

Regional innovation policy in Taiwan and South Korea: The impact of science parks on small and medium-sized enterprises' productivity distributions

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Abstract

In this paper the effectiveness of regional innovation policy creating science parks is evaluated with respect to small and medium-sized enterprises (SMEs) using a regional economics approach. Science parks created to support innovation and regional growth often target productivity gains associated with agglomeration economies. However, spatial proximity of firms also stimulates selection, whereby less competitive firms are forced to exit, and hence a cluster of high-productivity, surviving firms is observed at the regional level. Empirical studies show that high or low-productivity firms or both may spatially sort into a region. Using estimates of firm-level total factor productivity, science park sorting and selection behaviour of Taiwanese and South Korean SMEs is mapped and analysed. The results indicate heterogeneity in location choice of SMEs arising from the economic environment of science parks. Overall, the empirical evidence suggests that policy establishing science parks can generate real productivity improvements if the incentives are reinforced through national level policies, otherwise such incentives may end up protecting inefficient firms.

Keywords: Firm-productivity; Small and medium-sized enterprises; Agglomeration; Selection; Science parks; East Asia

JEL classification: R1, R11, R12, R58, D240

1 Introduction

Establishment of science parks to stimulate technological innovation and regional growth is considered an important policy measure. Both Taiwan and South Korea are countries that have shown remarkable growth and whose policy instruments have included establishment of science parks. Both countries have placed great emphasis on the growth of small and medium-sized enterprises (SMEs) as an engine of economic growth. However, at the national level the overall economic models pursued by each country are quite different. The dominance of the SME-network model in Taiwan and the scale-based technological development model in South Korea has affected the efficiency of SMEs in a varied manner. The objective of the research presented in this paper is to determine the impact of incentives offered through science parks on SME-level productivity and to address the concerns raised by Ahn (2001) regarding East Asian growth models.

The idea of developing regional innovation systems became popular in industrialized economies in the 1980s (Hassink, 2002). These policies are unique as their implementation is region-specific, but they are formulated and enforced through national programs. A key feature of these policies is the institutional setup and infrastructural buildup manifested through creation of science parks and supported by financial incentives to help clustering of industries. As Hassink (2002) explains, the objective of science parks is to support regional potential by encouraging horizontal and vertical cooperation among universities, SMEs and large firms through transfer of knowledge and diffusion of technology. Regional innovation-support systems, including those offering incentives to deal with financial constraints faced by small technology-intensive firms (Storey and Tether, 1998), have been extensively studied for OECD and European countries (OECD, 1996) but in a very limited manner for East Asian economies (Okubo and Tomiura, 2012).

However, none of these studies have specifically focused on SMEs. Therefore, the current paper is an attempt to examine the effectiveness of these policy instruments through comprehensive analysis of regional productivity distributions for SMEs in Taiwan and South Korea.

While firm-level productivity is a key performance indicator in the growing literature on heterogeneous firms, additional analysis is required to understand the impact of science parks on the productivity distribution of incumbent firms. There is a consensus in the regional economics literature that firms located in large cities are often more productive than those located elsewhere due to agglomeration benefits (Rosenthal and Strange, 2004). However, contemporary progress in spatial economic analysis indicates that there may be other factors generating higher firm-level productivity in large cities. For example, observed higher average productivity of firms in large cities or industrial clusters may be due to competition-based selection (Combes et al., 2012). Alternatively, both low and high-productivity firms may spatially sort into large cities in order to take advantage of the economic benefits of large markets (Forslid and Okubo, 2014). The presence of multiple explanations for observed firm-level productivity distributions not only complicates the analysis but also renders it hard to pin down actual factor(s) driving the productivity-level of firms located in large cities and industrial clusters.

The main issues with the current literature on the effect of science parks on productivity are: limitations due to site-specific methodologies and potential selection bias as pointed out by Phan et al. (2005). Following Hasan et al. (2016), an attempt is made in the current paper to overcome these shortcomings by adopting a regional economics approach through adding a separate region housing science parks to the core-periphery analysis of the new economic geography model. As a consequence, the methodology is not restricted to a particular estimation model or specific park objective(s), but is instead based on a robust theoretical foundation that provides a solid basis for

generalization and policy evaluation. From a policy perspective, the results from this study suggest that science parks do help in correcting innovation market failures and improving regional growth, but they may also turn out to provide protection against market competition and therefore result in sorting by low-productivity firms. This latter kind of support does not lead to productivity growth, as is evident in the case of SMEs in South Korea. Lastly, it can also be inferred from the results that tax credits and tariff exemptions for research and development (R&D) expenses generally favor large corporations and do little to support innovation by and growth of SMEs.

The paper is structured as follows: in section 2, the research contribution of the paper is summarized, followed by a review of the relevant literature and a brief country-level analysis in sections 3 and 4 respectively. The model, hypotheses, data, empirical analysis and discussion of results are detailed in sections 5, 6 and 7, while a summary of the findings and some concluding observations are presented in section 8.

2 Methodology and significance of the study

The theoretical and empirical methodology adopted in this paper draw on the earlier contributions of Okubo and Tomiura (2012) and Forslid and Okubo (2014). As a first step in the analysis, productivity distributions for firms in cities and science parks are simultaneously analyzed to identify the impact of agglomeration and selection effects. This analysis is conducted for all manufacturing firms, as well as SMEs and large firms in both Taiwan and South Korea. Given that science park incentives are designed to support the growth of SMEs, and that self-selection by firms into a region containing a science park(s) is very likely, a two-stage Heckman (1979) selection model is also used to evaluate regional firm-level productivity distributions. This is followed by an estimation of the impact of policy incentives on firm-productivity using both

regression and matching techniques. Finally, to control for the effect of unobserved heterogeneity and resultant productivity variations on spatial sorting behavior of firms, the percentile-wise probability of location is estimated for science parks in the two countries.

A 3-digit NAICS firm-level panel data set for the period 2010-12 covering Taiwan and South Korea is used to implement the empirical strategy. For the purpose of spatial analysis, the two countries are divided into three exclusive regions based on population density and location of science parks. These regions include: urban areas with above median population density (large cities); urban areas with below median population density (small cities); and urban areas housing science parks (science park cities). Urban areas refer to either, a county, city or metropolitan city depending upon the administrative division of the relevant country. Following Anh's (2001) finding that a disproportionate amount of growth in Asia is due to increased inputs rather than improved efficiency, the current analysis digs deeper into the determinants of growth and the potential role of SMEs therein. Hall and Harvie (2003) point out that SMEs in Korea have faced a more unfavourable business environment particularly in terms of access to finance etc., hence it is reasonable to expect heterogeneity in SME performance across the two countries.

The definition of an SME is similar but not identical in the two countries. The upper employment limit in the manufacturing sector for an SME is 200 people in Taiwan as compared to 300 in South Korea. In this paper, SMEs are defined as manufacturing firms with employment up to 250 people and independent management.

The key results of the study are as follows: first, at the aggregate manufacturing level, firms located in science parks in both Taiwan and South Korea have an average level of productivity that is lower than that of large cities but higher than that of small cities (figure 1); second, in the case of SMEs, those located in science parks in Taiwan have the highest average productivity

whereas those in South Korea have the lowest average productivity (figure 2). For the interested readers, a similar analysis was also conducted for large firms. The results shown in figure 3 indicate the differences in productivity of large firms in the two countries.

