Scientometrics (2012) 92:63–73
DOI 10.1007/s11192-012-0726-5

Measuring the use of public research in firm R&D in the Hsinchu Science Park

Wen Chi Hung

Received: 18 March 2012 / Published online: 10 April 2012

Abstract Knowledge flow between public and private sectors is widely recognized as a way to stimulate innovation and regional development, particularly in science parks. This work employs a bibliometric approach, based on patent citation, non-patent citation, and public–private co-authorship of scientific publications to measure the use of public research in Hsinchu Science Park (HSP) in Taiwan. The result shows that the number of jointly published papers has increased constantly, implying the collaboration between HSP and universities has become more common. However, from the aspect of co-patenting, patent citation, and non-patent reference, technological innovation stemming from public research needs to be enhanced.

Keywords Public–private co-authored publication · Hsinchu Science Park · Taiwan · Co-authorship · Non-patent citation

Introduction

With the development of a knowledge-based economy, building relationships between public and private sectors is widely recognized as a tool to promote innovation and regional development. Science parks, aimed to promote research-based innovative activity and private–public collaboration, are now attracting worldwide attention. Science parks have made valuable contributions to industrial development and played an important role in facilitating public–private interactions by forming high-density R&D clusters, particularly in areas of emerging technologies.

W. C. Hung (✉)
Science and Technology Policy Research and Information Center, National Applied Research Laboratories, 14 F, No. 106, Section 2, He-Ping East Road, Taipei, Taiwan
e-mail: wchung@stpi.narl.org.tw

W. C. Hung
Institute of Business and Management, National Chiao Tung University, 118, Chung-Hsiao West Road, Section 1, Taipei, Taiwan

In Taiwan, considerable resources are being devoted to science parks. Hsinchu Science Park (HSP), built in 1980, is one of the most prominent high-tech research and development areas worldwide[1]. More than 400 high-tech companies, mainly involved in the semiconductor, computer, telecommunication, and optoelectronics industries, have been established in the park. The science park model has proven to be a highly successful approach for the development of high-tech industries (Castells and Hall 1994). However, compared to the innovation system that has been established throughout the generation, diffusion, and application of knowledge in Silicon Valley, HSP tends to focus on efficient product assembly, production, and professional division of labor. HSP currently faces a critical economic challenge and critical international competition. Whether HSP can stimulate and manage knowledge and technology flow among universities, R&D institutions, companies, and markets, and how to strengthen regional research base capability and better integrate existing R&D-intensive activities based on public–private partnerships, has become a popular issue for policymaking.[2]

Several previous studies have referred to the successful experience of HSP, and the successful factors that these studies have summarized include factors on input, such as sufficient human resources, investment in R&D, government support, neighboring universities and research centers, and the connection with Silicon Valley (Chang and Hsu 1999; Lee and Yang, 2000). Hu (2011) used patent citation to observe the evolution of knowledge creation and diffusion in HSP. However, the use of public science in firm R&D is a substantially less studied field that may gain more attention. Although in ideal cases public–private interactions can become advantageous for both academic and business sides and improve overall effectiveness of scientific and applied studies, the science park mechanism raises issues stemming from a lack of communication between research and business communities (European Commission 2007). Many programs in Taiwan focus on building connections between firms in science parks and academic research. This necessitates monitoring and evaluating the interactions of public–private interactions in science parks. Thus, this study employs a bibliometric approach, based on patent citation, nonpatent citation, and public–private coauthorship of scientific publications, to measure the use of public research, and to explore the role of public science in the knowledge creation and diffusion process in HSP.

Hsinchu Science Park

Hsinchu Science Park, founded in 1980, is one of the most significant areas for semiconductor manufacturing worldwide. The science park model has proven to be a highly successful approach for high-tech industry development. Instead of promoting industrial development, the Science Park mechanism is crucial for the creation of basic science, particularly in reinforcing the relationships among industries, universities, and research institutes. Many research-oriented universities and research institutes are located in near HSP. National Tsing Hua University (NTHU) and National Chiao Tung University (NCTU) are reputable for their science and engineering departments. Two major research institutes are located near HSP, including the Industrial Technology Research Institute (ITRI) and the National Applied Research Laboratories (NARL), which includes the

[1] Introduction of HSP is shown in Hsinchu Science Park Annual Report Available: http://www.sipa.gov.tw/.

