1 Introduction

It is widely recognized that science and technology parks are effective vehicles for promoting new technology-oriented firms, facilitating the commercialization of scientific research, and revitalizing regional economies (Colombo and Delmastro 2002; Link and Scott 2003). Since the late 1980s, the Chinese government has been promoting the formation and development of national science and technology industrial parks (STIPs). There has been increasing interest in similar policy in other developing countries. However, the argument that science parks are effective in realizing the previously mentioned roles is not unanimously accepted by all researchers, and some critics in fact consider them to be "high-tech fantasies" (Macdonald 1987; Massey et al. 1992; Bakouros et al. 2002).

Similar concerns exist in China as well. Cao (2004), Macdonald and Deng (2004), and Hu (2007), for example, question whether the STIPs have successfully fostered the on-park firms' innovation capability and the development of the regional economy. The on-park firms have been given a variety of preferential treatments by the government. For example, these firms have been provided tax exemptions, which were not given to the high-tech firms outside the STIPs until April 2008. The STIPs occupy large areas in large cities, which are now becoming congested. Questions arise as to whether the STIPs deserve such support and how the STIP policy can be improved.

This study uses data on high-tech firms within and outside the STIPs in China to investigate further the effectiveness of the STIPs, while paying special attention to the issues related to agglomeration economies and congestion problems. Concentrating the location of high-tech firms within the STIPs would help the government provide them with physical infrastructure and business support efficiently. According to the spatial economics literature (e.g., Fujita and Thisse 2002), the agglomeration of firms facilitates knowledge spillovers, the development of the division of labor, and the formation of skilled-labor markets. Since the STIPs are agglomerations of high-tech firms, they may well generate and enjoy such agglomeration economies. Moreover, synergies may be created between the STIPs and academic institutions in the same neighborhood and contribute to the development of the high-tech sector of the economy. However, agglomeration tends to be accompanied by congestion, which exerts negative effects on the activities within the agglomeration. If agglomeration economies outweigh congestion effects in the STIPs, preferential treatment and other supports given by the government to the on-park firms are easily justified. If congestion effects prove significant, however, the policy should be reformulated so that the space and infrastructure of the STIPs are used more effectively. For example, efficiency in resource allocation will be improved by replacing the on-park firms benefiting little from agglomeration economies with those which would benefit more.

Data on individual high-tech firms within and outside the national STIPs are unavailable. The data used in this study are aggregated to the STIP level for the on-park firms and to the city level for the off-park high-tech firms. For this reason, our empirical analysis falls short of the identification of the agglomeration economies and congestion effects. Suggestive evidence, however, is obtained by estimating the production elasticities of private capital and labor inputs as well as the productivity effects of past R&D expenditures and spillovers from universities and foreign ventures in the same city, separately for on- and off-park firms. The main finding is that congestion effects are highly likely to be stronger than agglomeration economies within the STIPs, whereas there is no evidence for congestion effects or agglomeration economies among high-tech firms outside the STIPs. Hu (2007) uses the data on 53 national STIPs and finds among other things that agglomeration has no dynamic effects contributing to productivity growth in the STIPs. Our study reinforces Hu's study with a comparison of the STIPs and the high-tech sector outside the STIPs and with an investigation into the congestion effects and static agglomeration economies.

The next section describes the development process of the STIPs in China. Based on the literature on agglomeration economies and congestion issues, Section 3 develops a conceptual framework that guides the empirical inquiry, which is presented in Section 4. A summary of the findings and the policy implications are contained in Section 5.

