DISCUSSION PAPER SERIES

Discussion Paper No. 39

An Empirical Study about the Impact of Knowledge Accumulation on the Development of Regional Industry

Nobuo Kobayashi
Kwansei Gakuin University

May 2008

SCHOOL OF ECONOMICS

KWANSEI GAKUIN UNIVERSITY

1-155 Uegahara Ichiban-cho

Nishinomiya 662-8501, Japan

An Empirical Study about the Impact of Knowledge Accumulation on the Development of Regional Industry[1]

Nobuo Kobayashi+

Abstract

This study mainly investigated two issues: firstly, the existence of a positive relationship between the accumulation of knowledge stocks in regional industries and their value addition, and secondly, the spillover effects of knowledge stocks from the central cities to the surrounding regions, by using patent data as knowledge stock indicators. The empirical result suggests that there are positive impacts of knowledge accumulation to value addition, and there are positive spillover effects to the surrounding regions. The spillover effects are especially clearer when the creators of knowledge stocks are diversified in central cities, and when the industrial structure of surrounding regions is similar to the central cities.

Nobuo Kobayashi

JEL: O18, O34, R11, R15

Key Words: knowledge accumulation, patent, spillover effect, regional industry

---

[1] This study is funded by the Japan Society for the Promotion of Science (JSPS) (Grant-in-Aid for Young Scientists (b)(No. 18730181)).

+School of Economics, Kwansei Gakuin University, 1-1-155 Uegahara, Nishinomiya, Hyogo 662-8501, Japan; E-mail: n-kobayashi@kwansei.ac.jp

1. Introduction

The effect of knowledge accumulation and spillover effects are assumed to be very important for the formation of industrial clusters and are the determinants of the strength/weakness of regional industries. In Japan, a number of regional industrial policies whose aim is to accelerate knowledge intensification or knowledge exchange have been put into effect in order to create a strong regional industry[2].

In the academic field, empirical studies have been actively pursued about knowledge accumulation and its spillover effect on the regional development. In Japan however, there have been few studies in this field though its importance is strongly recognized. Therefore, we cannot present a clear political vision about how to promote a favorable environment for fostering knowledge intensive industries. For this reason, also in Japan, there is a strong need for an empirical study about the relationship between knowledge accumulation and its spillover effect in order to make regional industrial policies more fruitful.

For these reasons, the purpose of this study is to investigate the relationship between knowledge accumulation, its spillover effect and the development of regional industry. More practically, our main interests are as follows:

i) Does regional knowledge accumulation positively affect regional development and value addition in Japan?
ii) Does regional spillover effect exist also in Japan?
iii) Are there any relationship between the extent of the spillover effect and the characteristics of regional industries?

The reminder of the paper is organized as follows. In the next section, we briefly survey previous studies in this field. Then, in section 3, we preliminarily check the basic relationship between knowledge accumulation and the value-addition in the regional industries. The regional spillover effect is surveyed in section 4, and the paper closes with some conclusions and suggestions for future research in section 5.

2. Previous Studies

A considerable number of empirical studies have been done on the relationship between regional intellectual or technological accumulation and industrial

[2] For example, technopolis development policy (1984-1998), "zunou-ricchi" (location promotion of knowledge intensive industries) (1988-1998), regional platform construction policy (1998-).

development from various points of view. These studies can roughly be classified into four main groups. That is, i) construction of knowledge production function (KPF) and its application to empirical studies, ii) empirical studies about the effect of R&D on the accumulation of intellectual properties, iii) evaluation of regional innovative activity by using patent data, and iv) empirical studies about the regional concentration of the spillover effect.

As representative studies in the early days in this field, Griliches (1979, 1986) constructed the knowledge production function (KPF)[3] and applied it to empirical study. This study constructed the basis of the survey in this field. Griliches (1986) made clear that R&D, especially basic R&D, is crucial to productivity, and R&D in private sector is more important to productivity and profit growth than federally funded R&D.

In empirical studies about the effect of R&D on the accumulation of intellectual properties, we can turn to an approach that describes the effect of the amount of R&D expenditure or number of R&D staff on the stock of intellectual property and its regional density. Giovanni and Santarelli (2001) made clear that R&D expenditure of regional universities and private companies positively affects patenting activities in the same region. Jaffe (1989) did an empirical study of U. S. data and made it clear that university R&D positively affects patenting activities in the private sector, especially in high tech industries like drugs, medical technology, electronics, optics and nuclear technology.

On the evaluation of regional innovative activity by using patent data, there have been several arguments from various standpoints. Acs and Audretsch (1989) estimates the knowledge production function by using the number of patents as a dependent variable, comparing its results with their former survey (Acs and Audretsch (1988)) that had used a commercialized innovation database[4]as

---

[3] Knowledge production function constructed by Griliches(1986) is as follows;

$$Q_t = Ae^{\lambda t} K_t^{\alpha} C_t^{\beta} L_t^{1-\beta}$$

where Q is the amount of products (shipments or added-value), C and L are inputs of capital and labor, $K = \sum_i W_i R_{t-i}$ is accumulated or still productive R&D stocks. R_t is the (real) amount of the investment of R&D during t period, W_i is the index that combines the past R&D investment and the knowledge level now. A is constant, λ shows a external technological change.

[4] The U.S. small business administration constructed a commercialized innovation database in 1982. This database is frequently used in empirical studies of innovative activities in the U. S. The database is based on over a hundred journals, and inventions are categorized by four-digit industrial

a dependent variable, showing the results' similarity between them, and then concluding that patent data is a reliable indicator of innovative activity. On the other hand, though admitting its usefulness, Griliches (1990) pointed out several problems about utilizing patent data as innovative indicators. For example, patent classification is different from industrial classification and it is difficult to match them. He also pointed out the difficulty of gauging the evaluation of each patent.

Among empirical studies which try to grasp the knowledge spillover effects, there are several studies that utilize the patent citation records. Jaffe *et al.* (1993) and Fischer *et al.* (2006) use patent citation data and measure the spatial concentration level of citations. The common conclusion of these studies is that there is a regional knowledge spillover effect, judging from the fact that patent citation is more densely distributed than the original spatial patent distribution pattern. Jaffe *et al.* (2000) checks the validity of patent citation data as a measure of the spillover effect by implementing a questionnaire survey to inventors, and concludes that the patent citation record is reasonably reliable data for knowledge spillover.

As stated above, a considerable number of empirical studies have been conducted on knowledge stocks, spillover effects and their effects on the development of regional industries. However, little is known about the following two points. First, few empirical studies have been made regarding the effectiveness of intellectual property accumulation to the value-addition of regional industry. That is, several studies have been attempted to measure the relationship between regional R&D intensity and the regional accumulation of intellectual property, but little is known about the relationship between the accumulation of intellectual property and the creation of value-added. Secondly, there have been few empirical studies about regional spillover effect in Japan. There have been several empirical studies about the spillover effect in Japan, but these studies have mainly focused on spillover effects of inter/intra industries[5] and did not focus on regional effects.

For the reasons mentioned above, this study focuses on Japanese regional industry, and on the relationship between the accumulation of intellectual property and the growth of value-added.

---

classification.

[5] As recent examples of empirical study about the spillover effects of inter/intra industries, see Tomita (2005), Kani (2006).