[2] Development of the vision and strategies of science parks in Taiwan are shown in White Paper on Science and Technology 2011–2014, and the National Science and Technology Development Plan.

National Center for High-Performance Computing (NCHC), the National Space Organization (NSPO), the National Chip Implementation Center (CIC), the National Nano Device Laboratories (NDL), and the Instrument Technology Research Center (ITRC). Three main participants, enterprises in HSP, universities, and research institutions, support innovation development in the Hsinchu region. HSP includes six major industries, such as IC, computers and peripherals, telecommunications, optoelectronics, precision machinery, and biotechnology. HSP is proud of hosting the most comprehensive semiconductor industry worldwide and has set a global example of success in this industry. In addition to the semiconductor industry, the optoelectronics industry in HSP also exhibits a brilliant performance. A comprehensive industrial chain has been constructed for flat panel display, LED, and solar energy. Table 1 shows the scale of six main industries. To explore whether the knowledge sources and public–private relation of firms in HSP alter with varying firm size, this study divided enterprises into two types: small and medium-sized enterprises (SMEs) and large enterprises. An SME refers to an enterprise in the manufacturing, construction, mining, and quarrying industry, with less than 200 regular employees, whereas a large enterprise refers to an enterprise in the manufacturing, construction, mining, and quarrying industry, with more than 200 regular employees.

Measuring the use of public research in firm R&D by bibliometric analysis

The use of public research in firm R&D is multifaceted. Schmoch (1997) delineated relation indicators between science and technology, including patents of scientific institutions, publications of industrial enterprises, citations to scientific publications in patents, and parallel observations of patents and publications. Although the articles published by industrial enterprises are limited in amount, and publications by firms are considered merely as a by-product of industrial activities, previous studies have identified a number of reasons why firms perform basic research in-house (Rosenberg 1990; O'Shea et al. 2005). Knowledge derived from scientific research provides great theoretical base for innovation-oriented corporate R&D activities. In addition, the most effective way to stay connected with the scientific network is to be a participant in the research process (Godin 1996). The publications to which a company is associated are mostly company-university coauthored papers. Consequently, company involvement in publications could also be considered to signal science-technology interactions (Godin 1993; Calvert and Patel 2003; Tijssen 2004; Tijssen and van Leeuwen 2006; Abramo et al. 2009). These co-authored papers reflect successful scientific collaborations and are likely to signify knowledge flows and research

Table 1 The sales and share of SMEs of six sectors in HSP

Sector	Sales (billion NT)		Share of SMEs (%)
	1990s	2000s	
IC	1,849.7	6,544.1	69.70
Computers and peripherals	1,174.7	1,073.3	67.35
Telecommunications	242.3	455.4	89.13
Optoelectronics	230.3	1,421.0	69.57
Precision machinery	18.9	101.2	81.82
Biotechnology	6.7	30.4	81.25

networking activities between companies (Katz and Martin 1997; Calero et al. 2007). Citations have commonly been used to observe the innovation process and are another way to observe the use of public research in firm R&D. A patent document contains the information of citations to patents or non-patent references. The information represents the technological antecedents of a particular innovation. Patent citations have thus come to be used to track the influence of past inventions across time and space. Patent citation data have been used to investigate patterns of knowledge diffusions (Caballero and Jaffe 1993; Jaffe et al. 1993; Jaffe and Trajtenberg 1999). Citations to non-patent references are interpreted as knowledge flows from public research to firm R&D (Roach 2009), or exchange processes between science and technology (Meyer 2006). Non-patent reference refers to the patent citation to scientific documents, such as publications, technical papers, and conference proceedings. Because these scientific documents are the primary form of public research output (Narin et al. 1997; Agrawal and Henderson 2002), they are better suited to measure the public to private knowledge flow. Table 2 shows a summary of the indicators used in measuring the use of public science to firm R&D.