The policy premium analysis confirms that on average, even after controlling for firm and industry characteristics influencing productivity, SMEs in Taiwanese science parks have higher productivity compared to SMEs located elsewhere in the country. Therefore, the productivity distributions indicate that regional policy interventions are much more effective in the case of Taiwan compared to South Korea. Third, the analysis of spatial sorting and competitive selection behavior indicates that both selection and one-sided sorting for SMEs occur in Taiwan, whereas two-sided sorting is prevalent in South Korea. However, analysis of the summary statistics for the log firm-level total factor productivity (TFP) distributions shows that across the three markets in both Taiwan and South Korea, the selection effect, while present, is of a much lower order of magnitude than the agglomeration effect.

3 The impact of clustering on firm productivity

In the regional economics literature there is a consensus that firms located in large cities exhibit higher productivity, and that there is a positive relationship between productivity levels and regional density of labor employment, as well as industrial activity. As noted earlier, three main explanations have been presented for these observed phenomena: agglomeration economies, competition-based selection, and spatial sorting.

In the case of urban regions, externalities are generally attributed to agglomeration economies associated with firms located in large cities and industrial clusters with the theoretical underpinnings dating back to Marshall (1890). The agglomeration literature explains productivity

gains resulting from labour market pooling, factor- sharing, and knowledge spillovers. Also in the case of industrial clusters, a positive association between regional plant-density and productivity has been empirically confirmed by Ciccone and Hall (1996) providing support for policies encouraging firm-clustering.

Apart from agglomeration economies, the high level of firm productivity observed in large cities has recently been explained in terms of competitive selection associated with large markets. Drawing on Melitz (2003), Melitz and Ottaviano (2008) show that with heterogeneous firms, monopolistic competition and free entry, as markets get larger firms' markups on price over marginal cost go down due to an increase in demand for factors of production and congestion costs. As heterogeneity of firms is explained in terms of their productivity, feedback of this effect results in the selection of firms that exit the market whose productivity is below the market cut-off level. The surviving mass of firms has higher average productivity, causing cumulative regional productivity levels to increase.

Another strand of literature that combines aspects of the new economic geography with an assumption of heterogeneous firms shows that high-productivity firms may sort into larger markets with trade liberalization. Baldwin and Okubo (2006) assume a setting with two regions, one small and one large, where capital is mobile between regions, subject to an adjustment cost, and units of capital in each region embody a particular level of labor productivity. Assuming monopolistic competition with fixed price–cost markups, decreasing trade costs cause the most efficient firms to relocate from the small to the large region. Baldwin and Okubo (2006) also establish that subsidizing firms to move from the large to the small region induces only the least productive firms to relocate. Based on the Melitz and Ottaviano (2008) setup, as well as finding that decreasing trade costs lead to agglomeration of efficient firms in the large region, Okubo et al.

(2010) also establish that less efficient firms relocate to the smaller region. However, as the two regions become increasingly integrated, inefficient firms eventually relocate to the larger region in order to access a larger pool of consumers. Finally, Forslid and Okubo (2014) use a structure similar to Baldwin and Okubo (2014), where higher capital intensity among more productive firms is also sector-specific. Their theoretical results generate two-sided sorting: firms with the highest return to capital have the strongest incentive to move from the small to the large region, which would include both the most productive firms and the least productive firms that are labor-intensive, that is, depending on the sector of production, such firms may lie at either tail of the productivity distribution.

The phenomenon of selection and spatial sorting clearly raises serious endogeneity concerns when evaluating the impact of spatial clustering policies on firm productivity. As noted by Baldwin and Okubo (2014), standard econometric analysis of agglomeration economies is very likely to overestimate the benefits of agglomeration on firm productivity due to the fact that only the most productive firms either survive in or relocate to larger and more competitive markets. In addition, as Forslid and Okubo (2014) point out, while agglomeration economies, selection, and sorting all result in higher than average productivity for firms located in a cluster, they also generate quite different shaped firm productivity distributions. In the case of agglomeration economies, all firms located in the core benefit, the productivity distribution shifting to the right. For the case of selection, the productivity distribution of firms in the core will be left truncated as the least-productive firms exit the core, while for two-sided sorting, the productivity distribution will be wider as the least and most-productive firms relocate to the core.

With respect to empirical evidence for the effect of policy on firm-level productivity at the country level, Martin et al. (2011) find that French industrial cluster policy has had no significant

effect on the productivity of firms, while Bernini and Pellegrini (2011) were able to detect a decline in the productivity of firms subsidized by the Italian government. In the case of Japan, Okubo and Tomiura (2012) found that average plant-level productivity is significantly lower in regions targeted by policy. However, none of these studies have investigated the competitive selection and spatial sorting of SMEs when policy incentives are offered through a science park(s).

4 Economic growth and innovation policy in Taiwan and South Korea

Economic growth observed in East Asia has inspired considerable academic research aimed at pinning down its determinants. High investment in human and physical capital has been identified as a major source of growth by Kim and Lau (1994), and Krugman (1994). In another strand of literature, studies such as those by Kim and Park (1985) and Young (1995) have examined and established the role of total TFP growth in high-performing East Asian economies.

Taiwan and South Korea have been widely recognized as countries representative of the successful developmental state-model based on export-oriented industrialization (Amsden, 1989). Although the two countries both share a commitment to export-led growth, there are significant structural differences in their approaches. Taiwan has realized economic growth centered on SMEs and as a result, has been able to become successfully integrated with global production networks supplying parts and equipment (Ito and Krueger, 1995). South Korea on the other hand has pursued an export-oriented strategy centered on large conglomerates in order to take advantage of capital-intensity and scale economies in production processes. The outcome of differences in their national approaches is also manifested in the respective industries that they specialize in. Taiwan has been more successful in integrated circuits, personal computers, industrial machinery, and the cellular phone industry. South Korea, however, has strength in capital-intensive information-technology

products, such as memory semiconductors and displays, as well as in traditional scale-intensive industries such as automobiles, shipbuilding, and steelmaking.

The observed differences in industry and product specialization can be analyzed using the national innovation systems approach. Nelson (1996) suggests that such variations are caused by differences in national institutional frameworks. At the national and industry-level, diversity in innovation systems originates from government policies and the role of the public sector. Policies for selecting and promoting strategic industries and the development of relationships between industrial and national innovation systems are closely related, hence design and development of innovation systems needs serious consideration. From a policy viewpoint, resource allocation is the key factor that affects the organization of R&D and the pattern of industrial development.

According to Park (1998), for Taiwan and South Korea, it is reasonable to argue that their governments, through intervention, have contributed to their rapid growth and industrialization. Without this direct intervention, it was highly unlikely that the private sector itself could have launched and maintained an investment and export-led development strategy. This viewpoint has been endorsed by Rodrik (1994) who argues that government was able to successfully subsidize and coordinate investment decisions. In the context of the current study, policy for establishment of science parks is one of the state-sponsored measures to support R&D, as well as to promote the growth of SMEs.

Inspired by the success of California's Silicon Valley, the Taiwanese government embarked on upgrading its economy with technology and capital-intensive industries. In 1979, a statute was enacted for the establishment of science parks. The first park was established in December 1980 in Hsinchu city, and it now stretches over both the city and county of Hsinchu. The park was a public project in its entirety, developed using public land and publicly-funded infrastructure. The

central government provided strong policy regulations along with preferential fiscal and other investment incentives. Similar science parks were subsequently established in central and southern Taiwan with the objective of providing a favorable environment with appropriate incentives to attract current technologies and skilled human resources. The primary policy tool in the case of science parks was provision of tax credits against R&D expenses (Lien et al., 2010). Taiwan has also had a long history of policy support for SME development (Seong, 1995). However, in the wake of recent fiscal difficulties and revenue shortfalls, the policy tool of R&D tax credits has been widely criticized as being beneficial only for a few large firms, leaving behind the remaining 97 percent of SMEs in Taiwan.

