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The Spillover Effect of R&D on the Manufacturing Industry in Taiwan

Hsiao-Lan Liu*

(Preliminary Draft)

Abstract

As shown in the literature with the new growth theory, R&D is regarded as a crucial factor to economic growth. Because R&D not only improves production technology for itself, it also has the significant externality (spillover) effect on the other firms. Some of empirical studies prove that the spillover effect of R&D only emerged in the inter-industry (Berstein, 1988; Cuneo and Mairesse, 1984; Goto and Suzuki, 1989; Griliches, 1992), while, Glaeser *et al*. (1992) and Henderson *et al*. (1995) have found significant knowledge spillover within and between industries. In this paper, we follow the model developed by Berliant, Peng, and Wang (2002) to examine the R&D externality within industries associated with the spatial distribution the firms in Taiwan, in which both the Euclidean distances to the mean and an overall dispersion are incorporated on the examination of the externality effect. Using the data collected by the Industrial Census in the Taiwan Area in 2001, we employed three-digit manufacturing industry's data to analyze the R&D spillovers effect in various areas, and classified the manufacturing industries into high R&D industry and low R&D industry. We show that the externality (spillover) effect of R&D in each region can be supported only on the high R&D industry, in which the more agglomeration firms of northern region have the highest spillover effect. However the R&D individual input is not a significant production factor on both the high and low R&D industries.

JEL Classification Numbers: D51, L60, R12

Key Words: Externality, R&D, Spillovers, Spatial Distribution

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* Department of Land Economics, National Chengchi University, Taipei, Taiwan 116, R.O.C. (Tel.) 886-2-2938-7422; (Fax) 886-2-2939-3509;(E-mail)slliou@nccu.edu.tw

1. Introduction

In the modern economy, research and development (R&D) inputs on firms and industries are not evenly distributed across space and therefore regions may not have the identical productivity. As pointed out by Lucas (1988, 1993) and Black and Henderson (1999), the R&D reveals localization and spillovers, presumably through personal face-to-face contacts. That makes cities or regions the engines of economic growth. Therefore, the R& D –induced production externality provides an important basis on which an aggregate production function may no longer face diminishing returns and society's output may grow perpetually. Thus, other things be equal (including the R&D investment on individual firm), the firm with a higher aggregation of R&D in a specific region has a higher productivity than that of the firm in a region with less aggregation R&D. Furthermore, the cities or regions with the higher aggregation of R&D grow faster than rural areas with the less innovative activities.

According to the literature with the new growth theory, the knowledge or human capital accumulation is regarded as a crucial factor to economic growth. Because it not only improves production technology for itself, but it also has a significant externality (spillover) effect on the other firms (Romer, 1990; Grossman and Helpman, 1991; Aghion and Howitt, 1992). In general, this knowledge can be regarded as either technical knowledge (Shell, 1966), Patens (Jaff *et al*. 1993), or R&D (Romer 1986). In the framework of new economic geography, Fujita and Thisse (2002), and Ottaviano and Thisse (2004) specified a perfectly competitive R&D sector that operates under an endogenous growth externality. They documented that agglomeration and growth are perfectly correct, in part because having agglomerated R&D sectors cause higher growth due to the endogenous growth externality. However, such a positive relation cannot be identified empirically in a robust fashion as documented by Berliant and Wang (2004).

Just 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 the firm than within-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 Arrow (1962), the elaboration on an early formalization; the paper by Romer (1986) are recent and influential statements. According to Marsall (1890), the Marshall-Arrow-Romer (MAR) externality concerns knowledge spillovers in cities between firms in an industry. They emphasize that the concentration of an industry in a city or region facilitates R&D spillovers between firms and therefore, increase the productivity of the industry.

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

Specifically, using patent data, Jaffe *et al* (1993) 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 effect of R&D is much higher than the R&D input by firm itself. On the other hand, a growing empirical literature 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; and Rosenthal and Strange, 2001). These studies have had relatively little to say about the causes of agglomeration, while Jacobs (1969) points out that uncompensated knowledge of spillovers are a significant element for spatial agglomeration. Audretsch and Feldman (1996) use a spatial Gini coefficient to measure geographic concentration. They show that innovative activity is substantially more concentrated than overall production and that industries that emphasize research and development tend to be more spatially concentrated. But there is very little empirical research to discuss the spillover effect of R&D with spatial distribution of firms.

