Regional innovation policy in Taiwan and South Korea:
Impact of science parks on firm-productivity distributions

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Abstract

This paper evaluates the effectiveness of regional innovation policy creating science parks. 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. Using firm-level data for Taiwan and South Korea, we find that the impact of agglomeration and selection is heterogeneous across firm-types. Analysis of specific industries reveals that there is a positive relationship between the technology-intensity of the production process and firm-level productivity, and the productivity gains of small and medium-sized enterprises are higher in Taiwan. Overall, the empirical evidence suggests that policy establishing science parks can generate real productivity improvements if the incentives offered are industry-specific, otherwise such incentives may end up protecting inefficient firms.

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. However, there is a lack of consensus on the appropriate methodology for evaluating the effectiveness of policy instruments such as technology incubators, and this exercise becomes even more complex if the overall economic models pursued at the national level are different. The dominance of the small and medium enterprise (SME) network model in Taiwan and the scale-based technological development model in South Korea requires developing a strategy for analysis that is not influenced by scale. With this objective, we follow a regional economics approach that analyzes and compares the total factor productivity (TFP) distribution of firms located in science parks with firms located elsewhere.

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 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. Therefore, this paper is an

attempt to examine the effectiveness of these policy instruments through comparative analysis of regional productivity distributions for firms 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 causes of higher firm-level productivity associated with 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, high-productivity firms may sort into large cities in order to take advantage of the economic benefits of large markets (Baldwin and Okubo 2006). The presence of multiple explanations for firm productivity not only complicates the analysis but also renders it hard to pin down the actual factor(s) driving the productivity-level of firms located in large cities and industrial clusters.

A review of the regional economics literature shows that the focus has largely remained on the effects of large cities (Rosenthal and Strange, 2004), small cities (Gabe, 2004) and industrial clusters (Ciccone and Hall, 1996; Cooke, 2002) on productivity, but a detailed study of the effect of science parks on productivity is still missing. There are three main issues with the current literature on the effect of science parks on productivity. First, site-specific methodologies, such as the case study of 72 US parks by Luger and Goldstein (1991) and 45 Italian parks (Colombo and Delmastro, 2002), are often adopted, making generalization difficult and leaving little margin for meaningful policy recommendations. Second, the empirical evidence for firm

profitability, survival rates, employment growth etc., is generally mixed (Löfsten and Lindelöf, 2002). Third, and most importantly, the variable of interest used for the evaluation of science parks might suffer from selectivity bias as pointed out by Phan, Siegel and Wright (2005). For example, an endogeneity problem may arise if the analysis uses the rate of firm survival as the dependent variable, given that science incubators are designed specifically to increase the life span of firms.

Our contribution addresses these issues by presenting a research methodology not restricted to a particular estimation model or specific park objective(s), but based instead on a robust theoretical foundation which provides a solid basis for generalization and policy evaluations of different contexts.

From a policy perspective, the results from this study suggest that efficiency in the utilization of public incentives, offered via science parks, increases with the technological level of the industry. Moreover, 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 if extended to industries that are not technology-intensive. This latter kind of support does not lead to productivity growth as is evident in the case of SMEs in South Korea. Lastly, tax credits and tariff exemptions against research and development (R&D) expenses generally favor large corporations and do little to support innovation and growth in SMEs.

2. Methodology and significance of the study

The methodology adopted in this paper is based on an extension of Combes et al. (2012). Broadly, productivity distributions for firms in cities and science parks are simultaneously analyzed to identify the impact of agglomeration and selection effects. The analysis includes

estimates for aggregate manufacturing and also specific industrial sectors defined on the basis of technology-intensity of the production process. The detailed strategy used to evaluate the effectiveness of science parks includes: (i) estimating the impact of science parks on the TFP of incumbent firms; (ii) comparing regional growth patterns while controlling for the impact of science parks; (iii) segregating the effects of agglomeration from selection to identify actual drivers of firm productivity; and (iv) assessing the impact of incubation policies on the growth of SMEs.

In order to implement this empirical strategy, and drawing on a model developed by Combes et al., a firm-level panel data set for the period 2010 to 2012 covering Taiwan and South Korea, is used to analyze simultaneously, productivity distributions for firms in cities and science parks, at the level of both aggregate manufacturing and also specific industries. The industries are chemical manufacturing, computer and electronics manufacturing, and scientific and technical services, which differ on the basis of the technology-intensity of their production process, measured by the percentage of their workforce employed in technology-oriented jobs (Hecker 2005). 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. With respect to definitions of an SME, they are similar but not identical in Taiwan and South Korea (Hall and Harvie 2003). 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.

Using these delineations, and controlling for potential bias, the log-TFP distribution of firms for each regional market is estimated.

The key results of the study are as follows. First, at the aggregate manufacturing level the results for both Taiwan and South Korea indicate that the productivity shock provided by science park incentives is not strong enough to help incumbent firms cross over the mean productivity level of firms located in large cities (see Figure 1). Second, the analysis of individual industries generates the surprising result that only firms employing a higher proportion of technology-oriented workers display an increase in productivity when located in a science park. As the proportion of technology-oriented workers drops, so does the level of mean productivity (see Figures 2-4). Third, in light of the objective of supporting innovation and growth in SMEs through science parks, the productivity distributions indicate that they are much more effective in the case of Taiwan compared to South Korea (see Figure 5). Finally, specific summary statistics, relating to the log-TFP distributions for firm, covering the three markets in each country are analyzed in order to separate agglomeration from competitive selection effects, the results indicating that in both countries, the latter 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 and industrial activity. As noted earlier, three main explanations have been presented for these observed phenomena: agglomeration economies, competition-based selection, and sorting.

In the case of agglomeration economies associated with urban regions, a detailed review of relevant studies and their findings is reported in Rosenthal and Strange (2004), who themselves estimate that if city size is doubled, productivity increases by 3 to 8 percent. 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 their 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 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.

There is also a strand of the literature indicating sorting of high-productivity firms into large markets. This sorting phenomenon raises serious endogeneity concerns when evaluating the impact of spatial-clustering policies on firm productivity (Baldwin and Okubo 2006). Thus the sorting phenomenon is likely to confound much of the existing empirical literature on firm

productivity along with the estimation of agglomeration benefits and congestion effects associated with clustering of firms.

The theoretical basis of this paper is based on the nested model of Combes et al. (2012) which distinguishes agglomeration from selection effects by introducing agglomeration economies in the manner of Fujita and Ogawa (1982) and Lucas and Rossi-Hansberg (2002), into an extended version of Melitz and Ottaviano. Under monopolistic competition with free entry, the downward-sloping demand curves of incumbent firms will shift inwards as new firms enter with differentiated products. Eventually in equilibrium, demand curves are tangent to firms' downward-sloping average cost curves, as the number of competing firms increase at one location. The reduction in profits results in reduced survival for low-productivity firms. Combes et al. structurally parameterize the magnitude of agglomeration and selection, and then estimate the strength of these two effects using two-digit industry-level data for large and small cities.