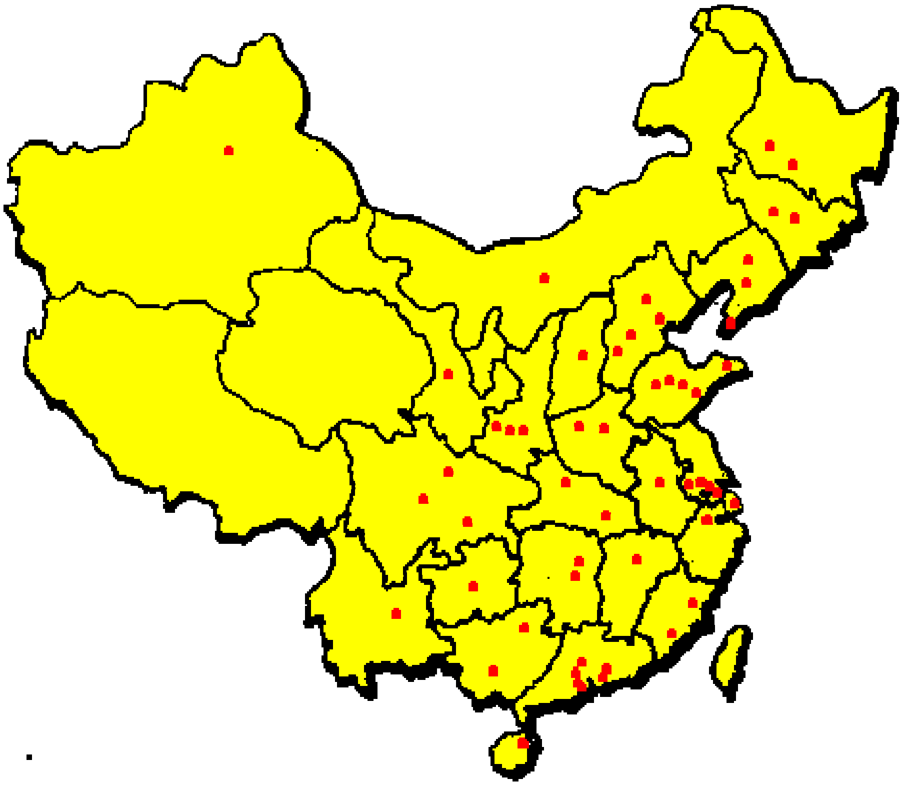
2 Development of STIPs

The first national science and technology industrial park in China is the Beijing Zhongguancun STIP, which was approved by the Chinese State Council in 1988, followed by 26 national STIPs in 1991 and by 25 in 1992. The establishment of the Yangling STIP in Shannxi province in 1997 and the recent approval of the Ningbo STIP in Zhejiang Province in 2007 brought the total number of national STIPs to 54. Four of them are located in the municipalities supervised by the central government, i.e., Beijing, Shanghai, Tianjin, and Chongqing. The 23 provincial capitals also host national STIPs. The remaining 27 national STIPs are located in generally developed cities along the coast, like Shenzhen and Qingdao or specialized cities such as Yangling, which is known for its modern agriculture. Figure 1 shows the geographic location of the national STIPs in China in 2006. Geographically, the distribution of the national STIPs is biased toward the eastern regions, followed by the central and western regions. This spatial pattern seems to reflect the distribution of industrial resources and technological capabilities across China.

For a firm to gain entry into the STIPs, it is required to be qualified as a high-tech firm. In China, there are certain criteria for qualifying as a high-tech firm. First, a high-tech firm is required to develop or use technology in the new and high-tech products or services listed in *the Catalog for High and New Technology Products* published by the Ministry of Science and Technology, such as electronics and information technology, aerospace technology, and biotechnology. Second, a high-tech firm is required to spend at least 3% of its annual gross revenue on Research and Development (R&D) to develop products or services. Third, of the high-tech firm's employees, 30% or more must have at least a college degree, and at least 10% must be engaged in R&D. Finally, a high-tech firm must be certified every year by a provincial-level government agency in charge of science and technology issues. Failure to meet these conditions disqualifies the firm from enjoying various policy incentives given to high-tech firms. Note that a high-tech firm does not have to be research-oriented. High-tech firms are mostly manufacturers.

High-tech firms are not necessarily located in the national STIPs. Many of them are located outside the national STIPs. In this paper, we refer to those high-tech firms in the national STIPs as on-park firms and those outside the STIPs as off-park firms. According to the Statistics Report of the China Torch High Technology Industry Development Center (hereinafter the Torch Center), there were 43,249 high-tech firms in China in 2006, and 27,293 were on-park and 15,956 were off-park. While the on-park firms are clustered in STIPs, the off-park firms are scattered. Another important difference is that on-park firms are more favorably treated by the government than off-park firms. For example, on-park

Figure 1: Geographic Distribution of the National STIPs in China by 2006



Source: The Annual Report of the Torch Center, 2007.

firms are exempted from corporate income tax for the first two years and enjoy a favorable tax rate of 15% from the third year on, whereas the normal corporate income tax rate is 25%. Their revenues generated by the use of newly transferred technology are only taxable beyond the first 300,000 yuan (or about US$ 45,000). Import licenses are not demanded by the customs office when they import materials and parts from abroad if the materials and parts are used to produce exports.

The government has given such privileges to on-park firms primarily because when the government started the STIPs, it gave the top priority of the STIP policy to the growth of national STIPs. Indeed, the national STIPs have grown at an astonishing speed. For the 14 years from 1992 to 2006, the annual growth rate of real output value per STIP was more than 40%, average labor productivity grew more than sevenfold, and the number of firms in the STIPs also grew more than seven times. Table 1 presents the data on the number of on-park firms in the 53 STIPs in 2001 and 2006. The number of on-park firms per national STIP increased from 458 in 2001 to 865 in 2006. During the same period, the real output per worker also grew from 88,000 yuan to 153,000 yuan. Table 1 also presents the data on the five largest STIPs in terms of the number of on-park firms in 2006, and the five fastest growing parks in terms of labor productivity measured by the value added per worker from 2001 to 2006. The largest STIP is the Beijing Zhongguancun Park, which had 18,096 firms in 2006. The five parks that experienced the fastest growth in labor productivity are located in economically less developed regions. This observation suggests that labor productivity has been converging among the STIPs, consistent with the result of the growth regression by Hu (2007).

In Beijing and Tianjin, the number of on-park firms more than doubled in the five years from 2001 to 2006. A question arises as to how the STIPs could manage to accommodate such a rapidly increasing number of firms. As mentioned earlier, the STIPs are located in large cities, where the ever-increasing scale and diversity of economic and cultural activities are taking place. It is difficult to imagine that the space and infrastructure for the STIPs can be increased without limit. According to the statistics provided by the Torch Center, the land areas of the national STIPs as a whole increased by 36.1 square kilometers, which is about 5% of their total land area, from 2001 to 2006. This should be regarded as a very small increase relative to the rapid growth in the number of on-park firms and their rapid expansion of production.

