Technovation 30 (2010) 376–385

Contents lists available at ScienceDirect

Technovation

journal homepage: www.elsevier.com/locate/technovation

An analysis of the effect of software intellectual property rights on the performance of software firms in South Korea

Dukrok Suh, Junseok Hwang *

Technology Management, Economics and Policy Program, College of Engineering, Seoul National University, 599 Gwanak-ro, Gwanak-gu, Seoul 151-742, Republic of Korea

ARTICLE INFO

Keywords:
Software copyright
Software patent
Firm's performance
Zero-inflated regression

ABSTRACT

This paper explores the effect of software intellectual property rights (IPRs) on the performance of software firms in South Korea using the statistics of software copyright registrations and patent applications along with the financial statements of firms. According to our empirical results, R&D and software R&D input has a strong positive effect on the production of software copyrights and patents, and large firms exploit software IPRs better than small firms. We also found that there are quite different trends in the selection of the legal means of protection; firms in the software industry prefer to copyrighting, whereas firms in the manufacturing industry prefer to patenting. In addition, software copyrighting has a positive effect on software revenue and total revenue of firms, but software patenting fails to show a positive effect on software revenue. Consequently, in contrast to the prevailing consensus indicating a high preference for patenting, it is obvious in our analysis that software copyrighting is more beneficial for software firms.

© 2009 Elsevier Ltd. All rights reserved.

1. Introduction

Over the past two decades, the rapid advance of information and communication technology (ICT) has largely relied on technological innovations in computing, networks, and software, which are essential for the efficient performance of hardware. The software industry plays an important role as an industry itself, including the producer of end-user and business software and the provider of computing services. Moreover, software is generally regarded as an indispensable element to other industries since it serves as an overhead capital required to perform core functionalities for efficient production for households, firms, and government organizations. The dependence on software for business, scientific, educational and entertainment purposes has created a highly competitive software industry and has induced a substantial investment of time and money for the creation of software products and services.

Software products are typical knowledge-intensive outputs, which require strong legal protection means in order to provide a proper and balanced incentive to the original developer of the software. For the complex characteristics of software, several legal means such as trade secrecy, license agreement, copyright, and patent are applied to fulfill this objective (Robert, 1984). Since each of the legal protection means has created and modified with its original purpose of protection, a protection means only covers a certain aspect of software intellectual property. For example, literal expressions of software are similar to those of literary works, thereby qualifying software for copyright protection. Therefore, copyrights protect source codes, binary codes, and supplementary documents from unauthorized access; moreover, software simultaneously possesses innovative and even inventive technical characteristics qualifying it for patent protection as well. As a result, patents also serve to protect the underlying technological ideas or functionalities of software.

One of the key driving factors for a firm's long-term competitiveness and economic growth stems from incessant technological innovations (Porter, 1998). Although not all the firm's innovations and innovative activities can be measured by external indexes such as R&D investment, quality of human resources, published papers and patents, patent statistics is one of the frequently used indexes to evaluate the innovative activities and potential competitiveness of firms (Hall et al., 1986; Cohen and Lemley, 2001; Encaoua et al., 2006; Schankerman and Noel, 2006).

The starting point of our research is the insight that software copyrights might serve as an indicator for a software firm's innovative activity in the same way as software patents do. The relationship between software copyrights and the performance of firms has not been evaluated in literature pertaining to software IPRs thus far. This is mainly due to the scarcity of reliable information on software copyrights in most economies. In Korea, the Computer Program Protection Act was legislated as a derivative law of the Copyright Act of 1987 for software

* Corresponding author. Tel.: +82 2 880 8679; fax: +82 2 880 8389.
E-mail addresses: dukrok@gmail.com (D. Suh), junhwang@snu.ac.kr (J. Hwang).

0166-4972/$ - see front matter © 2009 Elsevier Ltd. All rights reserved.
doi:10.1016/j.technovation.2009.08.005

protection, and it implemented an article that encourages the registration of software with the government agency, the Computer Program Protection Committee. Registering software copyrights provides obvious and effective incentives to the original developer of the software. The developer can establish the creation of software and the relevant rights with this process. In addition, in a legal dispute, it allocates the legal power of opposing third parties who may infringe on the copyright. The registration process is quick and inexpensive, and the legality of the resulting protection is beneficial for the registered software copyright. Moreover, this registration process requires rightly working binary files and then it effectively prevents from registering of false copyright. Because of these incentives, many software developers register their copyright with this system. As a result more than 100,000 software copyright registrations have been accumulated during the past 20 years. This study employed the statistics of software copyright registrations data along with patent application data to evaluate the relationship between software IPRs and the performance of software firms.

In this paper, we extended the patent production function to software copyrights and evaluated the determinants of software IPR production using the zero-inflated Poisson (ZIP) and zero-inflated negative binomial (ZINB) regression methods. We then evaluated the economic impact of software IPRs on the performance of firms and determined the legal method that is more effective in enhancing their performance. In view of our limited knowledge, this is the first study that empirically evaluates the impact of software copyrights.

Our empirical results indicate that software R&D investment and total R&D investment have a strong positive effect on software copyrights and patents. The software sale ratio, however, shows a negative effect on them, which implies that software IPRs are used in a supporting role to other products and services. There is a difference in the effect on software IPRs production between firms in the software industry and manufacturing industry; firms in the software industry show a positive effect on software copyright production and a negative effect on software patent production, whereas firms in the manufacturing industry show the opposite effect. Large firms, such as subsidiaries of conglomerates and stock exchange listed firms, creates more software copyrights and patents. In addition, software copyrighting has a positive effect on the performance of firms both on software revenue and total revenue, whereas software patenting fails to show a positive effect on software revenue. Consequently, in contrast to the prevailing consensus indicating a high preference for patenting, it is obvious, in our analysis, that software copyrighting is more beneficial to software firms.

The paper is organized as follows: in Section 2, we review previous literatures related to software copyrights and patents. Section 3 presents the hypotheses that we wish to test and the methodology that is applied in the paper. We then describe the data employed set out the results of the economic analysis and its interpretations in Section 4. In Section 5, we conclude this paper with remarks on legal protection means and innovative activities of the software.