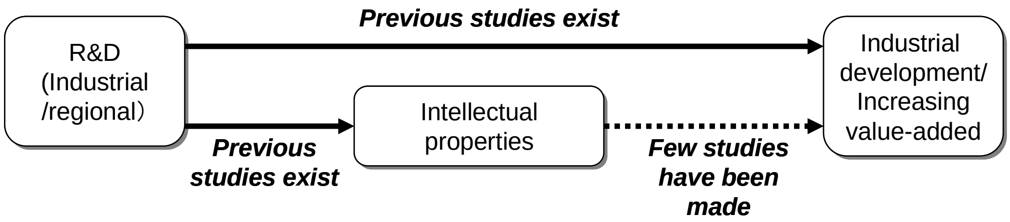

Fig. 1 Accumulation of previous studies

3. Basic relationship between knowledge accumulation and value-addition in regional industries

1) Models

Before estimating regional spillover effects, in this section we check the basic relationship between knowledge accumulation and value-addition in regional industries as a preliminary study. Based on Cobb-Douglas production function, we set four models as follows:

Model 1: Basic Cobb-Douglas production function

$$\ln(Y) = \beta_0 \ln(\alpha) + \beta_1 \ln(L) + \beta_2 \ln(K) + e$$

Model 2: Model which adds regional knowledge accumulation

This model assumes that knowledge accumulation positively affects the total factor productivity in the region. We use the number of patents as a proxy for regional knowledge accumulation.

$$\ln(Y) = \beta_0 \ln(\alpha) + \beta_1 \ln(L) + \beta_2 \ln(K) + \beta_3 \ln(P) + e$$

Model 3, 4: Model which adds lagged regional knowledge accumulation

As with model 2, this model assumes that knowledge accumulation positively affects the total factor productivity, but this model assumes that the effect of knowledge emerges with some lags[6]. Model 3 assumes a one year lag and model 4 two years.

[6] Patents are usually publicly released after 18 months from the application date. Therefore, it is possible that patents will positively affect value-added index after some lags.

2) Dependent variable and explanatory variables

As a dependent variable, we used value-addition in the Census of Manufactures, and as explanatory variables we used number of employees as an index of labor and value of fixed assets as an index of capital from the same source.

To estimate and utilize as an index of the knowledge stock of each region, we used the number of applied patents, again, of each region. There is an inherent problem when we intend to use the regional patent database for this purpose. Namely, patents are classified by the International Patent Classification (IPC) which is different from the Japan Standard Industrial Classification (JSIC). Therefore, we converted each patent IPC (subclass level[7]) to JSIC (two-digit level) to estimate the number of patents in each industry (Regarding the matching of IPC and JSIC, see appendix). There is another problem however: there are some industries whose number of patents are too small to estimate the effect of knowledge stock productivity. So we aggregated two-digit level industries into nine groups as shown in table 1.

Table 1. Comparison of aggregated nine sectors and two-digit manufacturing industries

Aggregated sectors	*Two digit manufacturing classification in JSIC*
1. Food and drink	Food, beverage, tobacco, feed
2. Other consumer goods	Textile, clothing apparel, furniture, printing and publishing, leather and fur, miscellaneous
3. Material industries of steel and non-ferrous metals	Iron and steel, non-ferrous, fabricated metal
4. Material industries of petroleum and chemicals	Chemicals, petroleum and coal, plastic, rubber
5. Other material industries	Lumber and wood, pulp and paper, ceramic
6. General machinery	General machinery
7. Electronic machinery	Electronic machinery
8. Transport equipment	Transport equipment
9. Precision and ordnance	Precision and ordnance

3) Analysis period

When deciding on the period, it is better to keep a continuity of data so as to improve the accuracy of the analysis. On the other hand, we have to pay attention to the following points when implementing either a regional analysis, industrial analysis or a

[7] The structure of IPC is as follows; Section(8) – Class(from 5 to 36 classes for each section) – Subclass – Main group – Subgroup. Total number of subgroup is approximately 70,000.

patent analysis in Japan.

i) It has become quite difficult to track continuous municipal data due to successive municipal mergers after 2003.
ii) JSIC was changed in 2002, and the two-digit level manufacturing industries classification has also changed. A possible period from which we can extract data on the same criteria is from 1985 to 2001.
iii) IPC was changed in 2006, so it has become quite difficult to keep a consistency of patent data from then.

For these reasons, I have established the analysis period in this study from 1985 to 2000.

4) Regions for analysis

It is usual that patents are applied by companies, so the number of patents would be more concentrated around the head offices than the real distribution of invention activities if we sum up the number of patents by using the applicants' residence. When implementing the analysis, we have to avoid such biases as best as possible so as to reflect the real effects of regional R&D to regional value addition. Therefore, we count the number of patent data by inventors' residence (not by applicants' residence), and avoid regions where head offices of major companies are concentrated. Additionally, patents are applied and maintained mainly by the manufacturing sector, especially the so-called high-tech industries (processing/assembling industries and some of the material industries). Therefore, it is better to choose regions where the high-tech manufacturing sector is densely located.

For these reasons, we have chosen three prefectures for this study: Nagano, Shizuoka, and Hiroshima. These regions are not included in the two large metropolitan areas of Tokyo and Osaka, and the agglomeration of high-tech industries is relatively high compared with other rural areas.

5) Empirical analysis

(1) Trend of the patent application

Table 3 shows the number of applied patents of each region. From this data, we can see three characteristics. First, though there are several fluctuations, the number of applied patents generally shows an uptrend. Secondly, the number of applied patents varies significantly with industries. Processing/assembling industries like general machinery and electronic machinery have many patents, and industries like consumer goods and other material industries have relatively few. And thirdly, the number of patents reflects the industrial agglomeration pattern of each region. For example, the Nagano prefecture has relatively more patents that belong to the precision/ordnance industry, and Hiroshima and Shizuoka have more from transport equipment.

