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Review Paper

The resource sharing under hi-education agglomeration

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In China, recent years have witnessed a trend of higher education agglomeration (HEA) which affects job markets and industries through diffusion, sharing, and matching mechanisms. The mechanisms in this new trend can be explained by some previous models in industrial agglomeration, but meanwhile have characters that deserve to be paid attention. Happening between educational and industrial sectors, as the following analysis suggests, this kind of resource sharing effects brought by HEA is quite different from that existing among industries. The former promotes not only the resource economization, but also the innovation performance that generated from the close-quarters flow of knowledge among their creators and users.

Key words: Resource sharing, hi-education agglomeration, university town, innovation performance.

INTRODUCTION

The number of undergraduate and post-graduate students in China has been growing at approximately 30% per year since 1999, and the number of graduates at all levels of higher education in China has nearly quadrupled in the last 6 years. The size of entering classes of new students and total student enrollments have risen even faster, and have presumably quintupled. Facing the ever-growing number of undergraduate and post-graduate students, the location and allocation of higher educational resources reveals to be a crucial problem. China currently spends about 2.5% of its GDP on investments in schooling. At the same time, roughly 30% of its GDP is devoted to physical investments compared with U.S. with 5.4 and 17% respectively and South Korea, 3.7 and 30%. China is below average even among its peers in its expenditure on investment in human capital. Serious challenges are facing the largest population in the world. Under limited budget for education, it is crucial to allocate educational resources well.

Fortunately, a new wine in old bottles may favor such needs, the booming university towns organized in a new way in several Chinese metropolises suggests a trend to agglomerate educational infrastructure. There are two main means of formations of university towns in previous Western studies. The first means is through natural accumulation of population around education industry, like Oxford and Cambridge in the UK. The other means is by government sponsor, often in response to readjusting and upgrading industrial structure. Famous examples of such are Route 128 in Boston, U.S., Tsukuba Science City in Japan, and Bangalore Software Technique Park in India. Still, they are significantly different from this new mechanism, a highly accumulated spatially continuous cluster of publicly financed universities or institutes under unified programming, or Higher Education Agglomeration (HEA), which we intend to address today. The improvement of these new formative university towns from its predecessors is its efficiency in allocating educational resources. There are at least three targets to achieve for an educational project: investing in human capital, improving efficiency of educational resources, alleviating pressures on the job market (Figure 1). Fortunately, there are existing examples. Some successful paradigms come from USA such as the Silicon Valley, the University system of Maryland, and the University system of Georgia. China's Silicon Valley, Zhongguancun Science Park (Z-Park) is also one worth emulating.

Another important component of the education sector is R&D. China has witnessed increasing input in R and D activities (Table 1), but still low compared with developed countries (2.62% U.S., 2.51% Germany, 4.53% Israel, etc) in GDP proportion. There are two main channels to conduct R and D and S and T, one is through public funding on R and D institution and higher education, the

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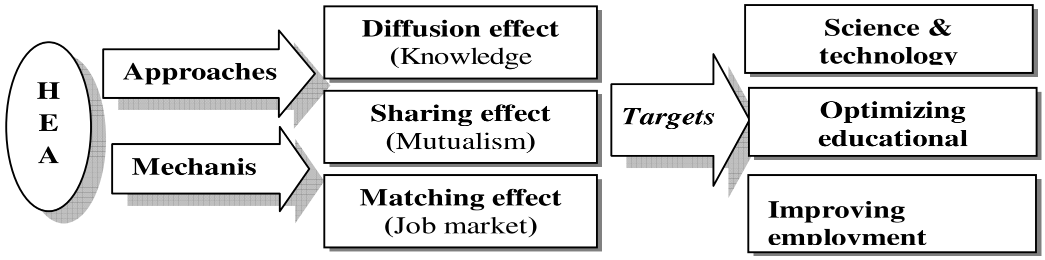

Figure 1. Targets and effects of HEA.

Table 1. Chinese R& D activities in recent 8 years.

