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Knowledge spillovers, human capital and productivity

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ABSTRACT

Knowledge spillovers in the form of human capital are often regarded as the engine of sustained growth and development. We employ a rich employer–employee matched dataset on the manufacturing industry in Taiwan, a newly industrialized economy, to quantify the significance of human capital spillovers and their effects on productivity gains. Using the ratio of higher-educated (university or above) employees in each city as the external human capital index of a plant (excluding the reference plant itself) and addressing the potential endogeneity of various unobservable factors attributable to the location of the plant, we find that within a given city, a 1 percent increase in the proportion of higher-educated employees will increase the productivity of plants in that city by approximately 0.93–1.15 percent. Furthermore, the productivity increases are found to be greater for high-tech plants and for those located in cities with science parks. This indicates that human capital spillovers are not only present, but stronger under greater technology intensities. Our measure of the monetary value of such spillover effects indicates that a 1 percent increase in the percentage of higher-educated employees in a city will raise the value-added per plant by US$15,937, or, equivalently, an increase of US$1.27 billion for the entire manufacturing industry.

1. Introduction

Knowledge spillovers are prevalent in the real world and particularly prominent in developed and newly industrialized economies. Over the past three decades, macroeconomists and growth theorists, following the lead of Romer (1986) and Lucas (1988), have regarded knowledge spillovers, in forms of either physical or human capital, as the engine of sustained growth and development. Of particular notice, Lucas (1988, p. 19) emphasized that "human capital accumulation is a social activity involving groups of people". Yet, whether knowledge spillovers can be regarded as a major driver of macroeconomic performance is ultimately a quantitative question. Due to the increased availability of micro datasets, macroeconomists have more often sourced such quantitative questions to micro evidence in recent years. In the present paper, we attempt to address this important issue using a rich data set from Taiwan's newly industrialized economy, where the growth of skill-intensive high-tech industries has played a crucial role in its rapid development. In particular, we would like to posit two key questions. Is there micro evidence showing the presence of such human capital spillovers, particularly in a given region?[1] If there is, just how do such spillovers occur and influence firm productivity and how large are these productivity gains?

As elaborated by Kuznets (1962, pp. 328–329), "creative effort flourishes in a dense intellectual atmosphere …; … the possibility of more intensive intellectual contact … afforded by greater numbers may be an important factor in stepping up the rate of

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[1] That is we focus on the so-called "local" human capital spillovers, which is different from global or network spillovers (see a discussion in Strulik, 2014).

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additions to new knowledge". Jacobs (1969) highlighted knowledge spillovers as the primary force for agglomeration of firms and geographical concentration of research activities. Rich but indirect empirical evidence has been documented by Rauch (1993), Jaffe et al. (1993) and Audretsch and Feldman (1996) based on wage payments and patent citations. In Glaeser et al. (1992) and Henderson et al. (1995), it was found that spillovers occur both within and between industries. Direct empirical evidence has not been provided until more recently when Moretti (2004) argued that with the same amount of inputs, plants located in cities with higher levels of human capital can produce greater outputs than similar plants located in cities with lower levels of human capital. Yet, such findings are not without challenge: in particular, Acemoglu and Angrist (2001) and Ciccone and Peri (2006) concluded that the external returns to human capital are negligible at conventional significance levels.

Our analysis is based upon the neoclassical production theory with two important modifications. On one hand, in addition to standard factor inputs and the characteristics of the production unit, we explicitly consider the effect of within-the-production-unit quality of labor on labor productivity, which may be referred to as internal human capital. On the other hand, we also allow the technology scaling factor of the production unit to depend on human capital spillover, which may be referred to as external human capital. While the measure of internal human capital is straightforward consisting of an array of workforce characteristics, the measure of external human capital deserves further elaboration. Specifically, using the city as the locality of analysis, we calculate the proportion of higher education (university and above) graduates in other production units as the external human capital index of each production unit. We shall say that human capital spillovers are present if an increase in the proportion of higher education graduates who are in the same city but outside of a given production unit raises the productivity of this production unit.

Our data constitutes a new employer-employee matched dataset consisting of 34,364 plants (our production units) in Taiwan with complete information about workforce characteristics of approximately one million employees working in these plants. The dataset covers a five-year period, 1998–2000 and 2002–2003. This rich dataset enables us to construct a clean measure of human capital spillovers as discussed above.

We expect that unobserved factors which affect both the human capital of a particular city and the productivity of a particular plant may exist. To avoid potential bias resulting from such unobserved heterogeneities, we include in our panel regressions, plants, industries and time-varying industry fixed effects in addition to an array of explanatory variables based on neoclassical production theory. We further allow for unobservable changes in proprietary technology, which is facilitated by means of industry fixed effects along with their interaction terms with factor inputs. After controlling for these potentially confounding factors, we find that in response to a 1 percent increase in the measured human capital spillover, the productivity of the focal plant rises by approximately 1.15 percent, which is statistically significant at the 1% level. This translates to an increase of US$15,937 in the value-added per plant or a sizable increase of US$1.27 billion for the entire manufacturing industry.

We have provided several robustness checks to assure the validity of our empirical results. We begin by employing the instrumental variable approach to addressing potential endogeneity problems, using two alternative instrumental variables (IVs): (i) the total number of employees in all newly-opened plants in each city in the previous year; and (ii) the total number of employees in all newly-opened plants in each city in the previous year minus the total number of employees in all plants closed in the previous year. We then go on to carry out a series of tests, beginning with the use of the 'total factor productivity' (TFP) estimation technique of Levinsohn and Petrin (2003), as the productivity index of the plant to resolve the potential endogeneity caused by any existing correlations between the input factors of production and unobservable shocks to productivity. We then restrict our attention to cities with science parks or to only 'high-tech' industries, where human capital spillovers are expected to be stronger. Finally, we carry out a series of sensitivity analyses, including re-weighting higher education during rapid college expansion, as well as allowing for other forms of spillover effects or controlling for the scale and composition differences of the plants and the human capital measures of different cities. We find that in all exercises, our findings are robust and the strength of human capital spillovers is in accordance with theory.

To that end, it may be informative to compare our paper with the most related work by Moretti (2004) using a two-year panel of plants. Specifically, our paper differs from Moretti's in three significant ways. First, the human capital spillover index constructed by Moretti is based on human capital outside of the three-digit industry in which the plant is located, which ignores the potential spillover effects between plants in the same industry. In contrast with Moretti, most three-digit industries in each city in our dataset contain multiple plants.[2] Therefore, the spillover effect between plants in the same industry should be considered and our human capital spillover index provides a clean and more precise measure. Second, by constructing an employer-employee matched dataset, we are able to control plant-level internal human capital based on workforce characteristics, which is ignored in Moretti due to the absence of the required employee data. Third and finally, our richer and longer panel dataset enables us to better control unobserved heterogeneities and to more easily circumvent endogeneity problems, particularly those which arise from the interaction between factor inputs and unobservable shocks to productivity.

2. Economic framework

2.1. Model and empirical specifications

We start from the basic foundation of neoclassical production theory, focusing on the impact of human capital spillovers on plant productivity. Suppose that a representative plant adopts Cobb-Douglas technology to produce a final product, Y, as follows:

[2] Table A1 in the Appendix reports the distribution of three-digit industries in each city.