not easy to identify and evaluate the long-term wider benefits and agglomeration effects of transport projects. However, there are an increasing numbers of methods being developed to evaluate the wider benefits of transport improvement. Jenkins et al. (2011) showed that inclusion of wider economic benefits, which include agglomeration benefits, raises the Benefit-Cost Ratio (BCR) of London Crossrail project from 2.55 to between 3.47 and 4.91. The inclusion of wider economic benefits raised the BCR of proposed East–West rail line in Melbourne by about 40 percent (Eddington 2008).

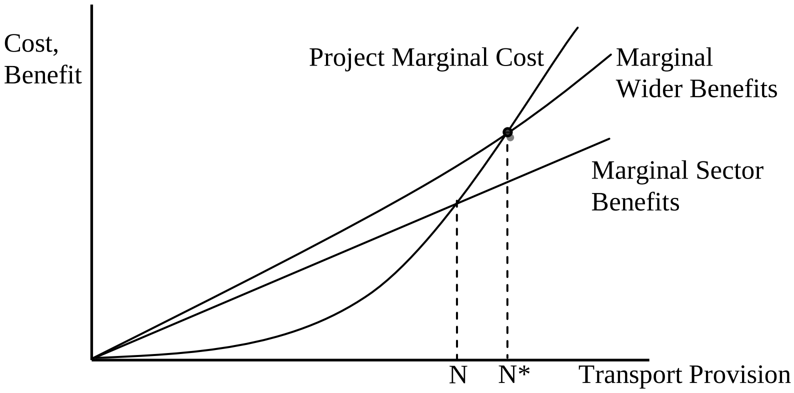

Figure 1: The externalities of transport improvement

Source: revised from Chatman and Noland (2011).

Based on recent research, UK Department of Transport (DfT 2010) has provided an "official guidance" for the overall assessment of the additional benefits of transportation investments, including agglomeration benefits.

2.2 Transport, agglomeration and productivity

The formation of agglomeration is the outcome of trade-off between various forms of increasing returns and all their associated of mobility cost (Fujita and Thisse 2002). Firms and Households choose to cluster together to harvest external benefits. Therefore, agglomeration effect is the various positive benefits related to geographic proximity, including increasing returns and external economies. Theoretical foundations for agglomeration economies are now well established by Fujita and Thisse (2002) and Duranton and Puga (2004).

Agglomeration effects can be divided into two catalogues: 1) location externalities (Marshall 1920), which are external to the firm but internal to the industry, such as the labour market pool, knowledge sharing and spillover; 2) urbanization externalities (Jacobs 1969), which are external to the firm and the industry but internal to the city, arise from the sharing of public goods, the proximity of input-output, inter-industry interaction and so on. While the firms and households choose to cluster in the certain areas, the cities will benefit from the urbanization externalities as well. As one of the main effects of agglomeration, productivity in the city areas will increase as the size of the city grows. There is also a body of empirical studies aimed to identify the relationship between city size and productivity, majority of which comes to positive conclusion (Moomaw 1983; Henderson 1986; Ciccone and Hall 1996; Ciccone 2002).The typical agglomeration elasticity of city size on productivity is ranged from 1 percent to 25 percent. There are a number of excellent up-to-date surveys of the empirical literature on the relationship between productivity and agglomeration (Rosenthal and Strange 2004; Melo et al. 2009).

However, the agglomeration is accompanied by additional costs, among which transport cost is the dominated one. Transport costs are crucial in determining the scope of economic activity that firms and households can access. Improvement of transport will improve the accessibility of economic activities and technology spillovers by reducing travel times or the costs of travel, giving rise to positive agglomeration benefits which will increase firm productivity and enhance consumer welfare. Therefore, transport improvement will be beneficial to agglomeration and productivity, directly or indirectly.

Production benefits caused by transport development may arise from improved mobility, inter-industry information flows, thicker labour markets, and better access to specialized services. Within the framework of Duranton and Puga (2004), Chatman and Noland (2011) concluded the mechanism of transport improvement on agglomeration as follows: 1) sharing, transport improvement might increase agglomeration economies by inducing city growth and facilitating labour market pooling; 2) matching, transport could decrease employment search cost, both by increasing accessibility in the immediate term and by increasing city size in the longer term; 3) learning, transport Improvement could enable easy knowledge sharing not only between firms but also during social activities and networking, facilitate additional learning.

Aschauer (1989) applied the method of production elasticity and concluded that transport infrastructure has a great impact on productivity. Lafourcade and Thisse (2011) pointed out the two possible ways in which transport infrastructure could affect firm production directly. Firstly, the stock of transport infrastructure available enters the production process as an unpaid input, directly contributing to firm production. Secondly, transport infrastructure is considered to enter the production process as a factor that augments the productivity of other inputs employed by firms. Based on scale economies, Holtz-Eakin and Lovely (1996) provided a general equilibrium model to explain the mechanism in which infrastructure affects regional economy from an enterprise perspective. Besides, improvement in transportation services can have a direct impact on labour productivity by lowering commuting time spent on getting to and from work (SACTRA 1999).