For the theoretical view, Berliant, Peng, and Wang (2002), Lucas and Rossi-Hansberg (2002) explore a spatial model associated with R&D externality, which formalizes the knowledge spillovers are regarded as uncompensated factor inputs in firms' production. In this paper, we follow the model that developed by Berliant, Peng, and Wang (2002), and specify the R&D in term of knowledge or human capital as shown in Romer (1986), and examine the R&D externality associated with the spatial distribution of the firms, in which both Euclidean distances to the mean and an overall dispersion are incorporated on the examination of the spatial externality effect using the data collected by the Industrial Census in the Taiwan Area in 2001. We employed three-digit manufacturing industry's data to analyze the R&D spatial spillovers effect in the Northern Region, Central Region and Southern Region[1], and classified the manufacturing industries into high R&D industry and low R&D industry.

It is useful to summarize and highlight the main findings of our paper. It is shown that the externality (spillovers) effect of R&D in the each region can be supported only on the high R&D industry, in which the more agglomeration firms of the Northern region have the highest spillover effect. This finding supports the R&D model with a spatial externality as developed by Berliant *et al*. (2002). However the R&D individual input is not a significant production factor on both the high and low R&D industries. This is because most of firms in Taiwan are small scale relative to that of in the other countries, and the effect of R&D cannot come out immediately. If we have the panel data, the result may be different.

The organization of the remainder of the paper is as follows. In section 2, we present the model structure. Section 3 introduces the regional and manufacturing development in Taiwan. Section 4 describes the data. Section 5 summarize the estimation procedure and analyze the spillover effect in the various industry. We conclude the paper in Section 6.

2. The Model

Consider a firm (represented by three-digit industry) located at a specific site in a region. And the individual firm employs capital (K), labor (L), floor space (F), and R&D capital (R) to produce goods using a constant returns to scale technology 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

$$Y = AK^{\alpha} L^{\beta} F^{\gamma} R^{\delta} S^{\lambda}, \qquad \alpha + \beta + \gamma + \delta = 1, \lambda > 0 \qquad (2\text{-}1)$$

[1] There are four regions in Taiwan Area, Northern Region, Central Region, Southern Region and Eastern Region. But the employment of secondary industry is only 1.4% in Eastern Region. Therefore, we omit the Eastern Region of Taiwan.

where S is specified as an aggregate R&D investment in the industry within the same region. And we classify the industry only by high-R&D industry and low-R&D industry. This production technology is constant returns to scale with respect to all private inputs {K, L, F, R}, while increasing returns with consideration of the aggregation of R&D in the same industry in a specific region. Observe that, the central feature of the model formation is to examine the effect of the uncompensated interfirm R&D on the firm's production. Because the technology is highly related to the R&D expenditure and the parameter *A* represents the technology, the production function can be rewritten as

$$Y = k^{\alpha} L^{\beta} F^{\gamma} R^{\delta} S^{\lambda} \tag{2-2}$$

Follow Berliant *et al*. (2002), we allow the magnitude of 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 effective knowledge spillover will be.

Let *z* denote the distance from the original industrial center in the region, and *R(z)* represents the total R&D input at location *z*. We then denote the centrality location of R&D on the industry by

$$\mu = \sum_z z \times R(z) \Big/ \sum_z R(z) \tag{2-3}$$

In the theoretical model by Berliant *et al*. (2002), the firms are identical with respect to all their inputs, and then the mean location of firms in the industry can be measured by weight mean associated with number of firms in each location. Since the firms are not identical, and we focus on the investigation of R&D spillover effect, thus instead of the number of firms, we employ the amount of R&D to capture the mean location. Therefore, μ represents the mean location of firms associated with the consideration of R&D. Incorporated the definition of mean location, the overall dispersion of firms on the R&D distribution is given by

$$\sigma = \sqrt{\frac{\sum_z R(z) \times (z-\mu)^2}{\sum_z R(z)}} \tag{2-4}$$

Therefore, the degree of effectiveness of interactions between a particular firm at location *z, Q(z)* will be

$$Q(z) = D - |z - \mu| - \varepsilon\sigma \qquad (2\text{-}5)$$

where *D* is the longest distance between town/village in the measure region, the second term specifies a cost function in terms of the distance between a particular town/village site and the mean site, and $\varepsilon \in (0,1)$ indicates the degree of penalty on overall dispersion of R&D. Thus one may regard our *Q* function as a proxy (with the first and second moments) for the (locational) distribution in which externalities enter the system based on an average or aggregation of individual measures.

