

# The spillover effects of R&D on manufacturing industry in Taiwan's metropolitan areas

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**Abstract** The literature of new growth theory regards Research and Development (R&D) as a crucial factor in economic growth. This is because R&D not only improves production technology, but also because of its significant externality (spillover) effects on other firms. This paper employs the model developed by Berliant et al. (J Econ Theory 104:275–303, 2002) to examine the externality of R&D within industries closely associated with the spatial distribution pattern of firms in Taiwan's Metropolitan Areas. Both the mean travel time (to represent the distances) and an overall dispersion are incorporated in this examination of the externality effect. The paper also employs quantile regression techniques to estimate the effects of agglomeration at various quantiles of production value. Based on the data collected by the Taiwan Area Industrial Census for 2001, this research considers all manufacturing industry and two-digit standard industry classification data of manufacturing industries to analyze the R&D spillover effect for various metropolitan areas. The paper analyzes the manufacturing industry as a whole. The electrical and electronic machinery industries, a representative of high-intensity R&D industry, and the apparel and accessories and

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leather industries, as representatives of low-intensity R&D industry, are also considered. This research concludes that there is an externality (spillover) effect of R&D in each metropolitan area for all three categories. Moreover, the research suggests that the medium and large a firm's scale the higher the spillover effect it receives will be.

**JEL Classification** D51 · L60 · R12

## 1 Introduction

In the modern economy, the research and development (R&D) inputs of firms and industries are not evenly distributed across space and as a result different regions may not have identical rates of productivity. As pointed out by [Lucas \(1988, 1993\)](#) and [Black and Henderson \(1999\)](#), investment in R&D results in localization and spillover, presumably through personal face-to-face contacts. This in turn causes cities or regions in which such R&D is present to become engines of economic growth. In other words, R&D-induced production externality provides an important basis from which to indicate an aggregate production function may no longer face diminishing returns and how the output of a society may grow perpetually. Thus, other things being equal, firms in regions with higher aggregations of R&D will have a higher productivity than that of firms in cities with lower aggregate R&D. Furthermore, cities with higher aggregations of R&D grow faster than those with less innovative activities.

According to the literature underlying the new growth theory, knowledge or human capital accumulation is regarded as a crucial factor to economic growth because it not only improves production technology in and of itself, but it also has a significant externality (spillover) effect on other firms ([Romer 1990](#); [Grossman and Helpman 1991](#); [Aghion and Howitt 1992](#)). In general, this knowledge can be regarded as technical ([Shell 1966](#)) and can be measured either by applications for patents ([Jaffe et al. 1993](#)), or investment in R&D ([Romer 1986](#)). Within the framework of new economic geography, [Fujita and Thisse \(2006\)](#), and [Ottaviano and Thisse \(2004\)](#) described a perfectly competitive R&D sector that operates under an endogenous growth externality. They relied upon the assumptions that agglomeration and growth occurring in combination are perfectly correct, in part because agglomerated R&D sectors cause higher growth due to the endogenous growth externality. It is important to note, though, that such a positive relation cannot be identified empirically in a robust fashion as shown by [Berliant and Wang \(2004\)](#).

How important is R&D to spatial agglomeration? [Jacobs \(1969\)](#) claims that R&D, or knowledge information, spillovers between industry clusters are more important for firms than intra-industry R&D spillovers. [Rosenberg \(1963\)](#) discusses the spread of machine tools across industries and describes how R&D is transmitted from one industry to another. According to [Marshall \(1961\)](#) and [Arrow \(1962\)](#), [Romer \(1986\)](#) proposed Marshall–Arrow–Romer (MAR) externality which is concerned with knowledge spillovers in cities between firms in an industry. Their work demonstrates that the concentration of an industry in a city or region facilitates R&D spillovers between firms and therefore, increasing the productivity of the industry.

Abundant empirical evidence shows that the aggregation of R&D in an industry has a positive effect on spatial agglomeration. Glaeser et al. (1992) analyze the six largest industries in each of 170 US cities. Their results are consistent with the presence of MAR externalities, in that industries grow sluggishly in cities with a high degree of specialization. Henderson et al. (1995) concludes that the knowledge spillover is significant both within and between industries. Some empirical studies show that the spillover effect of R&D only emerges within an industry (Berstein 1988; Cuneo and Mairesse 1984; Goto and Suzuki 1989; Griliches 1992; Chuang and Hsu 1999). Acs (2002) tested the MAR hypothesis and found that industrial R&D spillover was present across regional industry clusters for 36 cities and 6 separate industry clusters over a period of 4 years. They suggested that risk pooling, shared infrastructure, and thick labor markets are the fundamental sources of agglomeration.

More specifically, Jaffe et al. (1993) used patent data to conclude that knowledge spillovers are geographically concentrated—in the sense that patents are more likely to cite previous patents from the same area. Postner and Wesa (1983) further point out that the spillover effects of R&D are much higher than the R&D input of the firm itself. At the same time, a growing body of empirical literature from research on economic growth has established that the spatial concentration of manufacturing activity enhances productivity and growth (e.g., Moomaw 1981; Sveikauskas 1975; Nakamura 1985; Henderson 1986; Ciccone and Hall 1996; Rosenthal and Strange 2001).

While most of these studies have relatively little to offer about the causes of agglomeration, Jacobs (1969) points out that the uncompensated knowledge of spillovers is a significant element in spatial agglomeration. Audretsch and Feldman (1996) used a spatial Gini coefficient to measure geographic concentration. They showed that innovative activity is substantially more concentrated than overall production and that industries which emphasize R&D tend to be more spatially concentrated. However, there is very little empirical research to discuss the spillover effect of R&D in conjunction with the spatial distribution of firms.

Building on evidence from empirical studies of spatial concentration, Berliant et al. (2002), and Lucas and Rossi-Hansberg (2002) developed a theoretical model to explore a spatial model associated with R&D externality, which formalizes knowledge spillovers and regards them as an uncompensated factor inputs into the production of a firm. This paper, follows the model developed by Berliant et al. (2002), and defines R&D in the terms of knowledge or human capital shown in Romer (1986). The examination of the R&D externality associated with the spatial distribution of firms in which both travel time (to represent the distance) to the mean and an overall dispersion are incorporated in the consideration of the spatial externality effect. Using the Industrial Census of the Taiwan Area for 2001, the researchers employed data from the two-digit standard industry classification (SIC) of the manufacturing industry to analyze the spatial spillover effects of R&D in the three main metropolitan areas of Taiwan: Taipei metropolitan area, Taichung metropolitan area, and Kaohsiung metropolitan area.<sup>1</sup> Researchers first analyzed the manufacturing industry as a whole, and

<sup>1</sup> The metropolitan areas are defined by Directorate General of Budget, Accounting, and Statistics, Executive Yuan.

then chose the electrical and electronic machinery industry (SIC 36) to represent the high-intensity R&D industries. Subsequently researchers used the apparel and accessories and leather industries.<sup>2</sup> (SIC 22 and 23) to represent the low-intensity R&D industries in analyzing the spillover effect within industries in each of the different categories.

Although most theoretical and empirical studies agree that the spillover effect of R&D is much higher than the R&D input by firms themselves, very little research has discussed how the spillover effects of R&D vary from small scale to large scale. Is it increasing, or decreasing, or is there a constant return for firms of different scales? In order to figure out the extent of spillover effects for firms of different scales, this research employed *quantile regression* (QR) techniques in order to estimate the effects of agglomeration at various quantiles of production value.

The quantile regression, was developed by Koenker and Bassett (1978), and is capable of providing a complete description of the conditional behavior of the dependent variable. In general, researchers use a mean regression model that is unable to fully characterize entire conditional distributions. However, by focusing on certain quantiles of the conditional distribution, more information on the conditional behavior of dependent variables is revealed. Moreover, by specifying a QR model and estimating various QR functions, the entire conditional distribution of interest to researchers can be depicted so that a more complete description of the relationship between the dependent and explanatory variables is available. This means that the whole distribution of the variable of interest can be analyzed (Koenker 2005).

Using this approach this paper shows that the spatial spillover effect is significant in all industries regardless of the intensity of R&D. Most the firms in medium and upper level of production value can get more effects than lower level firms. This result implies that the R&D spillover effects in the manufacturing industry, high-intensity and low-intensity R&D industries have a scale economy with the production value. The results also indicate that the more agglomerated firms of the Taipei metropolitan area experience the highest spillover effects. This finding supports the R&D model with a spatial externality developed by Berliant et al. (2002).

The organization of the remainder of this paper is as follows. Section 2 presents the model structure. Section 3 describes the research data. Section 4 summarizes the estimation procedure and analyzes the spillover effects in various industries. Section 5 concludes the paper.

## 2 The model

Consider a firm located at a specific site in a region. The individual firm employs capital ( $K$ ), labor ( $L$ ), floor space ( $F$ ), and R&D ( $R$ ) to produce goods which exhibits a Cobb–Douglas form. The uncompensated knowledge spillover effect ( $S$ ) has a positive effect on the individual production of each firm. Therefore, the production function is given as:

<sup>2</sup> Owing to the number of the firms' limitation, we combined the apparel and accessories and leather industry (Chuang and Hsu 1999).

$$Y = AK^\alpha L^\beta F^\gamma R^\delta S^\lambda, \quad \alpha, \beta, \gamma, \delta, \lambda > 0 \quad (2.1)$$

where  $A$  denotes the production technology, and  $S$  is specified as an aggregate of R&D investment in the industries found within the same region. In this study, industries are classified only as high-intensity R&D industry or low-intensity R&D industry. This production function provides constant returns to scale with respect to all its factor inputs  $\{K, L, F, R, S\}$ , however, it reveals increasing returns in the aggregation of R&D in the same industry for a specific region. Furthermore, it should be observed that the central feature of the function (2.1) is to examine the uncompensated effects of inter-firm R&D on the production of a firm. Because the production technology is highly related to R&D expenditure and parameter  $A$ , in (2.1), represents production technology, the production function can be simplified as:

$$Y = K^\alpha L^\beta F^\gamma R^\delta S^\lambda \quad (2.2)$$

As noted by [Berliant et al. \(2002\)](#), this approach allows the magnitude of the knowledge spillover effect to diminish with distance. Thus, in addition to a relative distance measure, we incorporate a dispersion measure—the more concentrated firms are, the more significant the knowledge spillover effect.