While the positive relationship between the productivity and employment has been testified, transport improvement could lead to higher density employment, therefore increase urban productivity by enabling agglomeration economies. Eberts and McMillen (1999) indicated that transport improvement, which bring economic agents closer, could increase the potential for interaction and therefore enhance the benefits of agglomeration economies. Puga (1998) showed that the agglomeration equilibrium is even more centralized under the assumption of decreased transportation costs. Mori (1997) developed an analytical model that describes the formation of the megalopolis among central cities, largely in response to lower cost of transportation. The Core-Periphery structure model of Krugman (1991) argued that the combination of scale economies and moderate transportation costs will encourage the users and suppliers of intermediate inputs to cluster near each other. Venables (2007) developed a theoretical model to demonstrate that there are external benefits from transport investment related to agglomeration and that these can be measured from elasticity of productivity with respect to employment density. The relationship among transport, agglomeration effect and urban productivity can be illustrated simply by Figure 2.

Rice et al. (2006) examined the magnitude and geographical scope of agglomeration economies in the UK using proximity to "urban mass" as measured by auto journey times, and found agglomeration elasticity of 0.05. Graham (2007) examined the external relationship between productivity and effective employment density separately for different sectors of the economy, and finds that agglomeration elasticity that arise from the provision of transport infrastructure for the services sector (0.197) is larger than that for the manufacturing sector (0.07).

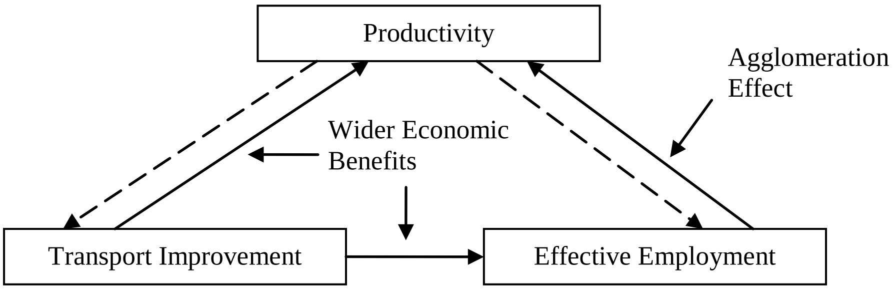

Figure 2: The relationship among transport, agglomeration effect and productivity

Noticeably, transport Improvement may or may not subsequently lead to a net productivity increase. There could instead be a simple redistribution of growth and employment from one area to another. Haughwout (1997) concluded for the United States that transport infrastructure investment may have weakened agglomeration economies by dispersing growth from areas of denser employment. Glaeser et al. (2008) argued that low-cost public transport may induce lower income households to live in or migrate to cities by increasing the ease of finding employment. Lafourcade and Thisse (2011) illustrated that decreasing transport costs is likely to exacerbate regional disparities.

Current studies are enough to accept the positive agglomeration effect on productivity, as well as in China (Au and Henderson 2006a). However, the paper is the first research that tries to assess the agglomeration effect in China from the perspective of wider economic benefits of transport. No country in the world has experienced such dramatic improvement in as China has during the last decades. Therefore, this paper aims to testify the existence and magnitude of agglomeration elasticity of inter-urban transport improvement and inner-urban transport improvement on productivity in Chinese cities. Moreover, to evaluate the agglomeration effect, we need to estimate how the urban productivity varies among different city size. China presents a unique opportunity to explore this because it has more than two hundreds cities of different size and keeps a sound record of the important economic data, such as GDP, for geographic units corresponding to the urbanized area of a city (Au and Henderson 2006b).

3. Methodology and data description

3.1 Methodology

This paper uses Cobb-Douglas production function to present the agglomeration of transport improvement on urban productivity. The production of city i:

$$Y_i = AK_i^{\alpha} L_i^{\beta} \tag{1}$$

Y is the output of the city. K and L are the capital input and labour input respectively. Divided by L, and we get the productivity function:

$$y_i = A(x_i) k_i^{\alpha} l_i^{\alpha+\beta-1} \tag{2}$$

y_i is the productivity of city i; k_i and l_i represent the capital stock per employment and employment of city i respectively. $A(x_i)$ is Hicks-neutral technology. x_i is a vector of influence on productivity and includes the agglomeration effect $\underline{u}_i$. Taking logarithms yields:

$$\ln y_{it} = con + \sigma \ln \underline{u}_{it} + \eta \ln k_{it} + \delta \ln l_{it} + \lambda_n X_{itn} + \varepsilon_{it} \tag{3}$$

X_{itn} is a vector of n control variables which could influence on productivity. We add $(\ln l_{it})^2$ into the model to control for the externality of employment. ϕ_t is included in the model to control the time trend of sample.

