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Exploitation of Public Technology for Industrial Use

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***Abstract*—**The purpose of study is to demonstrate how the characteristics of technology and the process required for development of technology affect technology transfer from public organisations to industry on the technology level. In addition, using the advantage of the analytic level and the novel means of measuring technology convergence, we examine the characteristics of converging technologies as compared to non-converging technologies in technology transfer process. In sum, our study finds that a technology from the public sector is likely to be transferred when its readiness level is closer to generation of profit, when its stage of life cycle is early and when its economic values is high. Our findings also show that converging technologies are less likely to be transferred.

***Keywords*—**Interdisciplinary; Technology transfer; Technology convergence.

I. Introduction

AMONGST manifold ways of knowledge diffusion, 'technology transfer', the direct transfer of innovation based on inter-organisational licensing contract, has received significant attention as a representative means to diffuse innovation. At the very beginning of the booming of technology transfer, performance of public research organization's technology transfer seemed sluggish [1]. University resources, either technological asset or human capital, have been prevailingly considered not fully exploited as a source of economic growth and competitiveness [1]. However, the actual licensing activity, especially that of universities, has remarkably increased for the several past decades [2]. In the mean time, as for firms, external technology acquisition has been firmly established as innovative strategy [3].

Observing the increase of technology transfer activity, policymakers executed the large amount of policy initiatives to improve the efficiency of technology transfer, especially technology transfer from public sector to private sector [4]. Although it is certain that the amount of licensing contract greatly has increased, the increase has been largely attributed to the increase of input, i.e. claim of innovation and patenting, while the propensity of licensing has dropped [2]. For that reason, scholars pay a lot of attention to underlying mechanism and obstacles of technology transfer, in order to suggest means to improving the efficiency of the market for technology.

The purpose of study, in consist with the purpose of previous literature, is to demonstrate how the characteristics of technology and the process required for development of technology influence on technology transfer, mainly focusing on technology transfer in performing national R&D projects.

The remainder of this study is organized as follows. The article introduces the heuristic framework of technology transfer based on technological perspective; it then formulates hypotheses. Data and empirical methodology descriptions are followed by a discussion of the results and concluding remarks.

II. Theoretical Background and Hypotheses

A. The Definition of Technology Convergence

The definition of technology transfer varies by literature, but in general, technology transfer is defined as 'the movement of know-how, technical knowledge, or technology from one organizational setting to another.'[1]. Typically, the process of technology transfer consists of various subsequent activities. After scientific and technological discovery, researchers declare their novel innovation, and then Technology Transfer Office (TTO) perform patenting the innovation, linking the innovation with its demand side, i.e. industrial firms, and making a license contract with firms [2].

A number of scholars found diverse factors that affect technology transfer. Basically, firms must consider the trade-offs and associated risks inherent in technology transfer [5], and the trade-offs of technology transfer are attributed to the factors whose level is categorised into transfer object, transfer agent, demand environment and transfer recipient (Bozeman 2000). Scholars analyse on the standpoint of several factors within one level or factors within integrated levels; distinct characteristics between transfer objects in technology transfer [4], [6]; licensing efficiency of university [7]; and the effect of spatial distance between agents and resources [8].

However, majority of previous literature overlooks the characteristics of what are actually transacted in technology transfer. Therefore, we review the determinants of technology transfer in the contexts of technology and related process in the R&D organisation and develop hypotheses based on those contexts. In particular, taking advantage of this view, we comparatively examine the characteristics of converging technology in technology transfer.

B. The Determinants of Technology Transfer

Convergence generally describes the concept of discrete items moving towards unity or uniformity, or the merging of

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distinct technologies, devices, or industries into a unified whole [9]. Such convergence, especially technology convergence, arises as a hot topic not only in academic fields but also in industry because strategic decisions on converging technologies and associated products can critically influence the competitiveness of both enterprises and nations [9].

Therefore, converging technologies in technology transfer can appeal to be attractive for firms. Technology convergence creates a new function resulting from the integration of different technological elements [10], and derived technological changes play key roles in driving even industry convergence by potentially destructing existing market structure and order [11]: it provides its owning firms with the opportunities to break into value chain based on new niche market and thus challenge existing industry leaders for dominance [12].

Since critical mass of demands for technologies and technological competencies is a major factor in determining market impact technology transfer success [13], the substantial market impact and technological competencies of converging technologies would attract more firms than non-converging technologies would.