2. Literature review

In reality, software copyrights and patents do not have a long history. Prior to 1960, there was no conflict in terms of intellectual property with regard to manipulating software, because software was not sold as an independent product without a hardware system. After the US Copyright Office permitted the registration of computer programs as copyrighted works in 1964, software was protected as copyrighted works (Calvin, 1975). Since copyrights provide a shelter only to literal expressions and do not have any protection mechanism for technical aspects such as data structures and algorithms, which are the core features of software, some countries actively investigated *sui generis* legal protection means for computer software. In 1980, the US Congress accepted the recommendation of the National Commission on New Technological Use of Copyrighted Works, and this led to the Computer Software Copyright Act (Bordoloi et al., 1996). Subsequently, software protection under copyright system was generally accepted worldwide. The World Trade Organization's (WTO) Trade Related Intellectual Property Rights (TRIPs) agreement also defined computer software as literary works in Article 10.1, forming a global consensus on computer software as copyrighted objects.

Software patents have a much shorter history, and the patentability of software is still being debated. The US Supreme Court approved software as statutory subject matter first in the *Diamond v. Diehr* case (1981) and continuously broadened its scope thereafter. In 1994, the *In re Alappat* case helped in expanding the scope of software patents to the new algorithms in general purpose computers. In 1998, in the *State St. Bank* & *Trust Co. v. Signature Financial Group* case, it was admitted that internet business method patent is a type of software patent, which does not require hardware dependent implementation (Cohen and Lemley, 2001). As a result of this expansion in the scope of software patents, the share of software patents increased rapidly from 2% in the early 1980s to 15% in 2002 in the United States Patent and Trademark Office (USPTO) (Robert and James, 2004).

However, this trend of pro-software patents is not witnessed in every countries. Except for the US, a conservative approach is still taken on software patents with different levels in the EU and Japan (Park, 2005). The European Patent Office (EPO) officially does not grant patents to software without technical characteristics and inventive steps. It implies that software patent should be granted only to software that is coupled with a hardware system. In July 2005, the European Parliament rejected the Directive on Computer Implemented Inventions for the consolidated software patent reviewing standard among EU countries, and then the patent offices of EU countries still apply strongly restrictive conditions on software patents as before.

Many social studies on software discuss the pros and cons of legal protection means for software and find how to plug the loopholes in these means (Diallo, 2003; Matt and David, 2007). According to Oz's (1998) survey, there is a gap in the understanding of the legal protection means for software IPRs between software engineers and lawyers practicing in this field. Generally, the copyright system is preferred to the patent system as a method for software IPRs protection, but lawyers exhibit a higher preference for the patent system than do software engineers. They also contend that the current patent reviewing system has not been able to keep up with the frontier technology. As a result, many 'trivial' software patents has been granted, which is not technical invention but describes pervasive concepts of the software industry. The worst side effect is a slowdown in technological innovations (Bergstra and Klint, 2007).

Meanwhile, there is little economic research on software IPRs since the software industry is a highly innovative and rapidly growing industry, which does not have sufficient stable statistics for conducting economic analysis. A common problem of economic researches on software patent is the definition of software patents, resulting in incompatible data due to the employment of differing definitions (Bessen and Hunt, 2007). Patent statistics cannot be matched with the corresponding industry since patent information does not have industry classification codes. Moreover, as software is used by all industries and firms, a classification of software patents is more difficult than that of pharmaceutics, electronics, or machinery. Consequently, it is difficult to determine what can be classified as a software patent.

As explained before, the US courts make judicial decisions broadening the patentability of software and narrowing the scope of copyright on software in subsequent lawsuits in the 1990s. Lerner and Zhu (2007) focus on the current transition of the legal protection means for software from the copyright system to the patent system, and analyze the economic data of the patent propensity behaviors of US software firms that are classified as interface firms and non-interface firms after the *Lotus v. Borland* (1995) case that denied the copyrightability of user interface of software. According to the empirical analysis, the patent propensity in interface firms was certainly increased after narrowing the rights of copyright holders. Moreover, a high preference for patenting was closely related to the firms' high performance in view of the increment of R&D investment, revenue, and diversity of products.

Schankerman and Noel (2006) explore the economic efficacy of software patents. They find that R&D investment in the software industry brings about a technological diffusion among the firms in the industry, whereas patents of market competitors reduce R&D investment and patent value. In addition, the concentration of patents with a competitor reduces R&D investment and patenting. Therefore, they do not accept the prevailing opinion that strategic patenting behavior harms innovation in the software industry.

Empirical researches on the economics of software copyrights are extremely limited mainly because of the scarcity of copyright statistics. According to our limited knowledge, Slottje's (2007) study is the only one empirical study on copyright value. They analyze the impact of copyright on the value of the National Football League (NFL) franchises and on the teams' ticket sales when the NFL teams change their logos periodically; this study covers an area that is rather different from our study.

While previous researches on software IPRs mainly employed patent statistics as their empirical data, this study can be clearly differentiated from other studies as it employs copyright data as well as patent data. Since software copyright requires a fully working program and source codes, it could be a good indicator for the diversity of software products and services of firm as well as for a result of their innovative activities. Hence, we examine the possibility of software copyright as a meaningful proxy of innovation activity of software firms in this study. In addition, an analysis of the software IPRs might illustrate the importance of the software IPRs to the performance of firms.

3. Research hypotheses and methodology

3.1. Research hypotheses

Before evaluating the effect of software IPRs on the performance of firms, we first investigate the relationship between R&D investment and software IPRs. Although all R&D activities are not directly connected with formal software IPRs, software patent data have been served as a meaningful indicator for the R&D outputs of firms. Many previous researches have explored that there is a positive link between R&D activities and patenting (Griliches, 1990; Graham and Mowery, 2003). The more patents reflect the economic results of R&D activities, the more meaningful they become as output indicators of these activities.

Hypothesis 1. Large software R&D investment leads to more software IPRs.

Innovative activities and the resulting IPRs are not created in a short period. The incumbent firms that have accumulated R&D resources could show a larger number of IPRs than start-up firms. Although some innovative software start-up firms that have technological competency might succeed in their business, in reality, patents do not work as expected for start-up firms, and incumbent firms efficiently exploit their IPRs to create effective barriers to prevent market entry by start-up firms (Mann and Sager, 2007).

Hypothesis 2. Firms with longer experience show more software IPRs.

Software development is not restricted to the software industry firms. Almost all firms use IT systems in their business and own some software IPRs. In our observed data, half of the firms did not belong to the software industry; moreover, this ratio increases with respect to software patents and copyrights. Robert and James (2004) shows that the software publishing industry accounts for only 5% of software patents, while the manufacturing industry accounts for two-thirds of software patents in the US. However, the effectiveness in producing software IPRs is quite different. In simple terms, a firm whose core business lies in the IT/software industry is expected to outperform firms whose core business lies in other industries in terms of software IPRs.

Hypothesis 3. Firms in the software industry show more copyrights and patents than those in the non-software industries.