In South Korea, the establishment of science parks began in 1997, as part of an effort by the central government to increase its support for enhancing the innovativeness of SMEs and development of inter-firm networks. The evaluation of South Korea's SME-oriented innovation-support indicates mixed results as is evident from the diverse views expressed in Kim and Nugent (1994) and Park (1998). Chung (1999) however, is of the opinion that the differences in these findings are largely due to lack of a systematic evaluation procedure. Although the World Development Indicators (World Bank, 2014) indicate that over the period 2003-11, R&D expenditure as a share of South Korean GDP rose from 2.5 to 4 percent, studies point out several weaknesses in its innovation system such as a lack of interplay between universities and the private sector, as well as a dearth of diffusion mechanisms to transfer research results from public research establishments to industry, and particularly to SMEs (Kim, 1997).

5. Model and estimation strategy

5.1. Outline of model

To distinguish between agglomeration and selection effects, the theoretical analysis presented in Arimoto et al. (2009) and Combes et al. (2012) as detailed in Hasan et al (2016) is followed. The model is designed to examine the implications for these two effects on the distribution of firm-level productivity in a given region. Intuitively, the agglomeration effect will shift the log-total TFP distribution to the right by improving the productivity of all firms in the region, but at the same time keeping the shape of the distribution unchanged. On the other hand, the selection effect will drive less productive firms out of the market, resulting in left truncation of the log-TFP distribution. Therefore, it is possible to identify the two effects by comparing the characteristics of the distribution of firm-level productivity among various regions. The detailed model along with necessary derivations is given in the supplementary index.

5.2. Hypotheses

Using the model and previous findings in the literature, the following hypotheses can be stated:

Hypothesis 1 (*Agglomeration*): Policy incentives offered through science parks are likely to cause an increase in the mean of the log-TFP distribution for SMEs located in a region.

Hypothesis 2 (*Sorting and Selection*): Provision of public incentives through science parks results in two-sided sorting in the case of low mean firm-level productivity, compared to competitive selection and one-sided sorting in the case of high mean firm-level productivity.

Hypothesis 3 (*SME Performance*): SMEs in Taiwan are more likely to outperform those in South Korea on account of national policy and business environment differences between the two countries (Hall and Harvie 2003).

6. Empirical analysis

6.1 Data and TFP Estimation

A brief mention of data sources and geographical units of analysis is provided in the introduction. Table 1 here provides regional spread of all firms. More details are given in the supplementary material part. The empirical analysis of the paper depends on bias free estimates of TFP. The residual approach is prone to suffer from several biases including those from selectivity and simultaneity. The detailed methodology to obtain bias free estimates is given in the supplementary material component. For brevity we start our discussion from the estimation results in the next part.

6.2. TFP estimation results

The results for the estimated coefficients on the factors of production, capital and labor, in the case of Taiwan and South Korea, are shown in table 2. The baseline TFP estimates are computed using OLS, the results showing some interesting findings: the capital coefficient is biased downwards in the case of Taiwan while it is biased upwards in the case of South Korea. This result is exactly in line with factor-intensity in the production process and the direction of bias as explained in Van Beveren (2010). The coefficients for the inputs shown in table 2 indicate a production function with decreasing returns to scale. Some interesting results are observed here in line with Hall and Harvie (2003). As Korean firms faced a more severe negative shock due to the Asian currency crisis as compared to Taiwan, it can be seen that the market response was to employ less variable inputs, i.e., labor. The instrumental variable estimate corrects for the simultaneity bias but still the coefficients suffer from selectivity bias. Comparing the Olley-Pakes estimates to the OLS estimates shows that in the case of Taiwan, the coefficient on labor is lower compared to the OLS results, but it is higher in case of Korea.

To avoid the possible endogeneity problem, an IV/2SLS method can also be used, but the estimates are likely to be biased due to the selectivity problem discussed above and, therefore, are not considered reliable.

Keeping in mind the shortcomings of the methods used above, TFP was estimated using the method proposed by Olley and Pakes (1996), and Levinsohn and Petrin (2003). The TFP distributions were separately drawn for the designated regions. In this approach, the return on capital is used as a proxy for investments made by the firm along with control variables such as the number of employees to control for size. The summary statistics of the log-TFP distribution estimates, as detailed in table 3 for both countries, were examined for each of the three defined regions. Large cities have the highest mean value of firm-level log-TFP, followed by that of science park firms which suggests firms in large cities continue to benefit the most from agglomeration economies and the impact of science park intervention is not enough to overcome this. An estimate for competitive selection is made using the value of minima and the tenth percentile of the distributions in each region. Increasing values of these two as we move from small city, to science-park, and then to large city indicates that low productivity firms cannot survive in a more competitive environment.

6.3. Policy evaluation

Three approaches are taken to analyze the impact of policy intervention on SME productivity. First, a simple regression equation is estimated where the potential effect of a science park is captured through a dummy variable. Second, a matching technique is used to estimate the average treatment effect of science parks on SME-productivity through comparing similar plants. Third, a Heckman (1979) selection model is used to control for self-selection bias.

6.3.1. Policy impact analysis

Following the methodology outlined in Okubo and Tomiura (2012) the following reduced form regression model is estimated:

$$TFP_{it} = \alpha Policy + \mathbf{K}_{it} + \varepsilon_{it}, \quad (1)$$

where TFP refers to the log-TFP of SME i in year t , and \mathbf{K} is a vector of SME control variables in logarithmic form such as size and capital, and ε_{it} is assumed as the *i.i.d.* error term. We use robust standard errors to correct for measurement errors in the dependent variable. The main variable of interest is the *Policy* dummy. If *Policy* has a statistically significant positive coefficient, it implies that SMEs located in science parks have a higher level of TFP on average compared to SMEs located elsewhere. However, it is important to note that the results from estimating equation (1), which are reported in table 4, are likely to suffer from reverse causality on account of either competitive selection or sorting, and should therefore be interpreted as indicating correlation only.

6.3.2. Treatment effect

In order to control for unobserved heterogeneity between firms located in science parks and outside, a matching technique is used. Matching has been used in previous studies in this context, including Martin et al. (2011). The current dataset is a sample of SMEs, some of whom received a “treatment” based on a policy premium and the agglomeration benefits of being located in a science park, and the remaining SMEs located elsewhere in the country did not get “treatment”. The interest is in finding out if the “treatment” influences an outcome variable, i.e., an SME’s TFP. In an ideal world, TFP would be observed when an SME is treated, denoted as y^1 , and TFP would also be observed when the same SME is not treated, denoted as y^0 , so that the only difference is the presence or absence of the treatment. Based on these observations, the difference between the two outcomes across all the subjects in the dataset could be used to obtain a measure of the average impact of science park policy. However, as this ideal experiment is not possible, randomized

treatment is adopted instead. The defining characteristic of observational data is that treatment status is not randomized, implying that the outcome and treatment are not necessarily independent. The goal of the estimators employed here is to utilize covariates to make treatment and outcome independent, once conditioned on those covariates.

Therefore, to control for heterogeneity in the changes in TFP resulting from being located in a science park (treatment) across SMEs, we use a Mahalanobis nearest-neighbor matching algorithm to construct a refined control group of SMEs, those not experiencing incentives offered through a science park, by matching characteristics with those that experienced the incentives (Abadie and Imbens, 2006). The matching algorithm selects comparable SMEs with similar levels of employment, capital investment and return on capital as matching covariates. The causal effect of the treatment is estimated as the mean difference in productivity between the treated and the untreated groups. The average effect of the treatment on the treated group is given by $E(y^1 - y^0 | Policy)$, where $Policy = 1$ if plants are treated, and 0 otherwise. This estimation is useful for explicitly evaluating the effects on those SMEs, for whom the science park program was actually intended, the results being reported in table 4.