Data and methodology

This study employs two types of codified knowledge: patents and papers, to assess the knowledge source and flow from public science to firms in HSP. The current study uses the United States Patent and Trademark Office (USPTO) because it is the major patent system worldwide, and Taiwan has great patenting activity in the USPTO because a US patent provides relatively strong protection in a competitive technological market. The front page of the USPTO patent provides systematic ally-compiled citation information. First, it contains a list of citations to other patents that could represent the technological antecedents to this invention, to help trace the source of innovation/knowledge. Therefore, a patent reference could be applied to trace the knowledge sources of firms in HSP. The front page of the USPTO patent also contains citations to scientific documents, which are typically considered a general indicator of ''interaction'' between science and technology. Because non-patent references can include items that are not considered scientific output, this study implements a procedure to identify non-patent citations that refer to scientific papers covered by the Science Citation Index Expanded and the Social Science Citation Index. This analysis covers all USPTO patents in which at least one assignee is located in HSP.

Joint publication and joint patenting is another facet used to observe the interaction of science and technology. The scientific publication in this paper is also restricted to the research papers covered by the Science Citation Index Expanded and the Social Science Citation Index. This analysis covers all research papers that list at least one author affiliate address, referring to a firm located in HSP. The count of coauthored papers is defined at the level of main institutions. For example, a coauthored paper is written by three researchers: one from the Taiwan Semiconductor Manufacturing Company (TSMC), and two from different departments at National Taiwan University. The count is once for TSMC, and once for National Taiwan University. The current study assumes that co-publication data are a good indicator of collaborative research activity. The ''public–private co-authored publication'' in this work means a research collaboration between a public sector and an enterprise that results in one coauthored publication. A publication produced by m public research institutes/universities and n enterprises is counted as $m \times n$ public–private research collaborations. It counts as a bilateral collaboration. This study also allocates

Table 2 Indicators used in measuring the use of public science to firm R&D

Indicator	Rationale	Criticism	Published study
Publications of industrial enterprises or Joint publications between industry and academe	Firms in high technology industries perform basic research in-house Some industrial publications have very high effect on the research community Industrial publication is an effective way for becoming involved in the communication of scientific communities and gaining access to the most recent research results	Publications by firms are considered merely a by-product of industrial activities	Nelson 1990; Godin 1993; Calvert and Patel 2003; Tijssen 2004; Calero et al. 2007; Abramo et al. 2009
Joint patent between industry and academe	Innovations that are patented are expected, by definition, to be commercially useful Emergence of the "entrepreneurial university" in which the commercialization of knowledge has become the third mission next to teaching and research The growth of university-owned patents and university-invented patents	Only a small fraction of researchers in academia patent	Petruzzelli 2011
Citations to patent references	Knowledge spillovers may leave a paper trail in citations to prior art recorded in patent Patent citation data have been used to investigate patterns of knowledge diffusions	Only a small fraction of researchers in academia patent	Jaffe and Trajtenberg 1996; Nelson 2012; Roach and Cohen 2011
Citations to non-patent reference	Non-patent references (NPRs) encompass references to various non-patent documents, such as scientific articles, technical papers, conference proceedings, and disclosure NPRs linked to scientific literature MPRs provide empirical evidence that the technical invention is in some way related to scientific research activities	The NPRs do not appear to reflect the cognitive contribution of a paper to the invention, but rather the interaction between science and technology	Tijssen 2001; Meyer 2006; Breschi and Catalini 2010; Roach and Cohen 2011

papers affiliations into regions and countries according to the locations of public and private sectors. Thus, the public–private collaboration in the paper publication can be analyzed at the regional and country level.

Results

As of 2010, a total of 434 companies were registered in HSP, and patents in HSP accounted for approximately 42 % of the total Taiwan USPTO patent output. Firms in HSP belonging to SMEs accounted for 65 %; large enterprises are the main body of patents issued in HSP. Large enterprises have issued 25,445 patents, whereas SMEs have issued only 1,978 patents from 1990 to 2009. However, irrespective of whether the scale of enterprises is large or small, the number of granted patents has grown rapidly in recent years. Table 3 shows the top ten assignees in Taiwan. Six of the ten assignees have been registered in HSP in the 1990s and 2000s, showing that HSP firms are main innovators in Taiwan. The Industrial Technology Research Institute (ITRI), the research institute near HSP, has also been ranked third in the 2000s, indicating the importance of ITRI patenting activity in Taiwan.