Innovative activities are a major source of competitiveness for firms (Griliches, 1990; Porter, 1998). Ernst (2001) also find a strong linkage between patent application and an increment in subsequent sales with 2–3 year time lag. As mentioned in Hypothesis 1, software copyrights and patents are the outputs of software R&D investment, and they also serve as the inputs of final services and products of a software firm and simultaneously induce an increment in the firm's financial output.

Hypothesis 4. More software IPRs lead to high performance of software firms.

Subsidiary firms of conglomerates (or group companies) pay more attention to software IPRs, especially software patents, than start-ups and venture firms. According to Mann and Sager (2007), they show that large firms in the manufacturing and software industry acquire patents for strategic purposes as well as for innovative activities, and exploit their IPRs effectively as a means of creating barriers to entry for market competitors. In this study, we will verify that these characteristics have a positive effect on software IPRs production.

Hypothesis 5. Large firms pay more attention to software patents.

3.2. Methodology

The most popular estimation method for categorical data is the Poisson regression model, which is based on the Poisson distribution. It assumes that the variance of the sample is equal to its mean. Since our observation has high variance, i.e., overdispersion, we cannot adopt this method and the alternative method for obtaining efficient estimation is the negative binomial regression model. In our data, a large share of observed firm does not have any copyright and patent on their software; hence, we employ the zero inflated version of the negative binomial regression method. A zero-inflated distribution is a mixture of two distributions, the delta distribution on zero (the distribution that takes only the value zero; 'perfect state') and a distribution on the non-negative integers (i.e., including the value zero; 'imperfect state'). A sample is in the perfect state with probability p and in the imperfect state with probability $1-p$. If a sample is in the perfect state, it only takes the value zero; if it is in the imperfect state, it follows the distribution on non-negative integers (Minami et al., 2007). The negative binomial distribution used for the imperfect state is given by

$$Pr(Y=y)\begin{cases} p+(1-p)\left(\dfrac{\tau}{\lambda+\tau}\right)^{\tau}, & y=0 \\ (1-p)\dfrac{\Gamma(y+\tau)}{y!\Gamma(y)}\left(\dfrac{\tau}{\lambda+\tau}\right)^{\tau}\left(\dfrac{\lambda}{\lambda+\tau}\right)^{y}, & y=1,2,\ldots \end{cases} \quad (1)$$

where λ and τ are the mean and size parameters, respectively, the mixture distribution is the zero-inflated negative binomial (ZINB). As τ goes to $+\infty$, or equivalently, $1/\tau$ approaches 0, the negative binomial distribution is reduced to the Poisson distribution, and thus the ZINB can be viewed as a flexible extension of the zero-inflated Possion (ZIP) model. The mean and variance of the ZINB are given by

$$E(Y)=(1-p)\lambda$$

and

$$Var(Y)=(1-p)\lambda\left(1+p\lambda+\frac{\lambda}{\tau}\right)$$

The variance of the ZINB distribution is therefore a quadratic function of the ZINB mean, and is in the same form as that of the variance of the negative binomial distribution, $\lambda+(1/T)\lambda^2$. Thus, the variance of the ZINB distribution, ZIP distribution, and the negative binomial distribution can all be expressed as a quadratic function of their respective overall means.

In order to identify possible factors that might contribute to software copyright and patent, we set up an IPRs production function model. This production function model relates the number of software copyright registrations and software patent applications to the firm's age, software R&D investment, software sale ratio, the industry in which the firm is active, and other characteristics.

$$\begin{aligned} E(\mathrm{SWIPR}_i) = \exp(&const+\beta_1\ln(\mathrm{SW}R\&\mathrm{D}_i)+\beta_2 LIST_i+\beta_3\mathrm{GROUP}_i \\ &+\beta_4\mathrm{SOFTWARE}_i+\beta_5\mathrm{MANUFACT}_i+\beta_6\ln(Age_i) \\ &+\beta_7\mathrm{SWSaleRatio}_i) \end{aligned} \quad (2)$$

In this economic specification, the expected number of software IPRs for a firm is conditional on the firm's characteristics. The right-hand side variables capture the effect of R&D investment, intensity of software sales, age, industry dummy, subsidiary dummy and stock exchange listed dummy. This equation can be interpreted as 'software IPR production function', where the right-hand side contains the input factors. Bessen and Hunt (2007) performs a similar economic analysis using a software patent production function. Our study differs from their study in two ways. First, our dependent variables are not only software patent applications but also software copyright registrations. The patent application process requires explicit technological progress and highly formalized documents with a strict review conducted by the patent office, and it takes much time and effort to satisfy these conditions. On the contrary, software copyright registrations can be achieved by submitting source codes, binary files, and supplementary documents, which are outputs of software development process. For this, software copyright might be a more suitable index than software patent for measuring software innovations. In this study, we will test this possibility. Second, Bessen and Hunt (2007) research uses total R&D and capital variables in the firm level as inputs for software patents, whereas our study uses software-related R&D as input variables for software intellectual properties.

4. Empirical analysis

4.1. Data

The data employed in this study are composed of three databases, namely, on copyright registrations, patent applications, and financial statements of software firms in 2004. The Computer Program Protection Committee, a government agency, operates the Software Copyright Registration System in South Korea. Since 1995, software firms, research institutes, universities, and even individual software developers have been registering their copyrights with the system to protect and to declare their rights publicly. Fig. 1 presents the trend of software copyright registration in Korea. During the IT boom in the early 2000s, more than 9000 software copyrights were registered; this number later diminished to around 8000 software copyrights per year.

Patent application statistics were obtained by keyword search method from the Korea Institute of Patent Information. We searched "Software, Program, Internet, Computer, Arithmetic, Login" as keywords for software patent on title, abstract and scope of patent documents in Sep. 2007. These keywords was taken from the result of by McQueen and Olsson (2003).