3.2 The measurement of effective employment density

To build the bridge from transport improvement to agglomeration economies, changes in accessibility and agglomeration index resulting from the transport improvement need to be measured firstly. Generally, accessibility of location i is a decreasing function of travel time or cost between location i and other locations from j to n. And agglomeration index is the aggregate of accessibility-weighted mass the firms or households in location i can access. For different purpose, the variable used to measure the degree of agglomeration may be employment, jobs, upstream and downstream firms, products and so on.

$$A_i = \sum_j^n f(c_{ij}) \omega_j \tag{4}$$

Where A_i is agglomeration index of location i, c_{ij} is the travel cost between location i and location j, ω_j is the variable used to generate agglomeration index. $f(c_{ij})$ is the weight used to measure the accessibility from location j and location i. Locations that are further away from location i usually have smaller weight. Graham et al. (2010a) examined the accessibility formulas used in current literatures: cumulative or adjacent weight $f(c_{ij}) = 1$ if c_{ij} is within a specified value or location j is adjacent to location i, otherwise $f(c_{ij}) = 0$; exponential weight $f(c_{ij}) = \exp(-\alpha c_{ij})$; logistic weight $f(c_{ij}) = [1 + \exp(-\alpha c_{ij})]^{-1}$; and inverse weight $f(c_{ij}) = c_{ij}^{-\alpha}$. Besides, market potential theory also give some measure of market potential, which could be referred to evaluate agglomeration. Among others, Harris Market Potential (Harris 1954) $HMP_i = \sum_j^n \omega_j / d_{ij}$ and Krugman Market Potential

(Krugman 1992) $KMP_i = \sum_j^n T_{ij}^{1-\sigma} E_j \big/ G_j^{1-\sigma}$ are widely used in current literature[1]. Referring to current measurement of accessibility, Graham (2007) gave the formula of effective employment density to measure the degree of agglomeration. The effective employment density of city i:

$$u_i = \frac{l_i}{(\sqrt{(A_i/\pi)})^{\alpha}} + \sum_{j \neq i}^{n} (\frac{l_j}{c_{ij}^{\alpha}}) \tag{5}$$

Where l_i is a measure of employment in city i, α is the decay parameter. A_i is the land area of city i, and $\sqrt{(A_i/\pi)}$ is an estimate of average distance between employment within city i. c_{ij} is the transport cost or travel time between city i and city j. However, c_{ij} may be endogenous with productivity, since higher productivity cities have the ability to built better transport conditions and lower transport cost. Besides, the data on transport cost among each city is unavailable in China. Therefore, we use the straight line distance d_{ij} to substitute c_{ij} in order to reduce the endogeneity, as geographical distance is the most important factor in transport cost, especially when the distance among each city is quite long. d_{ij} is calculated based on geographic coordinate of each city. Distance decay reflects the smaller influence that more distant employment has (Mare and Graham 2009). Besides, the distance decay parameter α also indicates the condition of inter-urban transport. In conformity with most commonly used definition (Graham 2007; Mare and Graham 2009), the distance decay parameter α is assumed to be 1.

However, the value of distance decay parameter α has such an important effect on the existence and magnitude of agglomeration benefits from transport investments that it should be empirically estimated in principle. Indeed, there are some studies aimed to evaluate the value of distance decay parameter α, although adopting different methods. Graham et al. (2010a) use non-linear regression model to get 1.659 of alpha estimation and 0.044 of agglomeration elasticity for the UK economy. Hering and Poncet (2010) estimated a power function of transport cost and distance for 56 cities in China, and got a power (alpha) of 1.528 by using a gravity trade model. Disdier and Head (2008) examined 1467 estimates of distance effect on bilateral trade from 103 papers, and found that the average distance decay parameter is about 0.9, with 90% of estimates lying between 0.28 and 1.55. There are also other estimations of distance decay parameter, ranged from 0.3396 (Song 1996) to 3 (Fotheringham 1981). According to current literature, $\alpha = 1$ is a reasonable assumption of distance decay parameter. We will further discuss the value of distance decay parameter α and its role on agglomeration elasticity in section 5.

Besides, we found that effective employment density u_i is not compatible with estimating model (3), because it is highly correlated with l_i in the model. Therefore, the first part of formula (5) was discarded (see formula (6)) when calculating the effective employment density of city i:

$$\underline{u}_i = \sum_{j}^{i \neq j} (\frac{l_j}{d_{ij}^{\alpha}}) \tag{6}$$

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[1] d_{ij} is the geographical distance from location i to location j. T_{ij} is the transaction cost from location i to location j, E_j is the expenditure on manufacturing goods in location j, and G_j is the manufactures price index in location j.

This paper believes that $\underline{u}_i$ index can better reflect the employment that city i can access between cities. The scatter graph between $\ln y$ and $\ln \underline{u}$ of pooled data is shown in Figure 3.