Year	2000	2001	2002	2003	2004	2005	2006	2007
Internal Expenditures on S&T activities[1]	205.0	231.3	267.2	312.2	400.4	483.6	575.7	704.0
Government Expenditure for Scientific Research[2]	57.6	70.3	81.6	94.5	109.5	133.5	168.9	205.0
S&T Proportion in Total Gov. Expenditure[3]	3.6	3.7	3.7	3.8	3.8	3.9	4.2	4.0
Expenditure on R&D[4]	89.6	104.3	128.8	154.0	196.6	245.0	300.3	366.4
Proportion of Expenditure on R and D to GDP[5]	0.9	0.95	1.07	1.13	1.23	1.34	1.42	1.49

Units: Billion yuan (1, 2, 4); % (3, 5). Source: From National Bureau of Statistics of China (http://www.stats.gov.cn/)

other is by funding from industrial enterprises. Because they share similarities in factors of production such as laboratory, network, etc, it is reasonable to establish a connection between them. More importantly, we need to devise a mechanism for resources to be shared under the coexistence of private and public properties. This paper seeks a basic method to share facilities between public and private sections.

RELEVANT STUDIES

Marshall (1890) emphasized three different types of transport costs of moving goods, people, and ideas-that could be reduced by industrial agglomeration. The concept of Marshallian externalities has been much used in the economics and regional science literature. Agglomeration economy causes “snowball effect” in which a growing number of agents want to congregate in order to benefit from a larger diversity of activities and a higher specialization.

Lots of literature has analyzed the urban agglomeration economy and industrial agglomeration. Fujita and Francois’s book “Economics of Agglomeration” (2002) is a study of the reasons for the existence of a large variety of economic agglomerations. Duranton and Puga (2003) studied the micro-foundation of urban agglomeration economy, based on sharing, matching and learning mechanisms.

Previous studies mainly address knowledge spillover effect on firm level, they consider knowledge and innovation as an external effect in industrial agglomeration, by spatially clustering, new industry booms. However, as long as knowledge and innovation are specialized, diversified and merged into an independent industry, it is important to set a two department’s model to specify the interaction between education and industry. It is also important to investigate the geographical effect of educational agglomeration. Beeson and Montgomery (1993) used data from the U.S. to support the observation that the probability of being employed as a scientist or engineer and the probability of being employed in a high- tech industry were both found to increase with the amount of R&D funding at local universities.

DIFFUSION EFFECT

Kim and Marschke’s paper (2005) examines the influence of university research on innovation in industry by a number of means: through scholarly publications and the material published in universities’ patent applications, at

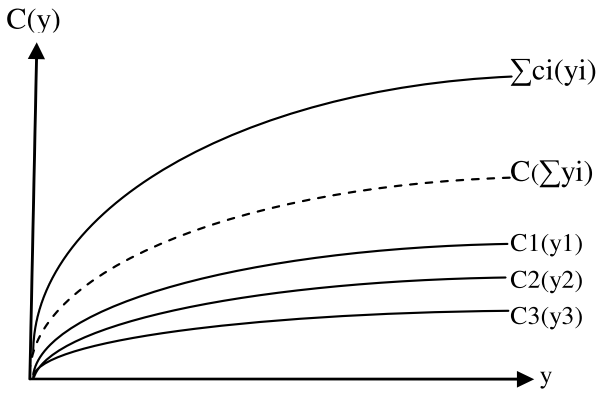

Figure 2. Decreasing cost to scale: C(∑yi)< ∑ci(yi).

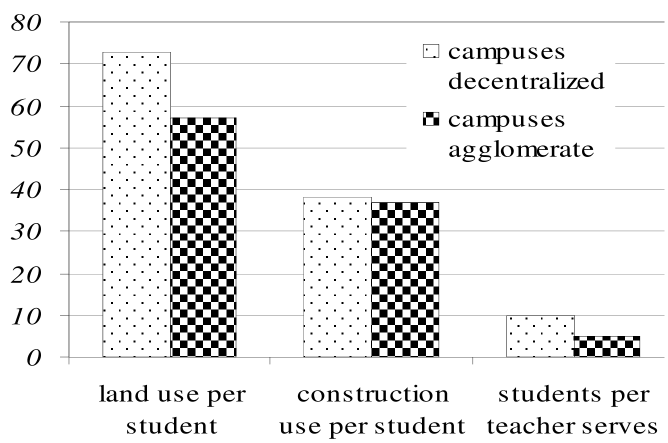

Figure 3. Resource allocation improvement.

conferences where scholarly work is presented and where industrial and academic research personnel commingle, and via informal social networks.