Table 2 Number of applied patents and their change by industries

Prefecture	Aggregated sectors	No. of patents of each year																1985-2000 total	
		1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	No.	%
Nagano	1. Food and drink	15	16	37	33	25	34	34	33	39	43	37	37	47	45	41	37	553	0.8%
	2. Other consumer goods	26	36	90	161	170	187	155	133	129	153	148	210	205	242	275	303	2,623	3.7%
	3. Material industries of s	78	48	198	234	265	214	154	144	168	164	187	193	252	248	349	321	3,217	4.5%
	4. Material industries of p	153	154	182	254	255	323	311	304	253	265	277	248	282	317	318	347	4,243	6.0%
	5. Other material industri	29	26	141	123	82	85	69	68	56	112	122	104	97	107	89	106	1,416	2.0%
	6. General machinery	290	270	964	1,907	1,969	2,123	1,795	1,833	1,281	959	1,166	1,360	1,792	2,125	2,428	2,846	25,108	35.4%
	7. Electronics machinery	273	287	1,017	1,430	1,609	1,581	1,546	1,157	1,022	818	1,089	1,147	1,392	1,605	1,805	2,133	19,911	28.1%
	8. Transport equipment	31	32	50	54	71	97	79	102	114	98	175	146	171	98	126	116	1,560	2.2%
	9. Precision and ordnance	127	183	526	1,061	949	1,006	847	681	628	409	546	743	975	1,045	1,311	1,288	12,325	17.4%
	Total	1,022	1,052	3,205	5,257	5,395	5,650	4,990	4,455	3,690	3,021	3,747	4,188	5,213	5,832	6,742	7,497	70,956	#####
Shizuoka	1. Food and drink	73	74	108	124	126	135	132	111	156	173	127	156	137	133	138	165	2,068	1.4%
	2. Other consumer goods	222	174	292	421	632	681	614	794	739	815	847	715	731	668	700	715	9,760	6.6%
	3. Material industries of s	223	269	376	501	555	563	533	639	724	794	912	900	948	848	805	852	10,442	7.0%
	4. Material industries of p	427	503	839	950	955	985	1,038	1,010	1,045	943	913	945	1,042	950	993	1,085	14,623	9.9%
	5. Other material industri	101	106	185	217	218	198	210	256	299	314	363	365	370	330	312	316	4,160	2.8%
	6. General machinery	1,240	1,268	1,836	3,143	3,394	3,435	3,679	3,467	3,420	3,326	3,494	3,356	3,458	3,211	3,287	3,060	48,074	32.4%
	7. Electronics machinery	352	433	897	1,398	1,464	1,517	1,651	1,867	1,936	1,964	2,350	2,565	2,773	2,789	2,678	2,774	29,408	19.8%
	8. Transport equipment	517	336	537	1,011	1,013	955	1,079	1,071	1,031	1,178	1,309	1,202	1,102	1,138	1,085	1,084	15,648	10.6%
	9. Precision and ordnance	239	344	624	896	1,013	898	893	784	845	890	965	973	1,102	1,103	1,250	1,264	14,083	9.5%
	Total	3,394	3,507	5,694	8,661	9,370	9,367	9,829	9,999	10,195	10,397	11,280	11,177	11,663	11,170	11,248	11,315	148,266	#####
Hiroshima	1. Food and drink	16	33	31	72	71	79	31	47	48	48	34	50	46	41	57	45	749	1.2%
	2. Other consumer goods	35	51	53	79	68	82	71	77	80	110	119	130	158	122	175	156	1,566	2.4%
	3. Material industries of s	372	419	453	520	501	518	393	429	410	362	360	381	396	425	392	385	6,716	10.4%
	4. Material industries of p	435	461	522	567	564	604	505	525	576	480	536	477	443	524	586	597	8,402	13.0%
	5. Other material industri	99	138	101	173	210	176	156	145	148	127	169	192	193	194	208	178	2,607	4.0%
	6. General machinery	1,593	1,816	2,075	2,151	1,992	1,993	1,831	1,975	1,912	1,523	1,438	1,260	1,270	1,363	1,372	1,312	26,876	41.5%
	7. Electronics machinery	141	116	339	543	469	525	431	420	390	296	254	280	290	292	324	466	5,576	8.6%
	8. Transport equipment	482	685	755	780	776	861	852	673	673	367	261	247	305	375	350	290	8,732	13.5%
	9. Precision and ordnance	150	146	251	277	214	258	217	247	249	186	177	200	193	205	263	255	3,488	5.4%
	Total	3,323	3,865	4,580	5,162	4,865	5,096	4,487	4,538	4,486	3,499	3,348	3,217	3,294	3,541	3,727	3,684	64,712	#####

Source: Author's calculation from patent database (offered by NRI Cyber Patent, Ltd.)

(2) Empirical results

Table 3 to 5 shows the regression results of each model. Several points can be mentioned. First, models which include intellectual property stocks have more explanatory power in most industries and regions. Among thirty regions and industries (that is, 9 sectors plus the whole manufacturing industry for the three prefectures), model 1 has the highest explanatory power in only three cases. As for the other 27 cases, models which include the number of intellectual property stocks have relatively high explanatory power. Judging from these results, knowledge stocks affect the value-addition in most cases.

Secondly, the accumulation of intellectual property positively affects regional industries. As with the hypothesis, the coefficients of the intellectual properties stocks are positive in most cases, and much of them show ample significance levels[8].

Thirdly, there are some cases which model 3 or 4 has the best explanatory power. After analyzing the number of models with the best explanatory power among models which intellectual property stocks positively affect the value-addition, the results are as follows;

Model 2: 16 sectors/regions (the coefficients are significant in 8 sectors/regions)
Model 3: 4 sectors/regions (the coefficients are significant in 4 sectors/regions)
Model 4: 6 sectors/regions (the coefficients are significant in 6 sectors/regions)

Judging from these results, the effect of knowledge stocks upon the value-addition usually emerges within the same year, but there are some cases where some lags can be seen. That is, there is some possibility that regional knowledge stocks positively affect the value-addition with some lag via the commercialization of these properties.

---

[8] There are only two exceptions, namely, the precision/ordnance sector and the transportation vehicle sector in the Hiroshima Prefecture. In the Hiroshima prefecture, these industries are occupied by big companies, so the trend of the number of patents is supposed to reflect the performance of them. However, the real reason of these results is not clear in this study, so we have to leave its resolution for future research.

Table 3. The results of multivariate regressions (Nagano prefecture)

		Model 1	Model 2	Model 3	Model 4
All Industries	Constant	++	++	++	+
	Employee	(-)	(-)	(-)	(-)
	Fixed assets	+++	+++	+++	+
	No. of patents		(+)	++	(+)
	Adjusted R^2	0.86	0.87	0.89	0.80
1. Food and drink	Constant	(-)	(-)	(-)	(+)
	Employee	+++	+++	+++	++
	Fixed assets	+++	+++	+++	+++
	No. of patents		++	++	(+)
	Adjusted R^2	0.96	0.97	0.97	0.96
2. Other consumer goods	Constant	+++	+++	+++	+++
	Employee	+++	+++	+++	+++
	Fixed assets	+++	+++	+++	++
	No. of patents		+++	+++	+++
	Adjusted R^2	0.77	0.98	0.95	0.95
3. Material industries of steel and non-ferrous metals	Constant	(-)	(-)	(-)	(-)
	Employee	+++	+++	+++	+++
	Fixed assets	+++	+++	+++	++
	No. of patents		(+)	+++	++
	Adjusted R^2	0.87	0.87	0.93	0.85
4. Material industries of petroleum and chemicals	Constant	(-)	(-)	(-)	(-)
	Employee	+++	+++	+	++
	Fixed assets	+++	+++	+++	+++
	No. of patents		+++	(+)	++
	Adjusted R^2	0.96	0.98	0.95	0.97
5. Other material industries	Constant	(-)	(-)	(-)	(-)
	Employee	+++	+++	+++	+++
	Fixed assets	+++	+++	+++	+++
	No. of patents		(+)	(+)	++
	Adjusted R^2	0.66	0.87	0.74	0.84
6. General machinery	Constant	(-)	(-)	(-)	(-)
	Employee	++	+	+	+
	Fixed assets	+	(+)	(+)	(+)
	No. of patents		(+)	++	(+)
	Adjusted R^2	0.67	0.71	0.76	0.53
7. Electronics machinery	Constant	(+)	(+)	(+)	(+)
	Employee	(-)	(-)	(-)	(-)
	Fixed assets	+++	+++	++	++
	No. of patents		(+)	(+)	(-)
	Adjusted R^2	0.87	0.88	0.86	0.82
8. Transport equipment	Constant	(-)	(-)	(-)	(-)
	Employee	+++	++	++	++
	Fixed assets	+++	+++	+++	+++
	No. of patents		(+)	(+)	(+)
	Adjusted R^2	0.93	0.93	0.91	0.90
9. Precision and ordnance	Constant	+++	+++	+++	+++
	Employee	++	(+)	(+)	(+)
	Fixed assets	(+)	(+)	++	(+)
	No. of patents		(-)	(+)	++
	Adjusted R^2	0.80	0.79	0.88	0.90

Notes: +++, ――― Significantly different from zero at the 1% level (+: positive, -:negative)
++, ―― Significantly different from zero at the 5% level (+: positive, -:negative)
+, ― Significantly different from zero at the 10% level (+: positive, -:negative)
Marks in parenthesis mean that they do not have explanatory power as much as 10% significance level.

