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Knowledge spillovers and firm performance in the high-technology industrial cluster

Yih-Luan Chyi [a], Yee-Man Lai [b], Wen-Hsien Liu [c,*]

[a] Department of Economics, National Tsing Hua University, No. 101, Section 2, Kuang-Fu Road, Hsinchu 300, Taiwan
[b] Chung-Hua Institution for Economic Research, 75 Chang-Hsing Street, Taipei 106, Taiwan
[c] Department of Economics, National Chung Cheng University, 168 University Road, Chiayi 621, Taiwan

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ABSTRACT

This paper attempts to empirically investigate the mechanisms underlying growth in Hsinchu high-tech clusters. We emphasize knowledge spillovers as one of the potential factors contributing to agglomeration benefits. This paper sheds light on the impact of external and internal spillovers on firm performance in Hsinchu high-tech clusters. The empirical results provide supporting evidence that the external R&D spillover is statistically significant in explaining net sales of firms in Hsinchu high-tech clusters.

1. Introduction

This paper empirically investigates the mechanisms underlying growth in the Hsinchu Science Park (HSP). The Taiwanese government established HSP in 1980 to attract high-technology (high-tech) firms, including start-up firms. The primary goal was to create HSP as a potential Silicon Valley of the East. The park is located near the Industrial Technology Research Institute (ITRI) and two major research universities in Taiwan: National Tsing Hua University and National Chiao Tung University. To encourage overseas Taiwanese engineers to return home, the HSP administration as well as ITRI opened branch offices in Silicon Valley to provide information and local contacts. In addition, the Taiwanese government has invested US$1679 million in infrastructure and facilities in HSP since its founding a quarter of a century ago. At the end of 2006, 388 tenants occupied HSP, growing at an annual rate of 12% during the past two decades. Until 2006, overseas Taiwanese returnees had constituted almost one third of these tenants. Total sales in HSP reached US$310 million in 2006, representing an annual growth rate of 38%. The number of employees has increased more than tenfold from 8275 in 1986 to 121,762 in 2006.[1]

Agglomeration economies and institutional networks may explain the success of the HSP high-tech clusters. On the one hand, economists generally define agglomerations and clusters as a geographical and sectoral concentration of firms (Krugman, 1991). Hence, proximity and specialization could be key sources of collective efficiency in HSP. On the other hand, researchers in economic geography focus on the synergy formed by firms in cooperative networks (Saxenian, 1994). The competitive advantages of firms or industries in HSP may well thank backward and forward linkages, labor pooling, and knowledge spillovers via inter-firm or inter-industry linkages. Among these factors contributing to agglomeration benefits, knowledge spillovers have attracted the most attention in the recent literature on new growth theory and industrial geography.

In empirical studies surveyed comprehensively by Nadiri (1993), spillover effects in general have significantly positive influences on productivity at both industry level and firm level. However, the magnitude of these effects varies substantially

* Corresponding author. Tel.: +886 5 2720411x34124; fax: +886 5 2720816.
E-mail address: WHL@ccu.edu.tw (W.-H. Liu).

[1] All these statistics quoted here are from the HSP website: http://www.sipa.gov.tw/english/file/201006018153839.pdf. Most growth rates are calculated by the authors.

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according to the different measuring methods used in assessing the inter-industry spillover. We apply the technology-based approach proposed by Jaffe (1986) to assess the proximity between HSP's firms in a technological space. Specifically, patents classified across various technological categories allow us to characterize firms' positions in the technological space. The total number of patent applications filed by firms in HSP to the Taiwan Intellectual Property Office (TIPO) from 2001 to 2005 is classified into 23 technological classes to reflect the distribution of patents and accordingly, the locations of firms in the technological space.[2] Based on firms' patent distributions among 23 technological sectors, we classify them into technological clusters by the *k*-means clustering technique. Consequently, measures of external and internal knowledge spillovers can be constructed.

Both internal and external knowledge pools relevant to advancing firms' performance in HSP are established. An econometric model for estimating the effect of knowledge spillovers on net sales is founded on the Cobb-Douglas production function. The data set we use is comprised of 92 HSP firms listed publicly in Taiwanese stock markets during 2000–2004. The empirical results suggest that the HSP high-tech clusters show evidence of important knowledge spillovers since the total R&D spillover and the external R&D spillover are both statistically significant in explaining net sales. In particular, the estimated total R&D spillover and external R&D spillover elasticities are higher than own R&D elasticities.

Furthermore, we examine the influence of domestic versus international knowledge spillovers on the production of the HSP firms in the semiconductor industry. Using panel data from firms in the U.S. and Taiwan, our empirical results of international knowledge spillovers show that the foreign knowledge stock has a positive impact on net sales.