During the information revolution, both developed country and developing country have witnessed a phenomenon. Those advanced technology industries tend to locate near the higher education and R and D sectors. The most famous example is the Silicon Valley with computer industry clustering near Stanford University. Z-Park, the first and largest national science park in China, has recently experienced rapid agglomeration of high-tech firms. This area accommodates over 50 universities including the two leading ones in the nation, Peking University and Tsinghua University, and more than one hundred research institutions including the Chinese Academy of Sciences, the Chinese Academy of Engineering. By the end of 2005, the area had one third of China's national laboratories and accounted for one fifth of China's total R and D expenditure.

Among the domestic enterprises in the Z-Park, most are those closely connected with universities and research institutions in this area. Cai, Yasuyuki and Zhou' paper (2007) suggests that research centers provide ample supply of new ideas and talents and hence nurture the birth of start-ups. In addition, many universities are keen in setting up new venture incubators within the campuses to encourage and help young graduates to try out their ideas and start up their own business. Peking University and Tsinghua University have established many university-affiliated hi-tech firms, some of which are leading firms in the Z-Park, such as Founder and Tsinghua Unisplendour from Peking and Tsinghua University respectively. A significant portion of CEOs of the well-known companies in the Z-Park are alumni of the universities located in Zhongguancun.

SHARING EFFECT

Scale economy in university system

In the industrial agglomeration economics, previous studies examine the return to scale effect by pooling of input and output, the sharing effect often happen in intermediate input. Smith's (1776) original pin factory example pointed out: having more workers increases output more than proportionately not because extra workers can carry new tasks but because it allows existing workers to specialize on a narrower set of tasks. In other words, the Smithian hypothesis is that there are productivity gains from an increase in specialization when workers spend more time on each task.

The same effect can be found in university town. For universities cluster to share input (educational resources) and output (human capital), in order to form scale economy. One difference we observe is that, unlike in industrial agglomeration where product increases with the scale of economy, HEA sees reducing educational resources per capital by enlarging campus scale. Because minimizing the cost is the dual problem to maximizing production in economic theory.

$$Maxmize: Y(\vec{C}) \cdot P - \vec{C} \cdot \vec{p};\ Subjetto: \vec{C} \cdot \vec{p} \leq B$$

The Dual problem comes to

$$Minimize: TC = \vec{C} \cdot \vec{P};\ Subjetto: Y(\vec{C}) \geq Y\ .$$

Thus, we use decreasing cost to scale effect to exam the effect brought by agglomeration (Figure 2). It is easy to calculate land use, educational construction area, faculty, volumes of library collection per student, before and after agglomeration effect happens, by using data from in new campuses in GZUC and their origin universities. Figure 3 suggests the educational resources per student in education agglomeration are higher than campus diversified (Table 2).

Table 2. Data from Guangzhou university city (GZUC).

Institutions	Floor area in GZUC (m^2)	Construction area in GZUC (m^2)	Prospective number of students in GZUC(m^2)	Total area(m^2)	Total construction area(m^2)	Total number of students now	Total number of faculty
Guangdong University of Foreign Studies	729927	—	12000	1450000	—	21014	1038
Southern China Normal University	899243	576000	16000	2052461	1260000	29,448	1700
Sun Yat-sen University	1131700	628800	20000	6170000	2271500	43,000	13,038
Guangzhou University	1417858	880000	25000	1417858	880000	21100	2411
Guangdong University of Technology	1601173	—	28000	2362055	1615894	45653	3412
Xinghai Conservatory of Music	189993	210000	4000	189,993	—	3403	504
The Guangdong Academy of Fine Arts	275724	257731	5000	378556	—	6000	360
South China University of Technology	1118520	660000	20000	2944534	1811935	70747	4,496
Guangdong University of Chinese Medicine	491951	500000	8000	966570	—	10000	1000
Guangdong Pharmaceutical University	647935	—	12000	1900000	—	18494	2387
Total	8504024	5720000	150000	19832027	10300000	268859	30346

Note: Statistics are from government's websites of each university.