6.3.3. Firm sorting and type of regional productivity distribution

To determine presence of spatial sorting by SMEs in science parks, the Heckman (1979) two-step estimator for selection models is used. The statistical significance of the coefficient of the inverse Mill's ratio indicates if there is any selection bias. To identify the process through which either low or high-productivity firms sort into science parks or large cities, a selection equation is used in conjunction with equation (1). Considering firm's sorting into science parks the relevant selection equation is as follows:

$$z_{it}^* = \alpha_0 + \alpha C_{it} + v_{it}, \quad (2)$$

where $z_{it} = 1$ if $z_{it}^* > 0$ implying Policy=1, and $z_{it} = 0$ otherwise. z_{it} is the dependent variable of the selection equation which is binary in nature and C_{it} is a vector of self-selection (sorting) choice variables. The choice variables include lagged county level wages, lagged county population density, and firms' return on capital and return on equity. For equations (1) and (2), ε_{it} and v_{it} are error terms which are assumed to be bivariate normal, with mean zero and covariance matrix $\begin{bmatrix} \sigma & \rho \\ \rho & 1 \end{bmatrix}$, where ρ is the correlation between the two error terms and σ is the variance of the error term from equation (1). The choice variables include lagged county-level wages, lagged county population density, and firms' return on capital and return on equity.

As noted earlier, any region that experiences both types of sorting will have a firm-level productivity distribution with fat tails. This contrasts with the impact of competitive selection which results in left-truncation of the firm-level productivity distribution. The results indicate a positive and significant value of the inverse Mill's ratio in the case of Taiwan which suggests that selection into science parks is linked with high productivity, whereas the results for Korea are the opposite, low productivity being associated with sorting into a science park.

Given that firm-level productivity distributions are simultaneously affected by agglomeration economies, competitive selection and sorting, it is important to segregate each effect before determining the type of productivity distribution. In order to filter out sorting from agglomeration and selection effects, the methodology of Forslid and Okubo (2014) is employed. First, the firm-level productivity distributions are demeaned to remove the agglomeration effect. Second, a region-specific regression equation is used to determine the likelihood of any firm lying within a certain percentile of the firm-level productivity distribution as indicated by the coefficient of a regional dummy variable, D_{region} :

$$Percentile = \beta_p D_{region} + \mu. \quad (3)$$

A positive value for the coefficient β on the regional dummy variable, with robust standard errors to correct for deviations from the *i.i.d.* assumption, indicates the likelihood of sorting within the given percentile of the log-TFP distribution. Conversely a negative value for β implies dominance of the selection effect. Therefore, the estimated β s for various percentiles pick up the difference between selection and sorting effects on the firm-level productivity distribution of the region under consideration in contrast to the rest of the country. For example, a negative (positive) estimate of β at low percentiles implies a dominant selection (sorting) effect at the lower tail of the productivity distribution. In order to estimate the β coefficient, regression analyses based on equation (3), are performed for all three regions (large city, science parks, and small city) utilizing the joint probability distribution of all SMEs, the results being reported in table 5, as well as illustrated in figure 3. Due to the β coefficients being significant both at low and high percentiles, they are used to develop profiles to identify the dominance of either selection or sorting, i.e., one-sided or two-sided effects on a region's firm-level log-TFP distribution. The results indicate that for lower percentiles, selection is more dominant in the case of Taiwanese SMEs compared to sorting in the case of Korean SMEs.

7. Discussion of empirical results

An analysis of the empirical results is divided into five parts as follows:

(i) Non-parametric comparisons are made of the firm-level log-TFP distributions in the aggregate manufacturing sector located in the three identified regions. This analysis helps in

understanding the extent to which policy intervention may act as a productivity shock and disturb the equilibrium where more productive firms are supposedly always located in large cities. Here, the highest mean log-TFPs are for firms located in large cities and the lowest mean log-TFPs are for firms located in small cities with the mean log-TFPs for science park-firms lying between the two, see figure 1. This shows that factors driving productivity gains of firms located in large cities are not affected by policy incentives elsewhere, although the establishment of science parks does lead to regional productivity growth.

(ii) A comparison is made between the inter-regional productivity distributions for SMEs. The results show that science park incentives are not sufficient to increase significantly the productivity of SMEs. It seems that the national level economic model has such a strong influence, that regional policies cause a weak impact. The log-TFP distribution for SMEs and the regional spread are shown in figure 2, indicating that policy supporting SMEs is much more effective in the case of Taiwan as most SMEs are in high-productivity regions, i.e., large cities or science park cities. Moreover, the creation of science parks has the greatest influence on the productivity of SMEs in Taiwan where they have the highest mean productivity level. This finding is in sharp contrast to similar analysis for South Korea where SMEs located in science parks have the lowest mean productivity level.

(iii) The empirical methods used to determine the policy premium of science park intervention on SMEs, using regression estimates and matching techniques confirm two points. The regression results indicate a correlation between higher levels of firm productivity and choice of location in a science park, which is positive for both Taiwan and South Korea, but only statistically significant in the case of Taiwan. The results from using the matching technique indicate that in Taiwan the average treatment effect is statistically significant, SMEs located in a science park having 12

percent higher TFP and the treatment effect is also statistically significant, TFP being 8 percent higher. By contrast in South Korea, the average treatment effect is negative but not statistically significant, while the treatment effect is positive and statistically significant, indicating that treated SMEs exhibit 13 percent higher TFP. As the literature considers the average treatment effect on the treatment less restrictive than the average treatment effect (Caliendo and Hujer, 2006), the support mechanism for Korean science parks can be interpreted as more rewarding than for their Taiwanese counterparts.

(iv) The competitive selection and spatial sorting patterns indicate how far incentives offered through science parks are able create a competitive or a protective economic environment for science park incumbent SMEs. In the case of Taiwan, high-productivity SMEs sort into science parks and low-productivity SMEs are forced to exit due to competitive selection. The situation is quite different in the case of South Korea where both low and high-productivity SMEs self-select into science parks indicating a double-sorting pattern similar to that described in Forslid and Okubo. Based on these findings it can be concluded that science parks in Taiwan generate a competitive environment whereas in South Korea the policy incentives act as a shield from market competition for low productivity SMEs. A review of figure 3, which graphically represents the β -profile for various percentiles estimated using equation (3), supplements these findings. The inverted S shape observed in case of South Korea indicates prevalence of double sorting as highlighted in Forslid and Okubo. By contrast, the profile for Taiwan is different in shape, both one-sided sorting by high productivity SMEs, and competitive selection for low productivity SMEs being observed.

(v) Finally, with respect to the impact of agglomeration versus selection, a region-wise comparison of the summary log-TFP distribution statistics is made for both Taiwan and South

Korea. Following Syverson (2004), the mean and minimum of the log-FTP distributions are used as indicators of rightward shift and left truncation. Based on the results reported in table 2 it is consistently found that although firms located in large cities benefit most from agglomeration economies, they also face the highest level of competitive selection. The results also indicate that the creation of science parks raises the level of TFP by a factor of four as compared to small cities, without causing a proportionate increase in the level of competition.