Let  $z_{ij}^r$  denote the distance of a firm  $i$  from the original center of industry  $j$  in region  $r$ , and  $R(z_{ij}^r)$  represent the R&D input of individual firm  $i$  of industry  $j$  in region  $r$  at location  $z_{ij}^r$ . We then denote the centrality of location of R&D in the industry  $j$  located in region  $r$  by

$$\mu_j^r = \sum_{z_{ij}^r} z_{ij}^r \times R(z_{ij}^r) / \sum_{z_{ij}^r} R(z_{ij}^r) \quad (2.3)$$

In the theoretical model by [Berliant et al. \(2002\)](#), firms are considered identical with respect to all their inputs, so that the mean location of firms in the industry can be measured using the weight mean associated with number of firms in each location. Since the firms are not identical in reality, and this research focuses on the investigation of R&D spillover effects, this paper employs the amount of R&D, rather than the number of firms, to determine the mean location of R&D. As a result,  $\mu_j^r$  represents the mean location of firms in industry  $j$  in region  $r$  associated with R&D investment. Incorporating the definition of mean location, the overall dispersion of firms on the R&D distribution in industry  $j$  located in region  $r$  is given as:

$$\sigma_j^r = \sqrt{\frac{\sum_{z_{ij}^r} R(z_{ij}^r) \times (z_{ij}^r - \mu_j^r)^2}{\sum_{z_{ij}^r} R(z_{ij}^r)}} \quad (2.4)$$

Therefore, the degree of the overall R&D effectiveness for industry  $j$  in a particular firm in region  $r$  at location  $z_{ij}^r$ ,  $Q(z_{ij}^r)$  will be:

$$Q(z_{ij}^r) = D^r - \left| z_{ij}^r - \mu_j^r \right| - \varepsilon_j \sigma_j^r \quad (2.5)$$

where  $D^r$  is the longest distance between the Central Business District (CBD) of town/village in the measure region  $r$ . The second term specifies a cost function in terms of the distance between a particular firm location (which is represented by the town/village site) and the mean site, while  $\varepsilon_i \in (0, 1)$ , indicates the degree of penalty for overall dispersion of R&D in industry  $i$ .

Thus one may regard our  $Q$  function as a proxy (with the first and second instances) for the (locational) distribution in which externalities enter the system based on an average or aggregate of individual measures.

Therefore, the R&D spillover effect on a firm at location  $z_{ij}^r$  associated with the spatial distribution of firms will be formulated as:

$$S(z_{ij}^r) = Q(z_{ij}^r) \times \sum_{z_{ij}^r} R(z_{ij}^r) \quad (2.6)$$

By taking the log of both sides of the equation (2.2), the production function will be:

$$\ln Y_{ij}^r = \alpha \ln K_{ij}^r + \beta \ln L_{ij}^r + \gamma \ln R_{ij}^r + \delta \ln F_{ij}^r + \lambda \ln S_{ij}^r \quad (2.7)$$

where  $S_{ij}^r$  is the aggregate R&D associated with the spatial distribution of firms in an industry in the same region, as defined in Eq. (2.6).

### 3 Data

The data to be analyzed in this paper were obtained from the Industrial Census Data of the Taiwan Area in the manufacturing sector for 2001. This census data set is collected by the Directorate General of Budget, Accounting, and Statistics, Executive Yuan, Taiwan every 5 years. The data for 2001 are the most recent. Owing to the limitations of such micro-scale data, especially in association with the location of firms, relatively limited attention has been given to understand empirically the effect of individual R&D investment and spillover from an industry on the productivity of individual firms within that industry. In this study, we employed data from two-digit standard industry classification of the manufacturing industry to analyze the spatial spillover effects of R&D on each firm within this two-digit industry. The researchers selected the electrical and electronic machinery industries to represent high-intensity R&D industry and the apparel and accessories and leather industries as representatives of low-intensity R&D industry, based on the relative percentage of the R&D expenditure to the total output for each of the three industries.<sup>3</sup>

<sup>3</sup> The 6.4% of electrical and electronic machinery industry total investment is invested in R&D which is the highest percentage in all industries. And only 0.46% of apparel and accessories and leather industry total investment is invested in R&D apparel and accessories and leather industry, see [Chuang and Hsu \(1999\)](#).

**Table 1** Center of each region

	CBD	Manufacturing industry center	Electrical and electronic industry center	Apparel and leather industry center
Taipei metro-politan area	Taipei city (Chungcheng district)	Sanchung city	Yunggho city	Chunggho city
Taichung metropolitan area	Taichung city (Central district)	Tantzú township	Taichung city (Baitwin district)	Taichung city (Natwin district)
Kaohsiung metropolitan area	aohsiung city (Sanmin district)	Kaohsiung city (Nantzú district)	Kaohsiung city (Nantzú district)	Kaohsiung city (Linya district)

The main purpose of this paper is to examine the R&D spillover effects on the productivity of firms in each of the studied metropolitan areas. The center of each metropolitan region is shown in Table 1.

In this empirical study, location  $z_{ij}^r$  in Equation (2.3) was measured from the Central Business District (CBD) of the metropolitan area in each town/village, that is, the CBD of each of the metropolitan areas specified in Table 1. These were regarded as reference points for the measurement of distance. The distance measurement in Equation (2.3) was then applied to the travel time survey.<sup>4</sup> Essentially then by economic distance rather than by geographical distance. Similarly,  $\mu_j^r$ ,  $j = M, h, l$  is the distance from the center of the manufacturing ( $M$ ), high ( $h$ )/low ( $l$ ) intensity R&D industry to the CBD of the metropolitan region  $r$  (Taipei, Taichung, Kaohsiung).

Of the three metropolitan areas, the Taipei metropolitan area is the most industrialized and most industries (of both high- and low-intensity R&D industries) agglomerate in this locale.

As Tables 2, 3, and 4 indicate, at least three-quarters of firms have an R&D investment of zero in all industries and metropolitan regions. This indicates that R&D investment is only concentrated in small number of firms. In this research, the R&D investment value is changed from 0 to 1, because after taking the log, it will become 0.

## 4 Estimates of the spatial spillover effect

### 4.1 The quantile regression technique

To fully understand the spillover effect of R&D investment in Taiwan's manufacturing industry, the researchers employed the QR model to investigate the relationship between production and other input variables. For given quantile  $\theta \in (0, 1)$ , the QR model is specified as:

<sup>4</sup> Travel time used to represent the travel distance.

**Table 2** Taipei metropolitan area

	Production value (PV) (NT\$ <sup>1</sup> Thousands)	Floor Space (FL) (m <sup>2</sup> )	Employment (Person)	R&D (NT\$ Thousands)	Capital (NT\$ Thousands)
Manufacturing industry ( <i>N</i> = 57,993)					
Mean	76,837.1	929.6	19.8	14,75.2	165,241.7
Std. error	2,302,697.7	24,187.7	182.3	48,186.3	6,639,323.0
q1	2,639.0	66.0	2.0	0.0	3,390.0
Median	6,350.0	100.0	4.0	0.0	8,865.0
q3	17,360.0	242.0	11.0	0.0	23,285.0
Max	400,317,258.0	4,113,099.0	26,836.0	4,359,247.0	1,183,454,315.0
Min	84.0	1.0	1.0	0.0	14.0
Electrical and electronic machinery industry ( <i>N</i> = 7,638)					
Mean	236,914.7	1,673.5	51.3	8,686.1	406,788.3
Std. error	2,716,419.1	15,449.6	265.0	119,215.9	3,802,777.9
q1	4,253.0	99.0	3.0	0.0	6,606.0
Median	12,029.0	194.0	8.0	0.0	17,945.0
q3	44,012.0	495.0	24.0	0.0	57,003.0
Max	131,407,534.0	744,278.0	8,509.0	4,045,716.0	119,047,473.0
Min	276.0	1.0	1.0	0.0	161.0
Apparel and accessories and leather industries ( <i>N</i> = 2,190)					
Mean	31,951.3	611.8	18.7	31.7	50,428.2
Std. error	90,552.4	2,703.3	44.9	332.6	239,155.6
Q1	2,329.5	83.0	2.0	0.0	3,278.3
Median	6,887.5	132.0	5.0	0.0	10,701.5
Q3	23,875.8	330.0	17.0	0.0	33,526.8
Max	1,528,841.0	53,862.0	713.0	9,551.0	6,666,581.0
Min	300.0	1.0	1.0	0.0	76.0

<sup>1</sup> NT\$: New Taiwan Dollar, 1US\$ = 33NT\$

$$\ln Y_{ij}^r = \alpha_1(\theta) \ln F_{ij}^r + \alpha_2(\theta) \ln R_{ij}^r + \alpha_3(\theta) \ln K_{ij}^r + \alpha_4(\theta) \ln S_{ij}^r + \alpha_5(\theta) L_{ij}^r + e_{ij}^r(\theta), \quad (4.1)$$

where  $\ln Y_{ij}^r$ ,  $\ln F_{ij}^r$ ,  $\ln R_{ij}^r$ ,  $\ln K_{ij}^r$ ,  $\ln S_{ij}^r$ ,  $\ln L_{ij}^r$  represent the variables of production value, floor space, R&D, capital, spillover effect and employment, respectively, while  $\alpha_1(\theta)$ ,  $\alpha_2(\theta)$ ,  $\alpha_3(\theta)$ ,  $\alpha_4(\theta)$ ,  $\alpha_5(\theta)$  are parameters and  $e_{ij}^r(\theta)$  is the corresponding error. Note that parameters  $\alpha_1(\theta)$ ,  $\alpha_2(\theta)$ ,  $\alpha_3(\theta)$ ,  $\alpha_4(\theta)$ ,  $\alpha_5(\theta)$  can be regarded as the marginal effects of production on floor space, R&D input, capital, spillover and employment effect. Let  $X_{ij}^r = [\ln F_{ij}^r, \ln R_{ij}^r, \ln K_{ij}^r, \ln S_{ij}^r]$  and  $\beta(\theta) = [\alpha_1(\theta), \alpha_2(\theta), \alpha_3(\theta), \alpha_4(\theta)]'$ . The QR parameter estimate  $\hat{\beta}(\theta)$  can be obtained by solving the minimization problem:



**Table 3** Taichung metropolitan area

	PV	FL	Employment	R&D	Capital
Manufacturing industry ( $N = 31,194$ )					
Mean	23,969.2	514.9	10.1	278.1	44,515.3
Std. error	435,374.5	8,720.8	76.6	11,193.8	1,764,333.2
q1	1,765.0	66.0	2.0	0.0	2,172.0
Median	4,473.5	132.0	3.0	0.0	6,025.0
q3	11,900.0	320.0	8.0	0.0	15,572.8
Max	69,064,858.0	1,151,385.0	7,112.0	1,253,380.0	244,472,358.0
Min	1.0	1.0	1.0	0.0	28.0
Electrical and electronic machinery industry ( $N = 560$ )					
Mean	103,701.1	1,240.9	45.7	2,480.7	271,324.7
Std. error	761,438.7	6,880.3	328.5	22,577.3	2,257,448.1
Q1	2,097.0	83.0	2.0	0.0	5,303.0
Median	6,012.0	165.0	4.0	0.0	14,005.0
Q3	25,064.0	462.0	15.0	0.0	37,419.0
Max	15,180,988.0	132,200.0	6,610.0	433,544.0	43,366,709.0
Min	334.0	1.0	1.0	0.0	265.0
Apparel and accessories and leather industries ( $N = 743$ )					
Mean	17,887.4	446.9	11.8	23.6	27,223.3
Std. error	52,616.0	889.8	27.1	258.9	95,604.6
Q1	1,353.8	75.0	1.0	0.0	2,003.8
Median	4,513.5	162.5	3.0	0.0	6,328.5
Q3	12,261.0	396.0	10.0	0.0	19,906.3
Max	687,363.0	8,059.0	311.0	5,856.0	2,051,171.0
Min	250.0	1.0	1.0	0.0	171.0

$$\begin{aligned}
& \min_{\beta(\theta)} \sum_{\{j: \ln y_{ij}^r - X_{ij}^r \beta_{\theta} \geq 0\}} \theta \left| \ln y_{ij}^r - X_{ij}^r \beta(\theta) \right| \\
& + \sum_{\{j: \ln y_{ij}^r - X_{ij}^r \beta_{\theta} < 0\}} (1 - \theta) \left| \ln y_{ij}^r - X_{ij}^r \beta(\theta) \right|. \quad (4.2)
\end{aligned}$$

In this paper, different values of  $\hat{\beta}(\theta)$  for  $\theta = 0.1, 0.2, \dots, 0.9$  are estimated.

## 4.2 Effects of variables for the Taipei metropolitan area

### 4.2.1 Manufacturing industry

The effects of each variable on production values distribution of manufacturing in the Taipei metropolitan area are presented in Fig. 1. The results indicate that the R&D

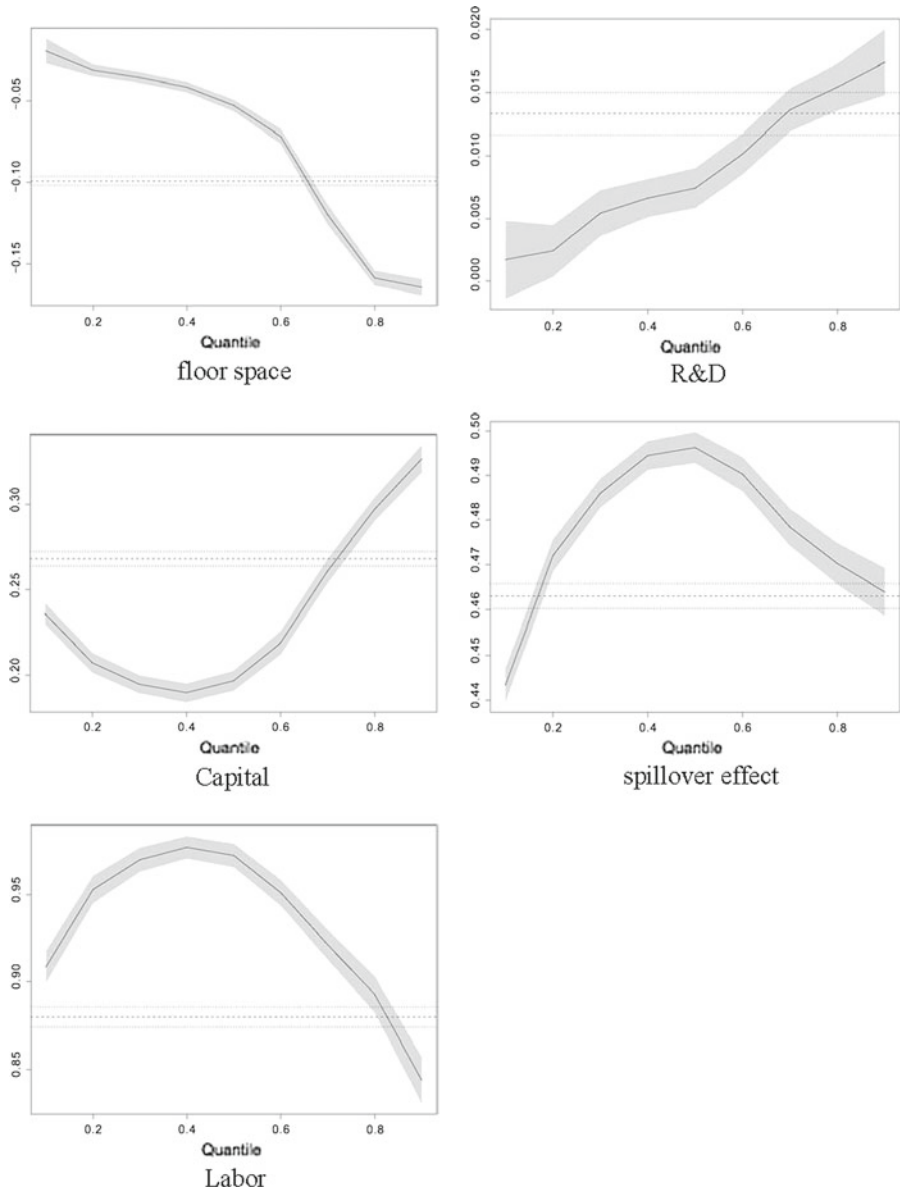
**Table 4** Kaoshuing metropolitan area

	PV	FL	Employment	R&D	Capital
Manufacturing industry ( $N = 18,614$ )					
Mean	56,605.9	1,001.5	16.5	713.7	100,838.1
Std. error	1,238,644.1	24,020.6	167.9	22,867.8	2,768,952.0
q1	2,075.0	50.0	2.0	0.0	2,637.3
Median	4,997.0	86.5	3.0	0.0	7,329.0
q3	13,938.8	247.0	10.0	0.0	18,770.3
Max	104,076,920.0	1,944,940.0	15,808.0	1,808,382.0	244,247,517.0
Min	169.0	1.0	1.0	0.0	31.0
Electrical and electronic machinery industry ( $N = 1,067$ )					
Mean	223,613.6	2,896.5	62.4	5,720.1	383,493.9
Std. error	2,011,593.1	22,118.9	327.8	41,660.4	3,228,698.9
Q1	2,991.8	80.0	2.0	0.0	5,469.8
Median	8,614.5	200.0	7.0	0.0	14,627.0
Q3	30,205.5	748.5	18.0	0.0	41,363.5
Max	52,951,953.0	580,160.0	5,998.0	818,891.0	71,656,586.0
Min	309.0	1.0	1.0	0.0	106.0
Apparel and accessories and leather industry ( $N = 282$ )					
Mean	33,005.7	883.2	23.4	76.2	75,903.5
Std. error	129,040.8	3,396.1	94.1	820.8	585,460.5
Q1	1,494.5	66.0	1.3	0.0	3,313.3
Median	4,855.5	153.5	4.0	0.0	9,612.0
Q3	12,615.5	377.3	10.0	0.0	29,174.0
Max	1,514,010.0	38,578.0	1,123.0	10,107.0	9,239,508.0
Min	307.0	1.0	1.0	0.0	152.0

input (except at the 0.1 and 0.2 quantiles), capital input, spillover effect and labor input all have positive coefficients but the floor space has negative coefficients at all quantiles and all coefficients are statistically significant at the 1% level. Figure 1, further reveals that the effects of capital, labor input and the spillover effect are more important than other variables at all quantiles in the distribution of production value.

Figure 1 shows the effect of R&D investment in each firm on production value. The quantile regressions, except at the 0.1 quantile is not significant, these coefficient estimates are positive and statistically significant at the 1% level (at 0.2 quantile is significant at 5% level). Moreover, the values monotonically increase. This implies that R&D investment is associated with an increase in production value and has scale economy.

It is worth mentioning that even the linear regression coefficient estimate (marked in the figure by a horizontal line) is statically significant. If we rely on the results of linear regression for inference, then we may overestimate the low to medium production value distribution and underestimate the upper distribution of production value.



**Fig. 1** Effects of inputs on production value of manufacturing industry of Taipei metropolitan

This is compelling evidence for the study of production functions to adopt the quantile regression approach.

The effect of capital investment on production value is positive and statistically significant at the 1% level. Moreover, it is monotonically decreasing at 0.1–0.4 quantiles in the distribution of the production value and monotonically increasing

at 0.4–0.9 quantiles. This indicates that at the medium level and upper level of the production value, the capital input has scale economies, and the lower level has scale diseconomies.

The effect of floor space on production is negative and statistically significant at the 1% level for all quantiles in the distribution of the production value, and the trend is decreasing. The effect of labor input is positive and statistically significant at the 1% level and it is monotonically increasing from 0.1 to 0.4 quantiles, while decreasing at the 0.4–0.9 quantiles.