Table 3. Classification of goods.

	Excludable	Non-excludable
Rivalrous	Private goods food, clothing, toys, furniture, cars	Common goods / (Common-pool resources) fish, hunting game, water, air
Non-rivalrous	Club goods cable television	Public goods national defense, free-to-air television

Resource sharing in university towns

Here we use classify different of goods from theory of public goods. Paul A. Samuelson is usually credited as the first economist to develop the theory of public goods (Table 3).

First of all, we define two kinds of resources, that is, common resources (CR): infrastructure including transportation, hot water supply, central air conditioner, Public library, stadiums, eco-system, recycle-system etc. which are often financed by municipality and collectively planned. The property right of CR often belongs to the common, usually supervised by university town administration committee. And Heterogeneous Resources (HR), which are those special educational resources only rich in certain agents. In GZUC's example, Sun Yat-sen University has abundant volume of library collection, Xinghai Conservatory of Music possesses variety of musical instruments, The Guangdong Academy of Fine Arts collects plenty of art education resources etc. These resources are financed by universities themselves. To put it in another way, the property right of HR often belongs to agent.

Lots of research focuses on software sharing, including

Table 4. Classification of resources in education sector.

Resources	Hardware resources	Software resources
Common resources	Roads, power system	Internet, broadcast
Heterogeneous resources	Biology laboratory, musical instrument	Library collection, professors

inter-library loan, inter-collegiate course enrollment, e-sharing etc. These studies are comparatively complete, some of these theories have already been put into practice, for example, OCLC, Online Computer Library Center is a nonprofit, membership, computer library service and research organization dedicated to the public purposes of furthering access to the world's information and reducing the rate of rise of library costs. More than 71,000 libraries in 112 countries and territories around the world use OCLC services to locate, acquire, catalog, lend and preserve library materials (Table 4).

Problem caused by private property in pooling of educational resources

In our mutualism system, CR is usually considered to be public good because it is non-rivalrous and non-excludable. It is no rare to see the free-rider effect of such resources and it costs much to exclude others to use it. HR belongs to each agent, but most of them are not considered to be private goods, because facilities such as basketball courts, classrooms, courses etc. are not completely exclusive. It is not easy to prevent them from being used by members from other agents. However, in order to reduce depreciation of their goods, agents gradually spend much input to keep their goods away from others, creating barriers among agents. Nevertheless, the educational resources, because of its positive externality, if remain open for the whole society, can bring more benefit than only serving one enterprise.

Although we expect higher efficiency in HEA, in fact, it still has some problems dealing with resource allocation. In GZUC, we can see a lot of resource left unused, while others are overused. For example, the duplicate of classrooms is a ubiquitous phenomenon, some lessons are inadequately provided such as dancing, piano, etc, and some educational resources such as laboratory are not opened to public. This improper allocation of educational resources is due to the special characters of HR and market failure.

One of the approaches to efficiently use these education resources is to implement market mechanism, however, due to monopoly of these scarce possessions, agents of these heterogeneous resources often charge high prices for their endowment, so called rent. It will cause another market failure, because of welfare loss. Recently, some new mechanisms have been suggested that, these scarce resources with positive social externality can be purchased by government through appropriate pricing. A simple model can explain such situation.

Heterogeneous resources sharing model for hardwares

In this model, the utility function of agent i supplying good G_i is $U_i[\ ]$, let $\sigma(x,t)$ denote the depreciation rate, with x denoting number of agents to share good G_i. When there are no agents to share good G_i, we place depreciation rate to be $\sigma(0,t)$. It is reasonable to regard $\sigma(x,t)$ increase with x, ($\frac{\partial\sigma(x,t)}{\partial x}>0$). On the other hand, if other agents consume this good, they will acquire same utility of $U_s[\ ]$, at this time the depreciation rate is $\sigma(x,t)$, $x\neq 0$. Let e^{-rt} be discount factor.