8. Summary and conclusion

The overwhelming success of a few science parks across the globe has convinced policymakers to provide for state-sponsored support to overcome innovation market failures. As this support has been made available from public funds it is critical that policy for establishment of science parks be subject to an appropriate evaluation process. More importantly, the gap in the available literature on a uniform methodology for performance evaluation of science parks indicates that the debate on effectiveness of science parks is still considered to be open (Salvador and Rolfo, 2011). Therefore, the research presented in this paper is an attempt to bridge the gap and to develop a consistent methodology for policy evaluation to ensure that empirical findings are objective and can form the basis for substantive policy recommendation(s).

The findings presented in this paper confirm that the impact of industrial clusters such as science parks is not homogenous across firms and the resultant productivity shock at the aggregate level of manufacturing is weak. The results of the current paper clearly point out that purposeful utilization of the policy is only possible if science park incentives are offered to firms that have strong production linkages with industries considered to be on the “national comparative advantage” list. Clusters managed in this way will add to the productivity of the region and

contribute substantially in removing regional disparities. The evidence that this has only been partially achieved is the lagging productivity distribution of science park firms.

For SMEs the research indicates that provision of a protective environment or tax credits, etc., is not sufficient to stimulate growth and development. Therefore, it can be seen in the case of South Korea that even after considerable time, the productivity-level of SMEs is not competitive. As the national model in South Korea has supported growth of large conglomerates, an alternative approach might be to develop a network of support between conglomerate firms and SMEs so that SMEs benefit from the growth of large firms. Otherwise, science park incentives will continue to insulate firms from the competition they might face in open markets.

References

- Abadie, A., & Imbens, G.W. (2006). Large sample properties of matching estimators for average treatment effects. *Econometrica* 74(1), 235-267.
- Ackerberg, D., Benkard, C. Lanier, Berry, S., & Pakes, A. (2007). Econometric tools for analyzing market outcomes. In Heckman, J.J., & Leamer, E.E. (Eds.), *Handbook of econometrics*, Amsterdam: North-Holland.
- Ahn, C.Y. (2001). A search for robust East Asian development models after the financial crisis: mutual learning from East Asian experiences. *Journal of Asian Economics*, 12(3), 419-443.
- Amsden, A.H. (1989). *Asia's next giant: South Korea and late industrialization*, Oxford: Oxford University Press.
- Arimoto, Y., Nakajima, K., & Okazaki, T. (2009). Agglomeration or selection? The case of the Japanese silk-reeling industry 1909-1916. RIETI Discussion Paper Series 10-E-003. Tokyo: The Research Institute of Economy Trade and Industry.
- Baldwin, R., & Okubo, T. (2006). Heterogeneous firms, agglomeration and economic geography: spatial selection and sorting. *Journal of Economic Geography* 6(3), 323–346.
- Caliendo, M., & Hujer, R. (2006). Micro-econometric estimation of treatment effects - An overview. In Hübler, O, & and Frohn, J. (Eds.), *Modern econometric analysis: Surveys on recent developments*, Berlin: Springer.
- Chung, S., (1999). Korean innovation policies for SMEs. *Science and Public Policy* 26(2), 70-82.
- Ciccone, A., & Hall, R.E. (1996). Productivity and the density of economic activity. *American Economic Review* 86(1), 54-70.
- Combes, P-P, Duranton, G., Gobillon, L., Puga, D., & Roux, S. (2012). The productivity advantages of large cities: distinguishing agglomeration from firm selection. *Econometrica* 80(6), 2543-2594.
- De Loecker, J. (2007). Product differentiation, multi-product firms and estimating the impact of trade liberalization on productivity. NBER Working Paper No. 13155. Cambridge, MA: NBER.
- Emerging Markets Information Service (EMIS). New York: Internet Securities.
- Forslid, R., & Okubo, T. (2014). Spatial relocation with heterogeneous firms and heterogeneous sectors. *Regional Science and Urban Economics* 46(2), 42–56.
- Hall, C., & Harvie, C. (2003). A comparison of the performance of SMEs in Korea and Taiwan: policy implications for turbulent times. Faculty of Business – Economics Working Paper 03-05. Wollongong: University of Wollongong.
- Hasan, S., Faggian, A., Klaiber, A., & Sheldon, I. (2016). Agglomeration economies or selection: an analysis of Taiwanese science parks. *International Regional Science Review* (forthcoming).
- Hassink, R. (2002). Regional innovation support systems: recent trends in Germany and East Asia. *European Planning Studies* 10(2), 153-164.
- Heckman, J.J. (1979). Sample selection bias as a specification error. *Econometrica* 47(1), 153–161.
- Ito, T., & Krueger, A.O. (1995). *Growth Theories in Light of the East Asian Experience*. Chicago, Ill: Chicago University Press.
- Kim, J-I., & Lau, L.J. (1994). The sources of economic growth of the East Asian newly industrialized countries. *Journal of the Japanese and International Economies* 8(3), 235-271.

- Kim, K.S., & Park, J-K. (1985). *Sources of economic growth in Korea: 1963-1982*, Seoul: Korea Development Institute.
- Kim, L. (1997). *Imitation to innovation: The dynamics of Korea's technological learning*, Cambridge, MA: Harvard Business School Press.
- Kim, L., & Nugent, J.B. (1994). The Republic of Korea's small and medium size enterprises and their support system. Policy Research Working Paper 1404. Washington DC: The World Bank.
- Krugman, P. (1994). The myth of Asia's miracle. *Foreign Affairs* 73(6), November/December, 62-78.
- Levinsohn, J., & Petrin, A. (2003). Estimating production functions using inputs to control for unobservables. *Review of Economic Studies* 70(2), 317-342.
- Lien, W-J., Wang, J-C., Wang, S-W., & Hsu, S-C. (2010). The economic impact of Taiwan's investment tax credits and its direction of adjustment. *International Journal of Technology Management* 49(1-3), 140-154.
- Marshall, A. (1890). *Principles of Economics*, London: Macmillan.
- Martin, P., Mayer, T., & Mayneris, F. (2011). Public support to clusters: a firm level study of French 'local productive systems'. *Regional Science and Urban Economics* 41(2), 108-123
- Melitz, M.J. (2003). The impact of trade on intra-industry reallocations and aggregate industry productivity. *Econometrica* 71(6), 1695-1725.
- Melitz, M.J., & Ottaviano, G.I.P. (2008). Market size, trade and productivity. *Review of Economic Studies* 75(1), 295-316.
- National Statistics. (2010). Taiwan: Directorate-General of Budget, Accounting and Statistics Executive Yuan (DGBAS).
- Nelson, R.R. (1996). *Sources of economic growth*, Cambridge, MA: Harvard University Press.
- OECD. (1996). *Reviews of national science and technology policy: Republic of Korea*, Paris: OECD.
- Okubo, T., Picard, P.M., & Thisse, J-F. (2010). The spatial selection of heterogeneous firms. *Journal of International Economics* 82(2), 230-237.
- Okubo, T., & Tomiura, E. (2012). Industrial relocation policy, productivity, and heterogeneous plants: evidence from Japan. *Regional Science and Urban Economics* 42(1-2), 230-239.
- Olley, G. S., & Pakes, A. (1996). The dynamics of productivity in the telecommunication equipment industry. *Econometrica* 64(6), 1263-1297.
- Park, S.O. (1998). Local innovation systems of small and medium-sized enterprises in Korea. Paper presented at the Annual Conference of the IGU Commission on the Organization of Industrial Space, Seville.
- Phan, P., Siegel, D.S., & Wright, M. (2005). Science parks and incubators: observations, synthesis and future research. *Journal of Business Venturing* 20(2), 165-182.
- Rodrik, D. 1994. Getting interventions right: how South Korea and Taiwan grew rich. NBER Working Papers 4964. Cambridge, MA: NBER.
- Rosenthal, S.S., & Strange, W.C. (2004). Evidence on the nature and sources of agglomeration economies. In Henderson, V., & Thisse, J-F. (Eds.), *Handbook of regional and urban economics*, Amsterdam: North Holland.
- Salvador, E., & Rolfo, S.E. (2011). Are incubators and science parks effective for research spin-offs? Evidence from Italy. *Science and Public Policy* 38(3), 170-184.