In this paper, a separate region housing science parks is added to the analysis in order to evaluate the effectiveness of the policy establishing these entities. Besides aggregate manufacturing level analysis, we also focus on the sample of specific industries defined in the previous section. This is undertaken in order to control for industry-level heterogeneity such as that due to differences in the form of production functions, market conditions for the supply of factors and demand for output etc. The choice of sectors is made in order to capture the impact of policy on firm productivity, as the technology-intensity of the production process varies. This study has another dimension where the analysis is restricted to the productivity gains in SMEs. Finally the extent of agglomeration and selection is identified by comparing the regional productivity distributions of firms in each country.

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The empirical analysis conducted in this paper depends on the estimation of a bias-free TFP distribution. The estimation methodology employed here is developed by Olley and Pakes (1996) and Levinsohn and Petrin (2003). These techniques are robust to the prime econometric concern of simultaneity which causes endogeneity in choice of factors in the production function. In addition, the former method also corrects the selectivity bias driving sorting behavior and is used whenever the dataset indicates firms exit from a market.

Many definitions of science parks have been proposed, mostly by professional organizations (UNESCO, 2006) and by parks themselves as a way to define their activities. Common among these definitions is that a park is a type of public-private partnership that fosters knowledge flows, often between park firms and universities and amongst park firms, and contributes to regional economic growth and development. Empirical support for agglomeration effects in science parks is provided by Jaffe (1989), Jaffe, Trajtenberg, and Henderson (1993), Audretsch (1998), and Rothaermel and Thursby (2005a, 2005b).

A comprehensive overview of the research related to science park performance is detailed in Dabrowska (2011). Most of the studies included in the review focus on the impact of science park intervention on innovative capability, survival rate, profitability and job creation. The empirical evidence is largely mixed and inconclusive (Monck, 2010), leaving little margin for any policy recommendation(s).

4. Economic growth and innovation policy in Taiwan and South Korea

Economic growth observed in East Asia has inspired considerable academic research to identify 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 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.

In the case of Taiwan, a well-known industrial technology policy has been the *Statute for Upgrading Industries* (SUI) which deals with provision of tax credits against R&D expenses (Lien et al. 2007). Figures show that the amount of R&D expenditure increased steadily from NT$94.828 billion in 1992 to NT$280.980 billion in 2005. Correspondingly, the amount of R&D tax credits increased more than ten times from NT$1.529 billion in 1992 to NT$16.318 billion in 2005. It is estimated that these tax credits account for approximately one third of the NT$100 billion of total tax revenue loss for the Taiwanese government annually (Lien et al.), which is close to 1 percent of Taiwan's GDP. 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 comparison to Taiwan, South Korea witnessed an increase in total R&D investment from ₩10.5 billion in 1970 ($28 million) to ₩7.89 trillion ($10.25 billion) in 1994 which corresponds

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to an increase from 0.32 to 2.61 percent of South Korean GDP (Zutshi 2009). A review of the World Development Indicators (World Bank, 2014) indicates that between 2003 and 2011 there was a persistent increase in R&D expenditure, its share of GDP increasing from 2.5 to 4 percent. However, even with increasing governmental involvement in technology policy, studies point out several weaknesses in South Korea's innovation system such as a lack of interplay between universities and the private sector; a dearth of diffusion mechanisms to transfer research results from public research establishments to industry and particularly to SMEs (Kim, 1997).

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 a science park. 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. Taiwan has had a long history of policy support for SME development. This policy has gone through a number of evolutionary stages, as the economy has developed and needs have changed (Seong 1995).

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 Park (1998) and

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Kim and Nugent (1994). Chung (1999) however, is of the opinion that the differences in these findings is largely due to lack of a systematic evaluation procedure.

5. Model and estimation strategy

5.1 *Outline of model*

Agglomeration effects impart higher productivity to cluster incumbents through transfer of knowledge and innovative ideas among workers, improvement in labor-matching, and sharing of commonly needed services among firms. These agglomeration effects, also termed as external economies of scale, offer benefits that are shared by all firms located in the cluster. On the other hand, owing to selection effects in clusters, intensification of competition shakes out less productive firms.

In order to distinguish between agglomeration and selection effects, we rely on theoretical analysis by Arimoto, Nakajima, and Okazaki (2009) and Combes et al. (2012). The model examines the implications of these two effects on the distribution of firm-level productivities in a given region. Intuitively, the agglomeration effect will shift the log-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 and thus cause 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 productivity among various regions. The salient features of the model, along with some key results are outlined as follows.

(i) Preferences and demand: consumers derive utility from differentiated varieties of manufactured goods and a homogeneous good. The latter is produced under constant returns to

scale using one unit of labor per unit of output. The differentiated goods are produced under a structure of monopolistic competition. By incurring a sunk-entry cost a firm is able to manufacture a differentiated good, using h units of labor per unit of output. The value of h differs across firms depending on their productivity which is randomly drawn, from a distribution with a known probability density function $g(h)$ common to all regions.

(ii) Production: in the monopolistically competitive industry, free entry ensures that firms enter until ex-ante profits are driven to zero. Using an optimal pricing rule, a zero cut-off profit condition for the mass of surviving firms N, can be derived, which is equivalent to the number of differentiated varieties produced in the region.

(iii) Agglomeration effects: each worker is assumed to supply a single unit of labor. If the agglomeration effect is present, it is assumed that labor productivity increases with the number of firms within a region. Thus the gain in productivity caused by external economies of scale, owing to the presence of N firms in the region, shifts the distribution of firms' log-TFP to the right.

(iv) Selection effect for different regions: for any region $r \in \{1, ..., R\}$, it is assumed that sunk-entry costs vary across regions based on the intensity of factor demands and provision of public policy incentives. Following Arimoto, Nakajima, and Okazaki, for each regional market the cut-off labor requirement increases for a unit increase in the entry cost faced by the firm. Hence, if entry costs are lower either because of some policy incentive or due to less competition in factor demands, this lowers the cut-off labor requirement of surviving firms. Reversing the argument, the cut-off productivity level in a region goes up as more and more firms compete with each other for the available supply of factors of production such as land, labor, etc. This

higher cut-off level is observed as the left truncation of the log-TFP distribution, which is the manifestation of the selection effect.

5.2 *Hypotheses*

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

(i) Hypothesis 1 (Agglomeration): agglomeration economies either due to specialization (localization) or diversification (urbanization) are likely to cause an increase in the mean and a rightward shift of the log-TFP distribution for the firms located in a region.

(ii) Hypothesis 2 (Selection): higher entry (sunk) costs in a region will increase the likelihood of a rise in the cut-off unit labor requirement and hence cause greater left truncation of the log-TFP distribution of surviving firms.