Table 1: Basic Information on the National STIPs

	Number of Firms		Real output per worker (1,000 yuan)	
	2001	2006	2001	2006
Mean	458	865	88	153
Standard Deviation	1,096	2,488	57	58
The largest five STIPs in terms of number of on-park firms as of 2006				
Beijing	7,911	18,096	351	436
Xi’an	1,921	3,200	210	454
Tianjin	1,149	3,058	247	410
Dalian	891	1,732	161	417
Guangzhou	817	1,293	354	709
The fastest growing five STIPs in terms of labor productivity from 2001 to 2006				
Changchun	519	831	73	321
Hefei	181	274	58	245
Taiyuan	351	659	47	180
Zhongshan	305	394	56	209
Xiangfan	73	141	48	177

Source: The Annual Statistics Reports of the Torch Center, 2002–2007.

This study uses data on input and output of high-tech firms taken from the Torch Center’s statistics report. In this data set, information on the on-park firms is aggregated to the STIP level and that on the off-park firms is aggregated to the city level. Because of missing data, we use the data of 49 STIPs and 41 non-STIPs covering the period from 2002 to 2006. The high-tech firms in the science park and those off the park in the same city share similar industry compositions. In Beijing, for example, perhaps the most prominent high-tech industries are software and bio-technology industries. They are equally active both within and outside of the STIP. As another example, take medium-level cities known for their machinery industries, such as Changchun or Taiyuan. Although the on-park and off-park high-tech firms may differ slightly in the composition of assemblers and parts suppliers, the difference is small. We assume that the on-park and off-park high-tech firms are comparable in each city.

Table 2 compares the on- and off-park firms in size and other respects. The first three rows of Table 2 indicate that while the number of on-park firms is larger than that of the off-park firms, the on-park firms have much smaller employment sizes than the off-park firms. These observations suggest that there is congestion in the national STIPs. Note, however, that the congestion, if any, does not result

Table 2: Comparison between high-tech firms within and outside the STIPs in 2006

	STIPs	Non-STIPs
Number of high-tech firms	27,293	15,956
Total number of workers (1,000 workers)	3,563	6,598
Number of workers per firm	131	413
Total Revenue (billion yuan)	2,567	3,404
Total Value Added (billion yuan)	509	791
Labor Productivity (1,000 yuan)	117.5	96.6
R&D expenditure (billion yuan)	72	47
Export (billion US dollar)	88	117
Percentage of highly educated workers with at least a university degree	32%	26%
Percentage of highly skilled labor with medium and advanced professional certificates	18%	15%

Source: The Annual Statistics Report of the Torch Center, 2007.

from free access. On the contrary, the entry into the national STIPs is strictly controlled by the STIP authority, and so is the land allocation to the on-park firms.

At least until recently, land has been an important production factor for high-tech firms in China because most of them have been mass producers. Their activities have centered on neither R&D nor designing. Still, they have been regarded as high-tech firms because they have been manufactured the so-called high-technology products based on the technologies that were relatively recently licensed or learned from foreign firms. In China, high-tech products have included heavy engineering products at least until recently. As mass producers, high-tech firms in China have needed land as a major factor input.

The on-park firms are smaller also in terms of revenues, value added, and export value than the off-park firms. But the on-park firms tend to have higher labor productivity than the off-park firms.1 There seem to be several reasons for the relatively high labor productivity of the on-park firms. Among them is that the on-park firms are more high-tech than the off-park firms, which is reflected in the on-park firms' relatively large R&D expenditure. Another possible reason is that the on-park firms tend to employ highly educated workers, whose salaries are likely to be high, compared with the off-park firms, as shown toward the bottom of Table 2. There is more to say about the reasons why the on-park firms tend to have higher labor productivity and smaller sizes, as will be discussed in detail below.

3 Framework of Empirical Inquiry

3.1 Agglomeration Economies

Our analysis begins by formulating a production function that can accommodate agglomeration economies, congestion, and other possible sources of productivity changes. Jacobs (1969) argues that the scale and diversity of large cities allow firms in different sectors to benefit from the cross-fertilization of ideas. Following her lead, Glaeser et al. (1992) and Henderson et al. (1995) distinguish dynamic agglomeration economies from static agglomeration economies. The former

[1] The labor productivity, which appears in Table 2, is the mean of the real value added divided by the number of workers.

contribute to productivity growth, whereas the latter contribute to productivity level. Hu (2007) finds that dynamic agglomeration economies are not significantly at work in the STIPs in China. The analysis developed below asks if static agglomeration economies are also missing in the STIPs.