Table 4. The results of multivariate regressions (Shizuoka Prefecture)

		Model 1	Model 2	Model 3	Model 4
All Industries	Constant	(+)	+++	+++	+++
	Employee	(+)	(+)	(+)	(+)
	Fixed assets	+++	+++	+++	(+)
	No. of patents		+++	+++	+
	Adjusted R^2	0.93	0.97	0.96	0.91
1. Food and drink	Constant	(-)	(-)	(-)	(-)
	Employee	(+)	(+)	(+)	(+)
	Fixed assets	+++	(+)	(+)	(+)
	No. of patents		(+)	(+)	(-)
	Adjusted R^2	0.81	0.84	0.78	0.73
2. Other consumer goods	Constant	(-)	(+)	(+)	+
	Employee	+++	+++	+++	+++
	Fixed assets	+++	+	+++	(+)
	No. of patents		++	(+)	+++
	Adjusted R^2	0.80	0.85	0.82	0.87
3. Material industries of steel and non-ferrous metals	Constant	(-)	(-)	(-)	(-)
	Employee	+++	+++	+++	+++
	Fixed assets	+++	(+)	(-)	-
	No. of patents		(+)	++	+++
	Adjusted R^2	0.80	0.80	0.84	0.93
4. Material industries of petroleum and chemicals	Constant	---	-	(-)	(+)
	Employee	+++	+++	+++	+++
	Fixed assets	--	--	--	--
	No. of patents		(+)	(+)	++
	Adjusted R^2	0.96	0.97	0.94	0.94
5. Other material industries	Constant	(+)	(+)	++	+
	Employee	+++	+++	+++	++
	Fixed assets	+++	+++	+++	+++
	No. of patents		(+)	(+)	(-)
	Adjusted R^2	0.94	0.94	0.93	0.90
6. General machinery	Constant	(-)	(+)	(+)	(-)
	Employee	+++	+++	+++	+++
	Fixed assets	+++	+++	(+)	(+)
	No. of patents		+	+	(+)
	Adjusted R^2	0.90	0.92	0.91	0.85
7. Electronics machinery	Constant	+	+++	+++	+++
	Employee	--	(-)	(-)	(-)
	Fixed assets	+++	+	(+)	(-)
	No. of patents		+++	++	+++
	Adjusted R^2	0.77	0.89	0.84	0.86
8. Transport equipment	Constant	++	++	++	+++
	Employee	-	-	-	--
	Fixed assets	+++	+++	+++	+++
	No. of patents		(+)	(+)	--
	Adjusted R^2	0.89	0.89	0.86	0.87
9. Precision and ordnance	Constant	++	++	+++	++
	Employee	--	--	---	---
	Fixed assets	+++	+++	+++	+++
	No. of patents		(+)	+	+
	Adjusted R^2	0.84	0.84	0.85	0.83

Notes: +++, ――― Significantly different from zero at the 1% level (+: positive, -:negative)
++, ―― Significantly different from zero at the 5% level (+: positive, -:negative)
+, ― Significantly different from zero at the 10% level (+: positive, -:negative)
Marks in parenthesis mean that they do not have explanatory power as much as 10% significance level.

Table 5. The results of multivariate regressions (Hiroshima Prefecture)

		Model 1	Model 2	Model 3	Model 4
All Industries	Constant	(+)	(+)	+	++
	Employee	++	+	(+)	(+)
	Fixed assets	+++	+++	+++	+++
	No. of patents		++	++	+
	Adjusted R^2	0.77	0.85	0.83	0.77
1. Food and drink	Constant	--	--	-	-
	Employee	+++	+++	++	++
	Fixed assets	+++	+++	+++	+++
	No. of patents		(+)	(+)	(-)
	Adjusted R^2	0.92	0.92	0.89	0.87
2. Other consumer goods	Constant	++	+	+	+
	Employee	+++	+++	+++	+++
	Fixed assets	+++	+++	+++	+++
	No. of patents		+	(+)	++
	Adjusted R^2	0.89	0.91	0.90	0.93
3. Material industries of steel and non-ferrous metals	Constant	(+)	(+)	(+)	++
	Employee	+	(+)	(+)	(+)
	Fixed assets	+	++	++	(+)
	No. of patents		+	++	++
	Adjusted R^2	0.22	0.34	0.51	0.60
4. Material industries of petroleum and chemicals	Constant	+++	+++	+++	+++
	Employee	+++	+++	++	+
	Fixed assets	+++	+++	++	(+)
	No. of patents		(+)	(+)	(+)
	Adjusted R^2	0.68	0.72	0.63	0.52
5. Other material industries	Constant	(+)	(+)	++	+++
	Employee	++	+	++	+++
	Fixed assets	+++	+++	+++	++
	No. of patents		(+)	(-)	++
	Adjusted R^2	0.77	0.75	0.68	0.83
6. General machinery	Constant	(-)	(-)	(-)	(-)
	Employee	++	+	+	(+)
	Fixed assets	+++	+++	+++	++
	No. of patents		(+)	(+)	(+)
	Adjusted R^2	0.87	0.87	0.85	0.80
7. Electronics machinery	Constant	(-)	(-)	(-)	(-)
	Employee	+	(+)	(+)	(+)
	Fixed assets	+++	++	++	+
	No. of patents		(-)	(-)	(-)
	Adjusted R^2	0.90	0.89	0.85	0.79
8. Transport equipment	Constant	(+)	+	+	(+)
	Employee	+++	(+)	(+)	++
	Fixed assets	(+)	(+)	(-)	(-)
	No. of patents		++	(+)	(-)
	Adjusted R^2	0.35	0.54	0.49	0.70
9. Precision and ordnance	Constant	+++	+++	+++	+++
	Employee	(+)	(-)	-	(-)
	Fixed assets	+++	+++	+++	++
	No. of patents		(-)	---	(-)
	Adjusted R^2	0.79	0.81	0.84	0.74

Notes: +++, ——— Significantly different from zero at the 1% level (+: positive, -:negative)
++, —— Significantly different from zero at the 5% level (+: positive, -:negative)
+, — Significantly different from zero at the 10% level (+: positive, -:negative)
Marks in parenthesis mean that they do not have explanatory power as much as 10% significance level.