(iii) Hypothesis 3 (SME Performance): Taiwanese SMEs might outperform South Korean SMEs due to the latter having been subject to a turbulent and uncertain business environment (Gregory, Harvie, and Lee 2002).

5.3 *TFP estimation*

The econometric analysis conducted in this paper primarily hinges on generating unbiased estimates of factors of production. The log-TFP distribution of firms located in any region is then predicted from the residual of the equation. For this study firm-level TFP is calculated assuming that the technology for revenue generated is Cobb-Douglas in the factors of production:

$$Y_{it} = A_{it} K_{it}^{\beta_k} L_{it}^{\beta_l} , \tag{1}$$

where, for firm i at time t, Y_{it} is physical output, K_{it} and L_{it} are the factors of production, capital and labor, and A_{it} is the Hicks-neutral efficiency-level of the firm which is unobservable to the researcher. Equation (1) can be written in logarithmic form as:

$$y_{it} = \beta_0 + \beta_k k_{it} + \beta_l l_{it} + \varepsilon_{it}. \qquad (2)$$

From (1) and (2) it can be deduced that $\ln(A_{it}) = \beta_0 + \varepsilon_{it}$ where β_0 is the mean efficiency-level, across firms over time and ε_{it} is the deviation from the mean, and which can be further decomposed into an observable and unobservable component:

$$y_{it} = \beta_0 + \beta_k k_{it} + \beta_l l_{it} + v_{it} + u_{it}. \qquad (3)$$

In (3), firm-level log-productivity is given by $\omega_{it} = \beta_0 + v_{it}$, and u_{it} is the independent and identically distributed (iid) measurement-error. The productivity level can be obtained from (3) by taking the exponential of the estimated parameter ω_{it}.

5.4 *Possible sources of bias in TFP estimation*

The productivity estimate from (3) may suffer from either simultaneity or selection bias each of which is discussed in detail as follows:

(i) Simultaneity bias: an ordinary least squares (OLS) estimate of (3) is unbiased only if the factors of production are exogenous from the firm's productive efficiency. However, Marschak, Andrews, and William (1944), long ago indicated that these factors are not independently determined as firms themselves either observe or are able to predict their efficiency and hence determine the quantity of freely determined factors accordingly. As the firm's productivity is not observed by the econometrician, its correlation with factors of production causes simultaneity bias in the estimation (De Loecker 2007). Levinsohn and Petrin (2003) illustrate that for a two-factor production function where labor is the only variable factor and capital is quasi-fixed, the capital coefficient will be biased downward if a positive correlation exists between labor and capital.

(ii) Selection bias: a second issue raised by Olley and Pakes (1996) relates to the entry and exit of firms which were traditionally dealt with in TFP estimation by constructing a balanced panel, i.e., by omitting all firms that enter or exit over the sample period. However, several theoretical models, such as that of Hopenhayn (1992), predict that the growth and exit of firms is motivated to a large extent by productivity differences at the firm-level. Since low-productivity firms have a stronger tendency to exit than their more productive counterparts, omitting all firms subject to entry or exit is likely to bias the results. This has also been confirmed empirically by Fariñas and Ruano (2005) for Spanish manufacturing firms. Firm's knowledge about their productivity level ω_{it} prior to their exit, is likely to generate correlation between ω_{it} and the fixed factor capital (Ackerberg et al. 2007). This correlation has its origin in the fact that firms with a higher capital supply will, ceteris paribus, be able to withstand lower ω_{it} without exiting (Van Beveren 2010). In sum, the selection bias or "endogeneity of attrition"- problem will generate a negative correlation between ω_{it} and k_{it}, causing the capital coefficient to be biased downwards in a balanced sample.

5.5 *TFP estimation methods*

In this section, the techniques used for estimation of unbiased and consistent production function coefficients are described. As noted above, OLS estimates are likely to yield biased values of the coefficients. To avoid this, several methods are used to ensure robustness of the results. These include two stage least squares (2SLS) with instrumental variables (IV), the semi-parametric Olley and Pakes (1996) and the Levinsohn and Petrin (2003) techniques. Fixed effects estimation is not used as it depends on the strong assumption that productivity of firms is time-invariant. Also, as noted by Wooldridge (2009), the fixed effects estimator assumes strict exogeneity of the

factors of production which is not very likely and implies that factors are not affected by the firm's knowledge of productivity.

(i) Instrumental variables: one method to achieve consistency of coefficients in the production function is through use of IV for the endogenous independent variables, i.e., the freely alterable factors in the production function. Ackerberg et al. (2007) explain Greene's (2004) requirements for the selection of valid instruments for the estimation of TFP. First, the instruments need to be correlated with the endogenous regressors (factors of production). Second, the instruments should not enter the production function directly. Third, the instruments should not be correlated with the error term (and hence with productivity). Besides factor prices, demand shifters are sometimes used as instruments in the literature. Keeping in mind data availability, recent values of county-level wages and population density are used as a measure of demand shifters to overcome the endogeneity of factors problem.

(ii) Olley and Pakes methodology: these authors were the first to introduce a semi-parametric estimation algorithm that takes both the selection and simultaneity problem directly into account. This estimator solves the simultaneity problem by using the firm's investment decision as proxy for unobserved productivity shocks.

Selection issues are addressed by incorporating an exit provision into the model. At the start of each period, each surviving firm decides whether to exit or to continue its operations. If it exits, it receives a particular sell-off value. If it continues, it chooses an appropriate level of variable factors of production and investment. The firm is assumed to maximize the expected discounted value of net cash flows and investment and exit decisions will depend on the firm's perceptions about the distribution of future market structure.

Olley and Pakes' technique is based on three key assumptions. First, the only unobserved state variable is the firm's productivity which evolves as a first-order Markov process. Second, investment is monotonically related to productivity and hence during econometric analysis, non-negative values of the investment variable are required. This investment is shown as a function of capital and productivity, $i_{it} = i_t(k_{it}, \omega_{it})$. The monotonicity assumption allows its inversion as $\omega_{it} = h_t(k_{it}, i_{it})$, so that productivity can be expressed in terms of capital and investment. Third, deflation on the basis of industry level prices implies that all firms face the same prices (Van Beveren 2010).

The Olley and Pakes technique proceeds in two stages. In the first-stage regression, using the relationship in (3) the coefficients on the free factors of production are derived. The second stage evaluates the temporal productivity-level in order to compare it with the lower bound or the threshold. Using coefficients from the first stage and the survival probability and by applying a non-linear least squares method, the coefficient on the capital variable is estimated. Although Olley and Pakes' technique is robust to simultaneity and selectivity problems, the empirical estimation using it may return unreliable results if either the investment variable has non-positive values or there are no firms exiting the market. An alternative is to use the Levinsohn and Petrin method which takes care of the simultaneity problem by using intermediate factors of production as a proxy for productivity instead of investment.