Agglomeration economies have been discussed in the literature on trade, urban economics, and economic geography as well as growth theory (e.g., Helpman 1984; Henderson 1988; Fujita et al. 1999; Romer 1986). We borrow the following production function from the international trade literature with a slight modification:

$$y = h(Y)F(v), \quad (1)$$

where y is the output of the individual firm, Y is the aggregate output Σy of a group of firms, $h(Y)$ is an increasing function, F is a constant-returns-to-scale function, and v is a vector of individual firm inputs.[2] In our model, there are two types of groups of firms: STIPs and non-STIPs. In other words, Y is the aggregate output of the on-park firms in an STIP, or that of the off-park firms in the same city. While an individual firm's output y is a part of Y, we assume that y is so small relative to Y that each firm takes Y as given and regards the favorable effect of an increase in Y on productivity as external economies. The aggregate output is given by

$$Y = \Sigma h(Y)F(v) = h(Y)\Sigma F(v). \quad (2)$$

If the firms in the same group face the same output price and the same factor prices, and if they are price takers, they will choose the same factor proportions and, hence, $\Sigma F(v)$ in the most right-hand side of equation (2) can be written as $F(V)$ where V is the aggregate input vector Σv, so that we have

$$Y = h(Y)F(V). \quad (3)$$

If the function $h(Y)$ has a constant elasticity, ε, or more specifically, $h(Y) = AY^{\varepsilon}$, rearranging equation (3) yields

$$Y = [AF(V)]^{1/(1-\varepsilon)}. \quad (4)$$

Since the aggregate production function (4) is homogenous of degree $1/(1 - \varepsilon)$,

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2 In Helpman (1984), the counterpart of Y is the aggregate output of an industry in a country, not in an area like a STIP within a country.

the function exhibits constant returns to scale if $\varepsilon = 0$, and increasing returns to scale (IRS) if $0 < \varepsilon < 1$. Note that the existence of IRS is consistent with the assumption that firms are price takers, since IRS are external in this model.

3.2 Congestion Effect

Following the lead of Aschauer (1989), Holtz-Eakin (1994), and other studies on the productivity effects of public-sector capital, we assume that the input vector v has three elements: private capital input k, labor input l, and a composite input of land and infrastructure g. Suppose that land represented by g is rented freely at the real rental price ρ (i.e., ρ is the nominal price divided by the output price), as long as g does not exceed an upper limit γ. Suppose that k and l are temporarily fixed for some reasons, such as financial constraints and skilled worker shortage. The firm's profit maximization conditional on k, l, and γ is written as

$$\max \ h(Y)F(k, l, g) - \rho g$$

$$\text{s.t.} \ \ g \leq \gamma \ . \tag{5}$$

The inner solution $g(\rho, Y, k, l)$ is increasing in Y, k, and l and decreasing in ρ. Substituting this conditional demand function for g in the production function yields

$$y = h(Y)F[k, l, g(\rho, Y, k, l)] \equiv H(\rho, Y, k, l). \tag{6}$$

This is the production function when constraint (5) is unbinding. It is easy to show that $H(\rho, Y, k, l)$ is homogeneous of degree 1 with respect to k and l. If $g(\rho, Y, k, l) > \gamma$, then the quantity of g that is actually used has to be bound to γ and the output is given by

$$y = h(Y)F(k, l, \gamma). \tag{7}$$

The production function (7) exhibits decreasing returns to k and l.

The STIPs control the number of on-park firms and land allocation. How does congestion take place in an STIP? As the number of firms increases in the STIP, the aggregate output Y increases, which contributes to the productivity of individual firms through an increase in $h(Y)$, leading to an increase in the demand for g. The STIP authority, however, may not be able to increase γ accordingly, because it accommodates a greater number of firms than before. On the contrary, newcomers may be allocated smaller γ. Moreover, to the extent that on-park firms share infrastructure which is a common property, an increase in the number of on-park firms will decrease the allocation of composite γ of land and infrastructure, leading to a congestion problem.

3.3 Diagnosis and Caveats

When congestion is a problem, the aggregate production function (4) is written as

$$Y = [AF(K, L, G)]^{1/(1-\varepsilon)}, \quad (8)$$

where upper case letters are used for aggregate variables. If F is of the generalized Cobb-Douglas function, the expression (8) reduces to

$$Y = (AK^{\alpha}L^{\beta}G^{1-\alpha-\beta})^{1/(1-\varepsilon)}. \quad (9)$$

When congestion is not a problem, the counterpart is[3]

$$Y = [A(1-\alpha-\beta)^{1-\alpha-\beta}K^{\alpha}L^{\beta}\rho^{-1+\alpha+\beta}]^{1/(\alpha+\beta-\varepsilon)}. \quad (10)$$

Let the production elasticities with respect to private capital input and labor input be a and b, respectively. It follows from (10) that if there is no congestion, $a + b$ is equal to $(\alpha + \beta)/(\alpha + \beta - \varepsilon)$, which exceeds unity. When the STIP is congested (i.e., g = γ), the aggregate production function is

$$Y = (AK^{\alpha}L^{\beta}\Gamma^{1-\alpha-\beta})^{1/(1-\varepsilon)}, \quad (10')$$

where Γ is the aggregate counterpart of γ. In this case, $a + b$ is equal to $(\alpha + \beta)/(1 - \varepsilon)$ and may or may not be greater than unity.