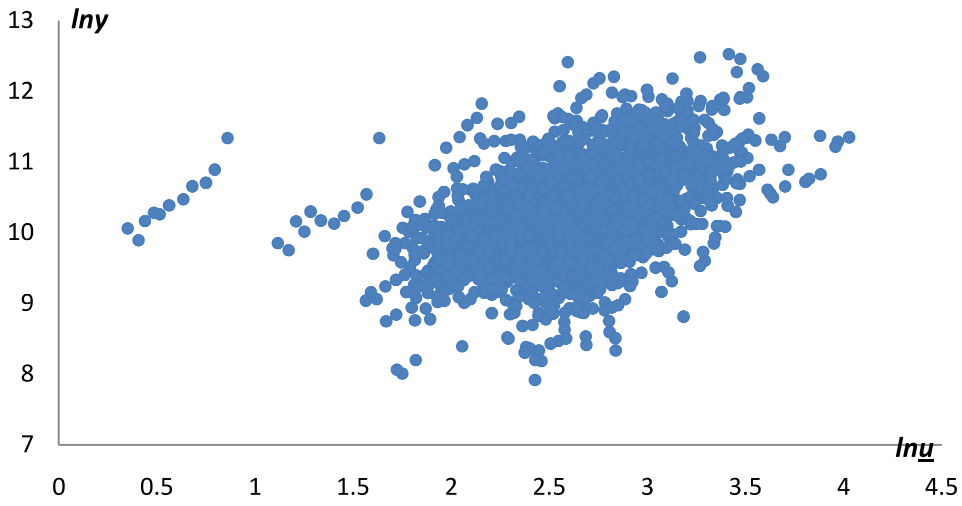

Figure 3: Scatter graph of $\ln y$ ***and*** $\ln \underline{u}$

3.3 Data and variables

We have data from 1999 to 2009 on 286 prefectural-level cities (including four "provincial-level" cities). Five natural-source-dominant cities[2], and three cities with unreliable data[3], based on the extraordinary year to year changes of key variables, are excluded from the dataset. The estimating sample of panel data is 278. Prefectural-level cities in China govern large rural area as well. However, while data are given for the whole area (the municipality), they are also given separately for the urbanized portion, called the "city proper" (Au and Henderson 2006a), which corresponds to the Metropolitan Statistics Area in the U.S. and UK. This paper uses the data of city proper of prefectural cities, which mostly sourced from *Urban Statistical Yearbook of China* (*Volume 2000 to 2010*). The main variables used in the paper are described as following:

y_i is the value added of non-agricultural sectors per employment within city proper in city i of each year at the constant price in 1990. The non-agricultural value added is derived from Gross Domestic Product of city in 2nd industry and 3rd industry. To make the real growth of output across cities comparable, we use the provincial-level urban resident consumer price index based on 1990 to deflate the nominal value added. The price indices are taken from the annual *China Statistical Yearbook* in the relevant period. The unit of measurement is in *1990 Yuan*.

l_i is the sum number of labour force employed in the enterprise, private sectors and self-employment within city proper in city i of each year. We also include the square of employment in the regression model to test the externality of employment. The unit of measurement of employment is in *ten thousands*.

k_i is the capital stock per employment within city proper in city i of each year. We had no way to construct a perpetual inventory series capital stock for each city, given the published investment

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[2] The following cities are excluded from 286 samples because the economy of those cities is dominated by natural source industries: Daqing (oil), Dongying (oil), Kelamayi (oil), Eerduosi (coal), Yuxi (tobacco).

[3] The following cities are excluded from 286 samples because of low quality of data documentary: Dongguan Shanwei and Wuhan in all years.

figures. But, the data on average balance of net value of fixed asset, average balance of net value of flowed asset and employment of *enterprise above designated size* is available for each city. We adopt the net value of fixed and flowed asset per employment of *enterprise above designated size* as the proxy variable of capital stock per employment. In using original book value, we assume that inflation rates are approximately offset by depreciation rates (Au and Henderson 2006b). The unit of measurement is in *ten thousands 1990 Yuan*.

In terms of covariates, we use the ratio of college students and middle school students in total population (edu) to control for the quality of labour force. We use the accumulated Foreign Direct Investment ($afdi$) since 1990 as the proxy variable for the technology influence. The unit of measurement is in *ten thousands US dollar*. Besides, to explore the effect of urban transport, the area of urban road per person ($road$) within the city proper of prefectural city is also included in the model. The unit of measurement is in *square meter*. Since regional disparity is obvious in China, we add region dummy variable to control for the region effect[4]. We have $de = 1$, if the city is located in eastern region; $dc = 1$, if the city is located in central region; $dw = 1$, if the city is located in western region.

However, there may be endogeneity between productivity and independent variables, that means the higher productivity may affect the urban road construction and give rise to higher density if firms and employment move to higher productive cities. To reduce this endogeneity, we use 2SLS and GMM regression methods. We pick up the area of urban road per person in 1990 ($road90$) and effective employment density in 1990 ($\underline{u}90$) as instrument variables, because they are long-lagged so as to be unaffected by unobservable variables affecting productivity since 1999. Besides, the road in 1990 and the employment in 1990 are correlated with the employment in the sample years. Table 1 displays summary statistics of variables for our analysis sample. The final estimating model in this paper is:

$$\ln y_{it} = con + \phi_t + \sigma \ln \underline{u}_{it} + \eta \ln k_{it} + \delta \ln l_{it} + \varphi(\ln l_{it})^2 + \lambda_0 \ln road_{it} + \lambda_1 \ln afdi_{it} + \lambda_2 edu_{it} + \varepsilon_{it} \tag{7}$$

Then, scale to return of the production function will be $\alpha + \beta = 1 + \hat{\delta} + 2\hat{\varphi}$; the agglomeration elasticity of transport on productivity will be $\hat{\sigma}$; The effect of urban transport will be $\hat{\lambda}_0$. $\hat{\phi}_t$, $\hat{\sigma}$, $\hat{\eta}$, $\hat{\delta}$, $\hat{\varphi}$, $\hat{\lambda}_n$ are parameters to be estimated.