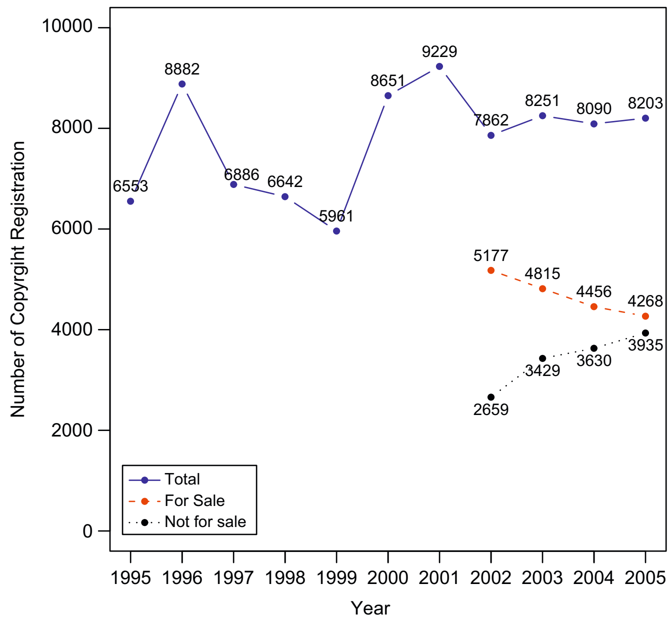
There are two alternatives for the measurement index on patenting results: patent application data and patent grant data. Although both indicators reflect the firm's innovative activities, they are absolutely different measures. A patent application for new inventions is submitted to the patent office, where the specification of the patent is reviewed, and on basis of review, the patent is either granted or rejected. It takes 18–24 months for this step with 15–70% of applications issued as new patents. According to Griliches (1990), patent grant ratios greatly vary with country and time and we also observe a stiff change of grant ratio on software patent in Korea. The main advantages of using patent application data rather than patent grant data are that the data are not directly affected by change in patent office examination policies, and that the date of filing an application is nearer to the time of the invention; this advantage is critical to software developers because the software industry witnesses rapid technological advancements (McQueen and Olsson, 2003).

Fig. 2 illustrates the trend of application, grant, and grant rate of software patents. The number of software patent applications dramatically soared around the mid-1990s and then decreased after the IT boom of the early 2000s. The grant rate of software patents after application reached 60% in the 1990s, and such a high patent grant rate is a common phenomenon in a rapid technology growing area. Subsequently, the rate stabilized at 35%, the same grant rate that other technology areas experience. Recently, approximately 9000 software patents were filed and around one-third of them were granted.

Statistics on software firms were obtained from the software statements system operated by the Korean Software Industry Association and financial statements of audited firms were taken from KIS-VALUE. We compiled these statistics by firm name and industry code and get the final data set with 676 firms. The descriptive statistics of the variables we employed in this research are summarized in Table 1.

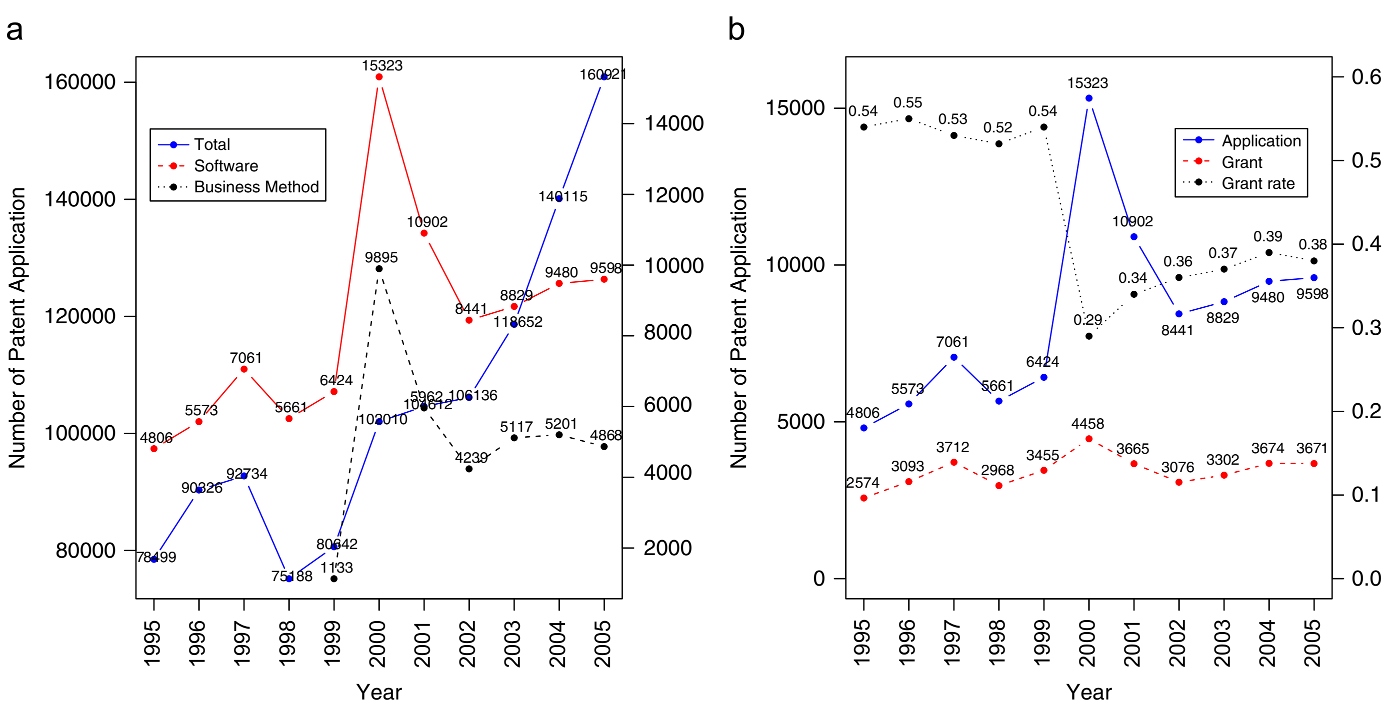
Information on software revenue and software employment was obtained from the software statements system. Since our data lacked of the precise software R&D investment, we proxied this value from total R&D investment to software employee ratio.[1] The software industry field was set to be true if the firm's official

[1] Instead of obtaining software R&D from software employment ratio, software R&D might be calculated from software revenue ratio. This does not change our results significantly; it affects slightly the estimated coefficient and the statistical significance level.



Note: The identification 'for sale' and 'not for sale' software copyright began in 2001, and it is a characteristic of software assigned by the copyright owner. As shown in the figure, the ratio of 'for sale' software decreased after the introduction of classification. We assume that this trend comes from the fact that the software used for firm providing service, not for firms producing products, is classified as 'not for sale' software and it accounts for a large share of software copyright registrations.

Fig. 1. Trend of software copyright.



Note: The classification of business method patents was officially started by Korean Intellectual Property Office (KIPO) in 1999.

Fig. 2. Trend of application of patent total, software patent and business method patent. (a) Patent application statistics, (b) patent grant stasticts.

standard industry code corresponded to the information process and computer operation industry (M72 in Korea Standard Industry Code, KSIC) and the manufacturing industry dummy was set to be true if the firm's industry code is in the manufacturing industry (starting with letter 'D' in KSIC).

