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Engineering graduate students' views on the effective ownership of academic patents

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Abstract For sustainable and effective innovation, who should own an academic patent obtained as a result of funded research? The issue of ownership can influence the motivation of academic researchers. In this paper, we address this issue from the perspective of engineering graduate students who have experience of R&D projects. We aim to investigate engineering graduate students' views on inter-organizations aspects of patent ownership; and patent ownership policies within university. In this paper, we carried out classification tree analyses of preferred ownership categories, using various factors related to 'researchers and the environment for R&D,' 'technology,' 'patenting activities,' 'sponsors,' 'currently existing ownership policy,' and 'compensation policy'. Our findings can help design an effective ownership policy that promotes innovation by incorporating the views of students who will be important asset for future innovation.

Keywords Academic patenting · Ownership issue · Engineering graduate students · Classification tree analysis

JEL Classification C38 · O31

1 Introduction

The main source of new knowledge creation is university education and research. Firms rely on specialized experts in academia to gain a competitive advantage. Meanwhile, academic researchers who are funded by industry can gain valuable insights from practical applications of their research. When these mutual interests align, both parties expect to create valuable research outcome, such as patent.

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Who should own those academic patents obtained as a result of industry funded research? In many countries, the practice of granting ownership of academic patents to firms is widely recognized as an exchange for research funding (Kim 2009). However, some competitive universities claim single ownership at the contract stage. On the other hand, it can be argued that when a firm owns an academic patent, it can commercialize inventions much more effectively. However, the benefits of academic patents tend to be monopolized by the funding firms. Although industry-funded academic research depends on the researchers' accumulated research and knowledge, the intellectual property rights to this kind of background knowledge are not recognized. In addition, when firms possess academic patents, they can suppress potential opportunities for further development of the technology by academic inventors beyond what will benefit the funding firm. Industry's single ownership of academic patents can cause conflicts with researchers in academia (Bercovitz and Feldman 2007; Sohn and Lee 2012); it also reduces researchers' motivation to fully collaborate with industries. This is especially true in the case of graduate students, who will lead innovation in the near future; their experiences of patent ownership will have an important impact on their future R&D activities (Sohn et al. 2013; Ju et al. 2014; Sohn and Ju 2015).

In addition to industry-funded research, issues regarding the IPRs of government-funded research have also been raised. Most countries allow universities to own the IPRs of government-funded research outcomes, following the 1980 Bay Dole Act, which aimed to support the commercialization of research outcomes (Weckowska et al. 2015). However, some believe that such IPRs should be in the public domain instead of belonging to a single university, given that government funding is made possible by taxpayers, and the government's R&D mission is to improve public resources and facilities. This view is actively discussed in terms of information environmentalism (Cunningham 2014) by applying four environmental analytical frameworks—welfare economics, the commons, ecology, and public choice theory—to the information environment.

Who should own patents developed as a result of funded academic research: the industry, university, inventor, or government? This ownership issue needs to be resolved to maintain and promote a sustainable and effective innovation ecosystem.

One way to motivate academic researchers is through "professor's privilege" (or a "teacher's exemption"), which allows university academics (including graduate research assistants) to own, use, and license the intellectual property rights (IPRs) to their research results. However, most EU countries (with the exception of Sweden) have shifted from "professor's privilege" to institutional ownership to accelerate the commercialization of academic research results (Rasmussen et al. 2006; Geuna and Rossi 2011).

In academia, IP ownership policies are generally classified as follows: (1) the resource-provider approach, (2) the maximalist approach, and (3) the supra-maximalist approach (Chew 1992). In the resource-provider approach, the university has the right to own an academic patent when the researcher has used university resources to develop his or her invention. In the maximalist approach, the university owns an invention as long as it has been developed using university resources; or it is related to the researcher/inventor's major area of study and it was developed during the course of the researcher/inventor's employment. The supra-maximalist approach is that the university claims all inventions developed by faculty members regardless of the use of university resources or the course of employment. These IP ownership policies assume that, by owning and managing academic patent rights, the university is enabling its faculty members to concentrate on research and new inventions, and that they in turn trust the university to provide adequate compensation.

The motivation of academic researchers can be affected by the extent to which the rewards for their efforts correspond to what they expect or feel they deserve. In other words, academic patent ownership policies can have an impact on the motivation of academic inventors. In addition, researchers can prefer different university patent ownership models and management policies, depending on factors such as individual research experience, the technological level of a research outcome, related technology markets, and the compensation a sponsor provides. Academic researchers' views on the ownership of academic patent rights and university patent management policies must therefore be examined considering these factors.