Table 1: Descriptive statistics of variables for production model

Abbr.	Median	Mean	Std. Dev.	Min.	Max.	No. of Obv.
y	29883.63	36383.40	26548.43	2738.96	274542.80	2923
$\underline{u}$	14.34	14.90	5.72	1.42	59.07	3058
k	264336.00	324034.10	254939.20	15976.41	3943248.00	2930
l	18.76	38.30	72.04	1.87	982.88	2936
$road$	6.11	7.23	4.75	0.14	64.00	2926
$afdi$	23690.99	174827.40	574036.50	7.00	9612319.00	2943
edu	0.09	0.09	0.03	0.01	0.28	2936
$\underline{u}90$	18.52	19.06	6.03	2.34	38.90	3058
$road90$	2.80	3.03	2.06	0.20	16.60	2739

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[4] According to official document, we define 84 cities in Beijing, Tianjin, Hebei, Jiangsu, Zejiang, Shanghai, Fujian, Guangdong, Shandong, Hainan as eastern region; 113 cities in Shanxi, Liaoning, Jilin, Heilongjiang, Anhui, Jiangxi, Henan, Hubei, Hunan as central region; 81 cities in Neimenggu, Guangxi, Sichuan, Guizhou, Yunnan, Shaanxi, Gansu, Qinghai, Ningxia, Xinjiang as western region.

4. Agglomeration effect of transport on productivity

4.1 OLS and GMM regression results

The panel data model can be estimated under two different assumptions: Fixed effect and Random effect. We use Hausman test to decide which assumption is better. Hausman test rejects the random effect model. And we control for the time effect in the model (Table 2). As dedicated by Graham et al. (2010b), effective employment density, as well as urban transport, may be endogenous. While the improvement of urban transport will increase the productivity, on the other hand, the growth of city will induce transport improvement and migration between cities as well. So we introduce instrument variable methods to deal with endogeneity. $road90$ and $\underline{u}90$ are chosen as the instrument variables in the paper. However, the statistic scope of urban employment in city proper had also changes since 1998. As such, effective employment density in 1990 is not highly reliable as instrument variable, and is excluded from the model. Besides, we also test the Homoskedasticity of panel data. The chi-square test result (41.03) rejects the null hypothesis of Homoskedasticity. We use robust 2SLS, Bootstrap IV and GMM IV methods to deal with endogeneity and heteroskedasticity simultaneously. The Hausman tests of regression results for these three different methods accept the null hypothesis that there is no systematic difference in coefficients. The GMM estimates are reported in Table 3.

As illustrated by the fixed effect model of Table 2 and Table 3, the OLS agglomeration elasticity of effective employment density is 0.170, which means that a doubling of accessibility to effective employment in city will improve the average productivity of city in China by 17 percent. This estimate is basically same as the pooled estimating result of Mare and Graham (2009) for New Zealand (0.171). The GMM estimate of agglomeration elasticity is much smaller (0.109), which is comparable to the results of Graham (2007) for UK (0.129 for whole economy). But the agglomeration elasticity of Chinese cities is still larger than the average agglomeration elasticity of Rawnsley and Szafraneic (2010) for Melbourne (0.07), and Hensher et al. (2012) for Sydney (0.021), maybe due to different sample scope and different regression method. In this study, we treated the city as the decision-making unit, as opposed to other researches which use industry-specific and more detailed level data. Compared to those studies from the perspective of urbanization economies, our regression results is still in the moderate level of current estimates of agglomeration elasticity, ranged from 0.03 to 0.292 as shown by the literature survey did by Rosenthal and Strange (2004) and Melo et al. (2009). Despite varieties in regression values, positive effects from the improvement of transport and agglomeration economies do exist in Chinese cities, as proved by other studies. And larger agglomeration elasticity in China implies that the improvement of inter-urban cities may play a bigger role in the productivity and growth of Chinese cities than that in the developed cities, partially because China has denser employment density which brings the benefit of better utilizing agglomeration economies. Another possible explanation may be that transport improvement can dramatically increase the flow of labour force among cities. The house registration system in China restricts the migration of labour force between urban and rural areas, and between cities (Au and Henderson 2006b). The improvement of accessibility to cities may counteract this impact to some extent. However, the flow of labour force from small cities to big cities, from rural to urban areas, from western to eastern and coastal regions, will cause serious congestion problem as well, which is a serious issue in megacities in China. Congestion could lead to agglomeration diseconomies. This will disbenefit the productivity of urban area, as discussed in the next part.