Section 2 provides a literature review of our study. The empirical methodology is presented in Section 3, the data description and empirical results are reported in Section 4, and the concluding remarks follow in Section 5.

2. Literature review

An externality is a fundamental characteristic of the knowledge good which is discernible via technology spillovers. Specifically, the spillovers take place once a firm can be benefited economically by other firms' R&D activities without incurring any cost.[3] Knowledge spillovers can be treated as externality motivated by R&D activity. Griliches (1992) distinguishes technology spillovers as two types: vertical spillovers and horizontal, or knowledge spillovers. Through transaction-based linkages, buyer-seller relationships among firms often incur vertical spillovers. But Griliches (1992) did not perceive it as a "true spillover" since it cannot spur additional innovations in other firms or industries so that the production capacity of an individual firm or industry can be raised. On the other hand, horizontal spillover basically refers to knowledge transmission. "Research performed in one firm can stimulate the creation of new knowledge or the fruition of previous ideas in another firm. In this case, new knowledge is disembodied from new goods and becomes part of a general pool of knowledge (i.e., public goods)." (Koo, 2005, pp. 6) This type of "true spillover" or knowledge spillover can be realized without direct input–output connections among firms or industries through technology-based linkages. Jaffe (1986) describes these linkages by the idea of "technological closeness." As two firms or industries employ more similar technology in production, innovations made by each firm or industry can be more useful to the other firm or industry.

Empirical approaches used in knowledge spillover studies, such as the technology flow approach and the cost function approach, have been surveyed by Nadiri (1993) and Cincera and van Pottelsberghe de la Potterie (2001). Recently, Koo (2005) reviewed two alternatives considered in the related literature: the production function approach and the paper trail approach. The spatial aspects in spillover, which are not considered in the technology flow approach and the cost function approach, have attracted the most attention in recent empirical studies (see, among others, Jaffe, 1989; Feldman, 1994, 1999; Adams and Jaffe, 1996; Anselin et al., 1997, 2000). In general, the production function approach seems to be the most widely used method to investigate the importance of knowledge spillovers in explaining firm-level or industry-level total factor productivity (TFP). Original studies were provided by Griliches (1979) with the methodology and Jaffe (1986) with empirical implementations. Jaffe (1986, 1989) specifically uses the knowledge production function framework to examine knowledge spillover effects. Considering corporate profits or patent counts as dependent variables, the empirical results in Jaffe (1986) suggest that there are significantly positive effects of knowledge spillovers on innovations. Furthermore, Jaffe (1989) innovatively modifies the standard knowledge production function by taking the spatial aspect of spillovers into account. His results corroborate the importance of geographic proximity for both university and industry research. Incorporating the effects of both geographic and technological proximity of R&D activity, Adams and Jaffe (1996) use the Cobb-Douglas production framework to measure intra-industry spillovers. They illustrate strong effects of R&D on productivity when firms or industries are densely located in geographical and technological spaces.[4]

The line of research focusing on the vertical spillover may underestimate spillover effects since the knowledge spillover relying on technology-based linkages can be realized without a direct input–output connection among firms or industries. Hence, the technology process approach designed only for demonstrating vertical spillovers is not adopted in this paper. In addition, neither the technology process nor the cost function approach is used, since the important spatial aspect of spillovers is not incorporated in either of these approaches. Furthermore, the paper trail approach is not feasible because firm-level data of patent citations are unavailable for us to directly measure the inter-firm knowledge spillover in the Hsinchu high-tech clusters. Consequently, we apply the concept of Jaffe's "technology closeness" by using the production function approach in our empirical study. Capron and Cincera (1998) examine the relationship between R&D activity spillover and productivity at the firm level by using the first difference GMM method. They conclude that while U.S. firms are generally concerned with their national spillover stock, Japanese firms are more open to the international stock and European firm do not seem to specifically take advantage of either source of spillover. Using a different approach to measuring the knowledge spillover pool, Tsai (2005) suggests that knowledge spillover is relatively strong when firms co-locate with geographical proximity. More recently, Aldieri and Cincera (2009) used the system GMM method to study the extent to which R&D spillover effects are strengthened by geographic

[2] We restrict our analysis to patents filed here to TIPO because, for the HSP firms, the quantity of patents granted by TIPO is much greater than the patents granted by the U.S. Patent and Trademark Office (USPTO). It will be difficult for us to construct a precise technological proximity between each pair of firms by using the USPTO data since most firms received a few (or even zero) patents from USPTO.

[3] The meaning of technology spillover has been comprehensively reviewed in Koo (2005).

[4] Empirical findings in the related literature are summarized in Table 1 of Adams and Jaffe (1996) and Tables A1 and A2 of Cincera and van Pottelsberghe de la Potterie (2001).