- Seong, S. (1995). Small and medium-sized enterprises and the structural adjustment of the Korean economy. In Park, E.Y. (Ed.), *Small and medium sized enterprises and economic development*, Seoul: Korea Development Institute.
- Statistics Korea. (2014). Seoul: Price Statistics Team, Economic Statistics Department, Bank of Korea (KOSTAT).
- Storey, D.J., & Tether, B.S. (1998). Public policy measures to support new technology-based firms in the European Union. *Research Policy* 26(9), 1037-1057.
- Syverson, C. (2004). Market structure and productivity: a concrete example. *Journal of Political Economy* 112(6), 1181-1222.
- Van Beveren, I. (2007). Total factor productivity estimation: a practical review. LICOS Discussion Paper Series 182/2007. Catholic University of Leuven: LICOS Centre for Institutions and Economic Performance.
- World Bank. (2014). *World development indicators*, Washington DC: World Bank.
- Young, A. (1995). The tyranny of numbers: confronting the statistical realities of the East Asian growth experience. *Quarterly Journal of Economics* 110(3), 641-680

Table 1
Regional distribution of firms and SMEs

Region	All Firms		SMEs	
	Taiwan	South Korea	Taiwan	South Korea
Small City	1090	987	503	576
Science Park	1174	780	521	391
Large City	2382	3299	1240	1774

Table 2
Production function coefficients for firms

Model/Variables	Taiwan			Korea		
	OLS	IV/2SLS	Olley-Pakes	OLS	IV/2SLS	Olley-Pakes
Capital	0.37*** (0.0118)	0.56*** (0.017)	0.29 ** (0.101)	0.66*** (0.019)	0.56*** (0.021)	0.13 * (0.203)
Labor	0.56*** (.0158)	0.21 *** (0.0108)	0.47*** (.029)	0.18*** (0.012)	0.21 *** (0.014)	0.39*** (0.018)
R-squared	0.62	0.57		0.42	0.57	

Notes: * Significant at 10% level, **significant at 5% level, and *** significant at 1% level

Table 3
Region-wise log-TFP distribution statistics

Statistics	Taiwan			South Korea		
	Small City	Science Park	Large City	Small City	Science Park	Large City
N	1090	1174	2382	987	780	3299
mean	4.106923	8.32283	11.76685	3.74814	7.700501	10.23615
max	8.708421	12.10286	17.08633	7.668521	12.15671	16.47615
min	-2.43337	1.005013	4.605112	-1.97747	2.925614	5.438199
range	11.14179	11.09784	12.48122	9.645994	9.231099	11.03795
variance	1.089898	1.201957	1.247379	0.898821	1.250404	1.734177
p10	2.932698	6.96137	10.49661	2.673442	6.423069	8.733301
p25	3.461043	7.634048	11.01647	3.192485	6.961631	9.353257
p50	4.063416	8.291471	11.66475	3.713572	7.623936	10.11305
p75	4.691591	8.983652	12.43476	4.324795	8.39128	10.9753
p90	5.439116	9.73185	13.19089	4.945438	9.115471	11.89248
p95	5.90151	10.1574	13.67761	5.36431	9.66293	12.70057
p99	6.822562	11.15639	14.81686	5.999806	10.62025	14.02616
IQR	1.230548	1.349604	1.418283	1.13231	1.429649	1.622047

Table 4
Regression and matching results

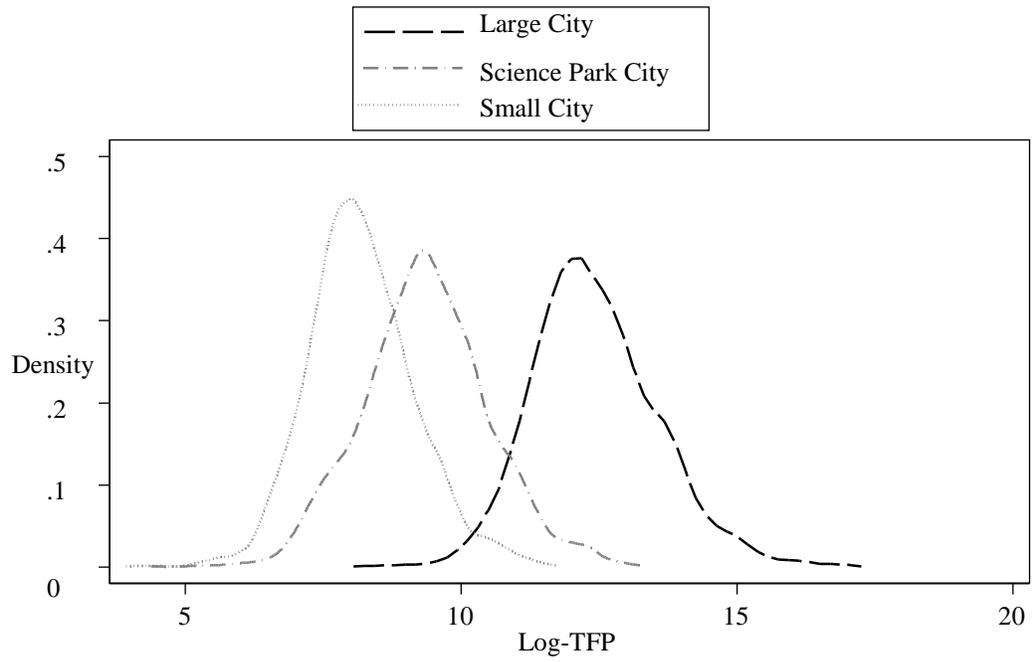
Dependent variable	<i>Log TFP</i>					
	Taiwan			South Korea		
Variables	OLS	Average treatment effect	Treatment effect	OLS	Average treatment effect	Treatment effect
<i>Science Park</i>	0.08*	0.124*	0.086*	0.05	-0.003	0.131*
	(0.05)	(0.074)	(0.0478)	(0.05)	(0.051)	(0.074)
<i>Employment (Log)</i>	0.039*			0.186		
	(0.020)			(0.039)		
<i>Capital (Log)</i>	0.276***			0.396***		
	(0.015)			(0.023)		
Observations	1933			2502		
R-squared	0.02			0.35		

Notes: *Significant at 10% level, **significant at 5% level, and *** significant at 1% level
Robust standard errors in parenthesis, clustered on industry.