Many studies have focused on ownership policies for patents obtained from university research. For example, Sellenthin (2004) studied the impact of university patent rights regimes on incentives for academic patenting; Kenney and Patton (2009) compared university ownership and inventor ownership in relation to technology commercialization and entrepreneurship; and Sterzi (2013) looked at the relationship between the ownership and value (as measured by forward citation) of academic patents. Although many graduate students participate in funded research with faculty members, and those students are also subject to the same academic patent ownership policy to the faculty members, there virtually no studies have examined research students' opinions about ownership issues related to academic patents.

The main purpose of this study is to identify the preferences of engineering graduate students in relation to: (1) inter-organization aspects of academic patent ownership, and (2) IP ownership policies within university. In this paper, we employ two classification tree analyses to identify patterns of ownership preference in these two areas. In order to classify the preferred type of ownership, we use explanatory variables derived from expectancy theory, as well as factors representing the characteristics of "researcher and the environment for R&D," "technology," "patenting activities," "sponsor," "currently existing ownership policy," and "compensation policy." Our findings are expected to promote an eco-innovation environment by reflecting the views of graduate students on the IPRs issue.

This paper consists of the following sections: Sect. 2 develops our hypotheses. Section 3 describes our data and methodology. Section 4 interprets the results of the empirical analysis. Finally, Sect. 5 provides a conclusion and some research limitations.

2 Theoretical background

In this section, we develop hypotheses based on theories and previous studies. First, we use expectancy theory to identify whether the relationship between rewards for research performance and research motivation affects an academic researcher's preference for a patent ownership policy. Second, we identify the role of academic researchers in academic patenting activities and their perception on ownership. Third, we review previous studies on factors that influence technology commercialization for developing hypothesis that academics' preference for academic patent ownership policy can be influenced by whether academics have the capability to facilitate the exploitation of academic research results.

2.1 Expectancy theory

Expectancy theory (Vroom 1964) focuses on motivation, arguing that the "intensity of work effort depends on the perception that an individual's effort will result in successful

performance and subsequently receive a desired reward" (Holdford and Lovelace-Elmore 2001). If the relationship between performance and a desired reward is ambiguous, an individual will not be motivated. In other words, if an individual believes that further efforts will lead to a successful performance, which will be amply rewarded, then he or she will put much more effort into the work to achieve a reward (Holdford and Lovelace-Elmore 2001).

This theory has been used to investigate the factors that influence individual effort, such as a user's efforts to participate in the crowdsourcing marketplace (Sun et al. 2015), managers' efforts to use business intelligence to manage big data effectively (Chang et al. 2015), consumers' efforts to engage in co-creation activities (Roberts et al. 2014), employees' efforts to work harder (Chiang and Jang 2008), and faculty members' efforts to conduct research (Chen et al. 2006).

Our study uses expectancy theory to analyze engineering graduate students' perception that (1) their research efforts will lead to successful performance—for example, by producing valuable academic patents (*expectancy*); (2) this successful research performance will lead to desired rewards, such as the ownership of an academic patent and royalty income (*instrumentality*); and (3) expected rewards that fulfill their own goals (*valence*) will result in the formation of a motivational force. In this study, we focus on the relationship between rewards for research performance (*instrumentality*) and research motivation.

2.2 Rewards for research performance

Rewards help to motivate faculty members and thus have an influence on research productivity, which is measured by the number of published books (including book chapters and cases), cited journal articles, and research grants an individual has produced (Chen et al. 2006). Rewards for research outcomes include tenure, promotion, pay rises, administrative assignments, chaired professorships, and reductions in an individual's teaching load.

During the past several years, many academic research results have been patented. The rewards for patented inventions include the ownership of academic patent rights or pecuniary incentives such as a "university's royalty and equity distribution formula" (Siegel et al. 2003). Initially, academic patents were owned by the academic inventors. "Professor's privilege" (or the "teacher's exemption") allowed academic inventors to own, use, and license academic patents arising from their research results. In 1990, regulations on research funding and employment laws were reformed in many OECD countries to facilitate the exploitation of research outcomes by allowing research institutions to file, own, and license academic patents. University ownership allows academics to concentrate on their research while offering them sufficient pecuniary rewards. This pecuniary incentive, which ranges from 22.8% (at Arizona State University) to 88.8% (at Carnegie Mellon) of licensing royalties, is offered to faculty members (Friedman and Silberman 2003; Link and Siegel 2005). Academic patents can also be owned by sponsoring companies through contracts; company ownership can increase opportunities for technology commercialization. However, such companies can also monopolize academic patents and suppress potential opportunities for further development of the technology.