6. Empirical analysis

6.1 *Data*

To determine the agglomeration and selection effects on firms' TFP in Taiwan and South Korea, firm-level data, disaggregated at the urban area-industry level, from the ISI Emerging Markets

Information Services (EMIS) are used here. The unbalanced panel data are for the years 2010 to 2012. The dataset has four main fields indicating the physical location, industry, operational status of the firm, and its listing and trading status on the stock market. The dataset also provides information about financial indicators relating to firms' balance sheet and income statements, such as non-current assets and sales revenues along with data on the profitability, liquidity and growth trend ratios. We extract information about each firm's total operating revenues, assets and number of employees to estimate the production function parameters. The industry classification is conducted at the 3-digit NAICS level, the specific categories being: chemical manufacturing (NAICS 325), computer and electronics manufacturing (NAICS 334), and scientific and technical services (NAICS 541).

The dataset is supplemented with urban area-level income and industry price data, available at the website of the National Statistics Office (DGBAS), Taiwan, and Statistics Korea (KOSTAT). These data are used to deflate the revenue Figures and form instrumental variables to be used with the 2SLS/IV estimation methodology.

6.2 *Data cleaning*

The raw data were cleaned using several steps: first, revenue was deflated by industry-level prices for the year 1996; second, using box plots, the data were examined for outliers, entities with top and bottom one percent TFPs being removed to avoid their influence on the results. This resulted in a final dataset of 4655 observations for Taiwan and 2260 observations for South Korea.

Table 1 shows the region-wise location of the chosen industries in the two countries. As these industries have a presence in all three regions, the geographical unit of estimation of each market is the relevant urban area. This division is justified, due to the fact that for big cities the

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market effects are likely to spillover to the entire urban area. In the case of science parks particularly the Hsinchu Science Park, ever increasing demand has forced a greater area in the relevant urban area being designated as the science park. For Taiwan the urban areas categorized as science parks are Hsinchu County, Tainan City, Yunlin City and Kaohsiung City whereas for South Korea the cities of Ansan, Busan, Changwon, Chuncheon, Daegu, Daejeon, Gyeongsan, Jeju, Pohang, Ulsan and Cheongwon County are categorized as science parks. The firms located in the Seoul science park are not included in the analysis as Seoul is categorized as a large city.

6.3 *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 Tables 2 and 3 respectively. The baseline TFP estimates are computed using OLS. The OLS estimate of (3) requires that $E(x_{it}\omega_{it}) = 0$, where x_{it} is any factor in the production function. As for the firm it is possible to observe or anticipate its productivity and thus decide the level of the factors of production so it is very likely that $E(x_{it}\omega_{it}) > 0$. The more flexible is the nature of the factor of production, the possibility of adjusting its level based on the expected productivity becomes more likely. In this estimation it may be difficult for the firm to change its capital but labor can be adjusted very easily in a short time. Statistics from the Durbin-Wu-Hausman test of endogeneity also confirm the non-reliability of the OLS estimates.

A review of first two columns of Tables 2 and 3 shows 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). To avoid the possible endogeneity

problem we employed the IV/2SLS method. However, the estimates obtained are likely to be biased due to the selectivity problem discussed above and 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 drawn for the cities with above and below the median population density and for the firms located in science parks. 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. Using these TFP estimates, the summary statistics of the log-TFP distributions were examined for each of the regions as detailed in Tables 4 and 5 for the two countries. It is evident that at the aggregate level, large cities have the highest mean value of log-TFP followed by that of science park firms. The selection is estimated using the minima of the distributions in each region. Comparison of shifts in mean and difference in minima shows that the impact of selection, although present, is less pronounced than agglomeration. Both of these results are in conformity with the findings of Combes et al. (2012).

6.4 *Discussion of results*

Analysis based on the empirical results can be divided into five parts:

(i) First we focus on non-parametric comparisons of the log-TFP distributions for firms in the 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 for the aggregate manufacturing sector, 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

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productivity gain in large cities are not affected by policy incentives elsewhere, although establishment of science parks does lead to regional productivity growth.

(ii) Next as the analysis becomes more industry-specific, firms in science parks are found to show varying trends in log-TFP distribution. The log-TFP distributions for the selected industries are shown in Figures 2, 3 and 4 respectively. In the case of intra-regional comparison of manufacturing firms in science parks, the results show that firms in the hi-tech computer and electronics industry have the highest mean log-TFP, whereas those in comparatively low-tech chemical manufacturing have a much lower value of log-TFP. This result confirms an earlier finding by Yang, Motohashi and Chen (2009) and suggests that within science parks, there is a direct relation between firm-level productivity and technology-intensity of the production process.

(iii) In terms of the results relating to inter-regional comparison, computer and electronics firms located in the large cities are the ones with the highest level of mean log-TFP, followed by those in science parks and then by the firms located in small cities (see Figure 2). However, as the technology-intensity of the production process is lowered, i.e., for the chemical manufacturing industry, firms in science parks lose their comparative advantage and end up with the lowest mean log-TFPs (see Figure 3). Inter-regional comparison for the scientific and technical services industry which employs a very high proportion of technology-oriented workers shows that firms located within science parks have higher mean log-TFP values in comparison to those located in large cities (see Figure 4).

(iv) A comparison is also made between the inter-regional productivity distributions for SMEs. The results show that science park incentives are not sufficient to help significant growth in SMEs. It seems that the national level economic model has such a strong influence, that

regional policies have a weak impact. The log-TFP distribution for SMEs and regional spread are shown in Figures 5 and 6. Figure 5 indicates that SME support policy 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 show 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.

(v) Finally, with respect to the impact of agglomeration versus selection, we perform region-wise comparison of summary statistics in case of Taiwan and South Korea. Following Syverson (2004), we consider the mean and minimum of the log-FTP distributions as indicators of rightward shift and left truncation. Using the results reported in Tables 4 and 5 we consistently find 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 creation of science parks provides a productivity boost that raises the level by a factor of two as compared to small cities without causing a proportionate increase in the level of competition.

7. 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,

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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 of this study 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 industry-specific incentives are designed and offered in science parks. There are a couple of possible strategies that could be adopted in this regard. First, firms in the high-tech sector, such as those involved in the design and development of computers, electronics, biotechnology etc., should be given priority of placement in a science park. Second, science park incentives should be 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. Thus we see that in case of South Korea even after decades of such measures the productivity-level of SMEs is not competitive. As the national model in South Korea has supported growth of large conglomerates, an alternate approach might be to develop a network of support between the conglomerates and SMEs so that SMEs benefit from the growth of the large firms. Otherwise, science park incentives will continue to insulate firms from the competition they might face in open markets. This concern is

on account of the survival of low-tech chemical manufacturing firms located in a science park with log-TFP productivity distributions that even lags that of small cities.