(3) Reverse correlation inspection

Next, we carried out an inspection about reverse correlation. We have a hypothesis that the accumulation of knowledge stocks would positively affect the value-addition of regional industries (we call it a "forward linkage hypothesis"[9]) in this study. However, there may be some possibilities of the reverse correlation that better performance of regional industries would positively affect the accumulation of knowledge stocks via the enrichment of R&D funds (we call it "backward linkages").

Table 6. Correlation coefficients between the number of patents and the value addition

		Patents & Value-addition(-2)	Patents & Value-addition(-1)	Patents & Value-addition	Patents & Value-addition(+1)	Patents & Value-addition(+2)
Nagano	All Industries	*0.21*	0.46	0.69	**0.78**	0.77
	1. Food and drink	*0.64*	0.77	**0.84**	0.83	0.77
	2. Other consumer goods	*-0.10*	0.20	**0.28**	0.23	0.01
	3. Material industries of steel and non-ferrous metals	*-0.24*	0.13	0.42	0.64	**0.65**
	4. Material industries of petroleum and chemicals	*0.60*	0.75	0.82	0.83	**0.85**
	5. Other material industries	*-0.10*	0.03	**0.42**	0.32	0.31
	6. General machinery	*0.18*	0.49	0.75	**0.83**	0.71
	7. Electronic machinery	*0.37*	0.50	**0.62**	0.61	0.52
	8. Transport equipment	**0.87**	0.81	0.84	0.79	*0.69*
	9. Precision and ordnance	-0.64	*-0.68*	-0.57	-0.21	**0.04**
Shizuoka	All Industries	*0.86*	0.88	0.95	**0.97**	0.96
	1. Food and drink	0.70	0.77	**0.83**	0.76	*0.66*
	2. Other consumer goods	**0.72**	0.59	0.52	0.32	*-0.03*
	3. Material industries of steel and non-ferrous metals	**0.69**	0.60	0.60	0.51	*0.36*
	4. Material industries of petroleum and chemicals	*0.53*	0.76	**0.86**	0.85	0.81
	5. Other material industries	**0.89**	0.89	0.84	0.72	*0.54*
	6. General machinery	*0.37*	0.59	0.78	**0.82**	0.66
	7. Electronic machinery	**0.97**	0.95	0.94	*0.92*	0.94
	8. Transport equipment	*0.57*	0.64	0.79	**0.83**	0.74
	9. Precision and ordnance	*0.69*	0.74	0.78	**0.79**	0.75
Hiroshima	All Industries	*-0.62*	-0.21	0.18	0.47	**0.72**
	1. Food and drink	*-0.19*	-0.12	0.32	0.31	**0.49**
	2. Other consumer goods	**0.18**	-0.12	-0.23	-0.28	*-0.33*
	3. Material industries of steel and non-ferrous metals	*-0.65*	-0.16	0.20	0.55	**0.75**
	4. Material industries of petroleum and chemicals	*-0.15*	0.32	0.41	0.60	**0.68**
	5. Other material industries	0.25	0.26	0.33	*0.24*	**0.33**
	6. General machinery	*-0.72*	-0.62	-0.48	**-0.26**	-0.34
	7. Electronic machinery	*-0.58*	0.07	0.35	**0.40**	0.20
	8. Transport equipment	*0.56*	0.70	**0.76**	0.75	0.75
	9. Precision and ordnance	*-0.49*	**0.43**	0.23	-0.44	-0.05

Notes: For example, Patents and Value-addition(+2) means the correlation coefficient between the number of patents from 1985 to 1998 and the value-addition from 1987 to 2000.
Bold numerals show the highest correlation coefficients among five models in each region/industry, and italicized numerals show the lowest.

Table 6 shows the correlation coefficient between the number of patents and the value addition (from two years before to two years after of the patents' application) of each region. Judging from the results, we can indicate the points as follows:

i) Seeing the entire picture of the manufacturing industries, all three prefectures support our hypothesis. The correlation coefficient between the number of patents and the value-addition of one year later is the highest in Nagano and Shizuoka, and that of two years later is the highest in Hiroshima.

[9] The words "forward linkage" and "backward linkage" are the terms used in the input-output analysis, and the usage in this paper is unusual. However, as I would like to express the notion in simpler terms, I have adopted these words here.

ii) Seeing the coefficients of each industry in the three prefectures, generally speaking, they are higher in the relationship between the number of patents and the value-addition in the same year or later, but there are several exceptions.

In general, "forward linkages" of knowledge accumulations are much more popular than "backward linkages". Therefore, our hypothesis usually holds. However, as mentioned above, some cases which show "backward linkages". Trends of concentration/dispersion of intellectual properties among industries and regions are quite divergent, and, as Porter (2003) points out, this may affect the spillover effects[10]. This issue is not completely clear in this study, so it remains as a matter to be discussed in a further study.

4. Inter-regional spillover effect

The analysis in the previous section demonstrated the positive effect of knowledge accumulation on the value-addion of regional industry. As a next step, we implemented the empirical analysis pertaining to the existence of an inter-regional spillover effect in this section. More specifically, we checked the issue of whether an increase of knowledge stocks in central municipalities positively affects the value-addion of surrounding regions.

1) Analytical method

(1) Selection of cities

The central municipalities under investigation have to have certain characteristics. First, they must support active manufacturing industries, and secondly, the agglomeration of manufacturing industries must have been undertaking the role of brains in production activities.

Using these viewpoints as samples to investigate the spillover effects to surrounding regions, we selected several municipalities for our study. We included the following municipalities (for a profile of each, see table 7):

Nagano prefecture – Nagano city, Matsumoto city, Ueda city, Suwa City, and the town of Sakaki

[10] Porter (2003) mentioned that the more the intellectual property is concentrated in a small number of companies, the less spillover effects occur within the region.

Shizuoka prefecture – Hamamatsu city and Shizuoka city

Hiroshima prefecture – Kure city, Fukuyama city and the town of Fuchu[11]

Table 7. Profiles of the municipalities under investigation

Pref.	Municipality	Profiles
Nagano	Nagano city	The capital of the prefecture with the largest population. This municipality has quite a diversified set of industries including electronics, general machinery and food processing companies. The volume of shipments from Nagano city ranks second among all cities in the prefecture.
	Matsumoto City	The second largest city in the prefecture producing the largest volume of shipments. The main industries include companies specializing in electronics (producing items such as IT-related devices), food processing, and beverages.
	Ueda city	The third largest city in the prefecture. A variety of industries are based in this city, including those specializing in transportation equipment, electronics, food processing and beverages.
	Suwa city	This city has been called the "Switzerland of the Eastern world". The main industries of the city are those producing precision-products such as watches, electronics, and robotics. The number of patents produced by this municipality has been by far the largest in the prefecture.
	Sakaki town	Though it is a small town whose population is only around 16,000, it has a large amount of manufacturing industries, especially in the processing/assembling industries. The main industries produce plastic-working machinery, equipment for construction, optical instruments, electronic data processing machines and other machinery types.
Shizuoka	Hamamatsu city	The city with the largest population and volume of manufacturing shipments. The main manufacturing industries in this city are involved in the production of transportation, electronics and precision equipment. Historically the city has been well-known as "the city of venture businesses" because many companies were founded here and have since become "blue-chips" companies.
	Shizuoka city	This city is the capital of the prefecture. An agglomeration of manufacturing industries, it has a relatively large share of companies specializing in electronic equipment, printing and wooden furniture.
Hiroshima	Kure city	Because the city had flourished as the principal contributor to the Japanese naval arsenal before World War II, it still has a relatively large share of heavy industries engaged in the production of iron and steel, ships, aircraft engines, and plant engineering equipment.
	Fukuyama city	The largest city in the eastern side of the prefecture, it produces the largest volume of shipments in the area. Major industries include producers of iron and steel, electronics (for example, electronics manufactures producing printed circuits and equipments related to their production).
	Fuchu town	The town where the headquarters of Mazda Motor Corporation is located. This town has by far the largest number of patents. Industries in this municipality specialize in transportation equipment, as well as in the production of some general machinery supporting the transportation sector.