Hypothesis 1: a converging technology is more likely to be transferred than a non-converging technology

The innovativeness of technology is time-variant: it depends on the circumstances of applicable product and market that vary by time and context [1]; hence, technological position that is contingent on R&D process and evolution of the technology can significantly influence on the success of technology transfer.

A notable context is the technology-readiness level, which primarily indicates how operational an R&D activity is [14]. Generally, until creating profits from associated products for a firm that acquires the technology, a technology entails various phases and considerable time under the risk of failure [15]. Generally, most licensed technologies require a lot of further developments of licensees in order to be commercially profitable, since invention at the moment of licensing is merely ‘proof of concept’ [2]. Therefore, due to tacitness of technology [16], firms as licensees would have to confront more cognitive difficulties in internalizing licensed technologies and with low technology readiness level than with high technology readiness level: that is, such difficulties may lower firms’ willingness to obtain the technology because of derived transaction cost from the tacitness [16].

Hypothesis 2: a technology with high technology readiness level is more likely to be transferred than that with low high technology readiness level

Another notable context involves the technology life cycle which depicts the change of competition and evolution of technology in technology paradigm. Technological progress and innovation has been shown to follow a clear pattern of evolution that presents the competitive dynamics and viability of both firms and industries [17]. The early stages of technology life cycle are marked by a diversity of product designs and unsatisfactory technology performance as competitors try to meet emerging customer needs [17]. On the contrary, the latter stages of that are characterised by existence of dominant technology in the market, the stabilised market sales, infrequent innovation activities and low possibilities of technology improvement [17].

In such context, according to the policy model in the cooperative technology paradigm that today’s governments chiefly emphasizes [18], the role of public research organisations is to complement competencies of the private sector especially in developing pre-competitive technology due to the competencies of public research organisations in technology venturing [1].

Therefore, as the stage of technology life cycle progresses, urgency to acquire technology would decrease to their lowest points, and thus, the motivation to seek external sources of technology also would decrease concurrently. In the late stage of technology life cycle, the possibilities of improvement driven by technology is at most marginal, whereas firms could take advantage of relatively supreme resource of public research organisation by acquiring their technologies in the early stage of technology life cycle.

Hypothesis 3: a technology at early stage of technology life cycle is more likely to be transferred than that at late stage of technology life cycle.

III. Data and Methodology

A. Data Sources

To demonstrate the propensity of technology transfer in practice, we first obtain the list of entire patents which public research owns and the list of transferred patents amongst those patents. As sample organisations amongst entire research organisations in Korea, 135 public research organisations that rank within upper 90% by licensing income and within upper 80% by licensing frequency from 2006 to 2009 are chosen. Amongst those organisations, 83 organisations (61.5%) provide the list of their patents including their transfer record, and the patents number 28,640. We exclude a few foreign patents since they cannot be generalised with the domestic patents, viz. the standards of approval and coverage of property protection vary by jurisdiction. Then, by matching the patent registration codes with those in the data of National Science and Technology Information Service (NTIS), we construct the details about projects that bear the patents and the patents per se. NTIS contains information about the features of wholly government-supported R&D programs and their outputs. Researchers who undertake any government-supported R&D project ought to register their R&D outputs, such as patents, as outputs of R&D activities. Additionally, we find more details about the patents through Korea Intellectual Property Rights Information Service (KIPRIS) database, regarding the number of claims, the number of inventors, application year and the technological field. In entire process, patent applications are referred rather than patents awarded because of substantial lags between application and issue [2].

B. Measurement of Convergence

To judge whether technology about which a patent describes is of convergence or not, we need to review the means of measuring convergence for science convergence, i.e. interdisciplinarity since few certain means for technology convergence exist despite significant attention to for technology convergence. Scholars usually demonstrate the structure of science convergence through bibliometric methods [19] such as multi-disciplinary assignation of articles, the cross-disciplinary citation among journal articles, the co-classification of journals' subfields or co-wording among journal articles. Industry-convergence studies use similar methods, the most representative seen in Curran et al. [9], which define and refine the methodology based on industry-level co-classifications in the International Patent Classification (IPC).

Referring those methods, we suggest an alternative means of measuring technology convergence, based on the multi-assignation of patent documents. The key measurement issue is how to define the original source of technological knowledge. A sensible way of defining the base level of multi-assignation is to set sourced R&D projects as the sources of techno-scientific domains, under the premise that technological knowledge derives from R&D activities [20].