Suppose that it is possible to obtain an unbiased estimate of $a + b$. This would inform us of the relative importance of agglomeration economies and diseconomies. If $a + b > 1$, it is likely that agglomeration economies outweigh congestion. This is not to say that congestion does not exist but that congestion if

[3] The solution to maximization problem (5) in the case of unbinding constraint is,

$$g = [(1-\alpha-\beta)h(Y)k^{\alpha}l^{\beta}]^{1/(\alpha+\beta)}.$$

This function exhibits constant returns to k and l and, hence, it is aggregated so that

$$G = [(1-\alpha-\beta)h(Y)K^{\alpha}L^{\beta}]^{1/(\alpha+\beta)} = [(1-\alpha-\beta)AY^{\varepsilon}K^{\alpha}L^{\beta}]^{1/(\alpha+\beta)}$$

substituting this expression to equation (9) and rearranging yield equation (10).

any is less important than agglomeration economies. If $a + b < 1$, it is likely that agglomeration economies, if any, is outweighed by congestion. Since firm-level data are unavailable, we are unable to isolate agglomeration effects from congestion effects. In an attempt to offer supplementary information, however, we will examine the association between employment and those variables, denoted by Z hereafter, which are expected to be correlated of productivity, A. If congestion is modest or negligible, employment size and productivity will be positively associated. If the association is found to be weak, the reason may well be congestion.

3.4 Correlates of Productivity

A possible Z variable is the scale of research and education activities of local universities, according to studies by Jaffe (1989), Acs, Audretsch, and Feldman (1991), Mansfield (1995), and Lynskey (2009) among others. Hu (2007) finds that the effect of this variable on productivity growth is insignificant, but he does not check the variable's effect on productivity level. Another variable that may be a correlate of the productivity A of high-tech firms is the foreign direct investment in their neighborhood. The empirical literature on the spillover effects of foreign direct investment research has not reached a consensus (see, e.g., Cornish 1997; Aitken and Harrison 1999; Keller and Yeaple 2003; Todo and Miyamoto 2006). However, the studies of foreign direct investment in China tend to support the argument that there are such effects (Chen et al. 1995; Ran et al. 2007). Moreover, Todo et al. (2006) find that knowledge spills over from foreign firms' R&D activities to high-tech firms. Similarly, Hu (2007) finds that the productivity growth of the STIP responds positively to the foreign direct investment that its host city receives.

Following Griliches (1979, 1988), we consider that a weighted sum of real R&D investment in the past, which we refer to as R&D stock hereafter, is likely to be correlated with productivity A. Jacobs (1969), Glaeser et al. (1992), and Henderson (2003) among others argue that productivity is improved by the cross-fertilization of diverse ideas, which is particularly active in large and diverse cities. Thus, variables that measure the urban scale and the diversity of industrial structure of the host city for high-tech firms may serve as Z variables.

4 Regression Analysis

4.1 Specification

Using panel data of 49 STIPs and 41 non-STIPs for five years from 2002 to 2006, we estimate the following functions for the STIPs and the non-STIPs separately:[4]

$$\ln(Y_{it}/L_{it}) = a \ln(K_{it}/L_{it}) + (a + b - 1)\ln L_{it} + Z_{it}\, c_Y + u_{Yi} + \lambda_{Yt} + e_{Yit}\,, \qquad (11)$$

$$\ln(L_{it}/N_{it}) = Z_{it}\, c_L + u_{Li} + \lambda_{Lt} + e_{Lit}\,, \qquad (12)$$

$$\ln(N_{it}) = Z_{it}\, c_N + u_{Ni} + \lambda_{Nt} + e_{Nit}\,, \qquad (13)$$

where subscript i indicates the i-th city, subscript t indicates the t-th year, and N is the number of firms in the group. Y, L, K, and Z denote the same variables as discussed in the previous section.[5] Their detailed definitions, means, and standard deviations are provided in Table 3. Variables u, λ, and e are the unobserved group effect, year effect, and random error, respectively. By specifying the regression model as a fixed-effect model, we try to eliminate the city-level, unobservable, time-invariant effects.

We use the per capita form in equation (11) because the estimated coefficient on the second term tells us whether the sum of the production elasticities $a + b$ is greater than unity. In the estimation of equation (11), we are concerned with the endogeneity problem arising from the facts that Γ and ρ, which appear in production functions (9) and (10), are unobservable, and that these unobservable variables are likely to influence employment L. No valid instrumental variable, however, is found in the available data. We hope that the use of the panel-data model estimation method mitigates the estimation bias substantially. As another approach to this issue, we will remove the first two terms on the right-hand side of equation (11) and focus on the question of how Z variables are correlated with Y/L, employment size L/N, and the number of firms N. In this approach, we cannot see if there are agglomeration economies (i.e., if ε is greater than unity), but we can infer whether congestion is severe.

[4] See Bhide and Kalirajan (2004) for a general discussion of the advantages of this kind of specification, in which $\ln Y$ is decomposed into $\ln(Y/L)$, $\ln(L/N)$, and $\ln N$, and each is regressed on a same set of controls Z.

[5] Precisely speaking, Z in equations (9) to (11) is a vector and it includes 1 to accommodate the intercept.