Table 2: Results of fixed effect and random effect of production model

	Fixed Effect		Random Effect	
	1.1	1.2	1.1	1.2
$\ln \underline{u}$	0.169***	0.170***	0.194***	0.196***
	(-7.89)	(-7.92)	(-8.94)	(-9.02)
$\ln k$	0.209***	0.209***	0.239***	0.241***
	(-13.74)	(-13.72)	(-15.70)	(-15.80)
$\ln l$	-0.265***	-0.271***	-0.273***	-0.277***
	(-6.70)	(-6.89)	(-6.78)	(-6.89)
$\ln l * \ln l$	0.024***	0.025***	0.025***	0.025***
	(-4.55)	(-4.63)	(-4.60)	(-4.65)
$\ln road$	0.084***	0.078***	0.087***	0.083***
	(-6.16)	(-5.89)	(-6.26)	(-6.21)
$\ln afdi$	0.108***	0.107***	0.106***	0.106***
	(-20.59)	(-20.54)	(-19.91)	(-19.86)
edu	-0.452*		-0.263	
	(-1.84)		(-1.06)	
con	6.618***	6.606***	6.180***	6.151***
	(-31.52)	(-31.48)	(-29.28)	(-29.17)
Time effects	Yes	Yes	Yes	Yes
Hausman Test		241.90***		301.49***
R2	0.3375	0.3367	0.3366	0.3359
F-test	207.46***	241.37***	1541.42***	1547.10***
N	2869	2870	2869	2870

*p<0.1, ** p<0.05, *** p<0.01

The contribution of capital is 0.186, and the contribution of labour force can be obtained by $\beta = 1 - \alpha + \hat{\delta}$, which is 0.569. Both OLS and GMM regression results imply that the growth of Chinese cities is mainly driven by labour force. Most of the cities are labour-intensive. The average return to scale is 0.740. This diminishing return to scale may due to the disproportionate hierarchy of Chinese cities. As shown in Figure 4, there are too many small cities with a population of less than one million, and some big cities with a population of more than five millions, but so few middle-sized cities. The hierarchy of Chinese cities is dumbbell shaped, rather than an ideal pyramid shaped. While the megacities confront congestion problem caused by the excessive concentration of population, the development of small cities is constrained by the lacking of accessibility to national market and employment, insufficient infrastructure and others.

In terms of the other covariates in the model, edu and $afdi$ are the proxy variables which represent quality of labour force and technology transfer respectively. The OLS and GMM regression results give positive coefficients for both edu and $afdi$. One percent increase of the foreign direct investment will improve the productivity of Chinese cities by 0.107 percent. While the coefficient of edu is positive but not significant, we remove it from the model. Not only the inter-city transport, but urban transport is considered in this model as well. Urban transport improvement will give lots of user's and non-user's benefit by saving travel time and cost, improving accessibility of freight and people, reducing congesting, and others. As expected by the current explanation, $road$ have a positive and significant impact on productivity. Compared to GMM result, OLS method underestimates the impact of urban transport to some extent. One standard deviation increase in road per capita for GMM estimate will improve the average productivity by 1.358 percent, a large effect.

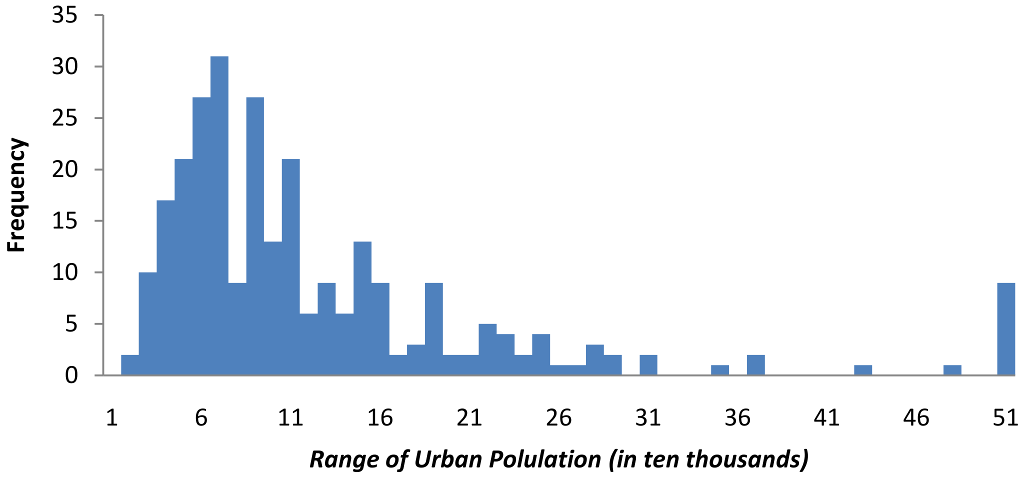

Figure 4: Histogram of population distribution in 2009

4.2 Region effects

As illustrated by Table 4, the regional distribution of cities and other resources is quite dispersed. The productivity and urban road is approximately 1.5 times larger than that of western region. Although the average distance from eastern cities to other cities is similar as that from central cities, the effective employment density in eastern region is significantly bigger than that in central region. This is because the eastern cities attractive more labour force. On the one hand, transport improvement will benefit the productivity by increasing the accessibility to national market and effective employment. On the other hand, the redistribution effect of transport may redistribute these benefits disproportionately, simply by amplifying the advantage of eastern cities. However, excessive concentration of population and firms will lead to agglomeration diseconomies as well, which have appeared in some big eastern cities. Therefore, we introduce the region dummy variables to test the regional disparity of agglomeration effect in this part.