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Table 1: Industry/regional distribution of firms

	NAICS					
	325		**334**		**541**	
Region	**Taiwan**	**South Korea**	**Taiwan**	**South Korea**	**Taiwan**	**South Korea**
Large City	164	312	1039	264	79	317
Small City	69	288	484	522	23	133
Science Park	77	139	627	163	23	24

Table 2: Production function coefficients for firms in Taiwan

Model/Variables	OLS	IV/2SLS	OP
Capital	0.37***	0.56***	0.29 **
Labor	0.56***	0.21 ***	0.47**
R-squared	0.62	0.57	

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

Table 3: Production function coefficients for firms in South Korea

Model/Variables	OLS	IV/2SLS	OP
Capital	0.66***	0.56***	0.13 *
Labor	0.18***	0.21 ***	0.39***
R-squared	0.42	0.57	

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

Table 4: Region-wise Log-TFP distribution Statistics (Taiwan)
(AM: Large City, BM: Small City, SP: Science Park)

Statistics	BM	SP	AM
N	840	1427	2388
mean	4.106923	8.32283	11.76685
max	8.708421	12.10286	17.08633
min	-2.43337	1.005013	4.605112
range	11.14179	11.09784	12.48122
variance	1.089898	1.201957	1.247379
p10	2.932698	6.96137	10.49661
p25	3.461043	7.634048	11.01647
p50	4.063416	8.291471	11.66475
p75	4.691591	8.983652	12.43476
p90	5.439116	9.73185	13.19089
p95	5.90151	10.1574	13.67761
p99	6.822562	11.15639	14.81686
IQR	1.230548	1.349604	1.418283

Table 5: Region-wise Log-TFP Distribution Statistics (South Korea)
(AM: Large City, BM: Small City, SP: Science Park)

Statistics	BM	SP	AM
N	981	334	945
mean	3.74814	7.700501	10.23615
max	7.668521	12.15671	16.47615
min	-1.97747	2.925614	5.438199
range	9.645994	9.231099	11.03795
variance	0.898821	1.250404	1.734177
p10	2.673442	6.423069	8.733301
p25	3.192485	6.961631	9.353257
p50	3.713572	7.623936	10.11305
p75	4.324795	8.39128	10.9753
p90	4.945438	9.115471	11.89248
p95	5.36431	9.66293	12.70057
p99	5.999806	10.62025	14.02616
IQR	1.13231	1.429649	1.622047

Productivity Distribution-Taiwan
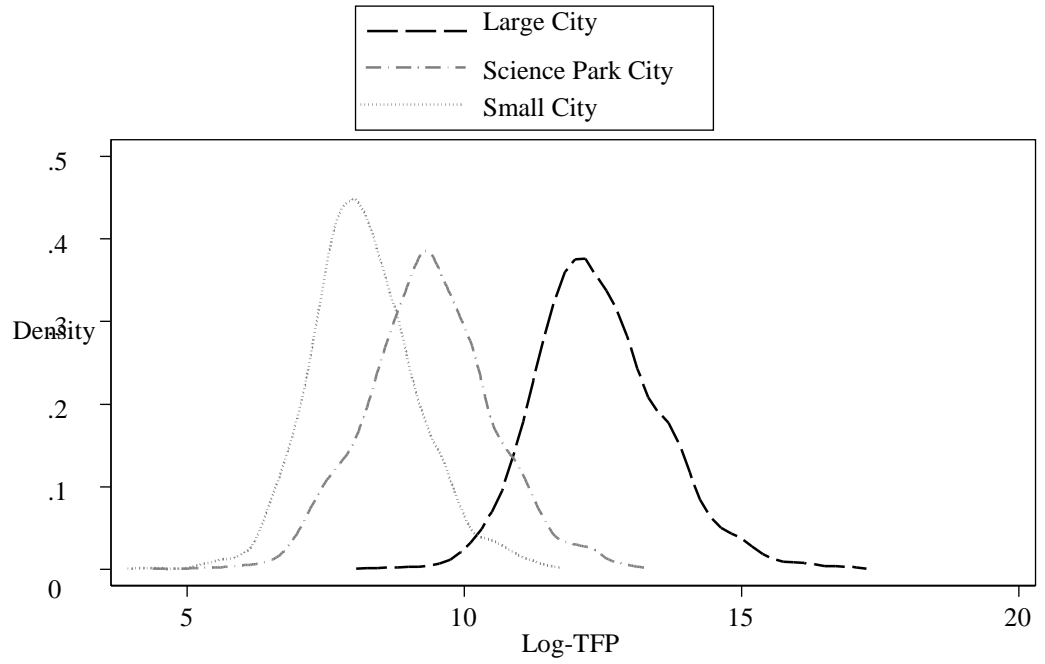
Productivity Distribution-South Korea
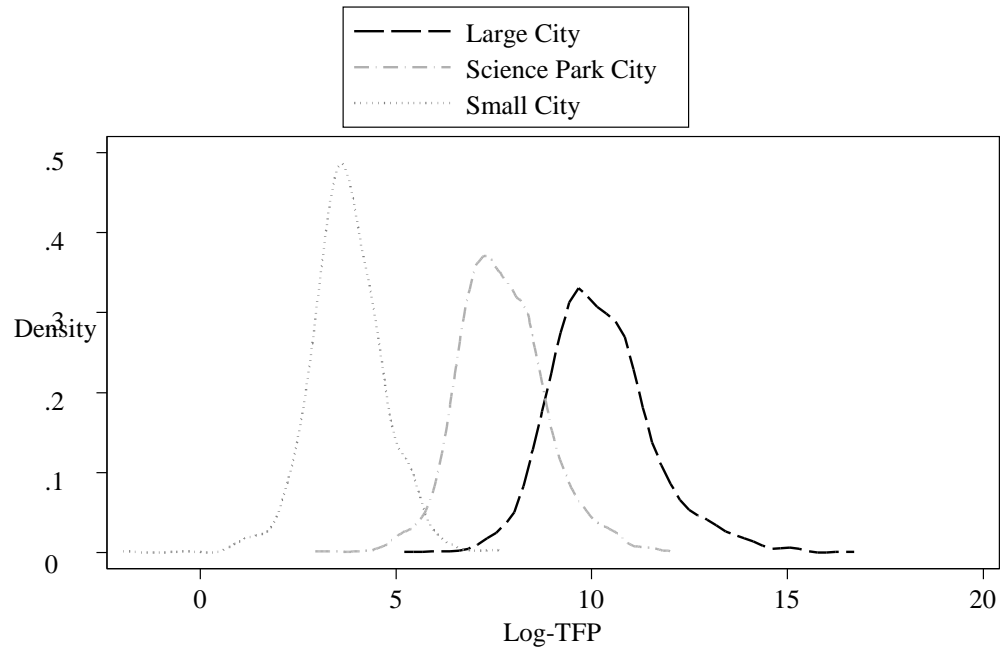
Figure 1: Region-wise productivity distribution plots for aggregate manufacturing in Taiwan and South Korea