Table 3: Definition, mean, and standard deviation of variables

Variable	Definition	Group	Mean	S.D.
Y/*L*	Average labor productivity in terms of output value added per labor (1,000 yuan)	On-park	117.5	58.7
		Off-park	96.6	71.4
K/*L*	Capital stock per labor (1,000 yuan)	On-park	273.3	130.3
		Off-park	248.4	175.1
L	Number of total employees within an STIP or outside it in the same city (1,000 workers)	On-park	81.2	80.0
		Off-park	118.1	150.3
N	Number of total firms within an STIP or outside it in the same city	On-park	666	1,845
		Off-park	294	492
L/*N*	Average firm size in terms of average number of workers per high-tech firm	On-park	124	83
		Off-park	403	212
R&D	R&D capital stock, which is constructed by using the perpetual inventory method with an assumed depreciation rate of 15% and three period lags (million yuan)	On-park	2.9	6.9
		Off-park	2.3	4.8
WP	Non-agricultural working population in an STIP-host city (1,000 persons)	City level	290	268
UID	Urban Industrial Diversity Index	City level	0.79	0.09
FDI	FDI capital stock, which is constructed by using the perpetual inventory method with an assumed depreciation rate of 15% and three period lags (million yuan)	City level	972	1,309
UT	Number of university teachers in an STIP-host city (1,000 persons)	City level	10.2	10.1

In the previous section, we discussed the effects of Z variables on employment *L*. In equations (11) and (13), however, the dependent variables are ln(*L/N*) and ln*N*. We choose this specification because the estimation of the effects of Z on ln(*L/N*) and lnN gives at least the same information as that on ln*L* and probably more. As mentioned earlier, vector Z includes five variables. The first is R&D stock, which is a weighted sum of the real R&D investment in the past. R&D investment is likely to have lagged effects, but its effects are subject to obsolescence. Thus, the weight is smaller for the investment in the more remote past as follows:

$$R\&D_{it} = (1-\delta)I_{it\text{-}1} + (1-\delta)^2 I_{it\text{-}2} + \cdots + (1-\delta)^n I_{it\text{-}n}\ , \tag{14}$$

where *I* is the annual real R&D investment of all the firms in group *i*, δ is the annual depreciation rate, and n refers to the number of years for which R&D outcomes remain usable. According to Nadiri and Pruch (1996), an arbitrary depreciation rate between 10% and 15% is often used to construct R&D stock. Griliches (1979) finds that the lag structure of the productivity effect of R&D reaches a peak at about the third year. Data on annual R&D investment of the high-tech firms are available only from 1999. In view of this data constraint, our main specification of regression uses the R&D stock variable that includes the lagged R&D investments up to n = 3 and depreciates them at δ = 15%, and the alternative specification for the robustness check uses the stock variable including R&D investments up to n = 5 with an annual depreciation rate of 10%.

The second variable included in vector Z is the stock of the past foreign direct investments that the host city for the high-tech firms in group *i* received. This variable, denoted by FDI, is constructed by assuming that the productivity effect of the past investment wears off at 15% per year for the first three years and disappears at the end of the third year. We also constructed an alternative FDI measure by applying a depreciation rate of 10% and the truncation at the end of the fifth year. The third variable included in vector *Z* is the number of university teachers, UT_{it}, in the host city of group *i*. This variable is intended to capture the knowledge spillovers from local universities.

The fourth and fifth variables included in vector *Z* are intended to capture the so-called urbanization economies, which arise from the scale and diversity of urban activities. We use the number of non-agricultural working population, WP_{it}, in the host city of group *i* as a proxy for city size. To measure the industrial diversity in a city, we use an urban industrial diversity index, following the lead of Henderson, Kuncoro and Turner (1995). This index is defined by

$$UID_{it} = 1 - \sum_{m=1}^{M} \left(\frac{E_{mit}}{\sum_{m=1}^{M_c} E_{mit}} \right)^2 , \tag{15}$$

where Emit is the number of employees in a two-digit industry m in the host city for group *i* in year *t*, and *M* is the total number of two-digit industries. There are 19 two-digit industries in total, including agriculture, manufacturing, mining, public utility, wholesale and retail, real estate, construction, finance, and education. *UID* takes a value between zero and unity. A greater value indicates the greater diversity of the city. The data on *FDI*, *UT*, *WP*, and *UID* are taken from *Chinese Statistics Yearbook* and *China Urban Statistics Yearbook*.

4.2 Estimation Results

Table 4 presents the fixed-effects model estimates of labor productivity function (11). The sample consists of the 49 STIPs in column (1), the 41 non-STIP data in column (2), and the pooled sample in column (3). As mentioned earlier, the fixed-effects here are city-level fixed effects. The pooled sample is used to examine whether the STIPs and non-STIPs differ much in the coefficients, especially the coefficient on *L*. For this purpose, we add interaction terms to the regressors, multiplying each variable in equation (11) by the dummy variable that is unity for STIPs and zero for non-STIPs.