Table 3: Robust OLS and GMM IV results of fixed effect with dummy variable

	Whole	Eastern	Central	Western	Whole	Eastern	Central	Western
	OLS				GMM			
$\ln \underline{u}$	0.170***	0.083***	0.221***	0.181***	0.109***	0.049*	0.150***	0.130***
	(-8.37)	(-4.70)	(-10.46)	(-10.24)	(-4.15)	(-1.83)	(-5.61)	(-4.77)
$\ln \underline{u} * de$		0.0854***				0.0608***		
		(-17.01)				(-7.24)		
$\ln \underline{u} * dc$			-0.0631***				-0.0542***	
			(-26.06)				(-9.54)	
$\ln \underline{u} * dw$				0.0130**				0.0291***
				(-2.31)				(-3.17)
$\ln k$	0.209***	0.214***	0.197***	0.206***	0.186***	0.190***	0.171***	0.176***
	(-9.35)	(-9.89)	(-9.03)	(-9.06)	(-9.46)	(-9.81)	(-8.89)	(-8.61)
$\ln l$	-0.271***	-0.185***	-0.190***	-0.268***	-0.319***	-0.256***	-0.264***	-0.320***
	(-5.87)	(-3.94)	(-4.23)	(-5.86)	(-6.66)	(-5.14)	(-5.41)	(-6.68)
$\ln l * \ln l$	0.025***	0.016**	0.014**	0.024***	0.030***	0.023***	0.023***	0.030***
	(-5.00)	(-2.98)	(-2.78)	(-4.90)	(-4.77)	(-3.61)	(-3.62)	(-4.70)
$\ln road$	0.078***	0.045**	0.074***	0.082***	0.307***	0.282***	0.323***	0.327***
	(-4.65)	(-2.73)	(-4.46)	(-5.00)	(-6.92)	(-6.22)	(-7.37)	(-6.83)
$\ln afdi$	0.107***	0.081***	0.098***	0.109***	0.092***	0.073***	0.081***	0.096***
	(-8.88)	(-6.74)	(-9.2)	(-8.8)	(-9.96)	(-8.52)	(-8.91)	(-10.6)
con	6.606***	6.853***	6.658***	6.579***				
	(-22.88)	(-24.59)	(-23.67)	(-23.00)				
Time effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R2	0.3367	0.3752	0.3682	0.3373	0.2885	0.3230	0.3029	0.2797
F-test	299.33***	185.18***	215.00***	367.66***	228.48***	232.44***	228.30***	196.48***
N	2870	2870	2870	2870	2636	2636	2636	2636

*p<0.1, ** p<0.05, *** p<0.01

Table 4: Regional disparity of main variables

Main Variable	Whole	Eastern	Central	Western
No. of City	278	84	113	81
Average distance among cities	1231.30	1150.21	1170.46	1336.52
Productivity	29883.63	42413.70	28256.93	27942.28
effective employment density	14.34	18.08	15.32	11.02
road	6.11	9.78	6.51	5.42

As shown in Table 3 and Table 5, western cities demonstrate the biggest agglomeration elasticity, both in OLS and GMM models. Although eastern cities have denser effective employment, but its effect on productivity growth is not as big as expected. This may due to the excessive agglomeration of population in eastern cities. The infrastructure, especially transport sector, can't carry so many people in urban cities. This argument can be proved by the fact that the coefficient of urban transport in eastern region is smaller than the average level. By contrast, western cities used to lack enough transport infrastructures. Transport improvement in western cities can increase the accessibility to technology, higher quality labour force, and bigger domestic and international market. The coefficients of edu and $afdi$ in the western region are also bigger than their counterparts in eastern and central ones. This implies that more transport resource should be transferred into western cities, rather than eastern cities which have already been too crowded to some extent.

Although three regions will benefits from transport improvement in general, one region may benefit more at the expense of the other. The redistribution effect of transport improvement among different regions can be indicated by the coefficients of $\ln \underline{u} * de, \ln \underline{u} * dc$ and $\ln \underline{u} * dw$. While central cities have advantage of location and natural resource, they don't benefit from the improvement of inter-urban transport as much as expected. In contrast, both the OLS and GMM estimates of $\ln \underline{u} * dc$ are negative. This means that central cities disbenefit from the redistribution of agglomeration effect. The labour force and productive resource in western regions will be draw away from western cities. Eastern cities get the most benefits from the redistribution.