Table 4 shows the distribution of countries with patents that have been cited by enterprises in HSP. The results show that the main knowledge sources are the United States and Japan, followed by South Korea, which is at a similar stage of industrial development to Taiwan. A comparison of the numbers in the 1990s and 2000s shows that a proportion of

Table 3 Top 10 assignees in Taiwan

1990–1999				2000–2009		
Rank		Share of patents in Taiwan (%)	In HSP or not	Rank	Share of patents in Taiwan (%)	In HSP or not
1	United Micrelectronics Corp.	16.68	Y	A Hon Hai Precision Ind. Co., Ltd.	12.30	Y
2	Taiwan Semiconductor Manufacturing Company	14.96	Y	Taiwan Semiconductor Manufacturing Company	10.37	Y
3	Industial Technology Research Institute	14.01		Industial Technology Research Institute	6.51	
4	A Hon Hai Precision Ind. Corp.	7.64	Y	AU Optronic Corp.	3.68	Y
5	Vanguard International Semiconductor Corp.	4.53	Y	United Micrelectronics Corp.	3.68	Y
6	National Science Council	4.44		Macronix, International Co., Ltd.	3.54	Y
7	Winbond Electronics Corp.	4.25		Via Technolgies, Inc.	3.18	
8	Mosel Vitelic Inc	1.85	Y	Mediatek Inc.	2.28	Y
9	Macroniox International Co., Ltd.	1.35		Delta Electronics, Inc.	2.18	
10	Mustek Systems Inc	1.19	Y	Inventec Corporation	1.50	

Table 4 Backward citation in HSP, by country

	1990s	2000s		
	Total (%)	Total (%)	SMEs (%)	Large enterprises (%)
Germany	1.02	1.37	2.00	1.32
Japan	25.79	19.01	29.28	18.13
Korea	5.74	4.28	3.91	4.33
Taiwan	9.99	18.01	11.29	18.72
US	48.13	42.08	50.04	41.51
Others	9.33	15.24	3.47	15.99

Table 5 Backward citation to Taiwan patents

	1990s	2000s		
	Total (%)	Total (%)	SMEs (%)	Large enterprises (%)
Self citation	55.42	59.13	24.38	60.69
Other firms within HSP	23.49	25.91	35.41	25.48
Others	21.08	14.96	40.21	13.83

the United States and Japan has continually declined, whereas the proportion of Taiwan has risen significantly from 9.99 to 18.01 %.

Comparing the difference between SMEs and large enterprises in the park shows that SMEs still relatively depend on the knowledge of the United States and Japan because of the higher proportion of cited patents in the United States and Japan and the lower proportion of cited patents in Taiwan than the number of large enterprises. This shows the different sources of knowledge between large enterprises and SMEs in the park, and the different development stages of enterprises of varying size. An approximate average of 10.65 % of the patents cited by firms registered in HSP is self-citations, and 4.67 % are cited from other enterprises in HSP (Table 5). Comparing the SMEs with large enterprises shows that the proportion of self-citations in large enterprises is significantly higher than the SMEs, indicating that they have a greater autonomy in R&D. A higher proportion of patent citations of other enterprises in HSP also indicates that large enterprises have more significant exchanges of knowledge resulting from geographical proximity than the SMEs.

By dividing the citation sources into enterprises, research institutions, universities, and others (Table 6), enterprises are the major patent citation sources for enterprises in HSP. The lower share of non-enterprises cited by the SMEs than the large enterprises shows that SMEs do not consider public science their dominant knowledge source. The most frequently cited research institute by enterprises in HSP is the Industrial Technology Research Institute (ITRI), accounting for nearly half of the research institutes cited. However, this share has shown a downward trend, and is assumed to relate to the maturity of industries in HSP. Although the major industries in HSP, such as the IC industry, have gradually grown stronger, ITRI has constantly searched for other emerging technologies to develop another industry niche in Taiwan.