First, we examined the software IPRs activities of the firms ($N=676$). The average number of patent applications in 2004 was 2.49, the maximum value of applications was 1088 and the total number of applicants was 1684. These applications accounted for 17.8% of the software patent applications in that year. Firms that

Table 1
Descriptive statistics of variables.

Variable	Mean	Std. dev.	Min	Max
Number of copyrights	0.86	5.25	0	102
Number of patents	2.49	43.03	0	1088
Revenue (million KRW)	264,441.92	2,542,364.4	20.41	57,632,360
R&D investment (million KRW)	5019.90	103,876.38	0	2,687,418
Software revenue (million KRW)	12,480.84	82,454.85	0	1,771,411
Software R&D investment (million KRW)	383.97	3277.71	0	81,738.74
Number of employee	511.32	3257.71	2	60,167
Number of employee in software	91.89	337.57	0	7031
Software employee ratio	0.53	0.40	0	1
Software sale ratio	0.29	0.38	0	1
LIST	0.28	0.45	0	1
GROUP	0.08	0.28	0	1
Software industry	0.4	0.49	0	1
Manufacturing industry	0.35	0.48	0	1
Age	12.96	9.43	1	59

did not apply for patents numbered to 572 (84.6%). The average number of software copyright registrations in 2004 was 0.86, the maximum value of the registrations was 102, and the total number of applicants was 582. These applications accounted for 7.2% of total software copyright registrations. The main reason, we thought, for the low percentage that our observation firms accounted for was the low barrier on software copyright registration. There is only a low filing cost for the registration and the maintenance of software copyright stimulating independent developers, research institutes and small software houses, and those copyrights holders are not included in our data set. Next, we examined the general characteristics of the observed firms. The average business age of the firms was 13.0 years, and 317 firms (46.9%) were relatively young firms whose age was less than 10 years. On the basis of these facts, we expect the software market to have low entrance barriers and a high portion of start-up firms. Furthermore, as our data consisted of the audited firms that are relatively large software developing firms, the actual business age in the software is expected to be much less than 13.0 years.

Thirty-two firms (5.8%) are listed on the Korea Exchange (KRX), which is the main stock exchange of South Korea, and 151 firms (22.3%) are listed on Korean Securities Dealers Automated Quotations (KOSDAQ), which is a specialized stock exchange for small or IT venture firms. In our observation, 268 firms (39.6%) specialize in software development and service; 234 firms (34.6%) run their business in the manufacturing industry; 174 firms in other industries. The core business area of our data categorized by KSIC and their proportion of copyright registrations and patent applications of software are listed in Table 2.

4.2. Empirical results

Since many of the observed firms have no software patent applications or software copyright registrations, we adopted and compared the zero inflated version of Poisson and negative binomial regression model to estimate the coefficients of the independent variables that we were interested in.

Table 3 presents the estimated results of the ZIP and ZINB on software copyright production. Vuong test statistics[2] of ZIP with standard Poisson and ZINB with standard negative binomial are statistically significant in all models; thus, we prefer the zero inflated model to standard model. Moreover, LR test statistics rejects null hypothesis on alpha in negative binomial model, and the ZINB model is preferred to the ZIP model. Thus, Model 4 with the lowest AIC and BIC scores is preferred to other models Among the four models. Our discussion in this section is mainly based on the results of Model 4.

R&D (Models 1 and 3) and software R&D investment (Models 2 and 4) show a positive effect on software copyrights at the 1% significance level in ZIP and at the 5% significance level in ZINB. According to the estimates, we expect that an approximately 10% increment in R&D investment may produce an additional software copyright. Since a software copyright implies that the firm holds a specific software product or service, this level of the effect is clearly productive. In addition, we confirmed that relatively large firms are more effective at exploiting software copyrights than the small and independent software firms from the positive estimates of stock exchange listed and subsidiary dummy variables.[3] The software industry dummy variable, i.e., a firm belonging to the software industry, indicates a positive effect on software copyright production, which implies that firms in the software industry exhibit a higher propensity for software copyright production than firms belonging to other industries. This result is very familiar to us, since firms in the software industry generally pay more attention to software copyrights to provide their products or services to the customer. Contrary to this result, the dummy variable on firms in the manufacturing industry depicts a statistically significant negative sign on the production of software copyright in all models. From this aspect, we infer that manufacturing firms are generally not concerned with on software copyright. We will discuss the reason for different preferences depending on the industry in Section 4.3.

The coefficients of software sale ratio are significant and negative in all models; hence, we conclude that the firms whose main business involves software do not have better copyright production than non-software-centric firms. This suggests that software copyrights are used in a supporting role to other products and services rather than for software product itself. Business age has a positive estimate without statistically significant level, which indicates that there is no difference in software copyright production among older firms and young firms.

[2] Vuong statistics is a type of loglikelihood ratio test to choose a better model among non-nested models. See Vuong (1989).

[3] Since a firm's size is formally determined by the number of employee it holds, we also test our hypothesis by considering a size variable, the results of which are not different from the results of this study. Moreover, two dummy variables, stock exchange listed and subsidiary, are highly correlated with size variable.

Table 2
Distribution of software firms in standard industry and their IPR activities.

Industry	Firm		Patent		Copyright	
	Number	Ratio (%)	Number	Ratio (%)	Number	Ratio (%)
Mining	2	0.3	0	0.0	0	0.0
Manufacturing	234	34.6	1241	73.7	109	18.7
Construction	41	6.1	0	0.0	1	0.2
Wholesale and retail	49	7.3	10	0.6	44	7.6
Transportation	4	0.6	2	0.1	0	0.0
Communication	14	2.1	339	20.1	61	10.5
Public administration and defense	4	0.6	0	0.0	0	0.0
Business service	309	45.8	88	5.2	363	62.4
Software[a]	*268*	*39.6*	*75*	*4.5*	*355*	*61.0*
Educational service	5	0.7	1	0.1	4	0.7
Entertainment, culture and athlete service	6	0.9	3	0.2	0	0.0
Personal service	8	1.2	0	0.0	0	0.0
Total	676	100	1684	100	582	100

[a] The software industry is a sub-industry of the business service industry in KSIC.

Table 3
Estimation results of software copyright production using the ZIP/ZINB.