Table 5: Return to scale and agglomeration elasticity of different regions

Regression Method	OLS				GMM			
Region	Whole	Eastern	Central	Western	Whole	Eastern	Central	Western
Scale to Return	0.778	0.846	0.838	0.780	0.740	0.790	0.782	0.738
Agglomeration Elasticity	0.170	0.168	0.157	0.194	0.109	0.109	0.096	0.159
Urban Transport Effect	0.078	0.045	0.074	0.082	0.307	0.282	0.323	0.327

5. Transport improvement and agglomeration elasticity

In the previous analysis, we adopt the distance decay parameter $\alpha = 1$, as the current research as Graham (2007) did. In this case, a doubling of effective employment density will improve the productivity of the city by 10.9 percent. This means that cities in more convenient cities will be more productive. However, as argued by Hensher et al. (2012), the distance decay parameter should be empirically estimated in principle. However, this is unrealizable, given the limited availability of city data in China. But, this distance decay parameter α is very important in determining the magnitude of agglomeration elasticity of transport improvement, because each α represents a different transport condition. Therefore, we assume different value for α in the effective employment density formula and regression the model to simulate the effect of transport improvement in this section.

As shown by Table 6, there is no significant difference among OLS, 2SLS and GMM estimates. The following analysis is based on the GMM regression results. Smaller α means better transport condition, and greater agglomeration elasticity. The distance decay parameter and agglomeration show an approximately logarithmic relationship. But, the agglomeration elasticity reaches its maximum value when the distance decay parameter is around 0.005. This implies that transport improvement has “Threshold Effect”. If the transport condition reaches the threshold point, the role of continuing transport improvement will decrease. With the improvement of transport, firms in one region can access bigger market and more effective employment. During the meantime, the competition among firms from different regions is becoming fiercer. At the initial stage, firm and cities may benefit more from the agglomeration economies. However, eventually competitive effect will excess the agglomeration economy finally. As argued by Krugman (1991), in the some extreme situation, low transport costs foster a single integrated market. In such cases, the agglomeration effect will not affect the productivity of the cities. Apparently, the current transport condition is far from such threshold effect in China. As such, transport infrastructure improvement is still urgently required, especially in central and western regions.

Table 6: Different agglomeration elasticity for different α

Alpha	Agglomeration Elasticity			Alpha	Agglomeration Elasticity		
	OLS	2SLS	GMM		OLS	2SLS	GMM
0.001	15.250***	16.250***	16.170***	0.9	0.191***	0.121***	0.122***
0.005	19.180***	17.080***	17.010***	1.0	0.170***	0.109***	0.109***
0.007	18.360***	15.440***	15.380***	1.1	0.151***	0.0973***	0.0980***
0.01	15.820***	12.490***	12.450***	1.2	0.135***	0.0871***	0.0878***
0.03	5.766***	3.870***	3.861***	1.3	0.121***	0.0781***	0.0787***
0.05	3.284***	2.095***	2.091***	1.4	0.108***	0.0701***	0.0708***
0.1	1.561***	0.955***	0.954***	1.5	0.0977***	0.0632***	0.0638***
0.2	0.773***	0.465***	0.465***	1.6	0.0884***	0.0573***	0.0578***
0.3	0.523***	0.316***	0.316***	1.7	0.0804***	0.0521***	0.0526***
0.4	0.401***	0.244***	0.245***	1.8	0.0734***	0.0476***	0.0481***
0.5	0.329***	0.202***	0.202***	1.9	0.0673***	0.0436***	0.0441***
0.6	0.279***	0.173***	0.174***	2.0	0.0619***	0.0401***	0.0405***
0.7	0.243***	0.152***	0.153***	2.5	0.0428***	0.0275***	0.0279***
0.8	0.215***	0.136***	0.136***	3	0.0317***	0.0202***	0.0205***

*p<0.1, ** p<0.05, *** p<0.01

Conclusion

Transport improvement will increase the accessibility of firms and households to employment and market, and cultivate wider economic benefits, as analysed in the transport theories. This process will lead to the concentration of population and industry in cities, which will in turn benefit the productivity of urban cities, as explained by agglomeration economics. This paper combines these two areas together to analyse the agglomeration effect of transport. Effective employment density that captures the accessibility of economic activity is calculated to test the agglomeration elasticity of transport improvement on productivity in prefectural cities of China.

The average agglomeration elasticity for the whole economy in China is 0.109, which means that a doubling of effective employment density will improve the productivity of the city by 10.9 percent. Although slightly bigger than that of the UK and New Zealand, agglomeration effect in Chinese cities is still in moderate level of the range of current estimates of agglomeration elasticity. Besides, agglomeration elasticities also vary across different regions of China, from 0.096 in central regions to a high of 0.159 in western regions, which means the redistribution effect of transport improvement will disbenefit the productivity growth of central cities, while benefitting the western regions on a relative large scale.

With the improvement of transport condition, the agglomeration effect on productivity will increase but eventually reach the threshold effect. However, the transport infrastructure is still the main bottleneck that constrains the economic growth of Chinese cities, especially in central and western regions. Having reliable estimates of the transport-agglomeration-productivity relationship, the potential policy implications are to continue to improve the inter-urban and intra-urban transport condition, and to quantify the wider economic benefits when evaluating the transport projects. Due to limited availability of data, the agglomeration elasticity is detected only in the city level. In the future research, micro-level and industry-specific data should be used to better determine the differences of agglomeration effects across different industries and different geographical scope.

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