The non-patent references cited by HSP in the 1990s is an average of 0.56 non-patent documents cited per patent, and the number rose to 0.61 after 2000 (Table 7). The

Table 6 Backward citation in HSP, by organization type

	1990s	2000s		
	Total (%)	Total (%)	Large enterprises (%)	SMEs (%)
Firms	93.74	95.42	95.64	92.29
Research institutions	1.82	0.60	0.60	0.65
Universities	0.78	0.73	0.75	0.43
Others	3.66	3.25	3.01	6.63

Table 7 The average number of NPRs per patent

	1990s	2000s		
	Total	Total	SMEs	Large enterprise
Average number of NPRs per patent	0.56	0.61	0.34	0.82

Table 8 The top 10 organizations of non-patent references

Country	Organization	Share (%)
USA	IBM	19.69
USA	University of California, Berkeley	11.19
Japan	Toshiba	7.83
Spain	University Granada	7.16
USA	Stanford University	7.16
Taiwan	National Chiao Tung University	6.71
Japan	Hitachi	6.26
USA	Motorola	5.82
USA	Lawrence Berkeley National Laboratory	4.92
Japan	NKK Corporation	4.92
Share of total non-patent citation		81.66

proportion of non-patent references cited by large enterprises is higher than the number of SMEs, with an average of 0.82 cited in each patent by large enterprises and only 0.34 cited by SMEs. From the organizational level, the major sources of non-patent references are the large enterprises and research universities in the United States and large enterprises in Japan (Table 8). The top three organizations are IBM, University of California, Berkeley, and Toshiba. National Chiao Tung University is the only organization in Taiwan among the top ten organizations. Because it neighbors HSP, the achievements in interaction and exchange between National Chiao Tung University and the industry have also shown on the proportion of non-patent references.

Among the enterprises that have cited non-patent references, TSMC accounts for the largest proportion, with nearly half of the non-patent references, followed by Macronix, UMC, and Realtek. These enterprises are all in the semiconductor industry, among which TSMC and UMC are wafer foundry companies, Macronix is an IDM company, and Realtek is an IC design company. These enterprises have had a significant proportion of non-patent references since 2000, a trend that has continued.

Figure 1 shows the volume of public–private coauthored publications in HSP. This longitudinal analysis represents steadily increasing numbers of scientific publications. Table 9 shows the breakdown of joint research papers by partners. National Chiao Tung University and National Tsing Hua University, both located in the area near HSP, are the primary partners for firms in HSP, implying the effects of geographic proximity and regional innovation cluster. Both of these universities have a wide range of cooperative partners. In addition to the cooperation with large enterprises such as TSMC and UMC, these universities also collaborate with other enterprises and SMEs. Conversely, the cooperative partners of non-Hsinchu universities are mostly certain enterprises. For example, nearly 77 % of papers published by National Cheng Kung University are in cooperation with TSMC, considerably higher than the 43 % of National Chiao Tung University and the 32 % of National Tsing Hua University. Because of geographical proximity, these two universities have more opportunities to interact and exchange with enterprises in the park, and thus, have a greater understanding of the needs of those enterprises. Two research institutes, National Nanotechnology Device Laboratories and the