The issue of academic patent ownership has been studied by many researchers. Kenney and Patton (2009) pointed out that the university ownership model is not optimal for commercializing technology or encouraging entrepreneurship. As alternatives, the inventor ownership model, public domain model, and non-exclusive licensing model have been

suggested. Sterzi (2013) compared university and company ownership of academic patents in relation to patent quality, which was measured by using the number of forward citations. The university ownership model was found to be not always optimal, in cases where "the university does not have superior knowledge and the academic inventor already has a strong reputation and connection with the private sector."

2.3 Academic researchers' perception of academic patenting and its ownership

2.3.1 The views of the faculty members

Faculty members play various roles in universities, being responsible for student education, new knowledge creation through academic research, and the commercialization of their research results—for example, through academic patenting or university spin off foundations (Göktepe-Hulten and Mahagaonkar 2010). Academics can benefit from involving themselves in patenting and licensing their academic research results. The benefits from these activities include career advancement and an increase of earnings (OECD 2003; Baldini et al. 2007), access to industrial knowledge and know-how (Grimaldi and Von Tunzelmann 2002; Baldini et al. 2007), and new experience or opportunity displaying researchers' abilities (Owen-Smith and Powell 2001; Baldini et al. 2007).

Baldini et al. (2007) conducted a survey of 208 professors in Italy to investigate the factors affecting an academic researcher's decision to engage in patenting activities. They asked Italian academics questions about the expected benefit of patenting activities, obstacles to patenting activities, and ways to promote patenting activities. They concluded that academic researchers tended to participate in academic patenting activities to enhance their own prestige or reputation and to stimulate new research. In addition, obstacles to patenting activities could be reduced or overcome through university patent management policies. Göktepe-Hulten and Mahagaonkar (2010) identified the determinants of scientists' patenting activities and compared scientists who collaborated with industry to those who did not. According to their findings, non-collaborating scientists tended to participate in patenting activities or invention disclosure to increase their own scientific reputation. By contrast, scientists collaborating with industry were not influenced by reputational expectations and preferred financial incentives to patenting activities.

Although commercialization activities can generate revenue, not all faculty members want to be involved in these activities. Why do some academic researchers choose not to engage in patenting or licensing activities? The first reason is the lack of support for patent-related activities, such as funding for patent costs and patent management consulting services. The second reason is the low probability of commercial success. Only a small number of patents are commercially licensed. The third reason is the academic's heavy teaching and administrative workload, which leaves little time for patenting activities (Baldini et al. 2007). The fourth is that patenting is a time-consuming and costly activity that uses up valuable research time. The final reason is that faculty members are unable to commercialize their research results because of ownership issues. Unless academics have a special contract, most patents derived from academic research are both supported and owned by government or a company. In addition, academics must disclose and assign their inventions to the University Technology Licensing Office (TLO). However, if they believe that the "TLO is mismanaging the process or generating insufficient income; or the TLO is investing insufficient resources in their invention or is incompetent," they are likely to

circumvent the TLO by establishing a firm or developing a close relationships with one or more firms (Kenney and Patton 2009).

2.3.2 The views of the students

How do students, who belong to academic research groups and have contributed to productive academic research, perceive academic patenting? Through activities such as entrepreneurial competitions, engineering design/product development courses, entrepreneurship courses, and start-up clubs, growing numbers of university students are becoming involved in intellectual property activities (Duval-Couetil et al. 2014). Students preparing to start businesses engage in academic patenting activities, either to protect their own innovative ideas or technologies from early imitation, or to attract venture capital (Walter et al. 2016). Graduate students planning corporate careers seek out research collaborations with industry and regard patenting as "an opportunity for networking, experience, and credentials" (Mendoza 2007). By contrast, graduate students building academic careers do not want to delay publication to preserve "intellectual property secrecy" (Mendoza 2007). Another interesting finding relates to student views of intellectual property rights (IPRs) ownership involving open source software. Some students involved in developing open source software prefer to serve the public interest through common information rather than to protect their research results via intellectual property rights. By sharing their software, open source developers can demonstrate their technical skills to potential employers and thus, "increase their salaries and advance their careers" (Lerner and Tirole 2002; Von Krogh and Spaeth 2007). In addition, they can acquire benefits including "reputation, learning, enjoyment, and peer recognition" (Hippel and Krogh 2003; Von Krogh and Spaeth 2007).