Table 5*β* Coefficients for science park SMEs in Taiwan and South Korea

Percentile	p1	p5	p10	p25	p50	p75	p90	p95	p99
Taiwan	-0.00956*	-0.00137*	0.00209*	0.00233**	0.00301*	-0.00032	-0.00025	0.000246	-0.00162*
South Korea	-0.00463*	0.00246*	0.000862	3.86E-05	0.000351	0.00139	0.000822	-0.0015*	0.00376*

Productivity distribution-Taiwan



Productivity distribution-South Korea

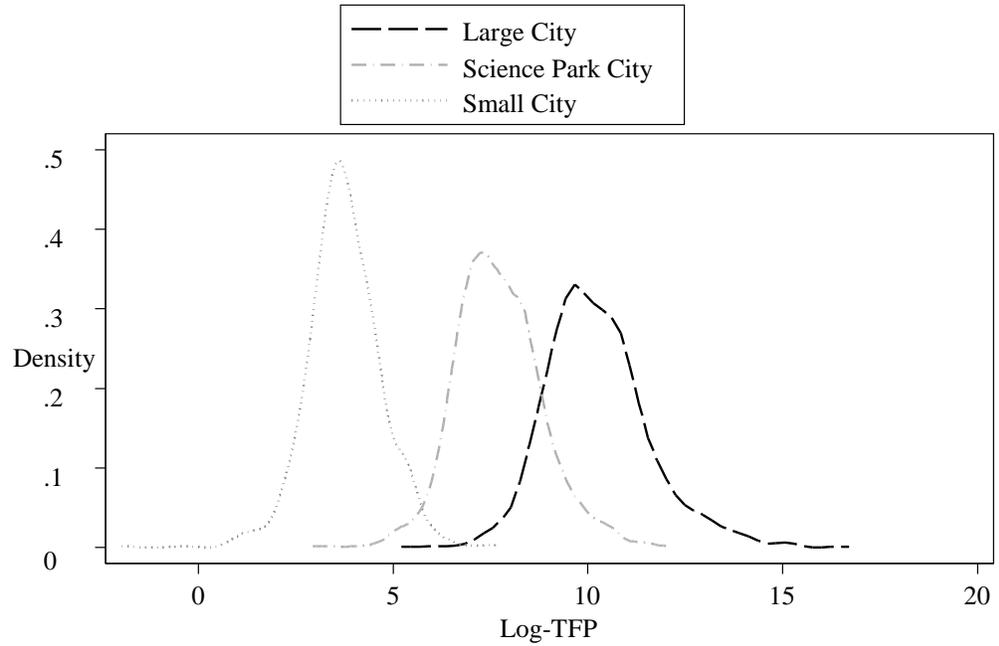


Fig.1 Region-wise productivity distribution plots for aggregate manufacturing in Taiwan and South Korea

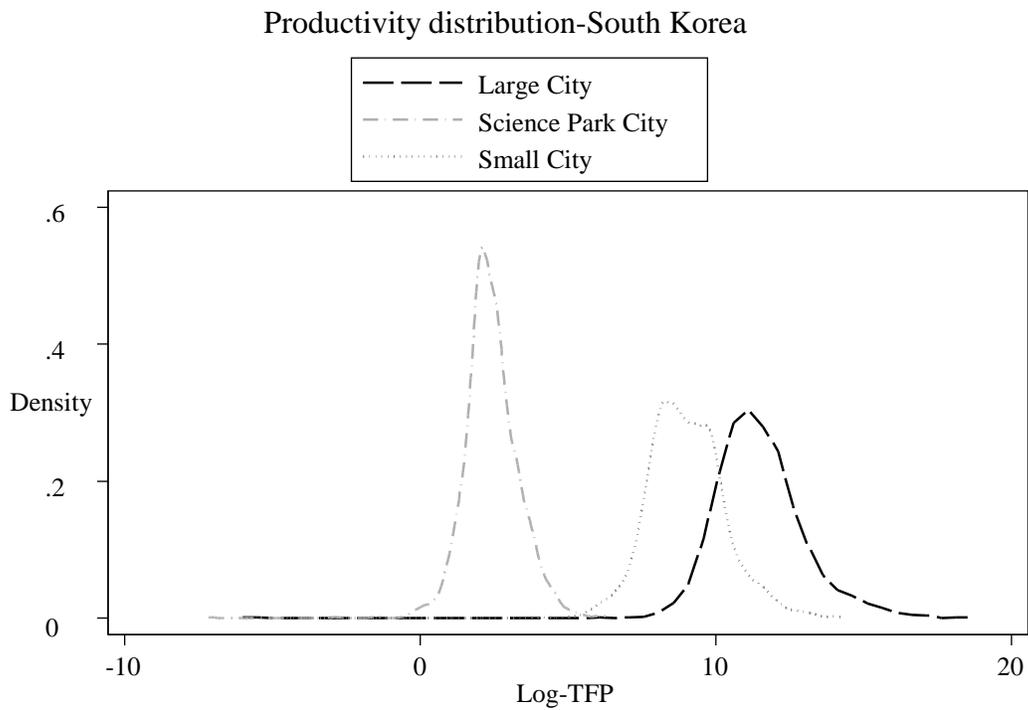
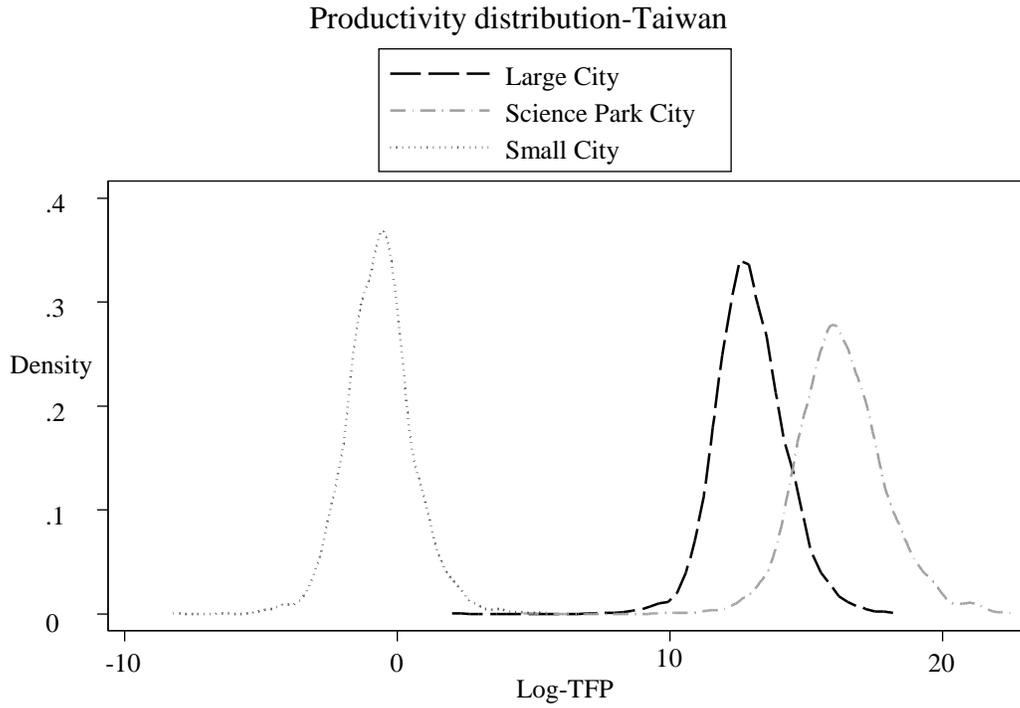


Fig.2 Region-wise productivity distribution plots for SMEs in Taiwan and South Korea