The estimated sum of the production elasticities with respect to the capital and labor $a + b$ is significantly smaller than unity in column (1), whereas it is almost equal to unity in column (2). These results suggest that congestion outweighs agglomeration economies in the STIPs but not outside the STIPs. Turning to the coefficients on the *Z* variables, we find in column (1) that R&D and foreign direct investment are positively associated with the productivity of high-tech firms, and that the number of local university teachers is positively associated with the productivity of the on-park firms. These results indicate the importance of intellectual activities including learning from foreign firms in pushing up productivity. The two variables related to urbanization economies, i.e., ln*WP* and ln*UID*, do not have significant coefficients in any column.

Table 4: Estimated Labor Productivity Function, 2002–2006

	Fixed-effects model		
	(1)	(2)	(3)
	STIPs	non-STIPs	interaction terms in pooled data
ln(*K*/*L*)	0.39***	0.65***	-0.26**
	(5.34)	(7.80)	(-2.03)
ln*L*	-0.32***	-0.06	-0.26**
	(-3.85)	(-0.64)	(-2.44)
ln*R&D*	0.07*	0.03	0.04
	(1.87)	(0.52)	(0.72)
ln*FDI*	0.10**	0.09	0.01
	(2.24)	(0.98)	(0.10)
ln*UT*	0.12**	-0.05	0.17
	(1.93)	(-0.24)	(0.92)
ln*WP*	-0.20	-0.11	-0.09
	(-1.10)	(-0.33)	(-0.35)
ln*UID*	0.06	1.61	-1.55
	(0.20)	(1.36)	(-1.50)
Sample size	245	205	450

Dependent variable is $\log(Y_{it}/L_{it})$. Year dummies and an intercept are included in the regression. The results concerning them are not reported in the table, but they will be provided upon request. Column (3) reports the estimated coefficients on the interaction of the *STIP* dummy and each regressor. Numbers in parentheses are *t* statistics. *, **, and *** indicate the 10 percent, 5 percent, and 1 percent significance levels, respectively.

The positive association with FDI and labor productivity in column (1) is consistent with the results of the growth regression analysis conducted by Hu (2007) as well as the other studies on the spillover effects of FDI in China. Nonetheless, our results concerning FDI need to be interpreted with caution. A large inflow of foreign direct investment into a city may not necessarily be a cause of the relatively high productivity in the city, but the former may be a result of the latter. It is conceivable that the agglomeration of highly productive firms in a city attracts a large inflow of FDI to the city. With our data and specification, it is difficult to establish a causal relationship between FDI and productivity. According to column (3), the STIP and the non-STIPs differ significantly in the coefficients on ln(*K/L*) and lnL. However, the differences between the STIP and the non-STIP in the coefficients on R&D, FDI, and the number of university teachers are insignificant, probably because the large standard errors of the estimated coefficients on these variables are very large in the non-STIP sample.

To check the robustness of these estimation results, the same regressions are run for the two overlapping three-year periods 2002–2004 and 2004–2006. The results are reported in Table 5. The first three columns of Table 5 report the results for the 2002-2004 period, while the last three columns report those for the 2004–2006 period. Not only the qualitative results but also the magnitudes of the estimated coefficients are generally similar between these two periods. Thus, we find no evidence for any structural change over time, and the main message from the table is the same as the one from Table 4. A relatively prominent difference is found in the coefficient on ln*UT* (i.e., the number of local university teachers), which is positive and highly significant in 2002–2004 but insignificant in 2004–2006. These results suggest that the local universities tend to lose importance as a source of knowledge spillovers. As another robustness check, the depreciation rate and the number of lags of R&D and FDI are changed from 15% to 10% and from 3 years to 5 years, respectively. The estimation results remain qualitatively the same, and are thus not reported in this paper.

We turn now to the regressions of employment size *L/N* and the number of firms *N* on the *Z* variables. The results are presented in Table 6. In the first three columns, the dependent variable is the log of *L/N*, and the factor input variables, *K/L* and *L*, are excluded from the right-hand side of the regression equation. This table shows that none of the *Z* variables, except for UID in columns (1) to (3), have significant coefficients. In Tables 4 and 5, R&D, FDI, and the number of university teachers had positive and significant coefficients in the function explaining labor productivity. Why do cities with high labor productivity share about the same firm sizes and the same number of enterprises as cities with lower productivity? In higher productivity cities, firms will expand operation size, or new firms will enter, if expansion and new entry are free and easy. Thus, the contrasting results shown in Table 6 and the previous tables are consistent with the hypothesis that on-park firms are faced with congestion.