Therefore, the R&D spillover effect at location *z* associated with the spatial distribution of firms will be formulated by

$$S(z) = Q(z) \times \sum_{z} R(z) \qquad (2\text{-}6)$$

Take log to both sides of equation (2-7), the production function will be

$$\ln Y = \alpha \ln K + \beta \ln L + \gamma \ln F + \delta \ln R + \lambda \ln S \qquad (2\text{-}7)$$

where *S* is the aggregate R&D associated with spatial distribution of firms in industry in the same region, which is defined by equation (2-6).

3. Regional Development of Taiwan

There are four regions in Taiwan Area: Northern Region, Central Region, Southern Region, and Eastern Region (see Fig. 3-1). From Table 3-1, it shows that most of the population and industries are concentrated in the Northern Region. The Northern Region is not only the major industrial area but also the political center (the Capital of R.O.C. is located in this region). The Southern Region is the second of the developed region in Taiwan, where there is the highest area of industrial land use. The Central Region is the third developed region. The last one is the Eastern Region, where it is a mountain area, and limited area for agricultural land use. Therefore, the share of industrial development in this region is sufficiently low. Because of this, the Eastern Region is not included in our studies.

Table 3-1 The Index of Regional Development (2001)

	Northern	**Central**	**Southern**	**Eastern**
Area (%)	20.41	29.19	27.78	22.62
Population (%)	43.34	25.27	28.71	2.68
Density (person/km^2)	1,317	537	641	73
Average Annual Income (NT$)	1,275,060	993,724	958,752	890,238
Industrial Land Use (ha)	4,123	3,378	5,176	222
Production Value (%)	60.9	16.7	21.5	0.9
Number of Plants	444,435	239,703	258,060	23,235

Source: Urban and Regional Development Statistics, R.O.C., 2002

From an industrial development perspective, there are a lot of textile, machinery, and electrical plants established in the Northern Region of Taiwan after World War II. And in 1980, Hsinchu Science Park was set up in this Hsinchu City and County (the southern area of this region), then the high-tech industries became the most important industries in the Northern Region, while the textile industry is still concentrated in this region. Therefore, the electrical & electronic machinery and textile industries are the two pillars of industrial development in the Northern Region. Most factories are developed along the belt aside from the railway and highway. Because most materials are imported from oversea and products are exported, the convenience of transportation plays a dominant role on the location choice for the firms.

At a different type of industrial development, the food, textile, machinery, chemical etc. industries developed very fast in Central Region after 1960. Food industry is the oldest industry in this region. From 1970, the government started to establish some rural industrial districts in the Central Region to promote the regional development in this area. One of the characteristics in the rural industrial district is that most of firms are small scale firms. Therefore, most of firms with employment are below 100 people in this region. In 2001, the top five industries are machinery & equipment industry, fabricated metal products industry, transportation industry, basic metal industry, and plastic products industry.

Finally, the observed industrial development revealed that the steel industry, machinery industry, ship industry, petroleum industry, chemical industry, and textile industry are the major industries in Southern Region. Kaohsuing City (the biggest city in Southern Region) is center of the steel industry where it drives a lot of downstream industries in this area. Kaohsuing metropolitan is also the petroleum development center of Taiwan. Hence, the Southern Region is the second-most developed region in Taiwan.

4. Data

The data will be analyzed in this paper is sourced from on the Industrial Census Data of Taiwan Area in the manufacturing sector in 2001. This census data set is collected by the Directorate General of Budget, Accounting, and Statistics, Executive Yuan, Taiwan every 5 years. The data of 2001 is the newest data. Owing to the limitation of micro data, especially associated with the firm's location, relatively limited attention has been given in understanding empirically the effect of individual R&D investment and spillovers from the same industry on the firm's productivity. Therefore, we employ the three-digit industry, and according to the percentage of the R&D expenditure to the total output, we classify the manufacturing industry into high R&D industry and low R&D industry[2] (see table 4-1).