The welfare can be measured by utility which the good provides plus present value of good.

In the condition with no sharing mechanism, the welfare gained by agent i using good i is denoted by:

$$W_1=\int_0^\infty U_i(G)dt+\int_0^\infty G_i\cdot(1-\sigma(0,t))\cdot e^{-rt}dt$$

If good i is public good, the welfare gained by whole society is denoted by:

$$W_2(x)=\int_0^\infty U_s(G)dt+\sum_{i=0}^{x}\int_0^\infty U_i(G)dt+\int_0^\infty G_i\cdot[1-\sigma(x,t)]\cdot e^{-rt}dt$$

At this time welfare gained by agent i is:

$$W_3=\int_0^\infty U_i(G)dt+\int_0^\infty G_i\cdot[1-\sigma(x,t)]\cdot e^{-rt}dt$$

If agent i opens use rights of G_i to other agents, they will pay the extra maintenance fee for G_i, in this occasion,

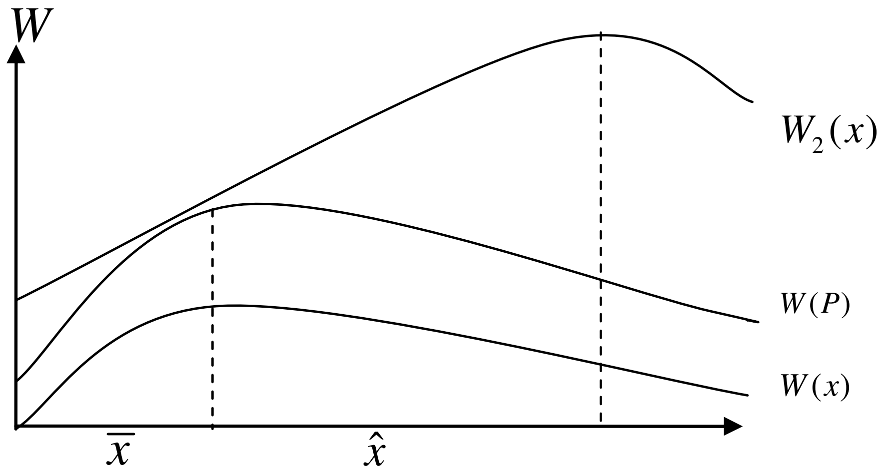

Figure 4. Functional images of welfare functions

their welfare decreases. The precondition of this problem is that W3<W1<W2, hence there exists pareto improvement. There are usually 3 solutions to solve this problem with the property right of G_i unchanged.

Solution 1: Agent i spent $C(t)$ in barrier cost. In this occasion, agent i would rather spent money on making barrier. If not do so, it will cost more on depreciation if opened to other agents.

The total social welfare is W(s1) = $\int_0^\infty U_i(G)dt+\int_0^\infty G_i\cdot[1-\sigma(0,t)]\cdot e^{-rt}dt-\int_0^\infty C(t)dt$

Solution 2: Agent i control the supply of G_i by pricing, let $P(x,t)$ denote the price per agent use of good G_i, because of agent i's monopoly on G_i, other agents are price takers of good G_i, then their demand of G_i, denoted by x, displays decreasing effect when $P(x,t)$ increasing, that is, the inverse function of $P(x,t)$, $x(P)$ is a decreasing function of variable P.

Agent i can maximize the welfare, by pricing P,

Agent i want to maximize

$$W(P)=\int_0^\infty U_i(G)dt+\sum_{i=1}^{x}\int_0^\infty G_i\cdot[1-\sigma(x,t)]\cdot e^{-rt}dt+\sum_{i=1}^{x}\int_0^\infty P(x,t)dt \quad (1)$$

And other agents aim to maximize

$$W(x)=\sum_{i=1}^{x}\int_0^\infty U_s(G)dt-\sum_{i=1}^{x}P(x,t)\cdot G \quad (2)$$

Let $\bar{x}$ And $\bar{P}$ be Nash Equilibrium solution of maximization problem (1), (2).