What do students think about the ownership of academic patents? A university student who develops a product or technology based on his or her own innovative idea owns the patent rights to that invention. However, if a student develops an idea with the support of a faculty member, university, or industry, can s/he still claim the ownership of any resulting academic patents or financial incentives? Silvernagel et al. (2009) investigated the views of faculty members and students on the ownership of student-generated intellectual properties. According to their findings, university students believed that they should own the intellectual property rights resulting from class assignments or research projects. The students argued that they did not gain significant ideas, expertise, or experience from faculty members or departments; instead, they paid a tuition fee to access institutional resources that can help them refine their own ideas. Most faculty members believed that they should own the IPRs associated with their research results.

Although the role of graduate students has become more important in academic research (Patel 1996), few studies dealing with ownership issues reflect the views of students.

2.4 Factors influencing technology commercialization

To accelerate the commercialization of academic research results, many countries allow universities to own any IPRs obtained as a result of funded research. Under these circumstances, student preferences regarding the university's academic patent ownership policy are likely to reflect their ability to facilitate the exploitation of their own research results. In this way, factors influencing technology commercialization or the creation of spin-offs can affect an ownership preference.

First, technology commercialization can be influenced by the following researcher-related factors: the researcher's experience (Audretsch 2000; Sohn and Moon 2003; Landry et al. 2006; Marion et al. 2012); gender (Landry et al. 2006); age (Audretsch 2000); personal characteristics (Roberts 1991); and academic degrees. Landry et al. (2006) have investigated the determinants of university spin-off creation. The resources that made possible the creation of spin-offs were knowledge assets, financial resource, organizational resource, social capital, and intellectual property. The authors found that "personal experience," "gender," "research fields," "the linkage between research and market," and "activity aiming to protect their intellectual property," were significant factors in the creation of spin-offs by academic researchers. In particular, as suggested by the theory of planned behavior (Ajzen 1991, 2002), the researcher's *attitude toward* technology commercialization and academic patenting, the *subject norm*, and the *perceived behavioral control* are connected to the formation of an intention to commercialize technology or to patent academic research. In addition, academic researcher's intention to commercialization has significant influence over new venture creation (Marion et al. 2012).

Next, the following "technology-related factors" can affect technology commercialization: the possible applications of the technology (Sohn and Moon 2003); technological fields and markets (Landry et al. 2006; O'Shea et al. 2008); technology protection (Landry et al. 2006); and university policies on technology transfer (Siegel et al. 2004). Kumar and Jain (2003) surveyed the state and practices of new technology commercialization in India to identify key factors that influence decisions and success in technology commercialization. The crucial factors in decisions to commercialize a new technology were found to be technology status, technology source, and the market potential of the end product.

In addition, the value of patent can be considered as an important factor for decision making of technology commercialization as well as the preference for patent ownership policy. The variables associated with patent value are the number of inventors, the field of technology, patent family, and forward citation (Harhoff and Hoisl 2007), the degree of utilization, the characteristics of inventors, the environment of the sponsor, the type of assignee, the technology field (Grönqvist 2009), and the number of developers, technology level, possibility of applications in other fields, the type of patent owner, technology commercialization experience, the expected lifetime of patent, and professor's privilege (Sohn et al. 2013).

2.5 Research questions

Who should own academic patent obtained as a result of funded research for pursuing sustainable and effective innovation? What do students think about academic patent ownership policies? What factors influence the preference of students in relation to inter-organization aspects of academic patent ownership; and IP ownership policies within university?

The ownership of academic patent rights is one of the rewards for patented inventions. Based on the factor "instrumentality" in the expectancy theory, the academic patent ownership issue can affect research motivation. In many universities, graduate students participate in funded research with faculty members. Those students are also subject to the same academic patent ownership policy to the faculty members. With regard to this matter, students' research motivation can be affected by academic patent ownership issue. In addition, the relationship between them can have an influence on the preference of students in relation to inter-organization aspects of academic patent ownership; and IP ownership policies within university. Our first hypothesis is as follows:

H1 The relationship between academic patent ownership and research motivation affects the preference of students in relation to inter-organization aspects of academic patent ownership; and IP ownership policies within university.