Table 5: Estimated Labor Productivity Function, 2002–2004, 2004–2006

	2002–2004			2004–2006		
	(1)	(2)	(3)	(4)	(5)	(6)
	STIPs	non-STIPs	interaction terms in pooled data	STIPs	non-STIPs	interaction terms in pooled data
ln(*K*/*L*)	0.37***	0.66***	-0.29	0.43***	0.63***	-0.20*
	(3.82)	(6.51)	(-1.10)	(3.82)	(6.14)	(-1.69)
ln*L*	-0.30***	-0.07	-0.23*	-0.35***	0.03	-0.38**
	(-3.25)	(-0.79)	(-1.95)	(-3.85)	(0.21)	(-2.17)
ln*R&D*	0.06*	0.10**	0.04	0.03	0.08**	-0.05
	(1.64)	(2.22)	(0.77)	(0.12)	(1.98)	(-0.60)
ln*FDI*	0.06*	-0.09	0.15	0.10***	0.12***	-0.02
	(1.72)	(-0.47)	(0.65)	(2.82)	(2.70)	(-0.34)
ln*UT*	0.17***	-0.08	0.25	0.09	0.08	0.05
	(2.73)	(-0.35)	(0.86)	(1.55)	(1.11)	(0.79)
ln*WP*	0.05	-0.25	0.30	-0.31	0.11	-0.42
	(-0.08)	(-0.74)	(0.91)	(-0.44)	(0.21)	(-0.76)
ln*UID*	0.03	1.19	-1.16	0.38	-0.93	1.31
	(0.12)	(0.81)	(-0.69)	(0.72)	(-0.51)	(0.64)
Sample size	147	123	270	147	123	270

Dependent variable is log(Y_{it}/L_{it}). Year dummies and an intercept are included in the regression. The results concerning them are not reported in the table but will be provided upon request. Columns (3) and (6) report the estimated coefficients on the interaction of the *STIP* dummy and each regressor. Numbers in parentheses are *t* statistics. *, **, and *** indicate the 10 percent, 5 percent, and 1 percent significance levels, respectively.

The coefficient on the UID is negative and significant in the employment size function as shown in columns (1) and (2) of Table 6, whereas it was insignificant in the labor productivity function as shown in Tables 4 and 5. These results indicate that firms in cities with highly diverse industries have smaller employment sizes, while such cities do not have particularly high productivity. The magnitude of the negative coefficient is significantly larger for the non-STIP areas. This is probably because while STIPs are congested whether or not they have diverse industries, non-STIP areas in general are not congested and only non-STIP areas with diverse industries are congested. The negative impacts of UID on employment size and insignificant impacts of UID on productivity reinforce Hu's (2007) finding that there is no evidence for dynamic urbanization economies.

Table 6: Estimated Functions of the Average Employment Size and the Number of Firms, 2002–2006

	Average Employment Size			Number of Firms		
	(1)	(2)	(3)	(4)	(5)	(6)
	STIPs	non-STIPs	interaction terms in pooled data	STIPs	non-STIPs	interaction terms in pooled data
ln*R&D*	0.01	-0.06	0.07	0.01	0.07	-0.07
	(0.49)	(-1.49)	(1.57)	(0.15)	(1.50)	(-1.38)
ln*FDI*	0.01	-0.07	0.08	0.00	-0.07	0.07
	(0.29)	(-1.21)	(1.15)	(0.04)	(-1.09)	(0.99)
ln*UT*	-0.08	-0.07	-0.01	-0.06	0.13	-0.19
	(-1.21)	(-0.48)	(-0.08)	(-1.06)	(0.81)	(-1.26)
ln*WP*	0.07	0.26	-0.19	0.08	-0.22	0.30
	(1.09)	(1.21)	(-0.90)	(1.33)	(-0.86)	(1.34)
ln*UID*	-0.58*	-2.47***	1.89**	-0.65	0.56	-1.21
	(-1.94)	(-3.20)	(2.44)	(-0.94)	(0.62)	(-1.52)
Sample size	245	205	450	245	205	450

The dependent variable is log(L_{it}/N_{it}) in columns (1) to (3) and log(N_{it}) in columns (4) to (6). Year dummies and an intercept are included in the regression. The results concerning them are not reported in the table but will be provided upon request. Column (3) and (6) report the estimated coefficients on the interaction of the *STIP* dummy and each regressor. Numbers in parenthesis are *t* statistics, and *, **, and *** indicate the 10 percent, 5 percent, and 1 percent significance levels, respectively.

5 Conclusions

Congestion is a common problem in cities across the developing world, especially those cities with industrial clusters that were formed spontaneously by firms and have been growing (e.g., Otsuka and Sonobe 2008). The industrial park is usually a solution to the congestion problem. In China, for example, local governments have developed numerous industrial parks to reduce the congestion caused by industries in their townships, cities, or provinces. The national STIPs are the highest grade of industrial parks in China. The analysis of this paper, however, reveals that while on-park firms these industrial parks may benefit from agglomeration economies, they are also faced with congestion problems, and that the negative effect of congestion on productivity outweighs the positive effect of agglomeration economies. The paper has also found that the productivity of high-tech firms, whether within or outside the STIPs, is positively associated with the foreign direct investment and the academic activities of local universities in the same city.

In the presence of congestion outweighing agglomeration economies, preferential treatment in favor of the on-park firms leads to inefficient resource allocation. In China, the preferential treatment has contributed to the growth of the STIPs by attracting a large number of firms to the STIPs. As the STIPs become overcrowded with firms, such a policy gives firms the wrong incentive. To alleviate the efficiency loss due to congestion, the STIPs should expel the firms that hardly generate synergistic effects and benefit little from agglomeration economies. Recently, the Chinese government reformed the STIP policy and began giving tax exemptions to every high-tech firm, whether within or outside the STIPs. This should be a good move if congestion outweighs agglomeration economies in the STIPs.

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