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Productivity Distribution-Taiwan
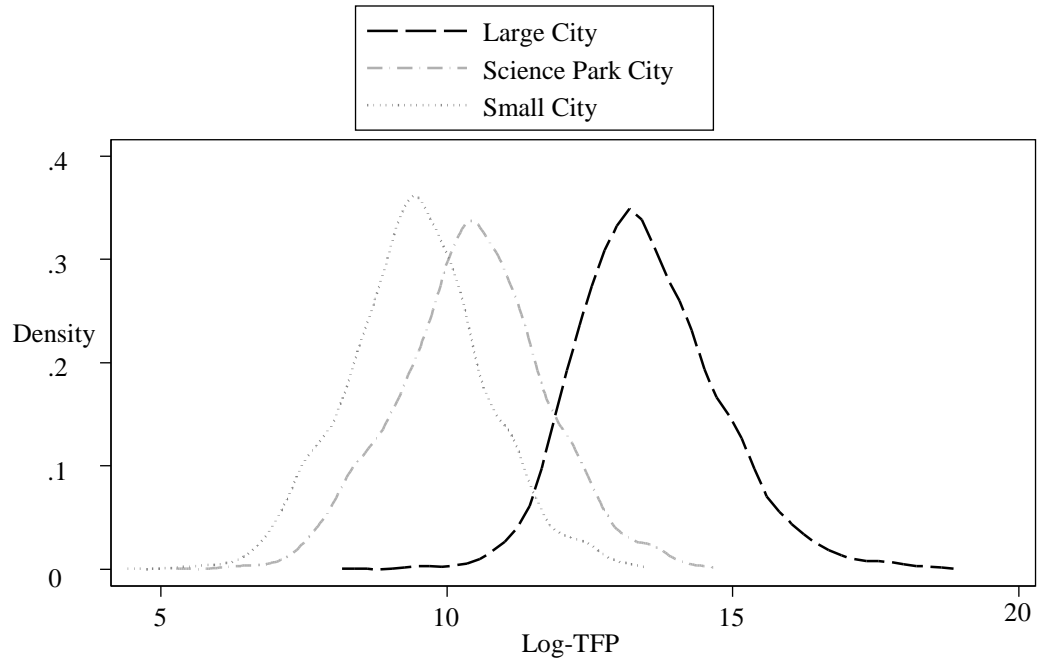
Productivity Distribution-South Korea
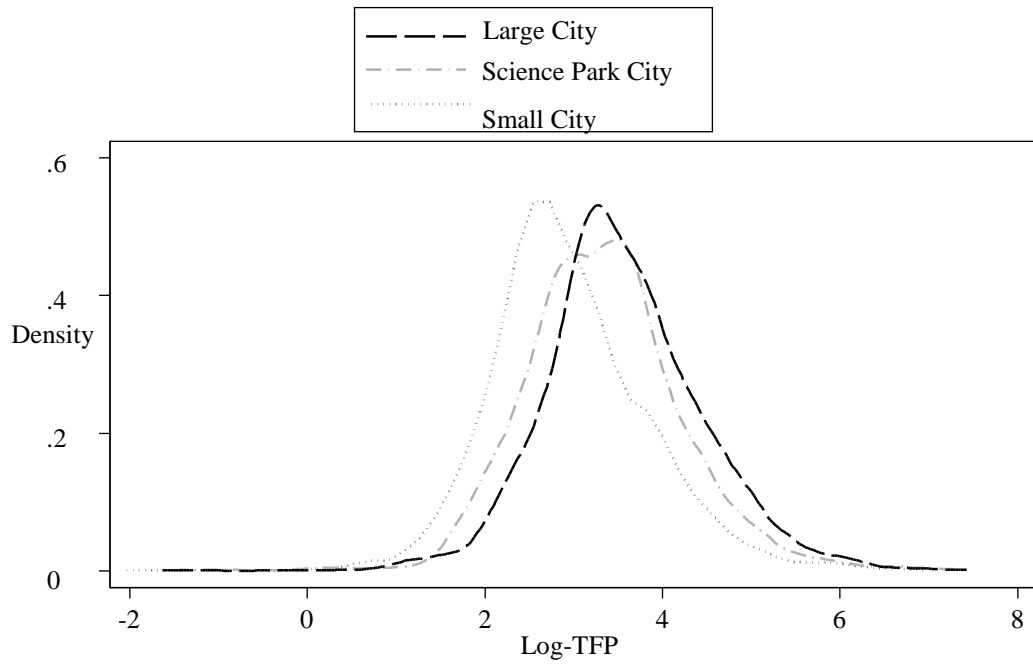
Figure 2: Region-wise productivity distribution plots for computer and electronics (NAICS 334) firms in Taiwan and South Korea
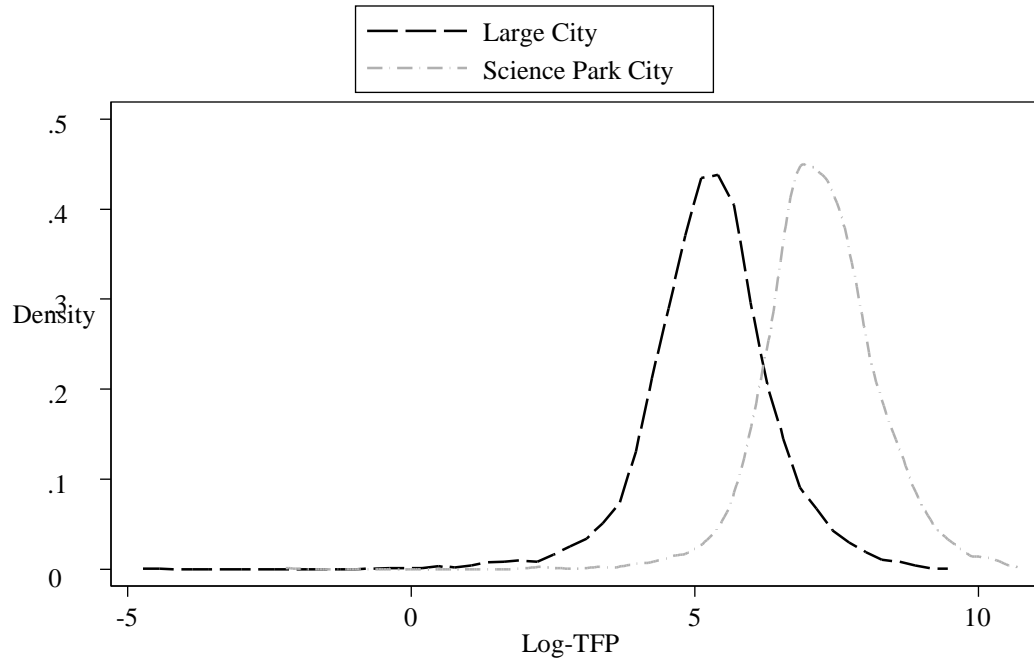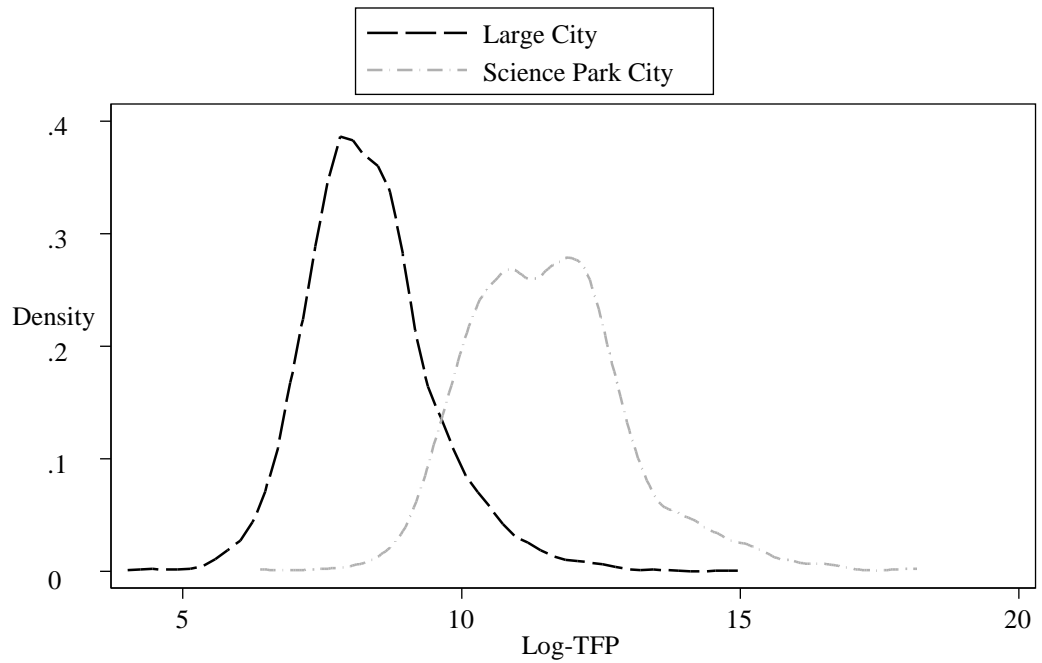