Students can further develop their ideas and prepare/start a business. Recently, there are a growing number of start-ups by university students. Under this circumstance, the preference of students in relation to academic patent ownership policy can be affected by the factors influencing technology commercialization or the creation of spin-offs. Second hypothesis is as follows:

H2 The factors influencing technology commercialization or the creation of spin-offs affects the preference of students in relation to inter-organization aspects of academic patent ownership; and IP ownership policies within university.

3 Data and methodology

3.1 Data

In this study, we design questionnaires in terms of the following topics: (1) "ownership" (based on expectancy theory); and (2) "researcher and the environment for R&D," "technology," "patenting activities," "sponsors," "currently existing ownership policy," and "compensation policy" (related to the factors affecting technology commercialization). These topics are associated with preferences for inter-organization aspects of academic patent ownership; and IP ownership policies within university.

The survey was targeted to engineering graduate students in Korea, one of countries that government actively supports academic research projects and there has been increasing collaboration between university and industry. In Korea, the laws on 'technology transfer promotion' and 'industrial education and industry-university cooperation' were enacted in 2001 and 2003, respectively. In accordance with these laws, most universities started to own the IPRs over research outcome of their faculty members in order to facilitate the exploitation of research outcome. However, the low utilization of academic patents is a major problem in Korea.

Our survey was administered in April 2009 through personal visits followed by email. It was conducted mainly with engineering graduate students who have experienced R&D projects, at five research-intensive universities having about 5000 enrolled students in Seoul, Korea. Our interviewer was able to contact approximately 500 graduate students, of whom 335 responded to our survey. Among respondents, 73% were male, 21% were female, and 6% gave no information about gender. In relation to academic qualifications, 52% of the participants held Master's degrees, 40% held Ph.Ds., 5% were in post-doctoral courses, and 3% gave no response. As for the respondents' majors, 21% majored in electrical engineering, 14% in mechanical engineering, 14% in materials engineering, 10% in computer engineering, 7% in chemical engineering, 5% in biological engineering, 5% in industrial engineering, and 24% in other subjects; 19% of the respondents had patented inventions.

3.2 Method

Classification tree analysis is the most frequently used method for knowledge discovery; it uncovers rules and relationships by subdividing the information contained in data (Sohn

and Moon 2004). It also classifies and predicts results by dividing the target group into smaller groups (in the form of a tree). A major advantage of classification tree analysis is that it expedites the process of classification.

We used the classification and regression tree (CART) developed by Breiman et al. (1984) to build an ownership preference model, using SAS Enterprise Miner software. The impurity measure used in building classification decision tree in CART is Gini index. We separated the data into training data (70% of the data) and validation data (30%) for model verification.

Our two target variables are categorical variables with multi levels. The levels for target variables related to our research questions were as follows: the target variable of "MODEL 1: The preferred agent of patent ownership" has four levels: (1) university, (2) researcher, (3) government, and (4) sponsor. The target variable of "MODEL 2: The preferred university patent management policy" has six levels: (1) the university owns patents created using university resources; (2) the university owns patents created in the course of employment; (3) the university owns all patents developed by faculty members; (4) the researcher owns the patent and entrusts its management to his or her university; (5) the researcher owns the patent and entrusts its management to any university or technology transfer organization; and (6) the researcher owns, uses, and licenses the patent.

The first three classifications are based on Chew's (1992) principles of intellectual property policies and the latter three on "professor's privilege." We have also suggested policy 5, which has not yet been implemented. Except in the case of large research universities, an academic institution's Technology Transfer Office (TTO) cannot specialize in many different technological areas. Policy 5 would enable university TTOs to specialize in particular areas to attract patent owners from other universities. National laboratory TTOs could perform the same function, making technology transfer more effective overall.

For classification tree analysis for two target variables, we use following explanatory variables: (1) variables regarding '*researcher and the environment for R&D*' include gender, age, academic degrees, actual industry experience, responsibility for research, the use of research notes, the laboratory's domestic competitiveness, and the number of researchers in a laboratory; (2) '*technology*'-related variables comprise of the technology field, the level of technology, research experience in technology field, technical innovations, the life cycle of the technology, possibility of applications in other fields, and the technology market; (3) '*patenting activities*' related variables are the burden of patent application and maintenance costs, and the method of patent commercialization; (4) '*sponsor*'-related variables include the sponsoring organization, the type of research, the period of sponsorship, and the time it would take the sponsor to agree to contract modifications; (5) variables regarding '*currently existing ownership policy*' cover the present patent ownership policy, the present patent ownership policy within the university, the association between patent rights ownership and research motivation, and the relationship between "professor's privilege" and the creation of added value; and (6) '*compensation policy*'-related variables consist of the interest in the reward policy for employee inventions, internal regulations of the reward policy, desirable forms of financial rewards and non-financial rewards, and conflicts related to the distribution of technology royalties. Detailed information on the explanatory variables is found in "Appendix" section.