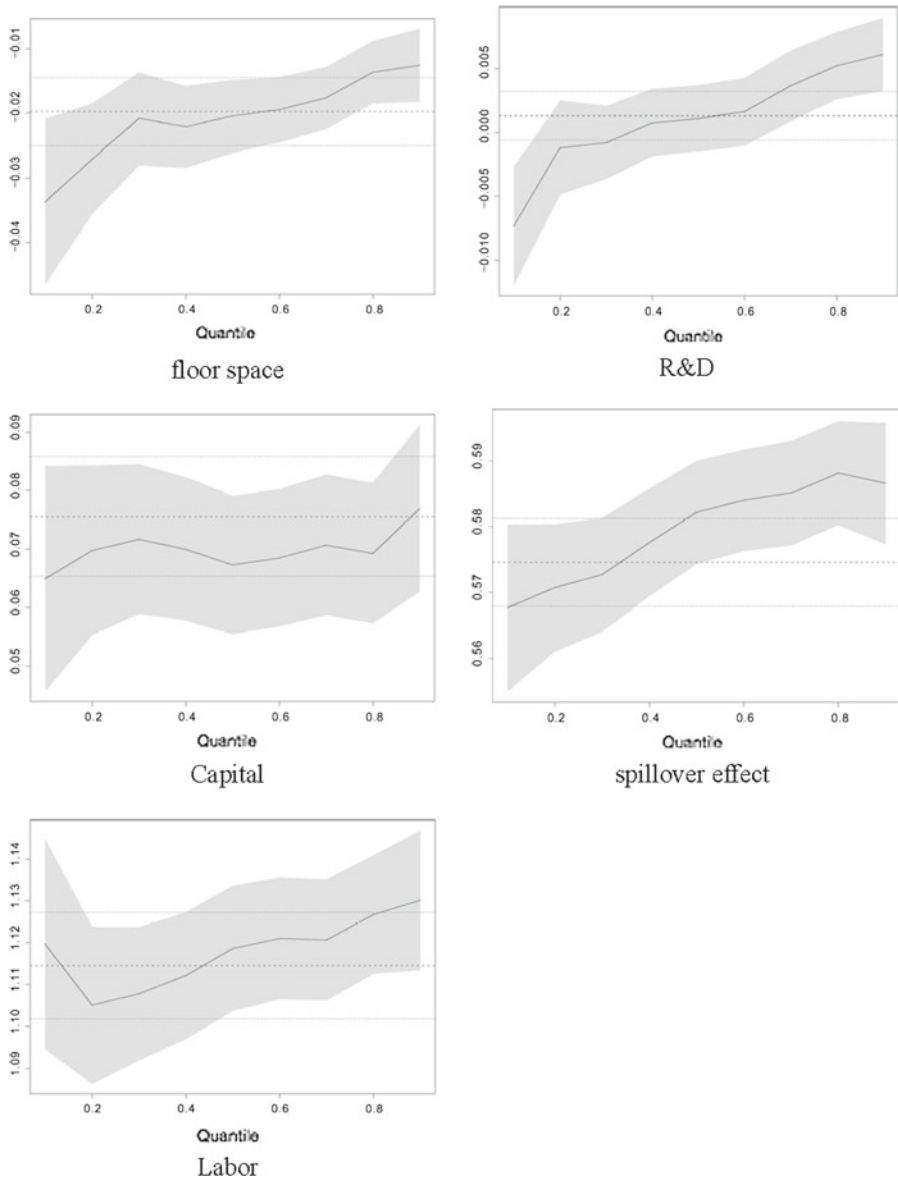
The effect of spatial externality (spillover effect) is positive and statistically significant at the 1% level and is monotonically increasing from 0.1 to 0.5 quantiles, while decreasing at the 0.5–0.9 quantiles. This result implies that the firms with lower production value can experience a greater effect from spatial externality when the production value is increasing and the medium and high production value can experience a less effect from spatial externality when the production value is increasing. This result indicated that the medium firms can get more spatial externality than small and large firms.

#### 4.2.2 *Electrical and electronic machinery industry*

In this study, the researchers chose the electrical and electronic machinery industry to represent high-intensity R&D industry. There are some differences between the effects of variables on the distribution of the production values for the electrical and electronic machinery industry and those for the manufacturing industry (see Fig. 2). For example, the effect of capital input on production is positive and statistically significant at the 1% level, and is increasing trend at 0.1–0.3, 0.5–0.7, and 0.8–0.9 quantiles, while decreasing trend at 0.3–0.5, and 0.8–0.9 quantiles. The effect of floor space on production is negative and statistically significant at the 1% level in all quantiles for the distribution of the production values, but the trend is increasing. The effect of spatial externality (R&D spillover effect on production value) is positive and statistically significant at the 1% level and is increasing from 0.2 to 0.9 quantiles, only decreasing at the 0.1–0.2 quantiles. The effect of R&D is only statistically significant at the 1% level at the 0.1 quantile (it is negative), 0.7, 0.8 and 0.9 quantiles (which are positive). It should be noted though that this implies that the higher production firms can gain a greater effect from R&D investment. The effect of labor input is positive and statistically significant at 1% level in all quantiles and it is decreasing from 0.1 to 0.2 quantiles, and increasing from 0.2 to 0.9 quantiles.

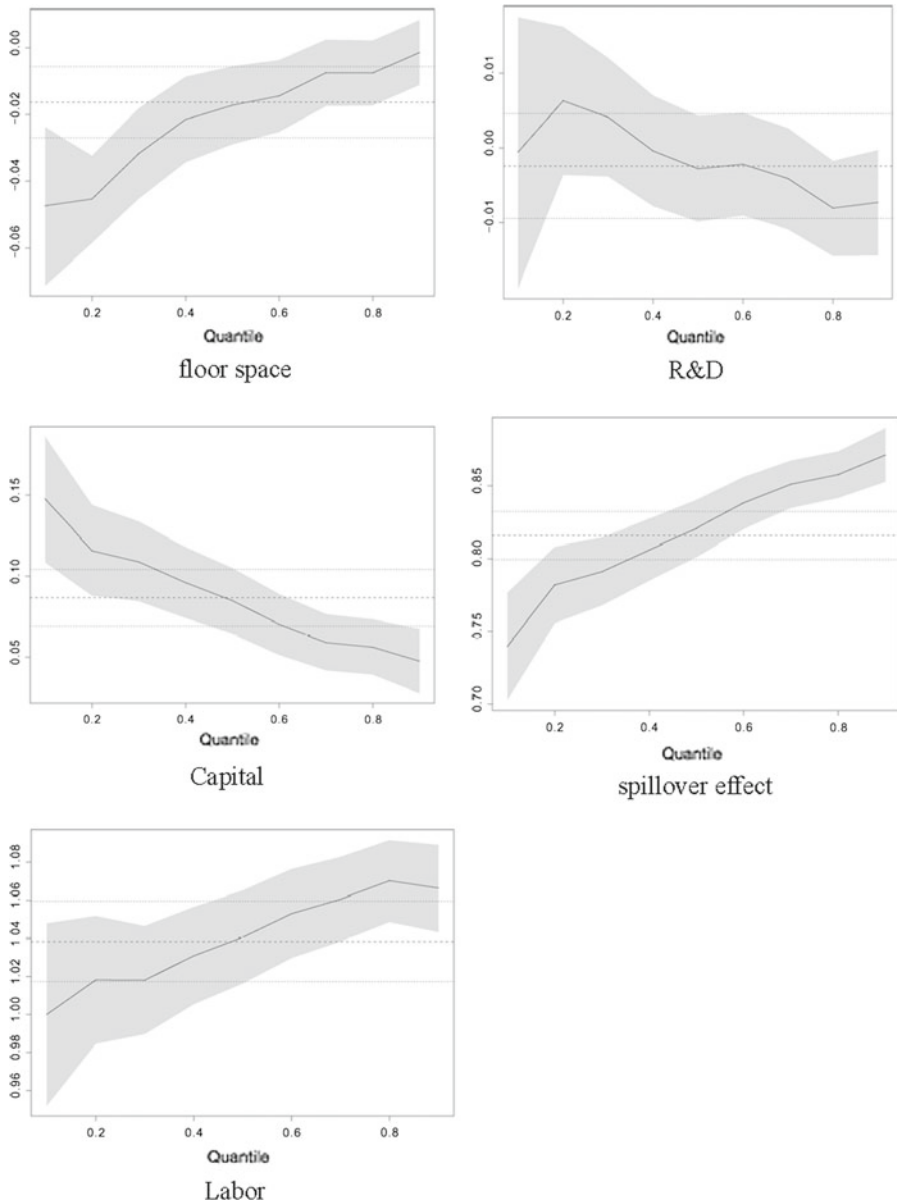
#### 4.2.3 *Apparel and accessories and leather industries*

The apparel and accessories and leather industries were chosen to represent low-intensity R&D industry. Like the electrical and electronic machinery industry, the effect of floor space on production value is negative and statistically significant at the 1% level. Moreover, it has an increasing trend at all quantiles. Other variables have different effects with the two other industries. For example, the effect of R&D on production is negative and statistically significant at the 1% level for 0.8 and 0.9 quantiles.



**Fig. 2** Effects of inputs on production value of high R&D industry of Taipei metropolitan

The effect of capital on production value is positive and statistically significant at 1% level but the trend is decreasing. The effect of spatial externality (spillover effect) is positive and statistically significant at the 1% level and shows increasing trend at all quantiles. The effect of the labor input is positive, and the trend is increasing at all quantiles (see Fig. 3).