[11] Hiroshima city is the largest city in the prefecture of Hiroshima: however, the city completely surrounds the town of Fuchu, where the headquarters of Mazda Motor Corporation (the biggest company in the prefecture) is based. Therefore, in this study we adopted Hiroshima not as a central city, but as a region surrounding the town of Fuchu.

(2) The model

Though the main objective of this section is to investigate the effect of knowledge accumulation on the value-addition of the surrounding regions, we had to add some other explanatory variables to the model to investigate the effects more precisely. However, it is almost impossible to add all factors to the model. Therefore, in the model we considered two issues related to the spillover effect.

i) The relationship between the concentration-diversification of the patent holders and the spillover effect.

It is generally said that the lower the number of patent holders, the more difficult the resulting spillover effect, because most of these patents are acquired and maintained as "defensive patents". On the other hand, when the regional industries agglomerate as subcontractors of a leading company in the region, the accumulation of intellectual properties of primary contractors are supposed to affect the value-addion of subcontractors via the dealings between them.

In this study, we use the average number of patents (AVP) per one company who applied for patents in the central municipality. If this number is large, the level of patent concentration possessed by a particular company will be greater. Therefore, if the former hypothesis is supported, the sign of AVP is "+" and if the latter, then the sign is "-".

ii) The relationship between the similarity of industrial structure and the spillover effect.

If the industrial structure of the central municipality and surrounding regions is similar, they are supposed to form the same industrial cluster and their technological bases are supposed to be similar. Therefore, the similarity of industrial structure is supposed to positively affect the spillover effect.

In this study, an index of the similarity of industrial structure between the central municipality and the surrounding regions was calculated. We calculated the "regional industrial structure similarity (RISS) index" as follows:

$$RISS_{c,s} = \sum_{n=1}^{23} \left| Spec_{c,n} - Spec_{s,n} \right|$$

Where $RISS_{c,s}$ is the index of regional industrial structure similarity between the central municipality c and the surrounding regions s, and $Spec_{c,n}$ is the modified coefficient of specialization[12] of the industry (n[13]) in the central municipality.

The greater the number of the index increases, the larger the gap in industrial structure between the central municipality and the surrounding region. Therefore, if the above hypothesis is supported, the positive spillover effect is larger when the index is smaller. The expected coefficient of *RISS* is then minus.

We constructed the "spillover effects estimation model" to include the two points noted above. In practice, the equation of the model is as follows:

$$\ln(VA_{s,t}) = C + \ln(K_{s,t}) + \ln(L_{s,t}) + P_{s,t} + P_{c,t} + AVP_{c,t} + RISS_{c,s,t}$$

Wherein:

- $VA_{s,t}$ is the value-addition of surrounding regions s in the year t,
- C is constant,
- $K_{s,t}$ is the capital stocks of surrounding regions s in the year t,
- $L_{s,t}$ is the labor stocks of surrounding regions s in the year t,
- $P_{s,t}$ is the number of patents applied for by the company in the surrounding region s in the year t,
- $P_{c,t}$ is the number of patents applied for by the company in the central municipality c in the year t,
- $AVP_{c,t}$ is the average number of patents per one company who applied for patents in the central municipality, *and*
- $RISS_{c,s,t}$ is the index of regional industrial structure similarity between the central municipality c and the surrounding regions s.

The expected sign of each explanatory variable is shown in table 8. In the

[12]Coefficient of specialization is an index that shows the level of specialization in each region of industry compared with the whole country. The index is usually calculated by the following equation:

$$S_{i,n} = (P_{i,n} / P_i)/(P_n / P)$$

where $S_{i,n}$ = coefficient of specialization of n industry in region i; $P_{i,n}$ = shipments of industry n in region i; P_i = total manufacturing shipments in region I; P_n = shipment of industry n of the whole country; P = total shipments of the whole country.

The main problem associated with this index is that the level of specialization of the industry whose index is greater than one is overestimated. That is, the index of the industry which has twice the composition ratio compared with that of whole country is two, so the gap with the national average is one. However, when the index of the industry which has half the composition ratio is 0.5, then the gap with the national average is only 0.5. To avoid the problem, we calculated the "modified coefficient of specialization" of the industries whose coefficient is less than one.

$$Spec_{i,n} = 1 - (1/S_{i,n})$$

By this modification, the modified coefficient of industries whose former coefficient was 0.5 becomes 1 – (1/0.5) = -1, so we can express the negative gap as the same weight as the positive gap.

[13] The number of two-digit classifications of the manufacturing industry is 23 during the period of this study.

practical analysis, we constructed pooled data for each prefecture and conducted a regression analysis.

Table 8. The expected sign of explanatory variables

Explanatory variables	Practical index	Expected signs	hypothesis
Growth rate of Capital stocks in the surrounding regions	Capital stocks in Census of Manufactures	+	The growth of capital stocks in the region positively affects the value-addition
Growth rate of labor stocks in the surrounding regions	Number of workers in Census of Manufactures	+	The growth of labor stocks in the region positively affects the value-addition
Knowledge stocks in the surrounding regions	Number of patents which companies applied for in the surrounding regions	+	The growth of knowledge stocks in the region positively affects the value-addition
Knowledge stocks in the central municipality	Number of patents applied for in the central municipality	+	Creation of knowledge stocks in the central municipality positively affects the value-addition of the surrounding regions via knowledge spillovers.
The index of patent concentration in the central municipality	The number of patents applied for per company in the central municipality	—	As the creator of intellectual property diversifies, there will be increased knowledge spillover which positively affects the value-addition in the surrounding regions.
		+	When industries agglomerate as subcontractors of the leading company, the accumulation of intellectual properties of primary contractors are supposed to affect the value-addition of subcontractors via the dealings between them.
The regional industrial structure similarity	The regional industrial structure similarity (RISS) index	—	A higher frequency of spillover effects occurs when there is a greater similarity between the industrial structure of the surrounding region and the central municipality (thus the index is smaller).

2) Empirical results

Table 9 shows the regression results. From these results, we can point out three points as follows:

i) The accumulation of knowledge stocks in the central municipality positively affects the value-addition in the surrounding regions.

The explanatory power of the number of patents applied for in the central municipality is significant at the 1% level at Nagano and Shizuoka, and at the 5% level at Hiroshima; all the signs are positive which is consistent with our hypothesis. The value of the coefficient is far smaller than those of capital and labor stocks, so the effect is limited judging from the magnitudes. However, the knowledge intensification in the central municipality surely has a positive effect on the value-addition in the surrounding regions via spillover effects.

ii) The dispersion of intellectual property applicants positively affects the spillover effects.