Productivity Distribution-Taiwan
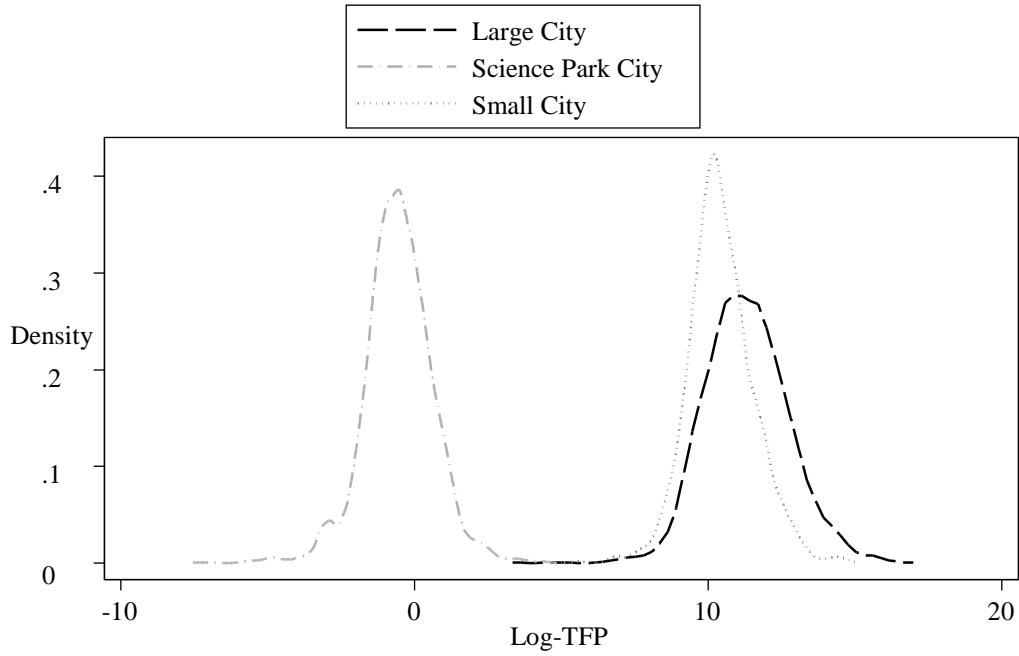
Productivity Distribution-South Korea
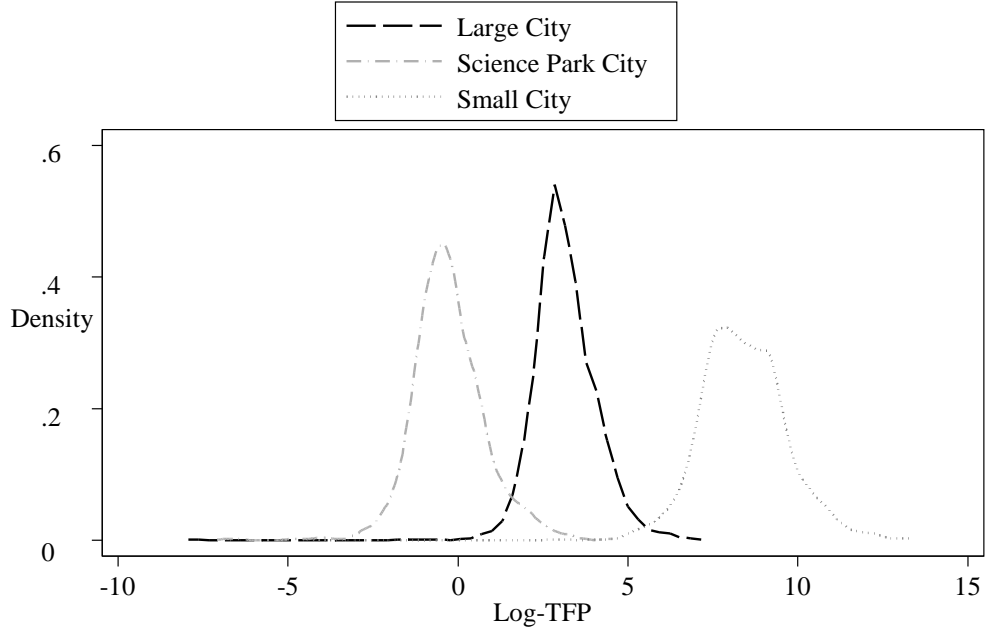
Figure 3: Region-wise productivity distribution plot for chemical manufacturing (NAICS 325) firms in Taiwan and South Korea
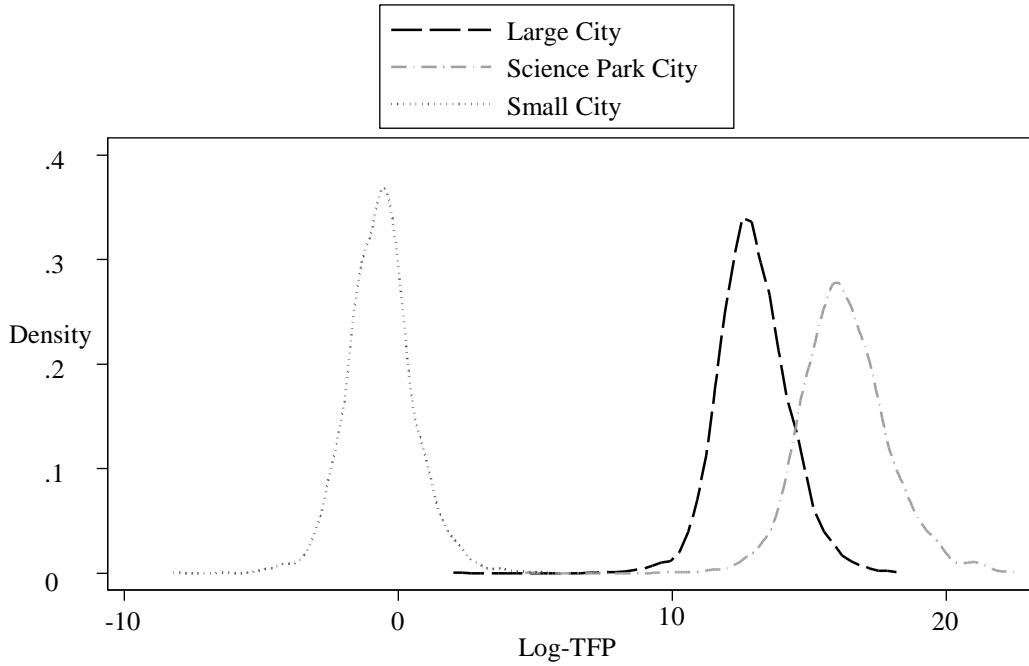
Productivity Distribution-Taiwan
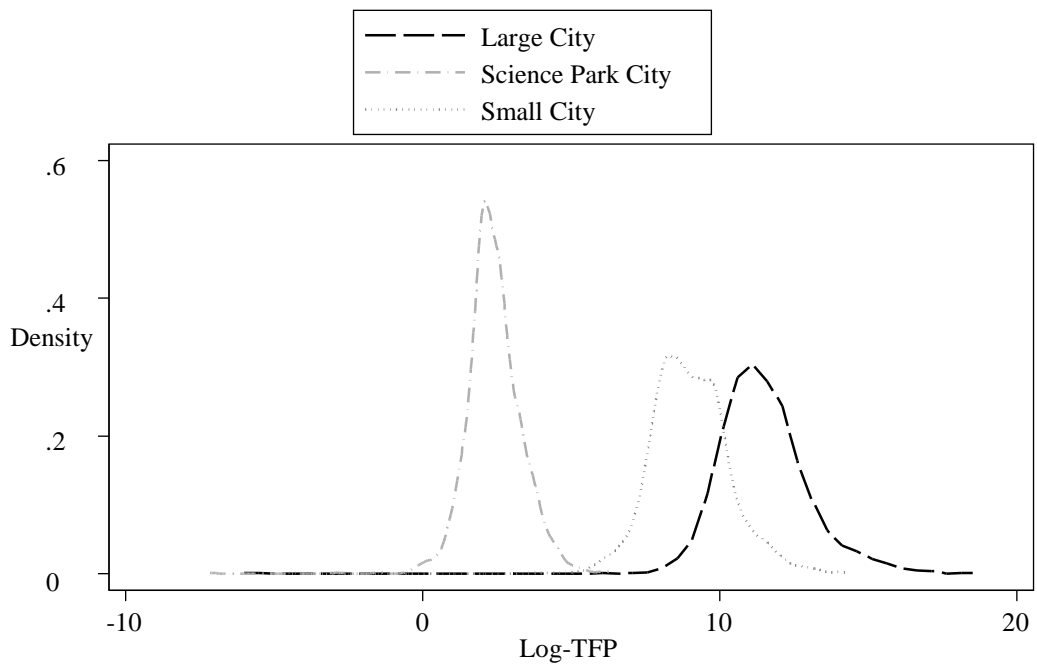