Another essential issue is the classification of technology. To derive better practical implications, a taxonomic framework should consider the standpoint of governmental policy aimed at technology convergence. NSF in the United States proclaims four major technology-convergence domains: nano-technology (NT), bio-technology (BT), info-technology (IT), and cognitive science (CS) [21]. The European Commission defines a similar typology (NT, BT, IT, social science, and humanities [22]. In the South Korean case, the Office of Science and Technology Innovation also proclaim the six major technology domains for convergence: NT, BT, IT, energy technology (ET), space technology (ST) and culture technology (CT); following this typology, entire R&D projects of Korea are classified as per those domains. In understanding these typologies, numerous experts have actually designed and introduced substantialised or substantialisable cases of technology convergence among macro-technology domains [21]. Thus, it is sensible to make typology a fundamental framework in analyzing technology convergence.

C. Variables and Method

We define the dichotomous dependent variable, *Transfer*, as followings: if the patent has been transferred to industry, no matter how many times licensing happens, Transfer equals 1; if not, 0. We construct the independent variable *Convergence* that equals 1 if the patent is a converging patent, and 0 otherwise. During or after the R&D activities, researchers register the produced patents, along with information on what projects contributed to the creation of the patents. Due to legal issues related to the ownership of patents and the distribution of profits—such as licensing fees—researchers carefully refer to the contributing R&D projects along with their ratios of contribution when reporting the patents created. We presume that the patent with the multi-assignations of heterogeneous macro-technology domains represents technology convergence.

Tech_ready_lvl indicates the technology-readiness level, obtained from the registered features of engaged R&D projects in NTIS. Based on the typology of OECD [23] for R&D programs, the NTIS mandates that researchers report their R&D project type when registering information on the projects. Like previous studies [24], we presume the continuous technology innovation model and code this variable as a linearly increasing value by level, i.e., 1: 'basic research,' 2: 'applied research,' and 3: 'experimental development.' The noteworthy issue is dealing with the values of this variable in cases of multi-assignation patents. We adopt the weighted average of each project whose value is based on the ratio of each project's contribution to the patent. *Tech_life_cycle* indicates the phase of the technology lifecycle, obtained from NTIS and adjusted in the same way as *Tech_ready_lvl*. According to Roussel et al. [25], *Tech_life_cycle* is coded as a linearly increasing value by the phase, i.e., 1: 'embryonic,' 2: 'growth,' 3: 'mature,' and 4: 'aging.'

We include control variables as follows. *Project_budget*, obtained from NTIS, represents the average amount of funding for the R&D projects to which the patent is attributed. To nullify the effect of inflation, we employ a logarithm value of deflated budget in millions of KRW. In addition, *Project_budget* is measured via the same rule for the weighted average. For strength of patent, we construct two more controls [14]. *Inventor*, which indicates the number of inventors and is obtained from KIPRIS, refers to the number of inventors. *Claim*, which indicates the number of inventors and is obtained from KIPRIS, denotes the number of claims, indicating technological scope.

We categorise the technological fields and use them as dummy variables on the basis of the first-digit IPC classification. Scholars have suggested that some specific technological fields have distinct transfer characteristics because of varying levels of codifiability [26]. In addition, application years are used as dummy variables since the likelihood that patent is licensed can be affected by length of time since patent disclosure, although a technology eventually becomes obsolete.

The definitions of variables are summarized in Table I.