Table 4-1 The R&D Data of 4-digit Manufacturing Industry

	High/Low R&D industry	R&D expenditure/Output (%)
Manufacturing Industry		1.46
Food	Low	0.98
Beverages and tobacco	Low	0.42
Textile mill products	Low	1.02
Wearing apparel & accessories and Leather	Low	0.49
Wood & bamboo products	Low	0.52

[2] The percentage above 2% will be divided into high R&D industry, see Chuang (1999)

Pulp, paper & printing processings	Low	0.40
Chemical materials and Rubber & plastic products	High	2.03
Petroleum & coal products	Low	0.65
Non-metallic mineral products	Low	0.86
Basic metal	Low	0.93
Fabricated metal products	Low	1.08
Machinery & equipments	High	2.23
Electrical & electronic machinery	High	6.14
Transport equipments	High	2.59
Miscellaneous industry	Low	1.62

Resource: Chuang and Hsu (1999)

The main purpose of this paper is to examine the R&D spillover effect on the firm's productivity in each region. Each region's center is shown in table 4-2.

In this empirical study, the location z in equation (2-3) is measured by the distance from each town/village center to the geographical center of the region. That is, the geographical center in each region on table 2 is regarded as a reference point on the distance measurement. It is obtained either along the highway or the higher R&D input town/village. Then, then this distance measurement in equation (2-3) is applied in GIS to calculate. Similarly, μ is the distance from the center of high/low R&D industry to the geographical center of the region.

Table 4-2 Center of each Region

	Geographical Center	High R&D Industry Center	Low R&D Industry Center
Northern Region	Taipei City (Chungcheng District)	Taoyuan Couty (Dayuan Town)	Taipei City (Shih-lin District)
Central Region	Taichung City (Centeral District)	Taichung County (Wurih Town)	Taichung County (Cingshuei Town)
Southern Region	Kaohsiung City (Sanmin District)	Taiwan County (Yonghean Town)	Pintung County (Donggang Town)

In these three regions, the Northern Region is the main industrial region in Taiwan, most of both high-R&D and low-R&D industries agglomerate in this region. As shown in table 3-3 to 3-8, for high-R&D industry, in terms of production value, the total output in the Northern region is 7.46 times of that in the Central region, and 5.3 times of that in the Southern region. And for the low-R&D industry, in terms of production value, the Northern region is still the highest output region; it is 2.5 times of that in the Central region, and 2.2 times of that in the Southern region. The detailed statistical data can be summarized in the following tables

Table 4-3 High R&D Northern Region

	Mean	Std. Dev.	Min	Max
Production Value (NT$ Thousands)	54,379,242.51	95,559,973.66	3,632.00	371,154,141.00
Floor Space (m^2)	526,368.00	874,709.02	198.00	4,443,027.00
Employment (person)	11,413.65	17,493.98	3.00	74,848.00
Capital (NT$ Thousands)	75,671,337.51	1,756,82,469	4,131.00	1,110,551,974.00
R&D (NT$ Thousands)	1,615,743.68	4,723,071.34	0.00	35,693,046.00

Table 4-4 High R&D Central Region

	Mean	Std. Dev.	Min	Max
Production Value (NT$ Thousands)	7,280,739.83	20,787,424.67	820.00	131,013,032.00
Floor Space (m^2)	101,101.42	230,006.81	25.00	1,381,076.00
Employment (person)	1,696.24	3,769.59	1.00	26,635.00
Capital (NT$ Thousands)	10,134,667.75	38,905,585.83	737.00	302,085,545.00
R&D (NT$ Thousands)	68,173.56	238,496.25	0.00	1,545,569.00

Table 4-5 High R&D Southern Region

	Mean	Std. Dev.	Min	Max
Production Value (NT$ Thousands)	10,334,633.53	31,332,813.11	625.00	203,979,942.00
Floor Space (m^2)	162,854.26	443,185.49	1.00	3,145,656.00
Employment (person)	2,226.35	5,562.52	1.00	42,192.00
Capital (NT$ Thousands)	970,455.01	33,902,291.21	1,073.00	242,720,336.00
R&D (NT$ Thousands)	129,399.47	477,387.02	0.00	2,827,547.00

Table 4-6 Low R&D Northern Region

	Mean	Std. Dev.	Min	Max
Production Value (NT$ Thousands)	33,127,294	70,738,957.89	719.00	559,541,136.00
Floor Space (m^2)	620,720.84	975,573.40	64.00	5,518,912.00
Employment (person)	10,397.93	14,507.04	1.00	74,524.00
Capital (NT$ Thousands)	55,587,220.24	163,159,356	597.00	1,215,192,707.00
R&D (NT$ Thousands)	218,853.24	560,467.27	0.00	3,772,383.00