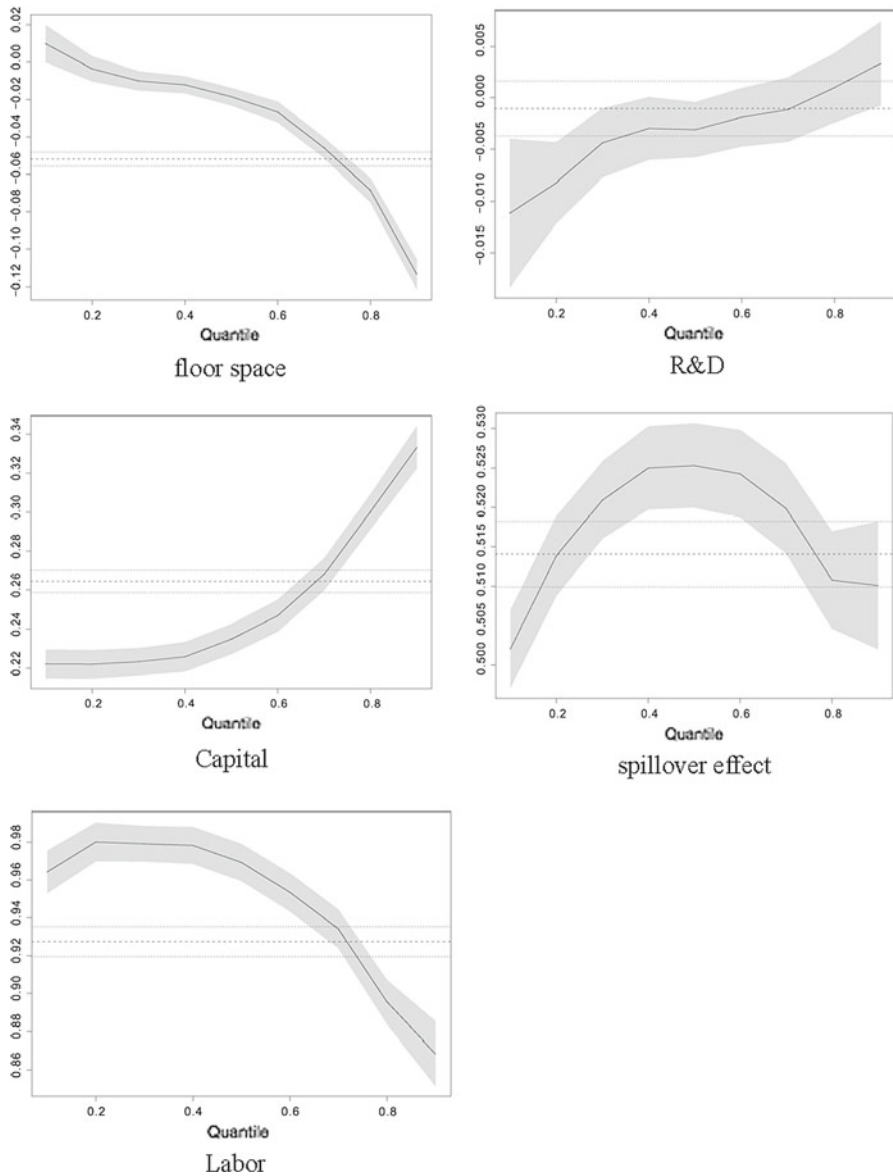


**Fig. 3** Effects of inputs on production value of low R&D industry of Taipei metropolitan

#### 4.3 Effects of variables for the Taichung metropolitan area

##### 4.3.1 Manufacturing industry

The effects of the variables on production value on the distribution of manufacturing industry in the Taichung metropolitan area are presented in Fig. 4. There are some



**Fig. 4** Effects of inputs on production value of manufacturing industry of Taichung metropolitan

similarities between the effects of the variables on the distribution of the production value of manufacturing industry in Taipei metropolitan area and those for the Taichung metropolitan area (see Table 5).

The results indicate that the capital, spillover effect, and labor input have positive coefficients at all quantiles all statistically significant at the 1% level; and the trends are similar to the manufacturing industry in Taipei metropolitan area (see Table 5).

**Table 5** The summary results of three metropolitans

Industry	Variable	Taipei	Taichung	Kaohsiung
Manufacturing				
	FL	D	D	D
	R&D	I	I	I→C
	K	D→I	I	C→I
	S	I→D	I→D	I→D→I
	L	I→D	I→D	I→D
Electrical and electronic machinery				
	FL	I	D→I→D→I	D→I→D→C→I
	R&D	I	I→D→C	I→D→I→D
	K	I→D→I	D→C→D	I→D→I→D→I
	S	I	I→C→D→I	I→D→I
	L	D→I	I→C→I	D→I→D→I→D→I
Apparel and accessories and leather				
	FL	I	D→I→C	C→I→D→I
	R&D	I→D	C→I	C→I→D→I
	K	D	C→I	I→D→I
	S	I	I→D	I→D→I
	L	I	C→D	D→C→D

*I* Increasing with scale, *D* decreasing with scale, *C* constant with scale

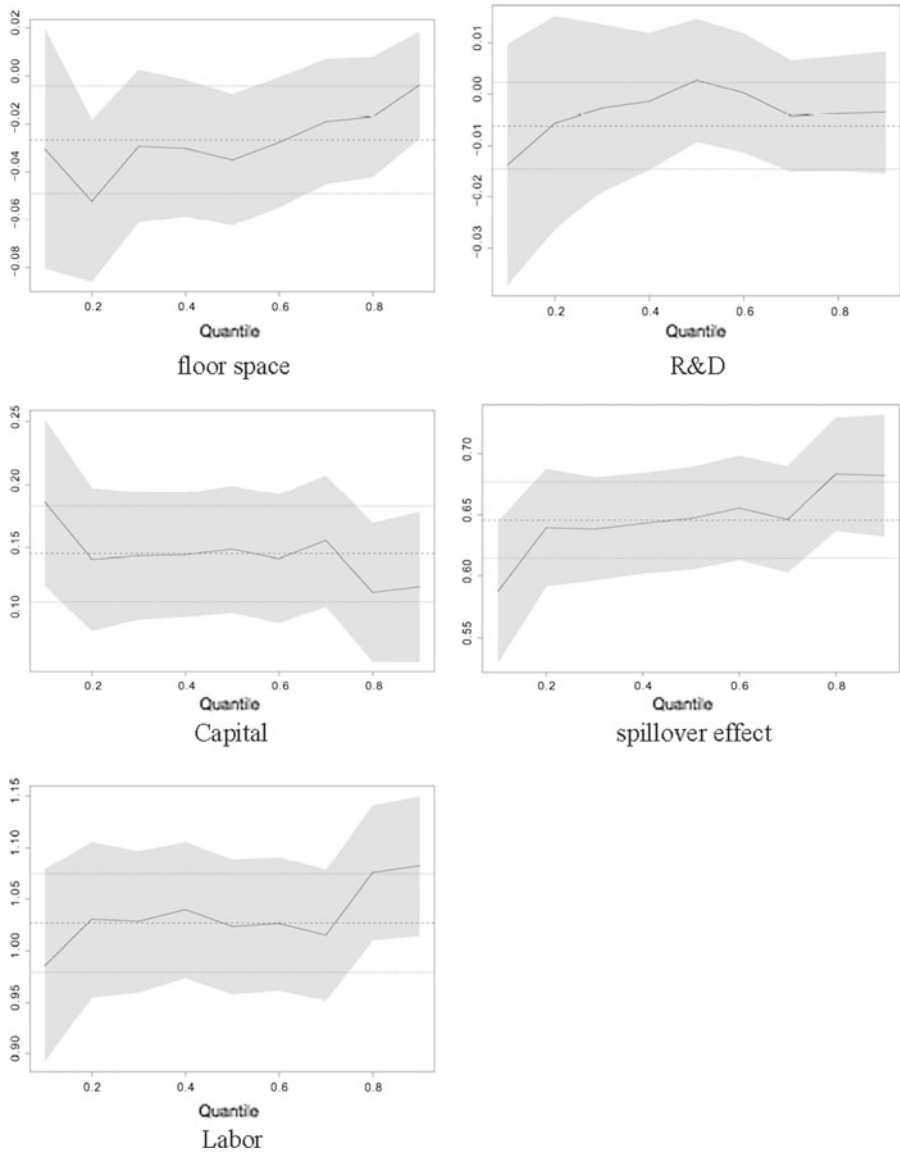
The spillover effect is an inverted U turn shape. While the floor space and R&D inputs are negative at all quantiles, it is only statistically significant at 0.3–0.9 quantiles for floor space variable, and at 0.1, 0.2, 0.3, and 0.5 quantiles for R&D variable. Figure 4 shows that the effects of capital input, the spillover effect and employment are more important than other variables at all quantiles in the distribution of the production value.

#### 4.3.2 Electrical and electronic machinery industry

Figure 5 shows the effects of the variables on the production value for the electrical and electronic machinery industry in the Taichung metropolitan area. The results indicate that the capital, spillover effect and labor input have positive coefficients at all quantiles. All the coefficients are statistically significant at the 1% level. Like manufacturing industry in this area, the floor space and R&D inputs are negative, and statistically significant at the 1% level at 0.2–0.6 quantiles for floor space, but only at 0.2 quantile for R&D variable. Figure 5 indicates that the effects of capital input, the spillover effect and labor input are more important than other variables at all quantiles in the distribution of the production value.

There are some important differences between these results and those for the electrical and electronic machinery industry in the Taipei metropolitan area. The R&D