4 Empirical analysis

First, we summarized responses to questions about the way in which academic patent ownership affects research motivation. When asked about the present ownership of academic patent rights, only 5% of the respondents said that researchers owned their own academic patents, while 30% said that patents were co-owned by the university and sponsor (Table 1). Second, in response to questions about their preferred form of ownership of academic patent rights, 61% of respondents said that researchers should own their own academic patents (Table 2). This result contrasts so dramatically with responses to the first question, shows that the current state of academic patent ownership merits further discussion. In addition, 3% of students without patents preferred the government as an agent of academic patent ownership; while no students with patents preferred the government as an academic patent owner.

Third, when respondents were asked which university patent management policy they preferred, option 4 (the researcher owns the patent and entrusts its management to his or her university) was the most popular at 41%, as illustrated in Table 3. In addition, 16% of the respondents without patents preferred to own their own patent rights, entrusting the management of those rights to any university or technology transfer organization; 18% of respondents with patents preferred option 1 (the university owns patents created using university resources).

Fourth, when asked about patent ownership conflicts and research motivation, 59% of the respondents agreed (or strongly agreed) that conflicts over patent ownership discourage future research. One can see that the efficient maintenance of ownership rights and management policies is important for encouraging sponsored research. A total of 32% of respondents with patents strongly agreed that there was a relationship between patent ownership conflicts and research motivation. Respondents without patents were rather neutral (Table 4). Lastly, when asked about the relationship between the professor's privilege and the creation of added value, 52% of respondents said that a researcher's freedom to choose the owner of his or her invention helped to create value for that technology in the future. However, 10% of respondents felt that such freedom would not be helpful; this may reflect their own focus on research and a lack of time to manage patents (Table 5).

4.1 MODEL 1: The preferred agent of academic patent ownership

Next, we performed a classification tree analysis of the preferred agent of patent ownership. The target variable of MODEL 1 consisted of four types: (1) university, (2)

Table 1 Current patent ownership

Level	Total respondents	%
Researcher	17	5
University	63	19
Sponsor	46	14
Co-ownership (sponsor and university)	102	30
Co-ownership (sponsor and researcher)	53	16
No response	54	16
Total	335	100

Table 2 Preferred form of academic patent ownership

Level	Total respondents	%	Respondents with patents	%	Respondents without patents	%
University	57	17	11	18	46	17
Researcher	206	61	42	68	164	60
Government	9	3	0	0	9	3
Sponsor	19	6	4	6	15	5
Plural response	9	3	4	6	5	2
No response	35	10	1	2	34	12
Total	335	100	62	100	273	100

Table 3 Preferred type of university patent ownership policy

Level	Total respondents	%	Respondents with patents	%	Respondents without patents	%
Option 1	36	11	11	18	25	9
Option 2	19	6	6	10	13	5
Option 3	32	10	4	6	28	10
Option 4	139	41	28	45	111	41
Option 5	51	15	6	10	45	16
Option 6	19	6	6	10	13	5
No response	39	12	1	2	38	14
Total	335	100	62	100	273	100

Table 4 Patent ownership conflicts and research motivation

Level	Total respondents	%	Respondents with patents	%	Respondents without patents	%
Strongly agree	70	21	20	32	50	18
Agree	126	38	19	31	107	39
Neutral	74	22	11	18	63	23
Disagree	28	8	10	16	18	7
Strongly disagree	5	1	1	2	4	1
No response	32	10	1	2	31	11
Total	335	100	62	100	273	100

researcher, (3) government, and (4) sponsor. As shown in Fig. 1, three rules regarding the preferred agent of academic patent ownership were discovered:

Rule 1–1: Students who thought that conflicts over ownership rights had a negative effect on research motivation (B12) tended to prefer owning their own academic patent rights (81.9%), if they had the support of a university or commercial firm (D1).