Table 4-7 Low R&D Central Region

	Mean	Std. Dev.	Min	Max
Production Value (NT$ Thousands)	13,180,107.27	18,640,149.16	578.00	119,552,104.00
Floor Space (m^2)	318,369.83	389,154.97	50.00	1,754,521.00
Employment (person)	5,069.25	6,506.19	1.00	28,895.00
Capital (NT$ Thousands)	12,187,606.98	16,405,646.57	1,274.00	84,978,490.00
R&D (NT$ Thousands)	81,954.34	199,487.08	0.00	1,180,676.00

Table 4-8 Low R&D Southern Region

	Mean	Std. Dev.	Min	Max
Production Value (NT$ Thousands)	14,862,641.14	33,315,715.98	468.00	241,258,012.00
Floor Space (m^2)	293,419.39	522,204.53	80.00	3,776,022.00
Employment (person)	3,882.30	6,750.44	1.00	44,959.00
Capital (NT$ Thousands)	15,695,651.32	41,719,368.16	622.00	289,274,012.00
R&D (NT$ Thousands)	68,934.36	262,171.33	0.00	2,019,214.00

5. Estimates of the Spatial Spillover Effect

Straightforward calculation shows that the floor space, capital inputs, R&D inputs and employment are highly correlated in an area. Therefore, the estimation equation (2-8) will have the multicollinearity problem. To solve this problem, divided *Y, K, F, R&D* by employment *L*, then the equation (2-8) can be rewritten as

$$\ln(Y / L) = \alpha \ln(K / L) + \beta \ln(F / L) + \gamma \ln(R / L) + \lambda \ln(S / L) \qquad (5\text{-}1)$$

As a consequence, we regressed the R&D spillover effect on the production output in terms of per employment. In addition, in this empirical analysis, the degree of penalty on overall dispersion of R&D, ε , is given by 0.2 and 0.8 on high R&D and low R&D industry, respectively.[3] Table 5-1 and 5-2 present the results of ordinary least squares (OLS) estimates of equation (5-1). As discussed above, we estimate separate models for high R&D industries and low R&D industries, for each level of geography — Regions.

Table 5-1 Regression for High R&D Industries in Each Region

	North Region	**Center Region**	**South Region**
Floor Space per	0.13609	0.22728***	0.28541***

[3] We employed ε between 0.2-0.5 [0.5-0.8] in regression analysis on the low [high] R&D industry, and find that it is not a significant effect on the results of externality.

Employment	(1.26)	(2.65)	(3.05)
Capt per Employment	0.62400*** (7.24)	0.74329*** (11.50)	0.62425*** (6.54)
R&D per Employment	0.04335 (1.49)	0.02245 (0.93)	0.01294 (0.42)
Spillover Effect per Employment	0.10724*** (3.29)	0.04799** (1.93)	0.08014** (2.39)
R^2	0.9923	0.9942	0.9881
Adjust R^2	0.9919	0.9939	0.9876
CI	21.55583	18.92641	20.09197
N	84	93	101

*The coefficient is significantly differently from zero at 10% level.

** Significantly different from zero at 5% level.

*** Significantly different from zero at 1% level.

Table 5-2 Regressions for Low R&D Industries in Each Region

	North Region	**Center Region**	**South Region**
Floor Space per Employment	0.31055*** (3.05)	0.17004** (2.12)	0.50389*** (3.78)
Capt per Employment	0.74544*** (13.51)	0.87427*** (13.50)	0.62417*** (8.73)
R&D per Employment	0.01420 (0.69)	-0.01912 (-1.06)	0.02756 (1.24)
Spillover Effect per Employment	0.03062 (1.42)	0.01658 (0.64)	0.03774* (1.66)
R^2	0.9962	0.9963	0.9916
Adjust R^2	0.9960	0.9961	0.9913
CI	18.08150	24.44945	19.03039
N	88	103	122

*The coefficient is significantly differently from zero at 10% level.