On the other side, maximization of $W_2(x)$ subject to $1-\sigma(x,t)>0$, can lead to result $\hat{x}$. Although this approach improve both agent i and the whole society, it is not the pareto optimal, for it is easy to proof $W_2(\hat{x})>W(\bar{P})+W(\bar{x})$ (Figure 4). This is because that other agent's payment for rent of G_i causes deadweight loss on whole society's welfare.

Solution 3: Because of the positive externality of educational resources, the social planners can purchase the social use of private good G_i, by estimating the real utility of G_i. First, the government should ban barrier and monopoly of G_i, and then the government can give an incentive ε to agent i, by compensating for depreciation loss of public supply of G_i, denoted by $\int_0^\infty G_i[\sigma(x,t)-\sigma(0,t)]\cdot e^{-rt}dt+\varepsilon$. On the other hand, other agents will gain complete utility from G_i and provide bonus to government, denoted by $\int_0^\infty G_i[\sigma(x,t)-\sigma(0,t)]\cdot e^{-rt}dt+\varepsilon$.

Thus, agent i gains:

$$\int_0^\infty U_i(G)dt + \int_0^\infty G_i \cdot [1-\sigma(x,t)] \cdot e^{-rt}dt + \int_0^\infty G_i[\sigma(x,t)-\sigma(0,t)] \cdot e^{-rt}dt + \varepsilon$$

$$= W_1 + \varepsilon > W_1,$$

thus, agent i improve its condition.

Other agents gain welfare of:

$$\int_0^\infty U_s(G)dt - \int_0^\infty G_i[\sigma(x,t)-\sigma(0,t)] \cdot e^{-rt}dt - \varepsilon > 0$$

The whole society's welfare is $W_2(\hat{x})$, the maximization utility of G_i, thus, this solution is Pareto Optimal. However, the model is based on the perfect information, in reality; it is difficult for the social planners to have full information. Thus, the first and foremost thing is to construct a platform in order to share the information.

MATCHING EFFECT

The last advantage brought by HEA is the economy of scale associated with a large labor pool. Marshal (1890) emphasized the risking-sharing properties of a large labor market. Theories in this field address that agglomerations make it possible for workers to match better across firm and industries. Rotemberg and Saloner (2000) provided a model of labor-market based on agglomeration where firms cluster together so that workers will come and invest in human capital, knowing that they do not face ex post appropriation. A matching process can cause externality, as the workforce grows and the number of the firms increases, the average worker is able to find an employer that is a better match for its skill.

Currently in China, the most common way to find job is through job fair, the internet, and recommendation of acquaintances. The real matching process happen in the campus, especially through job fair or career expo, which is a fair or exposition for employers, recruiters and schools to meet with prospective job seekers. Expos usually include company and organization tables or booths where resumes can be collected and business cards can be exchanged. The new student enrollment is 4.7 times larger in 2005 than in 1998. The total enrollment is 4.6 times larger in 2005 than in 1998. About 20% of university students who graduated in 2007 have so far failed to find employment, according to a blue paper issued by the Chinese Academy of Social Sciences. Last year, Guangzhou University City (GZUC), officially known as Guangzhou Higher Education Mega Center, witnessed the first group of graduate students flooding into job market. We can use previous models to examine the efficiency of education agglomerates.

The first and most common approach relies on uncoordinated random matching by agents (early examples are Butters, 1977; Hall, 1979; Pissarides, 1979; Peters, 1991). A typical motivation for this random search approach is that workers need to apply for a single job knowing where vacancies are but not knowing which particular vacancies other workers will apply to fill. We use Pissarides (1979) model to examine the agglomeration effect. Let F and *V* denote the stock of filled jobs and available vacancies and *U and E* denote the stock of unemployed and employed workers. The labour force is fixed at $\bar{L}$, $E+U=\bar{L}$.