The coefficient of AVP is negative in all the three prefectures, and among them, the coefficient is significant at the 1% level in Nagano, and at 5% the level in Hiroshima. These results demonstrate that when applicants for patents become more concentrated, fewer spillover effects occur.

iii) The hypothesis about the relationship between the similarity of industrial structure and the spillover effect is partially supported.

The coefficients of RISS are negative in Nagano and Hiroshima, and positive in Shizuoka. Among them, the variable is significant at the 1% level in the model of Hiroshima prefecture. Our hypothesis, that the greater the similarity between the industrial structure of the central municipality and the surrounding region, the more likely that knowledge spillover effects will occur between them, is supported in the model of Hiroshima prefecture.

Table 9. The regression results of knowledge spillovers from the central municipality to the surrounding regions

	Nagano		Shizuoka		Hiroshima	
	coefficient	t-value	coefficient	t-value	coefficient	t-value
ln(K)	0.3891	6.74***	0.2008	2.57**	0.5353	7.78***
ln(L)	0.6137	12.83***	1.5829	14.45***	0.6765	8.60***
Ps	0.0005	3.58***	0.0001	0.96	0.0000	-0.23
Pc	0.0001	2.94***	0.0001	3.19***	0.0001	2.17**
AVP	-0.0001	-0.45	0.0003	0.43	-0.0021	-4.02***
RISS	-0.0039	-2.93***	-0.0069	-0.88	-0.0009	-2.03**
Constant	4.2493	5.79***	-2.9110	-6.16***	1.6505	3.31***
Adjusted R^2	0.945		0.993		0.993	

Notes: *** Significantly different from zero at the 1% level
** Significantly different from zero at the 5% level
* Significantly different from zero at the 10% level

5. Summary and conclusions

This study investigated i) the status and change of regional knowledge accumulations and ii) the relationship between knowledge accumulation and the growth of value-addition of regional industries by using patent database. From the results, some points have become apparent and these are discussed as follows:

We summarize some basic discoveries from the preliminary study. Firstly, the volume of knowledge accumulation (embodied in the number of patents applied for) is larger in assembling/processing industries, and the number of patents reflects the industrial agglomeration pattern and their "boom/slump" of each region. Secondly, the increasing knowledge stocks in the region positively affect the value-addition in regional industry. The explanatory power of the number of patents is positively significant to the value-addition in the same year or one (or two) years later in most cases. Thirdly, the "forward linkages" relationship between the knowledge stocks and the value-addion is stronger than "backward linkages" in most cases. The results imply that the accumulation of intellectual property is acting as an input factor for value-addition of industry rather than as a result of the prosperity of regional industries.

Next, we summarize the results of spillover analysis. Firstly, the intensification of knowledge stocks in the central municipality positively affects the value-addition of the surrounding regions. Secondly, the hypothesis pertaining to the positive relationship between the similarity of industrial structure and the spillover effect is generally supported though it is difficult to draw a robust conclusion because not all of the regression results have shown significant supporting results. Thirdly, it is generally certified that the spillover effects occur more often when the creation of intellectual property is dispersed to many companies in the central municipality. This result is consistent with the conclusion of Porter (2003) that a greater concentration of intellectual properties among fewer companies results in fewer regional spillover effects.

This empirical study is about the relationship between the accumulation of intellectual properties and occurrence of value-addition, or interregional spillover effects. This issue has not been empirically surveyed especially in Japan. Therefore, though it is a very basic analysis and there exist several limitations with respect to the conclusions we can make, it is possible to draw out several interesting results as an initial effort in this field.

There are several issues that must be discussed further. First, although there is a positive relationship between knowledge stocks and value-addition, the practical trajectory from the intellectual property to the creation of value-added is still a "black box". The second issue relates to the general relevance of our findings for other regions. In this study, we chose three regions where the manufacturing sector is relatively active (and not located in the two biggest metropolitan areas). This was done in order to produce results that were of general utility and applicable to other regions. However, we must empirically check more further numbers of regions in order to test the general utility of our conclusions. Thirdly, as I mentioned in section three, the relationship between the concentration of intellectual property among a few particular companies and the possibility of “backward linkages” has not resolved by this study. These points remain to be studied in future research.