** Significantly different from zero at 5% level.

*** Significantly different from zero at 1% level.

As shown in table 5-1, the R&D spillover effect is sufficiently significant in high R&D industries in all three regions, especially in the northern region. However, the R&D investment is not significant on its productivity for all three regions. On the other hand, the capital input is more significant to the firm’s output for all three regions. These results can be interpreted as follows: (1) since we only employ oneyear data, the effect of individual R&D investment is difficult to be revealed immediately; (2) The uncertainty of the success on the R&D investment make the firms hesitate to invest the R&D funds much; (3) Most of firms and industries in Taiwan are relatively small scale; they have less incentive to innovate; (4) The effect of capital input can be come out much earlier than R&D input, especially investment on equipment. With the consideration of the budget constraint, there is a trade-off between the investment on R&D and capital, and if the R&D effect is more uncertain, then the firm will invest less on R&D, and invest more on capital. Therefore, since most industries invest very little compared to the other inputs on the production as shown in table 3.1, the insignificant effect of individual R&D effect is not surprised. However, many firms with little R&D investment concentrate in the same region, then there is a higher aggregation of R&D for the whole industry, and therefore positive spillover effect is significant on the individual firm, especially in the high R&D industries as the estimated results obtained in table 5-1.

Comparing the spillover effect in different regions, the Northern Region has a higher spillover effect elasticity with respect to output (0.107) than the Southern Region (0.0727) and Central Region (0.04612). This result is lower than inter-industry spillover effect in U.S.A. and Japan, which is about 10%-30% (Nadiri, 1993). In particular, this empirical result confirms the theoretical model by Berliant *et al*. (2002) that the externality (or spillover) of R&D is crucial depending on the configuration of firms. That is, the more agglomeration of firms, the higher the externality will be.

From table 5-2, the floor space and capital input are very significant to the output of low R&D industries. But the R&D input is not significant to the output for all three regions. The spillover effect of R&D is only significant with 10% level in the Southern Region. In addition, we find that the output of low R&D industry is highly related to the floor space and capital inputs.

6. Conclusion

In this paper we apply Berliant *et al*. (2002) model to test the spatial spillover effect of R&D on the manufacturing industry in Taiwan area. We use the data collected by the Census in Taiwan Area in 2001, and classified the 3-digit manufacturing industries into high R&D industry and low R&D industry. We find that the spatial spillover effect is significant in high-R&D industry in all three regions, but significant with 10% level in low-R&D industry only in Southern Region, while the R&D’s individual input on both high-R&D and low-R&D industries productivity are insignificant. This is because most of firms in Taiwan are small scale relative to that of in the other countries, and also the effect of R&D cannot come out immediately. If we have the panel data, the result may be different.

In addition, we found that the spatial spillover effect is highest in the Northern Region. This empirical finding confirms the spatial model by Berliant *et al*. (2002) that when the firms in an industry are more agglomerate in the same region, then the spillover effect of R&D on the firm would be higher. The establishment of Hsinchu Science Park may be a reason. If we can further prove, the Science Park’s location policy will be an important source of the spatial spillover effect. Along this empirical work, there are a few straightforward jobs to work on. First, if one can overcome the location and distance measurement problem by GIS, then one may employ the more micro data, such as four-digit industry or individual firm’s data to re-regress this issue, and the estimated results would be more fruitful. Second, more comprehensively, if we can use micro data based on the panel track, then one may find that R&D investment and spillover externalities have different effects on various industries in different periods, thus making the discussion more precisely. Third, if one has parallel data for other countries, then a comparison across different countries will make the analysis of this issue more interesting.

References

Acs, Z.J. (2002), Innovation and the Growth of Cities, Chelthenam: Edward Elgar.

Aghion, P. and P. Howitt (1992), "A Model of Growth through Creative Destruction," ***Econometrica*** 60, 323-351.

Arrow, K. (1962), "Economic welfare and the allocation of resources for invention," in : Richard Nelson, editor, The Rate and Direction of Inventive Activity, 609-626, Princeton: Princeton University.

Audretsch, D.B. and M. Feldman (1996), "R&D Spillovers and the Geography of Innovation and Production," ***American Economic Review*** 86, 630-640.

Berliant, M., S.K. Peng, and Ping Wang (2002), "Production Externalities and Urban Configuration," ***Journal of Economic theory*** 104, 275-303.

Berliant, Marcus and Ping Wang (2004), "Dynamic Urban Models: Agglomeration and Growth," in: Roberta Capello and Peter Nijkamp (edited), ***Urban Dynamics and Growths Advances in Urban Economics***, 533-582. Elsevier Publisher, Amsterdam, North-Holland.