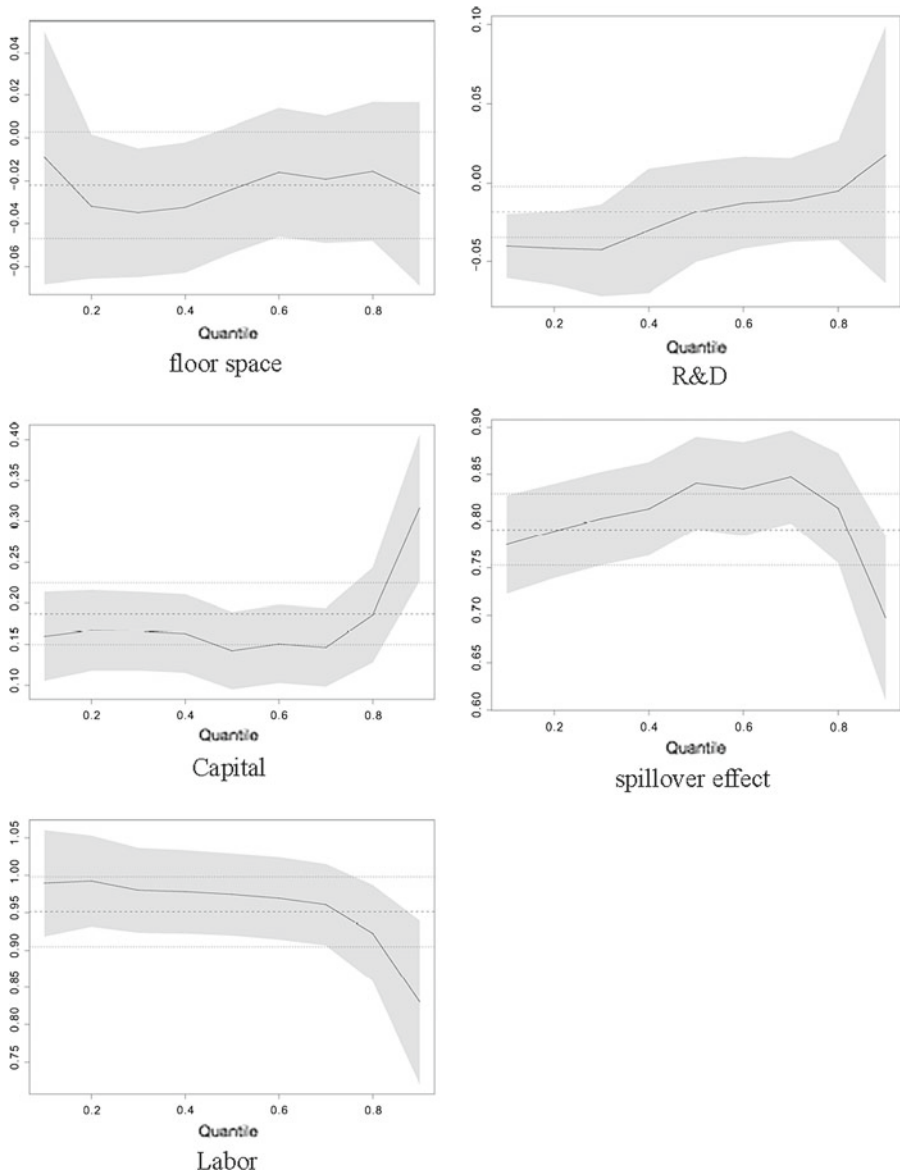


**Fig. 5** Effects of inputs on production value of high R&D industry of Taichung metropolitan

input only statistically significant at 0.2 quantile, and the sign is negative. The floor space for production is not statistically significant at 0.7–0.9 quantiles (see Table 5).

#### 4.3.3 Apparel and accessories and leather industries

The results pertaining to the effects of the variables on production value of the apparel and accessories and leather industries in the Taichung metropolitan area are presented



**Fig. 6** Effects of inputs on production value of low R&D industry of Taichung metropolitan

in Fig. 6. The results show that the effect of the capital input, spillover effect, and labor input on production are positive at all quantiles. The coefficients are statistically significant at the 1% level. The floor space variable and R&D input are negative and are statistically significant only at 0.3 and 0.04 quantiles for floor space variable, 0.2–0.3 quantiles for R&D input.

The capital variable is monotonically increasing from 0.7 to 0.9 quantiles. This result is different from those for industries in Taipei and Taichung metropolitan areas. The spillover effect is increasing from 0.1 to 0.7 quantiles but decreasing after the 0.7 quantile. The effect of labor input is decreasing trend. These two results are similar to those for industries in the Taipei and Taichung metropolitan areas (see Table 5).

#### 4.4 Effects of variables for the Kaohsiung metropolitan area

##### 4.4.1 *Manufacturing industry*

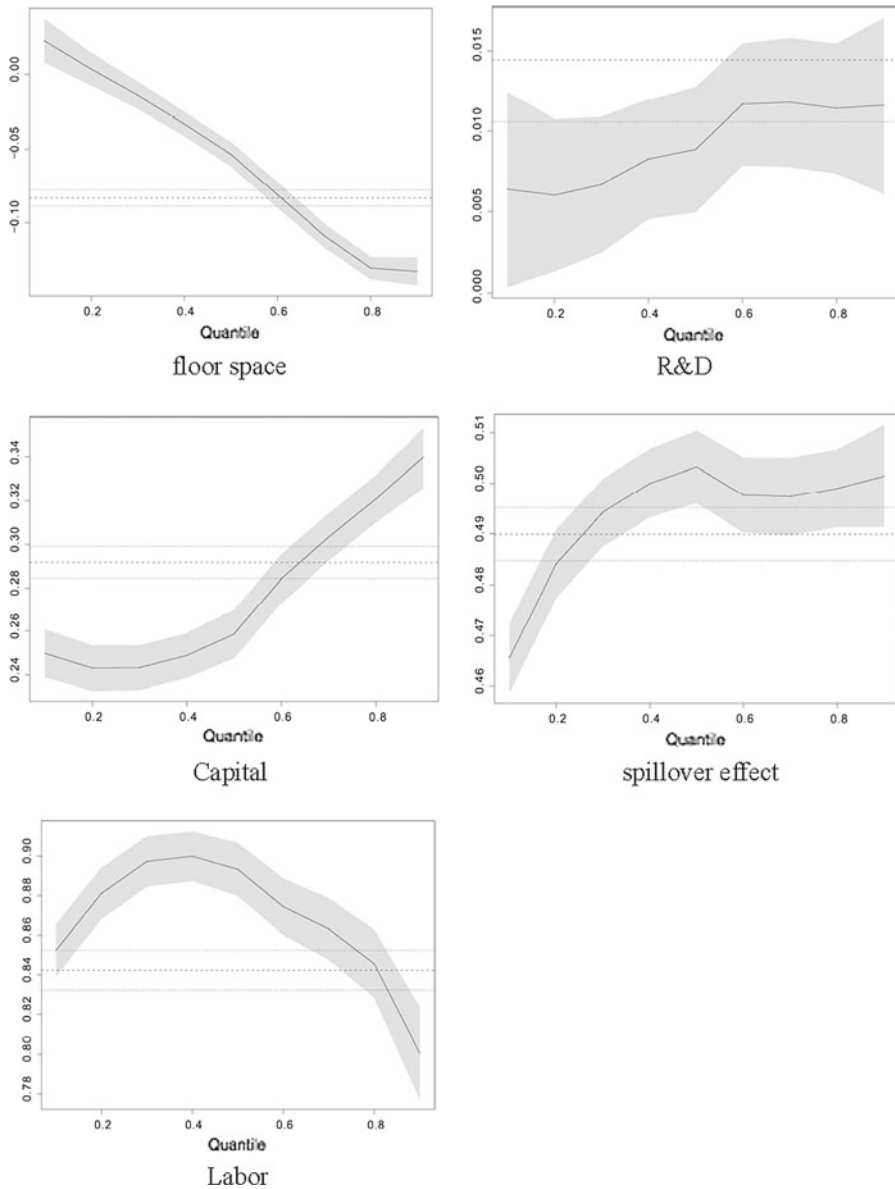
The effects of the various variables on production values distribution in the manufacturing industry of the Kaohsiung metropolitan area are presented in Fig. 7. The capital and labor inputs are similar to those of the manufacturing industries in the Taipei and Taichung metropolitan areas (see Table 5). In contrast, the spillover effect has an increasing trend at lower levels of production value distribution (0.1–0.5 quantiles) then an decreasing trend at medium levels (0.5–0.7 quantiles), and finally, an increasing trend at upper levels. This means that the higher production value firms can get more spatial externality. The effect of floor space on production value is positive coefficient at 0.1 quantile and negative coefficients at 0.3–0.9 quantiles and statistically significant at 1% level. The R&D input is positive coefficient at all quantiles and statistically significant at the 5% level. The trend is increasing at all quantiles. This means that the firm with upper level of the production value can get more R&D effect than lower level's firm. These results are different than those of the manufacturing industries in the Taipei and Taichung metropolitan areas.

##### 4.4.2 *Electrical and electronic machinery industry*

Figure 8, reveals that the floor space input is not statistically significant at all quantiles. This result is different from with other industries in all metropolitans (see Table 5). The R&D input is negative coefficient and only statistically significant at lower level (0.1–0.3 quantiles) and medium level (0.6 quantile) of production value. The capital input, spillover effect and labor input all have positive coefficients at all quantiles and all coefficients are statistically significant at the 1% level. The coefficients of capital input and spillover effect have increasing trend, these results are similar to the high R&D industry in Taipei metropolitan.

##### 4.4.3 *Apparel and accessories and leather industries*

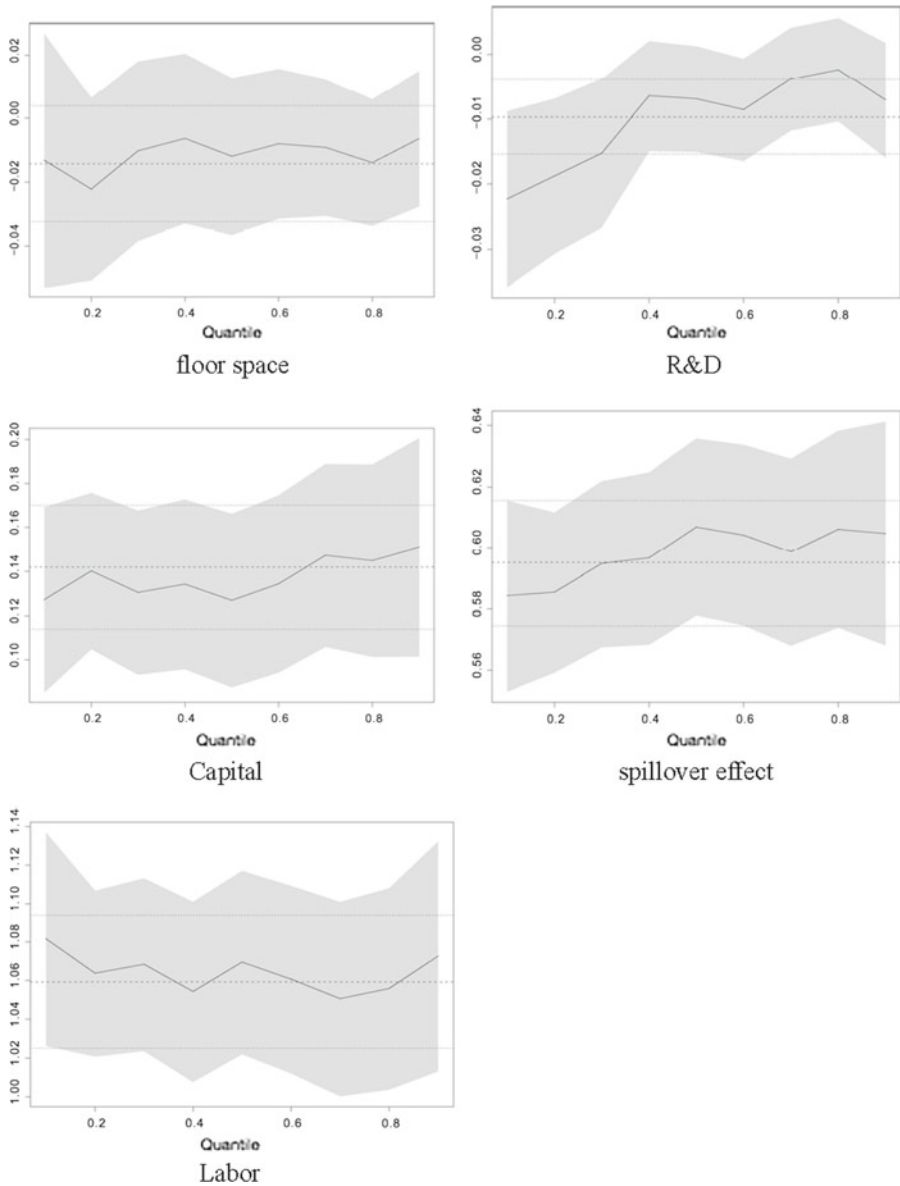
The effects of the different variables on production value distribution of apparel and accessories and leather industries in the Kaohsiung metropolitan area are presented in Fig. 9. The coefficients of floor space and R&D inputs are not statistically significant at all quantiles. The capital input, spillover effect, and labor input all have positive coefficients at all quantiles, and all coefficients are statically significant at the 1% level. The capital inputs and spillover effect have increasing trend on production value. The