The matching function $M = M(U,V) = KU^{\beta}V^{\gamma}, 0 \le \beta \le 1, 0 \le \gamma \le 1$, proxies for the complicated process of employer recruitment. Thus, the dynamics of the number of employed workers are given by $dE = M(U,V) - bE$. Since we are focusing on steady states, M and E must satisfy $M(U,V) = bE$. Let a denote the rate per unit time that unemployed workers find jobs, and α the rate per unit time vacant jobs are filled.
a and α are given by:

$$a = \frac{M(U,V)}{U}, \quad \alpha = \frac{M(U,V)}{V}.$$ Then,

$$\alpha = K^{\frac{1}{\gamma}}(bE)^{\frac{\gamma-1}{\gamma}}(\bar{L}-E)^{\frac{\beta}{\gamma}}, \frac{\partial \alpha}{\partial \beta} > 0, \frac{\partial \alpha}{\partial \bar{L}} > 0,$$

It suggests, the expansion of labor pool itself enlarges the opportunity of employment. Beside, agglomeration effect can improve the efficiency of matching by affecting index of β, γ which denote mobility of job market. For the cost for transportation of information and resources is reduced. Such research suggests an advantage brought by agglomeration of educational sectors near industry in solving structural unemployment. Structural unemployment is long-term and chronic unemployment arising from imbalances between the skills and other characteristics of workers in the market and the needs of employers. It involves a mismatch between workers looking for jobs and the vacancies available often despite the number of vacancies being similar to the number of unemployed people. Only through close communication between education and industry sectors can education alleviate pressures on job market. On the other hand, job market should in return send signal to education sector of what human capital is needed.

EMPIRICAL EVIDENCE IN GUANGDONG PROVINCE

Zhuhai may be the first city in china to implement the idea

Table 5. HEA in Guangdong Province.

	Total area (m^2)	Construction area (m^2)	Full-time enrollment	Faculty	Shared resources	Agents of universities
University Town of Shenzhen	2,000,000	510,000	5544	800	Shenzhen Science and Technology Library	4
GZUC	18,000,000	5,720,000	150,000	20000	Multi-function Gymnasiums	10
University district of Zhuhai	20,000,000	6,000,000	75,000	4000	National Laboratories	14

Source: Official websites of each university.

of university town. The foundation of the project of the University District of Zhuhai dates back to 2000. Because of the decentralized distribution of campus land, the project has aroused some dispute about land abuse. But, it provides experience for its emulators. The prospective students of University District of Zhuhai in 2010 will be 100,000. Guangzhou University City (GZUC), officially known as the Guangzhou Higher Education Mega Centre has bigger plans. Located in capital of China's Guangdong Province, GZUC is home to 10 of the province's universities' campuses, many of whom also have campuses located elsewhere. GZUC can accommodate up to 200,000 students, 20,000 teachers and 50,000 staff. GZUC is aiming to be a first-class national university campus; a center in south China for education of advanced talents, scientific research and exchange. In addition to ten universities, the mega center is home to an eco-park for sports and culture, including a stadium for 35,000 people, a hotel/conference center, libraries, recreation centers and large lakes and gardens. Beautiful University Town of Shenzhen is located aside the Xili lake in Nanshan District of Shenzhen with a total area of two square kilometers. University Town of Shenzhen began to be structured in 2002, and the whole construction of educational infrastructure was completed in September, 2003. As the unique full-time branch campus aggregation of some leading graduate schools authorized by the Ministry of Education, Shenzhen University Town is jointly founded both by Shenzhen Municipal Government and top Universities in China (Table 5).

CONCLUSION

Defined as a highly accumulated spatially continuous cluster of universities or institutes or their sub branches under unified programming, HEA can be explained by some previous models in industrial agglomeration on the one hand, but differentiated for its characters of educational function on the other hand. Because of limited hi-educational resources agglomerated spatially, and some functional establishments shared, and as well as usually near to or surrounded with interrelated hi-tech industries, HEA can produce at least such effects as below: Firstly, education sector facilitates process of R and D; Secondly, resource sharing between/among campuses make use of educational facilities more efficiently than before; thirdly, the close–quarters intercommunion and collaboration between universities and firms improve employments. Actually, evidences and statistics from Modern University Towns in Guangdong Province also suggest that under agglomeration, educational resources are better organized and used than in decentralized situation. But still there are some factors somewhere that obstruct the sharing practices, thus it is necessary for the local government to use subsidies to incent resource sharing between private and public sectors to maximize whole society's welfare.

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