Berstein, J.I., (1988), "Costs of Production, Intra-and Inter-industry R&D Spillovers: Canadian Evidence", ***Canadian Journal of Economics*** 21, 324-347.

Black, D. and J.V. Henderson (1999), "A theory of urban growth," ***Journal of Political Economy*** 107, 252-284.

Chuang and Hsu (1999), "Productivity, R&D, and Intra-and inter-industry spillovers in Taiwan's manufacturing industry," ***Academia Economic Paper*** 27, 407-432. (*in Chinese*).

Ciccone, A. and R.E. Hall (1996), "Productivity and the density of economic activity, ***American Economic Review*** 86, 54-70.

Cuneo, P., and J. Mairesse (1984), "Productivity and R&D at the Firm Level in Franch Manufacturing", in Z. Griliches (ed.), ***R&D, Patents and Productivity***, 375-392, University of Chicago Press.

Fujita, M. and J.-F. Thisse (2002), *Economics of Agglomeration: Cities, Industrial Location, and Regional Growth*. Cambridge: Cambridge University Press.

Glaeser, E.L., H.D. Kallal, J.A. Scheinkman, and A. Shleifer (1992), " Growth in cities," ***Journal of Political Economy*** 100, 1126-1152.

Grossman, G.M., E. Helpman (1991), *Innovation and Growth in the Global Economy*, Cambridge, MA: MIT Press.

Goto, A. and K. Suzuki (1989), "R&D Capital, Rate of Return on R&D Investment and Spillover of R&D in Japanese Manufacturing Industries", ***Rewiew of Economics and Statistics*** 71, 555-564.

Griliches, Z. (1992), “The Search for R&D Spillovers”,***Scandinavian Journal of Economics*** 94, 29-47.

Henderson, J.V. (1986), “Efficiency of Resource Usage and City Size”, ***Journal of Urban Economic***, 19, 47-70.

Henderson, J.V., A. Kuncoro, and M. Turner (1995), “Industrial development in cities,” ***Journal of Political Economy*** 103, 1067-1090.

Jacobs, J. (1969), “The Economiy of Cities,” Random House, New York.

Jaffe, A.B. M. Trajtenberg, and R. Henderson (1993), “Geographic localization of knowledge spillovers as evidenced by paten citations,” ***Quarterly Journal of Economics*** 108, 577-598.

Lucas, R.E. (1988), “On the mechanics of economic development,” ***Journal of Monetary Economics*** 22, 1-42.

Lucas, R.E. (1993), “Making a miracle,” ***Econometrica*** 61, 251-272.

Lucas, R.E., and E. Rossi-Hansberg (2002), ”On the internal structure of cities,” ***Econometrica*** 70, 1445-1476.

Marshall, A. (1961), Principles of Economics, London: Macmillan, Original publication in 1890.

Moomaw, R.L. (1981), “Productivity and City Size: A Critique of the Evidence”, ***Quarterly Journal of Economics*** 96, 675-688.

Nadiri, M. I., (1993), “Innovations and Technological Spillovers”, Working paper No. 4423, National Bureau of Economic Research.

Nakamura, R. (1985), “Agglomeration economies in Urban Manufacturing Industries: A Case of Japanese Cities”, ***Journal of Urban Economics*** 17, 108-124.

Ottaviano, G. and J.-F. Thisse (2004), “Agglomeration and economic geography,” in:J.V. Henderson and J.-F. Thisse, editors, *Handbook of Urban and Regional Economics*, 2563-2608, Elsevier Publisher, Amsrterdam: North-Holland.

Postner, H.H. and L. Wesa (1983), Canadian Productivity Growth: An Alternative (Input-Output) Analysis. Study Prepared for the Economic Council of Canada, Ministry of Supply and Service, Ottawa.

Romer, P. (1986), “Increasing return and long-run growth,” ***Journal of Political Economy*** 94, 1002-1037.

Romer, P. (1990), “Endogenous Technological Change”, ***Journal of Political Economy*** 98, 71-102.

Rosenberg, N. (1963), “Technological change in the machine tool industry, 1840-1910,” ***Journal of Economic History*** 23, 414-443.

Rosenthal, S.S. and W.C. Strange (2001), “The Determinants of Agglomeration”, ***Journal of Urban Economics*** 50, 191-229.

Shell, K. (1966), “Toward a theory of inventive activity and capital accumulation,”

American Economic Review 61, 62-68.