TABLE I
DEFINITION OF DEPENDENT AND INDEPENDENT VARIABLES

Variable	Description
Dependent variable	
Transfer	Dummy equal to 1 if the patent has been transferred to industry; if not, 0
Independent variable	
Convergence	Dummy equal to 1 if the patent is attributed to the R&D projects that are assigned to heterogeneous macro technological domains; if not, 0
Tech_ready_lvl	Weighted average of technology-readiness level of the R&D projects that contribute to the invention of the patent (1: basic research; 2: applied research; 3: experimental development)
Tech_life_cycle	Weighted average of the phase of technology lifecycle at which the R&D projects are assigned to the patent (1: embryonic, 2: growth, 3: mature, 4: aging)
Project_budget	Weighted average of the deflated average funding amount for the R&D projects to which the patent is attributed, a log value of millions of KRW
Inventor	The number of inventors of the patent
Claim	The number of claims of the patent
Y1999	Dummy equal to 1 if application year of the patent is 1999; if not, 0
Y2000	Dummy equal to 1 if application year of the patent is 2000; if not, 0
Y2001	Dummy equal to 1 if application year of the patent is 2001; if not, 0
Y2002	Dummy equal to 1 if application year of the patent is 2002; if not, 0
Y2003	Dummy equal to 1 if application year of the patent is 2003; if not, 0
Y2004	Dummy equal to 1 if application year of the patent is 2004; if not, 0
Y2005	Dummy equal to 1 if application year of the patent is 2005; if not, 0
Y2006	Dummy equal to 1 if application year of the patent is 2006; if not, 0
Y2007	Dummy equal to 1 if application year of the patent is 2007; if not, 0
Y2008	Dummy equal to 1 if application year of the patent is 2008; if not, 0
Y2009	Dummy equal to 1 if application year of the patent is 2009; if not, 0
Ipc_a	Dummy equal to 1 if the first digit of IPC of the patent is A; if not, 0
Ipc_b	Dummy equal to 1 if the first digit of IPC of the patent is B; if not, 0
Ipc_c	Dummy equal to 1 if the first digit of IPC of the patent is C; if not, 0
Ipc_d	Dummy equal to 1 if the first digit of IPC of the patent is D; if not, 0
Ipc_e	Dummy equal to 1 if the first digit of IPC of the patent is E; if not, 0
Ipc_f	Dummy equal to 1 if the first digit of IPC of the patent is F; if not, 0
Ipc_g	Dummy equal to 1 if the first digit of IPC of the patent is G; if not, 0
Ipc_h	Dummy equal to 1 if the first digit of IPC of the patent is H; if not, 0

Table II reports the means, standard deviations, and minimum and maximum values of the independent and control variables. For the empirical analysis, we conduct the probit estimation using the probit option on STATA 12

TABLE II
DESCRIPTIVE STATISTICS

Variable	Obs.	Mean	Std. D.	Min	Max
Convergence	28640	0.293	0.455	0	1
Tech_ready_lvl	28640	2.214	0.744	1	3
Tech_life_cycle	28640	1.654	0.606	1	4
Project_budget	28640	6.915	1.458	0.645	11.518
Inventor	28640	3.774	2.518	0	33
Claim	28640	9.354	6.682	1	230
Y1999	28640	0.000	0.010	0	1
Y2000	28640	0.000	0.013	0	1
Y2001	28640	0.000	0.019	0	1
Y2002	28640	0.001	0.034	0	1
Y2003	28640	0.011	0.103	0	1
Y2004	28640	0.029	0.167	0	1
Y2005	28640	0.066	0.249	0	1
Y2006	28640	0.182	0.386	0	1
Y2007	28640	0.251	0.434	0	1
Y2008	28640	0.222	0.416	0	1
Y2009	28640	0.237	0.425	0	1
Ipc_a	28640	0.101	0.301	0	1
Ipc_b	28640	0.090	0.287	0	1
Ipc_c	28640	0.146	0.353	0	1
Ipc_d	28640	0.005	0.074	0	1
Ipc_e	28640	0.012	0.108	0	1
Ipc_f	28640	0.022	0.147	0	1
Ipc_g	28640	0.254	0.435	0	1
Ipc_h	28640	0.370	0.483	0	1

IV. EMPIRICAL RESULTS

Table III shows the empirical results. The standard deviations of each coefficient are displayed in parentheses below each coefficient.

Hypothesis 1 is not supported; rather, we find the strongly significant opposite results: despite the technological and economic merits, converging technologies are less likely to be transferred than non-converging technologies. We can surmise, through literature, that the high commercial risk of converging technology [27] and transaction costs derived from cognitive distance between disciplines [28] can surpass the merits of converging technologies. In addition to costs to assimilate converging technologies, the internal change in organisational strategy required to utilise converging technologies effectually [11] can work as a burden for firms, leading firms to be reluctant to obtain converging technologies from public research organisations. In addition, Hypothesis 2 is supported by the results and thus shows significant role of technology life cycle in technology transfer, Hypothesis 3 is supported as well.

The scale of project budget turns out to contribute to technology transfer positively, the strength of patent, i.e. the number of inventors and claims do not. The results show no significant effects of scope and human resource, which contrast with the significant effects in technology transfer between firms [29]–[30].