**Fig. 7** Effects of inputs on production value of manufacturing industry of Kaohsiung metropolitan

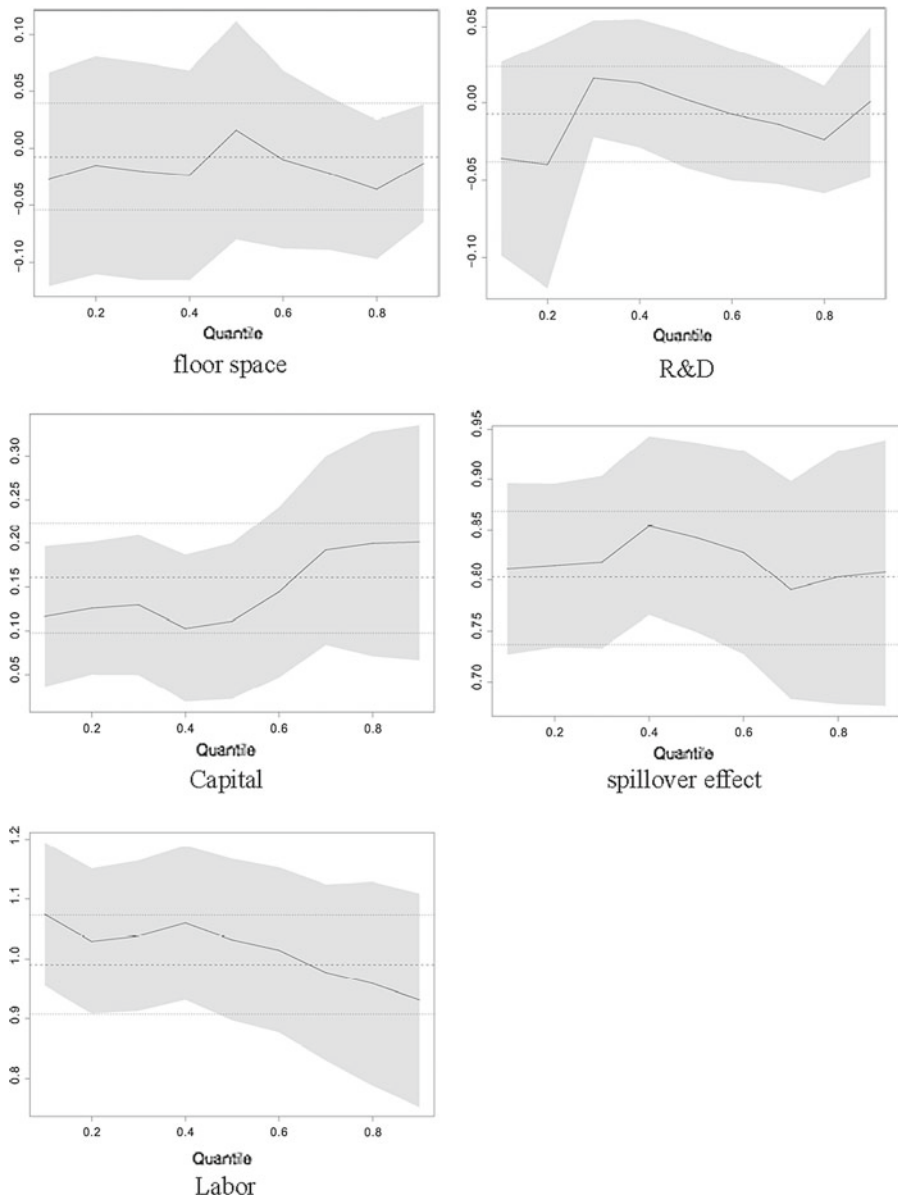
labor input has decreasing trend, which is similar to the low R&D industry in Taipei metropolitan (see Table 5).

As a final step, this paper compares the effects of R&D spillover effect among the three metropolitan areas (see Tables 6, 7 and 8). After normalizing the coefficients of spillover effect of R&D, it becomes clear that the Taipei metropolitan area has the



**Fig. 8** Effects of inputs on production value of high R&D industry of Kaohsiung metropolitan

highest spillover effect in all industries, regardless of whether they are total manufacturing industry, high- or low-intensity R&D industries. This result is similar to those of previous studies; the aggregation of R&D in an industry has a positive effect on spatial agglomeration.



**Fig. 9** Effects of inputs on production value of low R&D industry of Kaohsiung metropolitan

## 5 Conclusion

This paper applied the [Berliant et al. \(2002\)](#) model and quantile regression analysis to examine the spatial spillover effects of R&D on the manufacturing industry, electrical and electronic machinery industry (as representative of the high-intensity

R&D industry), and apparel and accessories and leather industries (to represent low-intensity R&D industry) in the Taipei, Taichung, and Kaohsiung metropolitan areas, respectively.

We employ the data collected by the Census in Taiwan Area in 2001, which show that the capital investment, R&D spillover effects and labor input on production are more important than those of other variables at all quantiles in the distribution of the production values. This means that the spillover effects of R&D are much higher than R&D inputs by firms themselves in all industries. This result is the same as that of [Postner and Wesa \(1983\)](#).

The spatial spillover effect of R&D is positive and significant in all industries for all three metropolitan areas. Although the trends are different among the different industries and areas, most of the firms in medium and upper level of production value can get more effects than lower level firms. The only exception is the low-intensity R&D industry in Taichung metropolitan in which the firms with upper level of production value have lower effect of R&D externality. This result implies that the R&D spillover effects in the manufacturing industry, high-intensity and low-intensity R&D industries have a scale economy with the production value.

The effects of R&D's individual inputs on production for the manufacturing, high-intensity and low-intensity R&D industries have different effects on different industries and different areas. In Taipei metropolitan area, the manufacturing industry has positive coefficients at 0.3–0.9 quantiles; the high-intensity R&D industry has negative coefficient at 0.1 quantile and positive coefficients at 0.7–0.9 quantiles. In Taichung metropolitan area all three industries have negative coefficient at lower level (3 industries) and medium level (manufacturing industry). In Kaohsiung metropolitan area, the manufacturing industry has positive coefficients at all quantiles. While the high R&D industry negative coefficients at lower and medium level of production value and for the low R&D industry, there is no significant coefficients at all quantiles. This is because most firms in Taiwan are small-scale relative to those found in other countries, and the R&D investment to GDP is 2.05% in 2000, lower than Korea (2.65%) and Japan (3.12%), and only 2% of firms have R&D investment, even high-intensity R&D industry only 9% of firms have R&D investment. Another reason is the effects of R&D investment cannot be realized immediately. If panel data were available, the results may have been different.

In addition, this research found that the R&D spatial spillover effects are important for productivity in all industries and all metropolitan areas. This result confirms that the spillover effect is important for intra-industry firms ([Jacobs 1969](#); [Romer 1986](#)).

Finally, the study found that the spatial spillover effect is highest in the Taipei metropolitan area which is the largest metropolitan area in Taiwan for all industries. This empirical finding confirms the spatial model presented by [Berliant et al. \(2002\)](#). When firms in an industry are more agglomerated in a city, then the spillover effect of R&D on the firm will be higher.

Following this empirical work, there are a few questions that remain to be addressed. First, a more comprehensive employment of micro-data based on an examination of the panel track, may find that R&D investment and spillover externalities on production have different effects on various industries in different periods. Second, by