Sveikauskas, L. (1975), "The Productivity of Cities", ***Quarterly Journal of Economics*** 89, 393-413.

The Report on 2001 Industrial and Commercial Census Taiwan-Fukien Area, Republic of China. Published by Directorate-General of Budget, Accounting and Statistics, Executive Yuan.

Urban and Regional Development Statistics, Republic of China, 2002, Published by Urban and Housing Development Department, Council for Economic Planning and Development, Executive Yuan.

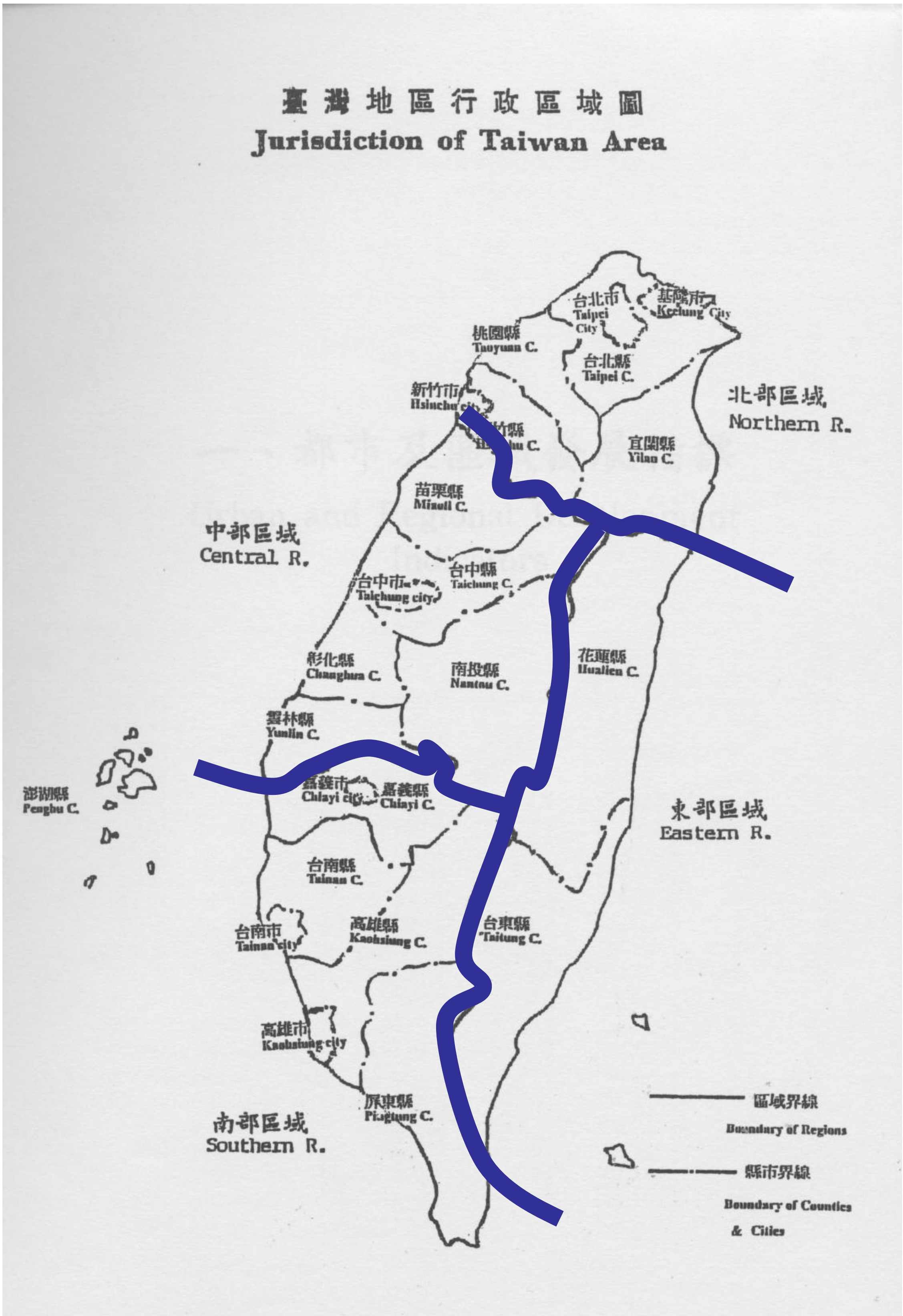

Figure 3-1 Jurisdiction of Taiwan Area