Table 5 "Professor's privilege" and the creation of added value

Level	Total respondents	%	Respondents with patents	%	Respondents without patents	%
Strongly agree	42	13	10	16	32	12
Agree	132	39	29	47	103	38
Neutral	97	29	18	29	79	29
Disagree	22	7	2	3	20	7
Strongly disagree	11	3	1	2	10	4
No response	31	9	2	3	29	11
Total	335	100	62	100	273	100

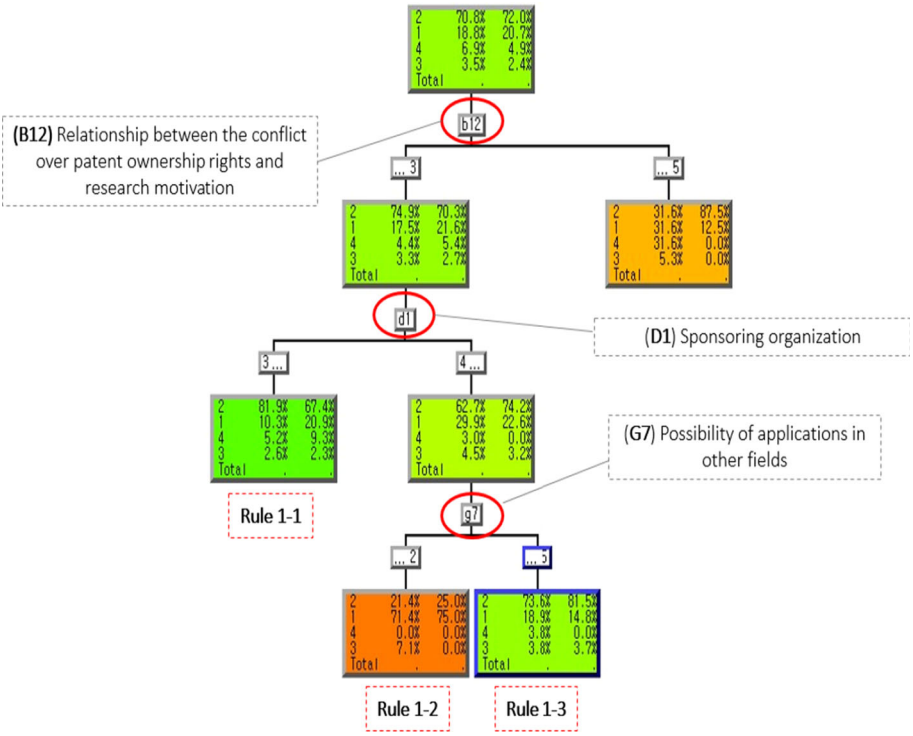

Fig. 1 MODEL 1 Results

Rule 1–2: Among respondents who thought that ownership conflicts had a negative effect on research motivation (B12), those who were supported by the government or without sponsorship (D1), and considered it unlikely that the technology could have applications in other fields (G7), preferred the university to own academic patent rights (71.4%).

Rule 1–3: If students who said that ownership conflicts had a negative effect on research motivation (B12) had government support or no sponsorship (D1), and felt there was an above average chance that the technology could have applications in other fields (G7), they generally preferred to own the academic patent rights themselves (73.6%).

Based on the results of the first classification tree analysis, we can infer the following:

1. Students considered the "relationship between conflicts over ownership rights and discouragement of research motivation" to be significantly associated with the preference for a particular owner type. Most engineering graduate students who thought that conflicts over the ownership right of academic patents could demotivate academic researchers preferred to own academic patent rights themselves.
2. The variables "sponsor organization" and "possibilities of expansion to various technology sectors" were considered to influence one's preferred owner of academic patent rights. Those who expected technology commercialization to be difficult (because there was a very low chance of expansion to other fields) wanted to pass ownership on to the university.

4.2 MODEL 2: The preferred university patent management policy

Next, we conducted a classification tree analysis to identify preferred university patent management policies. The target variable of MODEL 2 consisted of six levels: (1) the university owns patents created using its resources; (2) the university owns patents created in the course of employment; (3) the university owns all patents developed by faculty members; (4) the researcher owns the patent and entrusts its management to his or her university; (5) the researcher owns the patent and entrusts its management to any university or technology transfer organization; and (6) the researcher owns, uses, and licenses the patent.

As shown in Fig. 2, we derived the following five rules regarding university patent management policies:

Rule 2–1: If it took more than 6 months for a sponsor to agree to a modified contract (A4), students preferred the option: "the researcher owns the patent and entrusts its management to his or her university" (79.5%).

Rule 2–2: If it took less than 6 months for the sponsor to agree to a modified contract (A4), students who either chose patent licensing as a method of commercialization or had no experience (H6), given that the market for the developed technology was an existing or new business field (G1), favored the option: "the researcher owns the patent and entrusts its management to his or her university" (52.7%).