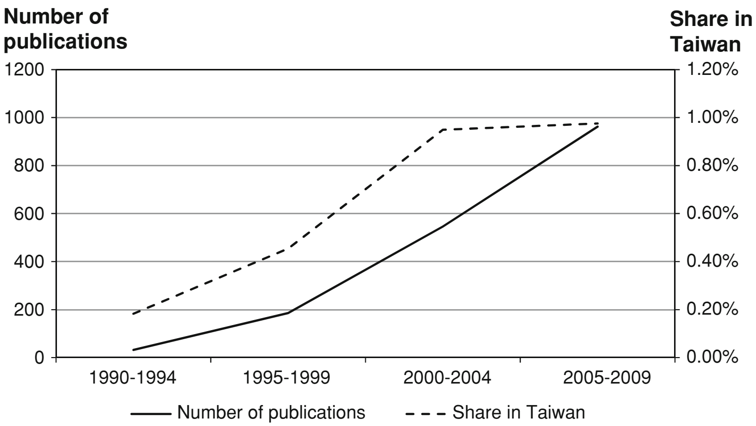

Fig. 1 Annual public–private co-authored publications of HSP, 1990–2009

Table 9 The top 10 co-authored publication partnerships

Country	Partner	Share (%)
Taiwan	National Chiao Tung University	12.38
Taiwan	National Cheng Kung University	6.13
Taiwan	National Tsing Hua University	5.61
Taiwan	National Taiwan University	3.09
Taiwan	National Nano Device Labs	1.55
Taiwan	National Sun Yat Sen University	1.29
Taiwan	National Cent University	0.97
Taiwan	National Taiwan University of Science and Technology	0.97
China	Fudan University	0.84
Taiwan	Ind. Technol. Res. Inst	0.77
Share of co-authored publication		34.69

Industrial Technology Research Institute (ITRI), also work intensively with firms in HSP in research publication.

Conclusion

The concept that public and private sectors interact in relatively complex ways, and that patent citation, non-patent citation, and coauthorship of scientific publications do not capture all the use of public research in firm R&D, is reasonable. However, the bibliometric method is still a useful tool to explore the interaction between the public and the private, and to measure the knowledge flowing from the public to the private sector. This study finds the recent collaboration between HSP and the public has become more common, and the number of jointly published papers has increased constantly, showing the achievements in knowledge creation from public–private collaboration. However, the trend of non-patent documents cited per patent rises only slightly, and the share of research institutes and universities as knowledge sources in patent citation has been declined, implying that although the interaction between the public and private in HSP is increasing, technological innovation stemming from public science remains low.

One reason is because of regulation limitations in Taiwan and the lack of motivation for researchers in universities to apply patents, resulting in a limited amount of patent applications. Another reason is that firms in HSP still rely heavily on leading countries such as the United States and Japan for technological innovation. Although the proportion of knowledge sources from other enterprises in HSP and internal R&D has gradually increased, the role of large foreign enterprises is still significant. The results of non-patent references show that large international enterprises are a crucial knowledge source for technological innovation and scientific research of enterprises in HSP. The share of scientific papers in Taiwan cited by HSP is lower than the share of Taiwan patents cited by HSP, indicating that the link between science and technology must still be strengthened and improved.

Compared to large enterprises, SMEs have a lower mastery level in technology autonomy and tend to be latecomers in technological innovation. From the aspects of knowledge creation and flow, the interaction between SMEs and Taiwan enterprises and public science in knowledge creation is not high, whereas the degree of dependence on foreign technologies is higher. Policymakers should contemplate how to establish actual interaction between enterprises and public science by formulating public–private collaboration policies so that firms can take advantage of academic research capabilities, and thereby improve industrial technologies.

References

Abramo, G., D'Angelo, C. A., Di Costa, F., & Solazzi, M. (2009). University–industry collaboration in Italy: A bibliometric examination. *Technovation, 29*, 498–507.

Agrawal, A., & Henderson, R. (2002). Putting patents in context: Exploring knowledge transfer from MIT. *Management Science, 48*(1), 44–60.

Breschi, S., & Catalini, C. (2010). Tracing the links between science and technology: An exploratory analysis of scientists' and inventors' networks. *Research Policy, 39*(1), 14–26.

Caballero, R., & Jaffe, A. (1993). How high are the giants' shoulders: An empirical assessment of knowledge spillovers and creative destruction in a model of economic growth. In O. Blanchard & S. Fischer (Eds.), *NBER macroeconomics annual*. Cambridge, MA: MIT Press.