Independent variables	ZIP				ZINB			
	Model 1		Model 2		Model 3		Model 4	
log(R&D Exp.)	0.128**	(0.015)			0.109*	(0.047)		
log(SW R&D Exp.)			0.156**	(0.016)			0.118*	(0.051)
LIST	0.419**	(0.107)	0.428**	(0.104)	0.117	(0.351)	0.124	(0.356)
GROUP	0.932**	(0.141)	0.945**	(0.137)	0.768	(0.501)	0.949†	(0.496)
SOFTWARE	0.636**	(0.144)	0.683**	(0.146)	0.446	(0.433)	0.397	(0.440)
MANUFACT	−0.354*	(0.148)	−0.206	(0.145)	−1.130†	(0.589)	−1.088†	(0.595)
SW sale ratio	−1.098**	(0.147)	−1.250**	(0.150)	−0.931*	(0.445)	−0.935*	(0.447)
log(Age)	−0.054	(0.080)	0.087	(0.081)	0.357	(0.260)	0.377	(0.270)
Intercept	0.630**	(0.235)	0.256	(0.245)	−0.770	(0.778)	−0.796	(0.796)
log(alpha)					1.313**	(0.232)	1.329**	(0.244)
log likelihood	−856.353		−846.516		−568.323		−567.494	
Vuong	3.63		3.78		2.56		2.52	
AIC	1744.706		1725.032		1170.645		1168.989	
BIC	1816.965		1797.291		1247.42		1245.764	

**, *, and † show the level of significance at 1%, 5%, and 10%, respectively.

Table 4 presents the estimated results of the ZIP and ZINB on software patent production. Vuong test statistics indicates that zero inflated model prefer to standard model, and the rejection of LR test statistics on null of alpha implies that the ZINB model is preferred to the ZIP model.

Estimated results of total R&D investment in Models 1 and 3 and software R&D investment in Models 2 and 4 are in accordance with previous software patent literature, and indicates that software patents have a strong positive relationship with software R&D inputs.

In software patent analysis, as with software copyright, we obtain positive coefficients on the stock exchange listed firms and subsidiary firms. Industry dummy variables, however, show the opposite sign to those of software copyright, i.e., negative for the software industry and positive for the manufacturing industry. We believe that these results were obtained mainly from global-level IT manufacturers in South Korea, such as Samsung Electronics and LG Electronics classified as the manufacturing industry, have a number of outstanding patent applications in our observations. From this result, we found evidence that firms in the software industry consider software patents as relatively unimportant or ineffective to protect their technology. To sum up, even though software copyright and software patent are used to protect software firms' innovative activities, we found that the industry characteristics provide completely different status to these two IPR mechanisms, and manufacturing firms prefer patent and software firms prefer copyright.

Table 5 presents the ordinary least squares (OLS) estimation results of the relationship between a firm's financial output (software revenue and total revenue) and its inputs (software patents and copyrights, software R&D, and software workers and firm's characteristics).

Two output measures (total revenue and software revenue) and two different types of R&D investment variables (total R&D and software R&D) are employed in these estimations. We are especially interested in how software IPRs affect financial outputs, which is not stable and strongly depends on what is chosen for the firm's output variable. With software revenue that is expected to be affected largely by both software patent applications and copyright registrations, the estimated coefficient of copyrights are positive at the 10% level in both Models 1 and 2, and those of software patents are negative at the 5% level in Model 2 and insignificant in Model 1. Therefore, we can interpret that software copyrights have a certain positive influence on the firm's software revenue, whereas

Table 4
Estimation results of software patent production using the ZIP/ZINB.

Independent variables	ZIP				ZINB			
	Model 1		Model 2		Model 3		Model 4	
log(R&D)	0.646**	(0.017)			0.195**	(0.038)		
log(SW R&D)			0.532**	(0.016)			0.210**	(0.048)
LIST	0.487**	(0.112)	1.612**	(0.103)	0.706*	(0.325)	0.587†	(0.334)
GROUP	0.745**	(0.126)	1.821**	(0.117)	2.932**	(0.496)	2.995**	(0.525)
SOFTWARE	−0.829**	(0.168)	−1.022**	(0.164)	0.142	(0.440)	−0.004	(0.452)
MANUFACT	0.013**	(0.072)	0.139	(0.092)	0.572	(0.398)	0.501	(0.412)
SW sale ratio	−0.026	(0.052)	−0.040	(0.073)	0.022	(0.153)	−0.013	(0.152)
log(Age)	−0.538**	(0.078)	0.399**	(0.078)	−0.620*	(0.261)	−0.415	(0.267)
Intercept	−2.038**	(0.170)	−4.176**	(0.200)	−0.918	(0.738)	−1.128	(0.747)
log(alpha)					1.932**	(0.147)	1.981**	(0.145)
log likelihood	−860.191		−944.853		−442.956		−445.686	
Vuong	2.29		2.46		6.31		6.73	
AIC	1752.381		1921.707		915.912		921.372	
BIC	1824.64		1993.966		983.654		989.144	

**, *, and † show the level of significance at 1%, 5%, and 10%, respectively.

Table 5
Estimation results of the effect of software IPRs on the firm's outputs.

Independent variables	Dependent variable							
	SW revenue				Revenue			
	Model 1		Model 2		Model 3		Model 4	
log(Copyright)	0.464†	(0.282)	0.476†	(0.259)	0.065	(0.070)	0.042	(0.101)
log(Patent)	−0.279	(0.307)	−0.691*	(0.280)	0.125	(0.077)	0.481**	(0.109)
log(R&D)	0.110*	(0.045)			0.005	(0.011)		
log(Employee)	0.213†	(0.124)			0.849**	(0.031)		
log(SW R&D)			0.081	(0.050)			−0.004	(0.019)
log(SW employee)			1.082**	(0.106)			0.259**	(0.041)
LIST	0.323	(0.310)	0.073	(0.284)	0.408**	(0.077)	0.635**	(0.110)
GROUP	1.588**	(0.546)	0.852†	(0.479)	0.587**	(0.136)	1.730**	(0.186)
SOFTWARE	3.225**	(0.356)	2.033**	(0.340)	−0.537**	(0.089)	−1.076**	(0.132)
MANUFACT	−0.413	(0.351)	−0.279	(0.322)	−0.069	(0.088)	−0.188	(0.125)
log(Age)	−0.319	(0.204)	−0.182	(0.184)	0.199**	(0.051)	0.494**	(0.072)
Intercept	3.631**	(0.717)	1.392*	(0.588)	5.603**	(0.179)	8.034**	(0.228)
Adjust−R^2	0.241		0.357		0.728		0.442	

**, *, and † show the level of significance at 1%, 5%, and 10%, respectively.

software patents have a weakly negative impact on it. With regard to total revenue, the sign of the estimates on patenting is changed to positive at the 1% level in Model 4. Thus, we believe that software patents are not directly used for firms' software products or services, and they would rather contribute to the firms' revenue in an indirect manner such as an embedded part of other products or an overhead facility of services. In brief, based on our analysis, we can suppose that software copyrighting is more beneficial than patenting to firms.