TABLE III
DEFINITION OF DEPENDENT AND INDEPENDENT VARIABLES

	Coefficient	Standard deviation.
Convergence	-0.165***	0.028
Tech_ready_lvl	0.271***	0.018
Tech_life_cycle	-0.104***	0.020
Project_budget	0.089***	0.009
Inventor	-0.001	0.005
Claim	0.002	0.002
AppYear dummies	Yes	
TechClass dummies	Yes	
_cons	-3.040***	0.087
LR chi2(4)	1454.25	
Prob > chi2	0	

* p < .1, ** p < .05, *** p < .01,
Note: In each p significance level, (1-p) × 100 percent posterior probability interval excludes zero.

V. DISCUSSION AND CONCLUSION

A. Discussion and Policy Implications

In this study, we empirically demonstrate the factors contributing to technology transfer from public organisations to industry on technology level. In sum, technology from the public sector is likely to be transferred when its readiness level is closer to generation of profit, when its stage of life cycle is early. Using the advantage of the analytic level and the novel means of measuring technology convergence, we examine the characteristics of converging technologies as compared to non-converging technologies in technology transfer. Our findings suggest that converging technologies are less likely to be transferred

On the basis of the results, our study offers the following managerial and policy implications. First, complementary support differentiated by technological potion (e.g. technology life cycle and technology readiness level) may help expedite technology transfer from public sector. While government establish diverse R&D tracks for industrial needs and fundamental function of public research organisations, technologies on some of tracks would suffer from difficulties in transfer relatively more, because of their technological potion, e.g. technology from fundamental studies; thus, to increase the efficiency of technology transfer, governing organisations as well as TTO would better provide an effectual means of complementing the transfer of such technologies. Moreover, the technological potion varies by time and environment; thus continuous monitoring of technology evolution and development at organisational level should be performed as well.

Secondly, policy design and actions for invigorating transfer of converging technologies are required. Despite the rosy prospect regarding converging technologies (e.g. their economic and technological impact) as in high technology, converging technologies in public sector undergo the difficulties at the commercialisation stage. Therefore, to achieve the potential impact of converging technologies and to benefit from them, policymakers should try to alleviate the factors suppressing transfer of converging technologies (e.g. cognitive distance and risk of converging technologies) and enact an anticipative regulation for multilateral use of the technologies. In particular, policymakers should understand the distinct pattern of demand for converging technologies in technology transfer as shown in this study and design convergence R&D programs based on such understanding for effective R&D investment.

B. Limitations and Further Research

Our study has certain limitations; based those limitations suggests following directions for future research. We primarily employ Out-the-Door criterion [1] as transfer, judging that it equates with success; however, this view does not indicate actual impact of technology transfer. Especially in case of converging technologies, their impact after transfer must be of major concern of policymakers and managers. Using other criteria, further research may be able to reveal the impact of converging technologies after transfer, more meticulously illustrating the nature of converging technologies in technology transfer. In addition, the nature of public-to-private technology transfer can differ from that private-to-private technology transfer. In latter case, rent dissipation effect [29] can lead firms to behave differently from their behaviour in the market for patent of public sector. Comparative study about two demands may enable us to depict the strategies of firms more thoroughly. In sum, a more systemic analysis of the aforementioned issues including organisations characteristics of TTO may provide a rich understanding on what governs technology transaction between firms and public sectors.

REFERENCES

[1] B. Bozeman, Technology transfer and public policy: a review of research and theory. Research Policy, vol. 29, pp. 627–655, 2000.
[2] J. G. Thursby, R. Jensen, and M. C. Thursby. “Objectives, characteristics and outcomes of university licensing: A survey of major U.S. universities,” *Journal of Technology Transfer*, vol. 26, pp. 59–97, 2001.
[3] D. Chatterji. “Accessing external sources of technology,” *Research-Technology Management*, pp. 48–56, 1996.
[4] A. Caldera, and O. Debande. “Performance of Spanish universities in technology transfer: An empirical analysis,” *Research Policy*, vol. 39, pp. 1160–1173, 2010.
[5] G. Jones, and A. Lanctot. “Determinants and performance impacts of external technology acquisition,” *Journal of Business Venturing*, vol. 9026, 255–283, 2001.
[6] S. Arvanitis, U. Kubli, and M. Woerter. “University-industry knowledge and technology transfer in Switzerland: What university scientists think about co-operation with private enterprises,” *Research Policy*, vol. 37, pp. 1865–1883, 2008.