Productivity Distribution-South Korea

Figure 4: Region-wise productivity distribution plot for scientific and technical services (NAICS 541) firms in Taiwan and South Korea

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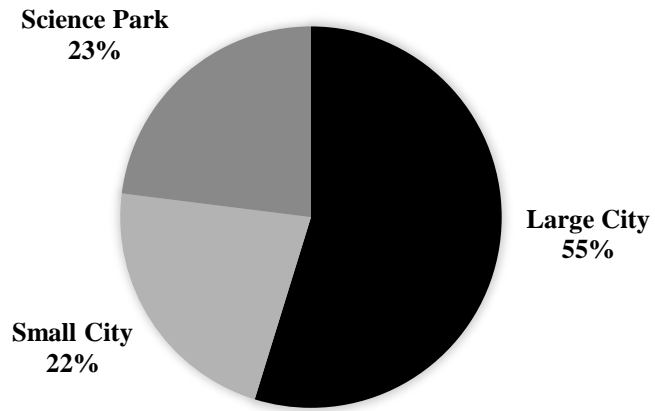## Productivity Distribution-Taiwan
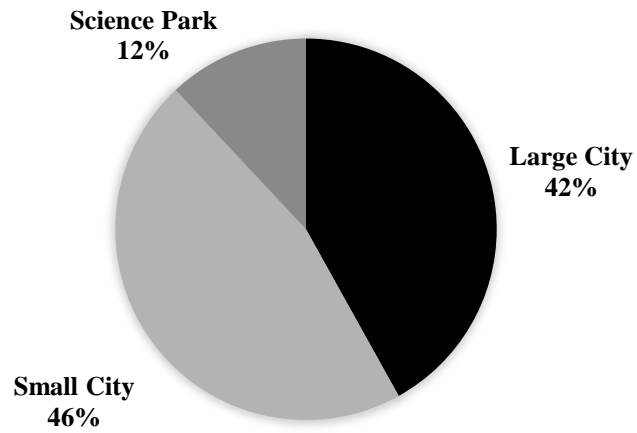

Productivity Distribution-South Korea

**Figure 5: Region-wise productivity distribution plots for SMEs
in Taiwan and South Korea**

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SMEs IN TAIWAN

Science Park
23%

Small City
22%

Large City
55%

SMEs IN SOUTH KOREA

Science Park
12%

Large City
42%

Small City
46%

Figure 6: Regional distribution of SMEs in Taiwan and South Korea