R&D investment has a statistically significant positive effect on software revenue, and software R&D also has a positive coefficient but lacks a significant level, which is in accordance with many previous studies and our intrinsic view on the relation between revenue and R&D.

On the number of employees and software employees' variable, stock exchange listed and subsidiary dummy, these variables are highly correlated to the size characteristics of the firm. Hence, all estimates related to these variables are positive on software revenue and total revenue, which are very straight results since these firms are generally considered to exhibit large outputs in financial measures.

Finally, as with our previous software IPR production analysis, we found evidence worth mentioning on industry dummies. The estimated coefficient of the software industry dummy is positively related to software revenue, but is negatively related to total revenue at the 1% level. Software firms gain their main revenue from the software business but their total revenue is smaller than firms belonging to other industries, which reflects the fact that in our observation, many firms in the software industry are start-ups or small venture firms.

4.3. Discussion

In this study, we employed various techniques to analyze the economic roles of software IPRs. With regard to the relationship between R&D and software IPRs, we confirmed that similar to software patents, software copyrights are also positively related with R&D input. The estimates of the ZIP and ZINB regression indicate that total R&D and software R&D have positive effects on the production of software copyrights and patents at the 1% significant level, with an exception of the ZINB regression on copyrights with the 5% level. Many previous literatures have acknowledged the positive relationship between (software) patents and R&D; we have added to it the evidence of the positive linkage between software copyrights and R&D. In addition, two dummy variables—subsidiaries of conglomerates and stock exchange listed status—have positive impacts on the production of software copyrights and patents. Thus, we infer that large firms are better at exploiting the means of software protection. Large firms recognize the importance of IPRs, value it highly, and reap the advantages from its production and management (Audretsch and Acs, 1991; Rogers, 2004). These facts induce the high propensity of IPRs coming from large firms relative to small firms. We confirm that these facts can be applied to software IPRs in the same manner as they apply to other IPRs.

Copyrighting of software has a positive effect on the performance of firms, both in terms of software revenue and total revenue; however patenting of software fails to show a positive effect on software revenue. As discussed in empirical results, a software copyright is generated from a software product or service, which is directly linked to software revenue and total revenue of the firm. However, unlike pharmaceutical patent, software patents do not map to a software product or service. Most innovative software products comprise several software patents, which render the effect of a specific patent small and vague.

We also found that firms in the software industry and manufacturing industries exhibit quite different tendencies on software copyright and patent. Firms belonging to the software industry prefer software copyright to patent and the manufacturing industry firms exhibit contrasting behavior. There could be several reasons for this difference. First, three-fourth of our observations belong to two industries, software and manufacturing, and these industries also occupied a large portion of software copyrights and patents. However, the characteristics of the industries are quite different. The proportion of stock exchange listed firms or subsidiary firms in the manufacturing industry is higher than those of the software industry. According to Mann and Sager (2007), large firms generally exploit their patents better than small firms or start-ups, and the difference in industry characteristics might result in dissimilar preferences on software IPRs. Second, since obtaining a patent requires redundant time and costs not only while the patent is granted from the patent office but also during the initial application process, small firms cannot bear the burden of such processes and the time involved. This makes firms in the software industry show a high preference for copyright over patent. Third, in view of the short software product life cycle, software patents may be depreciated in products or businesses during the time of the patent examination process. Hence, the software industry firms mainly rely on copyright as a protection means and consider it to be effective. In contrast, manufacturing firms utilize software as a part of their product and rarely use software as a final product. Since they can conceal their 'core software technology' within the products, manufacturing firms do not feel a pressing need for a registering their software copyrights.

On the effectiveness of software copyright and patent from an innovation perspective, we confirmed that software IPRs have a strong linkage with R&D resources (human and financial resources) and firms' characteristics. Firms in the software industry have accumulated a large amount of copyrighted software that embedded in their core technology as a result of innovation activities. Although copyright has clear limitations in the protecting of ideas or technologies such as algorithms, data structures, or even user interfaces, in our analysis, firms belonging to the software industry are leaning on copyright rather on patent since patenting process requires too much time and costs. In the worst scenario, after the grant of patent, software technology might be out of fashion due to the fast technology product cycle. In brief, the light process of the software copyright registering system with additional incentives compared with the conventional copyright system in other countries, makes copyright more valid to software firms as a protection means, and at the least the software industry firms consider it as a highly effect means. For software patent, accordance with prior studies on patent, our results indicate that software patents are exploited better by large firm than by small firms, and they contribute to the firm's output in an indirect manner. Accordingly, we consider that software patenting should not be in the spotlight to firms in the software industry, especially small and start-up firms, and it is not an easy task for them to make directly link with patent to their financial performance or business strategy in the current scenario.

Finally, we mention software copyright as an innovative index. Essentially, copyrights and patents allocate the incentive of the innovation to the creator in order to spur 'innovations' in economics and industries. This motivation applies to software copyrights and patents as well. We recognized that the major trend in terms of software protection has been shifted from copyrights to patents, and most empirical studies on software IPRs and innovations are now focused on 'software patents'. However, some studies already examined the possibility of software copyright as a measure of software innovation (Tang, 1997; Grecsek, 1988). In this paper, we have consistently emphasized the economic effects on software copyrights relative to those of software patents. We found that similar to software patents, software copyrights are positively related with R&D, that software firms in the software industry pay more attention to software copyrights than to software patents, and that software copyrights are linked to software revenue unlike software patent. Thus, software copyrights share many of characteristics of patents and is a good indicator of firm's innovation. Moreover, through careful analysis, we conclude that software copyrights is legally more effective in protecting software intellectual property, which slightly differs from the prevailing consensus that patenting is more effective than copyrighting and from the perception that the software industry now prefers patents (Bessen and Hunt, 2007; Lerner and Zhu, 2007).

5. Conclusions

The legal protection means for software protection are patent, copyright, license, and trade secrecy. These means have developed their unique object of protection, scope, time, and characteristics. They serve the purpose of protecting to a certain level. Software, however, is an industrial product with a technical aspect, a cultural product similar to literary works, and an innovative product with an inventive step. A cumulative, sequential, and gradual technical advancement of the software industry leads to improper results for software protection under the current legal protection means.

In this study, we explored the relationship between software IPR activity and firms' performance by using the ZIP and ZINB regression models fitted to the statistics on copyright registrations, patent applications, and financial statements. A firm's software R&D investment has a positive effect on software copyrights and patents. Moreover, it was evident that preferences for legal protection means differ according to the industry where the firm is involved. Firms in the software industry show a strong positive effect on software copyright and a negative effect on software patent, whereas firms in the manufacturing industry show a higher propensity for patent compared with firms in the software industry. Large firms, such as subsidiary firms of conglomerates and stock exchange listed firms have a positive effect on both software IPRs.