Calero, C., van Leeuwen, T. N., & Tijssen, R. J. W. (2007). Research cooperation within the bio-pharmaceutical industry: Network analyses of co-publications within and between firms. *Scientometrics, 71*, 87–99.
Calvert, J., & Patel, P. (2003). University–industry research collaborations in the UK: Bibliometric trends. *Science and Public Policy, 30*(2), 85–96.
Castells, M., & Hall, P. (1994). *Technopoles of the World: The making of 21th century industrial complexes*. London: Routledge.
Chang, P., & Hsu, C. (1999). The development strategies for Taiwan's semiconductor industry. *IEEE Transactions on Engineering Management, 45*(4), 349–356.
European Commission. (2007). *Regional research intensive clusters and science parks*. Available: http://ec.europa.eu/research/regions/pdf/sc_park.pdf. Accessed March 2012.
Godin, B. (1993). *The relationship between science and technology: A bibliometric analysis of papers and patents in innovative firms*. Unpublished D. Phil. thesis, University of Sussex. Accessed March 2000.
Godin, B. (1996). Research and the practice of publication in industries. *Research Policy, 25*, 587–606.
Hu, M. C. (2011). Evolution of knowledge creation and diffusion: The revisit of Taiwan's Hsinchu Science Park. *Scientometrics, 88*, 949–977.
Jaffe, A. B., & Trajtenberg, M. (1996). Flows of knowledge from universities and federal laboratories: Modeling the flow of patent citations over time and across institutional and geographic boundaries. *Proceedings of the National Academy of Science, USA, 93*, 12671–12677.
Jaffe, A., & Trajtenberg, M. (1999). International knowledge flows: Evidence from patent citations. *Economics of Innovation and New Technology, 8*, 105–136.
Jaffe, A., Trajtenberg, M., & Henderson, R. (1993). Geographic localization of knowledge spillovers as evidenced by patent citations. *The Quarterly Journal of Economics, 108*(3), 577–598.
Katz, J. S., & Martin, B. R. (1997). What is research collaboration? *Research Policy, 26*, 1–18.
Lee, W. H., & Yang, Wei-Tzen. (2000). The cradle of Taiwan high technology industry development—Hsinchu Science Park (HSP). *Technovation, 20*(1), 55–59.
Meyer, M. (2006). Measuring science-technology interaction in the knowledge-driven economy: The case of a small economy. *Scientometrics, 66*(2), 425–439.
Narin, F., Hamilton, K. S., & Olivastro, D. (1997). The increasing linkage between US technology and public science. *Research Policy, 26*(3), 317–330.
Nelson, A. J. (2012). Putting university research in context: Assessing alternative measures of production and diffusion at Stanford. *Research Policy, 41*, 678–691.
Nelson, R. (1990). Capitalism as an engine of progress. *Research Policy, 19*, 193–214.
O'Shea, R. P., Allen, T. J., Chevalier, A., & Roche, F. (2005). Entrepreneurial orientation, technology transfer and spinoff performance of US universities. *Research Policy, 34*, 994–1009.
Petruzzelli, M. A. (2011). The impact of technological relatedness, prior ties, and geographical distance on university–industry collaborations: A joint-patent analysis. *Technovation, 31*, 309–319.
Roach, M. (2009). *When do firms use public research? the determinants of knowledge flows from universities and government labs to industrial R&D*. Working paper. Available: http://www2.druid.dk/conferences/viewpaper.php?id=5988&cf=32. Accessed March 2012.
Roach, M., & Cohen, W. M. (2011). *Lens or prism? A comparative assessment of patent citations as measure of knowledge flows from public research*. http://www.nber.org/public_html/confer/2011/SI2011/PRIPP/Roach_Cohen.pdf. Accessed January 2012.
Rosenberg, N. (1990). Why do firms do basic research (with their own money)? *Research Policy, 19*, 165–174.
Schmoch, U. (1997). The relations between science and technology. *Scientometrics, 33*(1), 103–116.
Tijssen, R. J. W. (2001). Global and domestic utilization of industrial relevant science: Patent citation analysis of science-technology interactions and knowledge flows. *Research Policy, 30*, 35–54.
Tijssen, R. J. W. (2004). Is the commercialisation of scientific research affecting the production of public knowledge? Global trends in the output of corporate research articles. *Research Policy, 33*(5), 709–733.
Tijssen, R. J. W., & van Leeuwen, T. N. (2006). Measuring impacts of academic science on industrial research: A citation-based approach. *Scientometrics, 66*(1), 55–69.