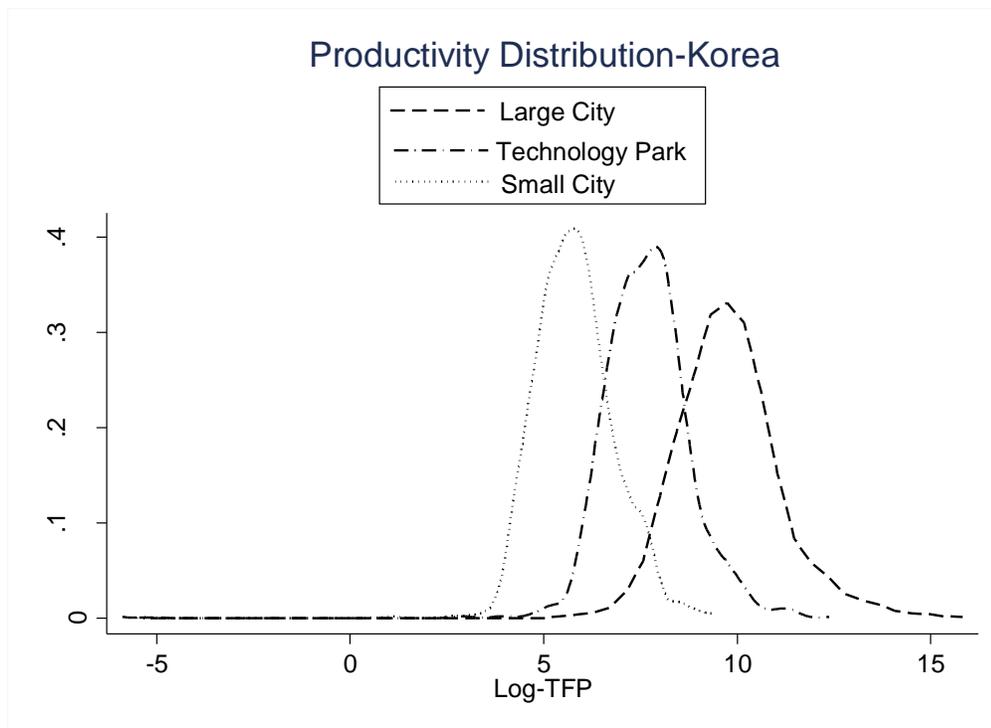
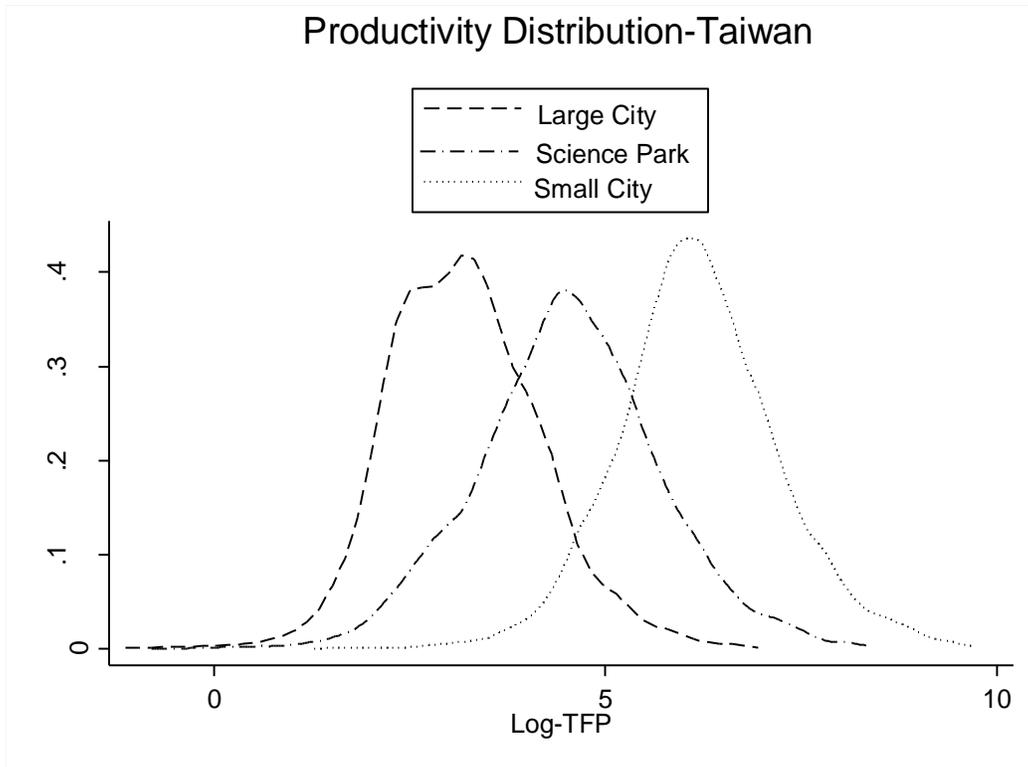


Fig.3 Region-wise productivity distribution plots for Large Firms in Taiwan and South Korea

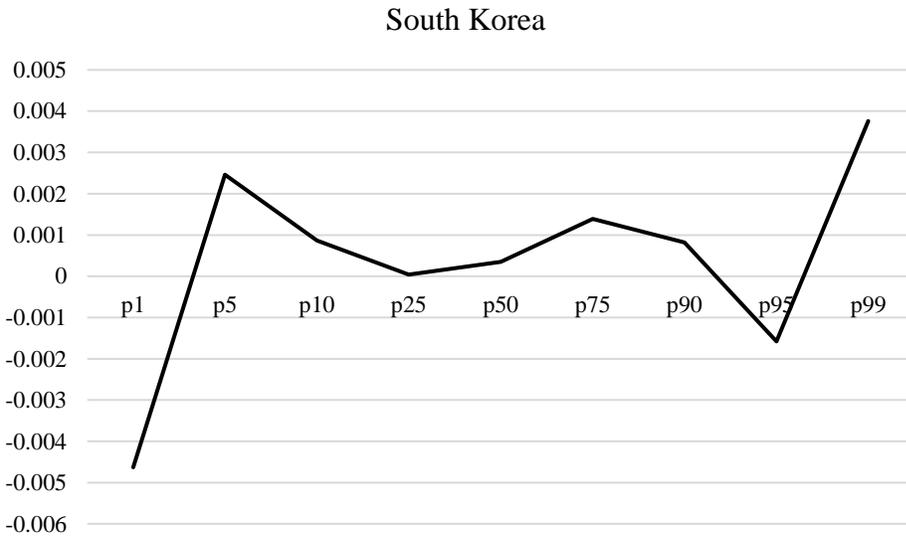
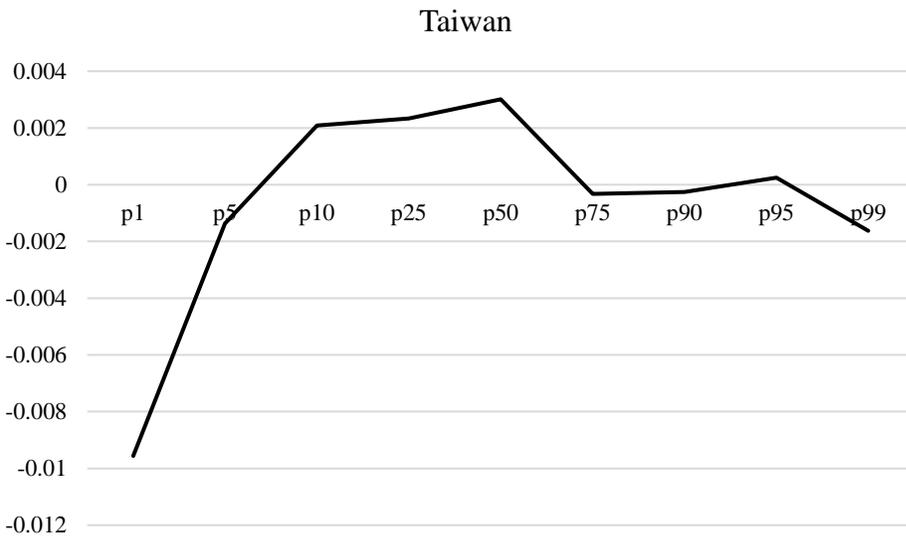


Fig. 4 β profiles for SMEs in science parks