In addition, software copyrighting is positively linked with both total revenue and software revenue, whereas software patenting is effective only for total revenue. Thus, we can conclude that software copyright is directly linked to software products or services of software firms, and software patent contributes to firms' revenue in an indirect manner such as by being part of non-software products.

Our results have important implications for the industry and legal policy. In order to encourage software innovations, policy makers should build different software policies for different industries. Firms in the software and manufacturing industries show quite different attitudes to software copyright and patent. This reflects the industry's characteristic features. The economic effects of software copyright and patent are also different. Moreover, it should be considered as a remedy of the copyright system for software to enhance software innovations. As discussed in Mann (2005), the existing copyright system is not well utilized, since it does not provide any explicit incentive to the software developer. Thus, providing more economic and legal incentives to the original developer for registering software copyrights such as the Korean software registering system, strengthens copyright protection and compensates for the current means of legal protection, which contributes better to software innovations.

Since we have analyzed a cross sectional data, further studies should be attempted to expand the panel data, which will provide more reliable results and facilitate the observation of the change in the effect of software IPRs over a period of time. In order to gain a better understanding of the economic effect of software IPRs, it would be useful to adopt a productivity index by DEA or SFA methodologies instead of a primitive output measure such as a revenue or a profit.

Acknowledgments

The authors highly appreciate anonymous referees to give precious comments, which contributes greatly to improve our paper. This research was supported by the KCC (Korea Communications Commission), Korea, under the CPRC (Communications Policy Research Center) support program supervised by the IITA (Institute for Information Technology Advancement) (IITA-2009-C1091-0901-0003).

References

Audretsch, D.B., Acs, Z.J., 1991. Innovation and size at the firm level. Southern Economic Journal 57 (3), 739–744.
Bergstra, J.A., Klint, P., 2007. About trivial software patents: the isnot case. Science of Computer Programming 64 (3), 264–285.
Bessen, J., Hunt, R.M., 2007. An empirical look at software patents. Journal of Economics & Management Strategy 16 (1), 157–189.
Bordoloi, B., Ilami, P., Mykytyn, P.P., Mykytyn, K., 1996. Copyrighting computer software: the look and feel controversy and beyond. Information & Management 30 (5), 211–221.
Calvin, N.M., 1975. Computer software and copyright. ACM Computing Surveys 7 (1), 45–72.
Cohen, J.E., Lemley, M.A., 2001. Patent scope and innovation in the software industry. California Law Review 89 (1), 1–57.
Diallo, B., 2003. Historical perspectives on ip protection for software in selected countries worldwide. World Patent Information 25 (1), 19–25.
Encaoua, D., Guellec, D., Martinez, C., 2006. Patent systems for encouraging innovation: lessons from economic analysis. Research Policy 35 (9), 1423–1440.
Ernst, H., 2001. Patent applications and subsequent changes of performance: evidence from time-series cross-section analyses on the firm level. Research Policy 30 (1), 143–157.
Graham, S.J., Mowery, D.C., 2003. Intellectual property protection in the U.S. software industry. In: Patents in the Knowledge-Based Economy. National Academies Press, pp. 219–258.
Grecsek, M.T., 1988. Software copyright: innovation, not imitation. Journal of System Management 39 (10), 28–30.
Griliches, Z., 1990. Patent statistics as economic indicators: a survey. Journal of Economic Literature 28 (4), 1661–1707.
Hall, B.H., Griliches, Z., Hausman, J.A., 1986. Patents and R&D: is there a lag? International Economic Review 27 (2), 265–283.
Lerner, J., Zhu, F., 2007. What is the impact of software patent shifts? Evidence from Lotus v. Borland. International Journal of Industrial Organization 25 (3), 511–529.
Mann, R.J., 2005. Do patents facilitate financing in the software industry?. Texas Law Review 83 (4), 961–1030.
Mann, R.J., Sager, T.W., 2007. Patents, venture capital, and software start-ups. Research Policy 36 (2), 193–208.
Matt, E.T., David, E.P., 2007. [Software patents] the good, the bad, and the messy. Communication of the ACM 50 (10), 47–52.
McQueen, D.H., Olsson, H., 2003. Growth of embedded software related patents. Technovation 23 (6), 533–544.
Minami, M., Lennert-Cody, C.E., Gao, W., Roman-Verdesoto, M., 2007. Modeling shark bycatch: the zero-inflated negative binomial regression model with smoothing. Fisheries Research 84 (2), 210–221.
Oz, E., 1998. Acceptable protection of software intellectual property: a ;survey of software developers and lawyers. Information & Management 34 (3), 161–173.
Park, J., 2005. Has patentable subject matter been expanded? A comparative study on software patent practices in the European patent office, the United States patent and trademark office and the Japanese patent office. International Journal of Law and Information Technology 13 (3), 336–377.
Porter, M.E., 1998. The Competitive Advantage of Nations. Free Press, New York.
Robert, H., James, B., 2004. The software patent experiment. Business Review (Q3), 22–32.
Robert, L.G., 1984. The legal protection of computer software. Communications of the ACM 27 (5), 422–426.
Rogers, M., 2004. Networks, firm size and innovation. Small Business Economics 22 (2), 141–153.
Schankerman, M.A., Noel, M.D., 2006. Strategic patenting and software innovation. SSRN.
Slottje, D.J., Millimet, D.L., Buchanan, M.J., 2007. Econometric analysis of copyrights. Journal of Econometrics 139 (2), 303–317.
Tang, P., 1997. The use of copyright as a measure of innovation: software applications in the digital age. Intellectual Property Quarterly, 71–91.
Vuong, Q.H., 1989. Likelihood ratio tests for model selection and non-nested hypotheses. Econometrica 57 (2), 307–333.

Dukrok Suh received a master degree in Computer Science from Yonsei University, South Korea. After that he worked as a software engineer in Korea Telecom Hitel (Internet Portal and Content Provider) for 5 years. He then joined Technology Management, Economics and Policy Program of Seoul National University and he recently received his Ph.D. degree in Economics from that program. His research is mainly focusing on innovation in software and productivity of software industry. His interests also cover open source software and privacy.

Junseok Hwang is an Associate Professor in Technology Management, Economics and Policy Program of Seoul National University in Korea. Prior to this, he was an Assistant Professor in the School of Information Studies at Syracuse University. He received his Ph.D. in Information Science and Telecommunications from University of Pittsburgh. His research interests include network economics, next generation internet, network convergence theory and social effect of network technologies.