**Table 6** Quantile regression results of Taipei metropolitan

OLS	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	
Manufacture industry										
F	-0.099** (0.001)	-0.019** (0.004)	-0.031** (0.002)	-0.036** (0.002)	-0.042** (0.002)	-0.053** (0.002)	-0.072** (0.002)	-0.120** (0.003)	-0.159** (0.002)	-0.164** (0.003)
R	0.013** (0.001)	0.002 (0.002)	0.002* (0.001)	0.005** (0.001)	0.007** (0.001)	0.007** (0.001)	0.010** (0.001)	0.014** (0.001)	0.015** (0.001)	0.017** (0.001)
K	0.268** (0.002)	0.236** (0.003)	0.207** (0.003)	0.195** (0.003)	0.190** (0.003)	0.197** (0.003)	0.219** (0.003)	0.261** (0.004)	0.297** (0.003)	0.327** (0.004)
S	0.463** (0.001)	0.443** (0.002)	0.472** (0.002)	0.486** (0.002)	0.495** (0.002)	0.496** (0.002)	0.490** (0.002)	0.478** (0.002)	0.470** (0.002)	0.464** (0.003)
L	0.880** (0.003)	0.909** (0.005)	0.953** (0.004)	0.970** (0.004)	0.977** (0.003)	0.973** (0.003)	0.951** (0.004)	0.921** (0.004)	0.893** (0.005)	0.844** (0.007)
Electrical and electronic machinery industry										
F	-0.019** (0.003)	-0.034** (0.007)	-0.027** (0.004)	-0.021** (0.004)	-0.022** (0.003)	-0.020** (0.003)	-0.019** (0.003)	-0.018** (0.002)	-0.014** (0.002)	-0.013** (0.003)
R	0.001 (0.001)	-0.007** (0.002)	-0.001 (0.002)	-0.001 (0.001)	0.001 (0.001)	0.001 (0.001)	0.002 (0.001)	0.004** (0.001)	0.005** (0.001)	0.006** (0.001)
K	0.076** (0.005)	0.065** (0.010)	0.070** (0.007)	0.072** (0.007)	0.070** (0.006)	0.067** (0.006)	0.069** (0.006)	0.071** (0.006)	0.069** (0.006)	0.077** (0.007)
S	0.575** (0.003)	0.568** (0.006)	0.571** (0.005)	0.573** (0.004)	0.578** (0.004)	0.582** (0.004)	0.584** (0.004)	0.585** (0.004)	0.588** (0.004)	0.587** (0.005)
L	1.115** (0.006)	1.120** (0.013)	1.105** (0.010)	1.108** (0.008)	1.112** (0.008)	1.119** (0.008)	1.121** (0.007)	1.121** (0.007)	1.127** (0.007)	1.130** (0.009)
Apparel and accessories and leather industries										
F	-0.016** (0.005)	-0.047** (0.012)	-0.045** (0.007)	-0.032** (0.007)	-0.021** (0.007)	-0.017** (0.006)	-0.014** (0.005)	-0.007 (0.005)	-0.008 (0.005)	-0.001 (0.005)
R	-0.002 (0.004)	-0.001 (0.009)	0.006 (0.005)	0.004 (0.004)	0.000 (0.004)	-0.003 (0.004)	-0.002 (0.004)	-0.004 (0.003)	-0.008** (0.003)	-0.007** (0.004)
K	0.087** (0.089)	0.147** (0.020)	0.116** (0.014)	0.109** (0.012)	0.096** (0.011)	0.085** (0.010)	0.070** (0.010)	0.059** (0.009)	0.056** (0.009)	0.048** (0.010)
S	0.815** (0.008)	0.740** (0.019)	0.782** (0.013)	0.791** (0.012)	0.806** (0.012)	0.821** (0.011)	0.838** (0.010)	0.851** (0.009)	0.858** (0.008)	0.871** (0.009)
L	1.038** (0.011)	1.000** (0.024)	1.018** (0.017)	1.018** (0.015)	1.031** (0.013)	1.041** (0.012)	1.053** (0.012)	1.061** (0.011)	1.070** (0.011)	1.066** (0.012)

Standard errors are in parentheses. \*, significant at the 5% level. \*\*, significant at the 1% level



**Table 7** Quantile regression results for Taichung metropolitan

OLS	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
<b>Manufacture industry</b>									
F	-0.052** (0.002)	0.010 (0.005)	-0.004 (0.003)	-0.010** (0.003)	-0.012** (0.002)	-0.019** (0.002)	-0.027** (0.003)	-0.046** (0.003)	-0.114** (0.004)
R	-0.001 (0.001)	-0.011* (0.004)	-0.008* (0.002)	-0.004* (0.002)	-0.003* (0.002)	-0.003* (0.001)	-0.002 (0.001)	0.001 (0.002)	0.003 (0.002)
K	0.264** (0.003)	0.222 (0.004)	0.222** (0.004)	0.223** (0.004)	0.226** (0.004)	0.235** (0.004)	0.247** (0.004)	0.268** (0.004)	0.333** (0.006)
S	0.514** (0.002)	0.502** (0.003)	0.514** (0.003)	0.521** (0.002)	0.525** (0.003)	0.525** (0.003)	0.524** (0.003)	0.520** (0.003)	0.510** (0.004)
L	0.927** (0.004)	0.964** (0.006)	0.980** (0.005)	0.979** (0.005)	0.978** (0.005)	0.969** (0.005)	0.953** (0.005)	0.934** (0.005)	0.869** (0.009)
<b>Electrical and electronic machinery industry</b>									
F	-0.027* (0.011)	-0.031 (0.025)	-0.052** (0.017)	-0.029 (0.016)	-0.030* (0.014)	0.014* -(2.507)	-0.028* (0.014)	-0.019 (0.013)	-0.004 (0.011)
R	-0.006 (0.004)	-0.014 (0.012)	-0.006** (0.011)	-0.003 (0.008)	-0.001 (0.007)	0.006 (0.447)	0.000 (0.006)	-0.004 (0.006)	-0.003 (0.006)
K	0.145** (0.019)	0.186** (0.033)	0.141** (0.029)	0.144** (0.026)	0.144** (0.025)	0.026** (5.811)	0.141** (0.026)	0.156** (0.026)	0.119** (0.030)
S	0.646** (0.016)	0.587** (0.029)	0.640** (0.024)	0.638** (0.022)	0.643** (0.021)	0.021** (30.252)	0.656** (0.022)	0.646** (0.022)	0.682** (0.025)
L	1.027** (0.024)	0.986** (0.047)	1.030** (0.038)	1.028** (0.035)	1.040** (0.034)	0.033** (30.723)	1.026** (0.033)	1.015** (0.032)	1.082** (0.035)
<b>Apparel and accessories and leather industries</b>									
F	-0.022 (0.013)	-0.009 (0.030)	-0.032 (0.017)	-0.035* (0.015)	-0.032* (0.015)	-0.024 (0.015)	-0.016 (0.015)	-0.019 (0.015)	-0.026 (0.022)
R	-0.018* (0.008)	-0.040** (0.010)	-0.042** (0.012)	-0.043** (0.015)	-0.030 (0.020)	-0.019 (0.016)	-0.013 (0.015)	-0.011 (0.014)	0.017 (0.041)
K	0.187** (0.019)	0.160** (0.028)	0.167** (0.025)	0.166** (0.024)	0.163** (0.024)	0.142** (0.024)	0.150** (0.024)	0.146** (0.024)	0.316** (0.046)
S	0.791** (0.020)	0.775** (0.027)	0.789** (0.026)	0.803** (0.025)	0.813** (0.025)	0.841** (0.025)	0.834** (0.025)	0.847** (0.025)	0.698** (0.044)
L	0.951** (0.024)	0.989** (0.036)	0.992** (0.031)	0.980** (0.029)	0.978** (0.028)	0.974** (0.028)	0.969** (0.028)	0.923** (0.033)	0.830** (0.056)

Standard errors are in parentheses. \* significant at the 5% level. \*\* significant at the 1% level

**Table 8** Quantile regression results for Kaohsiung metropolitan

OLS	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
<b>Manufacture industry</b>									
F	-0.083** (0.003)	0.023** (0.007)	0.004** (0.006)	-0.014** (0.005)	-0.033** (0.004)	-0.053** (0.004)	-0.081** (0.004)	-0.108** (0.004)	-0.130** (0.004)
R	0.014** (0.002)	0.006* (0.003)	0.006* (0.002)	0.007** (0.002)	0.008** (0.002)	0.009** (0.002)	0.012** (0.002)	0.011** (0.002)	0.012** (0.003)
K	0.292** (0.004)	0.250** (0.006)	0.243** (0.005)	0.243** (0.005)	0.249** (0.005)	0.259** (0.006)	0.284** (0.006)	0.302** (0.005)	0.321** (0.005)
S	0.490** (0.003)	0.466** (0.00350)	0.484** (0.003)	0.494** (0.003)	0.500** (0.003)	0.503** (0.004)	0.498** (0.004)	0.497** (0.004)	0.499** (0.005)
L	0.842** (0.005)	0.852** (0.007)	0.881** (0.007)	0.897** (0.006)	0.900** (0.006)	0.893** (0.007)	0.874** (0.007)	0.862** (0.008)	0.846** (0.009)
<b>Electrical and electronic machinery industry</b>									
F	-0.014 (0.009)	-0.013 (0.020)	-0.022 (0.015)	-0.010 (0.014)	-0.006 (0.014)	-0.012 (0.013)	-0.008 (0.012)	-0.009 (0.011)	-0.014 (0.010)
R	-0.010** (0.003)	-0.022** (0.007)	-0.019** (0.006)	-0.015** (0.006)	-0.006 (0.004)	-0.007 (0.004)	-0.009* (0.004)	-0.004 (0.004)	-0.002 (0.004)
K	0.142** (0.014)	0.127** (0.021)	0.140** (0.018)	0.130** (0.019)	0.134** (0.020)	0.127** (0.020)	0.134** (0.020)	0.147** (0.021)	0.145** (0.022)
S	0.595** (0.010)	0.584** (0.016)	0.585** (0.013)	0.595** (0.014)	0.597** (0.014)	0.607** (0.015)	0.604** (0.015)	0.599** (0.016)	0.606** (0.016)
L	1.059** (0.017)	1.082** (0.028)	1.064** (0.022)	1.068** (0.023)	1.054** (0.024)	1.070** (0.024)	1.061** (0.025)	1.051** (0.026)	1.056** (0.027)
<b>Apparel and accessories and leather industries</b>									
F	-0.007 (0.024)	-0.027 (0.048)	-0.015 (0.049)	-0.020 (0.048)	-0.024 (0.047)	0.016 (0.049)	-0.010 (0.040)	-0.022 (0.034)	-0.036 (0.031)
R	-0.007 (0.016)	-0.036 (0.032)	-0.040 (0.041)	0.016 (0.019)	0.013 (0.021)	0.002 (0.023)	-0.007 (0.022)	-0.014 (0.020)	-0.024 (0.018)
K	0.160** (0.032)	0.116** (0.041)	0.126 (0.039)	0.129* (0.041)	0.103* (0.043)	0.111* (0.045)	0.144** (0.050)	0.192** (0.055)	0.199** (0.065)
S	0.803** (0.033)	0.812** (0.043)	0.815** (0.041)	0.818** (0.043)	0.854** (0.045)	0.843** (0.048)	0.828** (0.051)	0.791** (0.055)	0.803** (0.064)
L	0.990** (0.042)	1.074** (0.061)	1.029** (0.062)	1.038** (0.064)	1.060** (0.065)	1.032** (0.069)	1.015** (0.070)	0.977** (0.075)	0.958** (0.087)

Standard errors are in parentheses. \* significant at the 5% level. \*\* significant at the 1% level

utilizing parallel data from other countries, an interesting comparison and analysis can be made.

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