Appendix The Correspondence List of JSIC and IPC in this Study

JSIC	IPC
1. Food and drink	A22B, A22C, A23B, A23C, A23D, A23F, A23G, A23J, A23K, A23L, A23P, A24B, A24D, C12C, C12F, C12G, C12H, C12J, C12L
2. Other consumer goods	D01H, D02G, D02J, D04B, D04C, D04D, D04G, D04H, D06B, D06N, D06P, D07B, A41B, A41C, A41D, A41F, A42B, A42C, A45F, D06Q, A47B, A47C, A47D, A47F, A47H, B27M, E04F, E06B, B41C, B41D, B42B, B42C, B42D, B44F, G09D, A01L, A45C, B68B, B68C, A24F, A41G, A44B, A44C, A45B, A46B, A63B, A63C, A63D, A63F, A63G, A63H, A63K, B43K, B43L, B43M, B44C, B44D, C06F, E04H, G09G, G10B, G10C, G10D, G10F, G10G, G10H
3. Material industries of steel and non-ferrous metals	B21B, B21C, B21D, B21F, B21G, B21H, B21K, B21L, B22D, B22F, B25H, B26B, B27B, B32B, B60D, B65D, B65F, C21B, C21C, C21D, C22B, C22C, C22F, C22K, C23C, C23D, C23F, C23G, C25C, C25D, E01D, E03B, E03C, E03F, E04D, E04G, E05B, E05C, E05D, E05F, E05G, E06C, F03G, F16B, F16F, F17B, F17C, F17D, F24B, F24D, G09F, H01B
4. Material industries of petroleum and chemicals	A01N, A43B, A43C, A61K, A61P, B25G, B29B, B29C, B29D, B29K, B29L, B41N, B60C, B82B, C01B, C01C, C01D, C01F, C01G, C05B, C05C, C05D, C05F, C05G, C06B, C06C, C06D, C07B, C07C, C07D, C07F, C07G, C07H, C07J, C07K, C07M, C08B, C08C, C08F, C08G, C08H, C08J, C08K, C08L, C09B, C09C, C09D, C09F, C09G, C09H, C09J, C09K, C10B, C10C, C10F, C10G, C10H, C10J, C10K, C10L, C10M, C10N, C11BC11C C11D C12N C12P C12Q C12R C12S G03C
5. Other material industries	A21B, A47G, A47K, A61J, B01L, B27H, B27J, B27K, B27L, B27N, B28B, B28C, B28D, B31B, B31C, B31D, B31F, B42F, B60J, C03B, C03C, C04B, D21B, D21C, D21D, D21H, D21J, E01F, E02B, E03D, E04B, E04C
6. General machinery	A01B, A01C, A01D, A01F, A21C, A21D, A23N, A24C, A41H, A43D, A46D, A47J, A62B, A62C, A62D, A63J, B01B, B01D, B01F, B01J, B02B, B02C, B03B, B03C, B03D, B04B, B04C, B05B, B05C, B05D, B06B, B07B, B07C, B08B, B09B, B09C, B21J, B22C, B23B, B23C, B23D, B23F, B23G, B23K, B23P, B23Q, B24B, B24C, B24D, B25B, B25C, B25D, B25F, B25J, B26D, B26F, B27C, B27D, B27F, B27G, B30B, B41B, B41FB41G B41J B41K B41L B41M B44B B65B B65C B65G B65H B66B B66C B66D B66F B67B B67C B67D B68F B68G C02F C12M C13C C13D C13F C13G C13H C13J C13K C14B C14C C25B C25F C30B D01B D01C D01D D01F D01G D02H D03C D03D D03J D05B D05C D06C D06G D06J D06L D06M D21F D21G E01B E01C E01H E02C E02D E02F E21B E21C E21D E21F F01B F01C F01D F01K F01L F01M F01N F01P F02B F02C F02D F02F F02G F02K F02M F02N F02P F03B F03C F03D F04B F04C F04D F04F F15B F15D F16C F16G F16H F16J F16K F16L F16M F16N F16P F16S F16T F22B F22D F22G F23B F23C F23D F23G F23H F23J F23K F23L F23M F23N F23Q F23R F24F F24H F24J F25B F25C F25D F25J F26B F27B F27D F28B F28C F28D F28F F28G G05B G06C G07B G07C G07D G07F G07G G12B G21B G21C G21D H01L
7. Electronics machinery	A45D, A47L, A61H, A61N, B23H, B61J, B61K, B61L, D06F, F03H, F15C, F21H, F21K, F21L, F21M, F21P, F21Q, F21S, F21V, F21W, F21Y, F24C, G01R, G01S, G01T, G01W, G05D, G05F, G05G, G06D, G06E, G06F, G06G, G06J, G06K, G06M, G06N, G06T, G08B, G08C, G08G, G10K, G10L, G11B, G11C, G21F, G21G, G21H, G21J, G21K, H01C, H01F, H01G, H01H, H01J, H01K, H01M, H01P, H01Q, H01R, H01S, H01T, H02BH02G H02H H02J H02K H02M H02N H02P H03B H03C H03D H03F H03G H03H H03J H03K H03L H03M H04B H04H H04J H04K H04L H04M H04N H04Q H04R H04S H05B H05C H05F H05G H05H H05K
8. Transport equipment	B60B, B60F, B60G, B60H, B60K, B60L, B60M, B60N, B60P, B60Q, B60R, B60S, B60T, B60V, B61B, B61C, B61D, B61F, B61G, B61H, B62B, B62C, B62D, B62H, B62J, B62K, B62L, B62M, B63B, B63C, B63H, B63J, B64B, B64C, B64D, B64F, B64G, F16D, G01V
9. Precision and ordnance	A61B, A61C, A61D, A61F, A61G, A61L, A61M, B63G, B81B, B81C, D06H, F41A, F41B, F41C, F41F, F41G, F41H, F41J, F42B, F42C, F42D, G01D, G01F, G01G, G01H, G01J, G01K, G01L, G01M, G01N, G01P, G02B, G02C, G02F, G03B, G03D, G03F, G03G, G03H, G04B, G04C, G04D, G04F, G04G, G09B

References

Acs, Z. J., L. Anselin and A. Varga [2002], "Patents and Innovation Counts as measures of regional production of new knowledge," *Research Policy*, vol. 31, 1069-1085.

Acs, Z. J. and D. B. Audretsch [1989], "Innovation in Large and Small Firms: An Empirical Analysis," *American Economic Review*, vol. 78(4), 678-690.

Acs, Z. J. and D. B. Audretsch [1989], "Patents as a Measure of Innovative Activity," *Kyklos*, vol. 42, 171-180.

Audretsch, D. B. and M. P. Feldman [1996], "R&D Spillovers and the Geography of Innovation and Production," *American Economic Review*, vol. 86(3), 630-640.

Cohen, W. M. [2005], " Patents and Appropriation: Concerns and Evidence, " *Journal of Technology Transfer,* vol. 30(1/2), 57-71.

Echeverri-Carroll, E. [2001], "Knowledge Spillovers in High Technology Agglomerations： Measurement and Modelling," in *Knowledge Complexity and Innovation Systems*, eds. by Fischer, M. M. and Fröhlich, J., Springer (Heiderberg), 146-161.

Fischer, M. M., T. Scherngell and E. Jansenberger [2006], "Patents, Patent Citations and the Geography of Knowledge Spillovers in Eurpe," in *Innovation, Networks, and Knowledge Spillovers,* ed. by Fischer, M. M., Springer (Berlin), 233-250.

Giovanni, R. P. and E. Santarelli, [2001], "Patents and the Geographic Localization of R&D Spillovers in French Manufacturing," *Regional Studies*, vol. 35(8), 697-702.

Glaeser, E. L., H. D. Kallal, J. A. Scheinkman and A. Shleifer [1992], "Growth in Cities, " *Journal of Political Economy*, vol. 100(6), 1126-1152.

Griliches, Z. [1979], "Issues in Assessing the Contribution of Research and Decelopment to Productivity Growth, " *The Bell Journal of Economics*, vol. 10, 92-116.

------------- [1986], "Productivity, R and D, and Basic Research at the Firm Level in the 1970's," *The American Economic Review*, vol. 76(1), 141-154.

------------- [1986], "Patent Statistics as Economic Indicators: A Survey, " *Journal of Economic Literature*, vol. 28(4), 1661-1707.

Hall, B. H. [2001], " The Patent Paradox Revisited: an Empirical Study of Patenting in the U. S. Semiconductor Industry, 1979-1995 ", *The Rand Journal of Economics,* vol. 32(1), 101-128.

Jaffe, A. B. [1989], "Real Effects of Academic Research," *The American Economic Review*, vol. 79(5), 957-970.

Jaffe, A. B., M. Trajtenberg and R. Henderson, [1993], "Geographic Localization of Knowledge Spillovers as Evidenced by Patent Citations", *The Quarterly Journal of Economics*, vol. 108(3), 577-98.

Jaffe, A. B. [2000], "Knowledge Spillovers and Patent Citations: Evidence from a Survey of Inventors," *The American Economic Review,* 90(2), 215-218.

Kani, M. [2006], "Kenkyu Kaihatsu Spillover to Seisan Kouzou: Nippon Seizougyou ni Okeru Sangyoukan Spillover no Kouka no Keisoku" (R&D Spillovers and Production Structures: Estimation of Interindustry Spillovers in Japanese Manufacturing), *The Kokumin-Keizai Zasshi,* vol.194(4), 35-50.

Koo, J. [2005], " Knowledge-based Industry Clusters: Evidenced by Geographical Patterns of Patents in Manufacturing, " *Urban Studies,* 42(9), 1487-1505.

------------- [2007], " Determinants of Localized Technology Spollovers: Role of Regional and Industial Attributes, " *Regional Studies,* vol. 41(7), 995-1011.

Porter, M. E. [2003], "The Economic Performance of Regions", *Regional Studies*, vol. 37(6/7), 549-578.

Tomita, H. [2005], "R&D no Spillover Kouka Bunseki; Nippon no High-tech Sangyo ni Okeru Jisshou" (Analysis of R&D Spillover Effects: An Empirical Study in Japanese High-tech Industries), *Economics Today,* vol. 26(2), 1-58.