[7] J. G Thursby, and S. Kemp. "Growth and productive efficiency of university intellectual property," *Research Policy* vol. 31, pp. 109–124.
[8] M. Woerter. "Technology proximity between firms and universities and technology transfer," *Journal of Technology Transfer*, doi:10.1007/s10961-011-9207-x, 2011.
[9] C. S. Curran, S. Bröring, and J. Leker. "Anticipating converging industries using publicly available data," *Technological Forecasting & Social Change*, vol. 77, pp. 385–395, 2010.
[10] F. Kodama, 1995. *Emerging Patterns of Innovation: Sources of Japan's Technological Edge*. Boston: Harvard Business School Press.
[11] F. Hacklin. *Management of Convergence in Innovation: Strategies and Capabilities for Value Creation beyond Blurring Industry Boundaries*, Heidelberg: Physica-Verlag, 2008.
[12] D. T. Lei. "Industry evolution and competence development: The imperative of technological convergence," *International Journal of Technology Management*, vol. 19, pp. 699–738, 2000.
[13] G. Azzone, and P. Maccarrone. "The emerging role of lean infrastructures in technology transfer: The case of the Innovation Plaza project," *Technovation*, vol. 17, pp. 391–402, 1997.
[14] S. Jeong, S. Lee, and Y. Kim. "Licensing versus selling in transactions for exploiting patented technological knowledge assets in the markets for technology," *Journal of Technology Transfer*, doi:10.1007/s10961-012-9252-0, 2012.
[15] C. S. Galbraith, and G.B. Merrill. "The effect of compensation program and structure on SBU competitive strategy: A study of technology intensive firms," *Strategic Management Journal*, vol. 12, pp. 353–370, 1991.
[16] A. Arora. "Contracting for tacit knowledge: The provision of technical service in technology licensing contracts," *Journal of Development Economics*, vol. 50, pp. 233–256, 1996.
[17] M. Nieto. "Performance analysis of technology using the S curve model: The case of digital signal processing (DSP) technologies," *Technovation* vol. 18, pp. 439–457, 1998.
[18] J. D. Roessner, and A. Wise. "Public-policy and emerging sources of technology and technical-information available to industry," *Policy Studies Journal*, vol. 22, pp. 349–358, 1994.
[19] F. J. van Rijnsoever, and L. K. Hessels. "Factors associated with disciplinary and interdisciplinary research collaboration," *Research Policy*, vol. 40, pp. 463–472, 2010.
[20] A. L. Porter, A. S. Cohen, D. Roessner, and M. Perreault. "Measuring researcher interdisciplinarity," *Scientometrics*, vol. 72, pp. 117–147, 2007.
[21] M. C. Roco, and W. S. Bainbridge. *Converging Technologies for Improving Human Performance*. Arlington: National Science Foundation, 2002.
[22] A. Nordmann. *Converging Technologies–Chaping the Future of European Societies*. Luxembourg: Office for Official Publications of the European Communities (EUR 21357), 2004.
[23] OECD. *Frascati Manual*. Paris: OECD, 2002.
[24] S. Jeong, Choi, J. Y., and Kim, J. "The determinants of research collaboration modes: Exploring the effects of research and researcher characteristics on co-authorship," *Scientometrics*. doi:10.1007/s11192-011-0474-y, 2011.
[25] P. A. Roussel, K. N. Saad, and T. J. Erickson, *Third Generation R&D*, New York: McGraw-Hill, 1991.
[26] R. Bekkers, and I. M. Bodas Freitas. "Analysing knowledge transfer channels between universities and industry: To what degree do sectors also matter?" *Research Policy*, vol. 37, pp. 1837–1853, 2008.
[27] G. Tegart, "Converging technologies and their implications for technology transfer: The cases of European networks (N EuroNet) and NBIC(nano-bio-info-cogno) technologies as drivers of change," *Innovation: Management, Policy & Practice*, vol. 7, pp. 468–476, 2005.
[28] P. Llerena, and F. Meyer-Krahmer. Interdisciplinary research and the organization of the university: General challenges and a case study, In *Science and Innovation: Rethinking the Rationales for Funding and Governance*, ed. A. Geuna, J. A. Salter, and W. Steinmueller. Cheltenham: Edward Elgar, 2003.
[29] A. Gambardella, P. Giuri, and A. Luzzi. "The market for patents in Europe," *Research Policy*, vol. 36, pp. 1163–1183, 2007.
[30] N. Palomeras, "An analysis of pure-revenue technology licensing," *Journal of Economics & Management Strategy*, vol. 16, pp. 971–994, 2007.