Rule 2–3: If it took less than 6 months for the sponsor to agree to a modified contract (A4), students who either chose patent licensing as a method of commercialization or had no experience (H6), given that the market for the developed technology was a convergent market (G1), favored the option: "the researcher owns the patent and entrusts its management to any university or technology transfer organization" (42.9%).

Rule 2–4: If it took less than 6 months for the sponsor to agree to a modified contract (A4), students who chose technology transfer or a spin-off as a method of commercialization (H6), given that the market for the developed technology was a convergent market (G1), favored the option: "the researcher owns the patent and entrusts its management to his or her university" (32%).

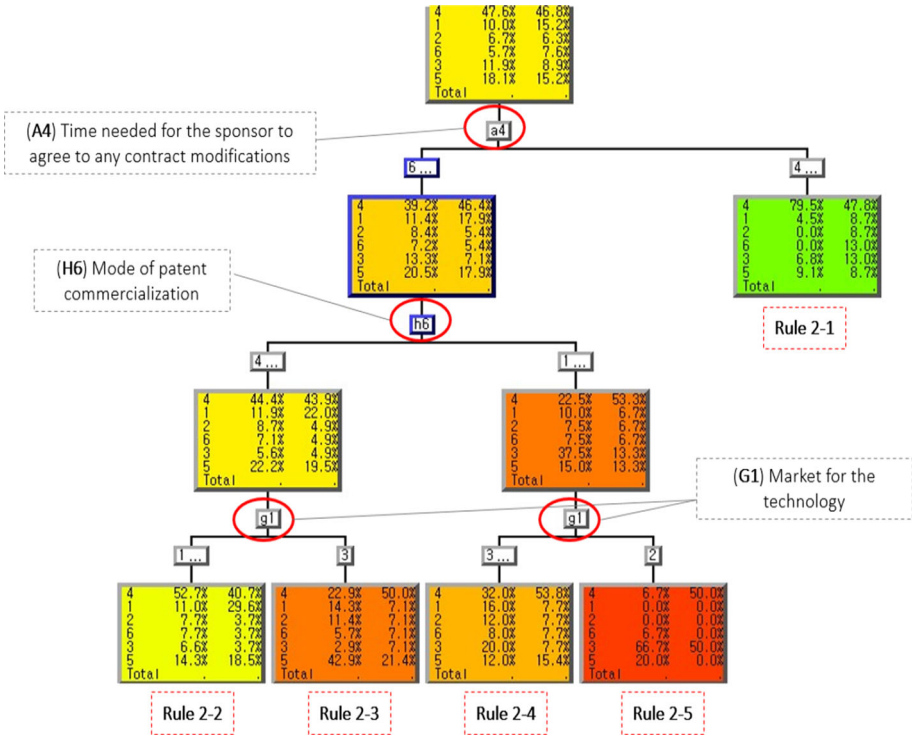

Fig. 2 MODEL 2 Results

Rule 2–5: If it took less than 6 months for the sponsor to agree to a modified contract (A4), students who chose technology transfer or a spin-off as a method of commercialization (H6), and who also thought the researcher should explore a new business model or create a new market (G1), preferred the option: "the university owns all inventions developed by the faculty" (66.7%).

Based on the results of the second classification tree analysis, we can infer the following:

1. Engineering graduate students consider the "time needed for the sponsor to agree to a modified contract," "mode of technology commercialization," and "technology market" to be significantly associated with university patent management policies.
2. Students who had experience of commercialization through a technology transfer center or spin-off and intended to explore a new business model wanted the university to own, use, and license all patents developed by faculty members.

5 Conclusion

Given the increase in government and industry funding for academic research, many academic patents have been developed. When academic patents are obtained as a result of government-funded research, universities file, own, and license academic patents. In case

of industry-funded research, industry, universities, and individual researchers still show strong differences in opinion when asked who should own academic patents. In addition, patent management policies within universities vary. The issue of academic patent ownership can affect the research motivation of senior academics as well as students involved in R&D projects.

Most related studies have focused on faculty members' perception of academic patenting and the ownership of academic patents. Although many graduate students are involved in funded R&D projects with faculty members and those students are also subject to the same academic patent ownership policy to the faculty members, none have investigated which ownership policy of academic patents students preferred; and what factors affect the preference of students in regard to inter-organization aspects of academic patent ownership; and IP ownership policies within university.

In this paper, drawing on the expectancy theory and various factors related to 'researchers and the environment for R&D,' 'technology,' 'patenting activities,' 'sponsors,' 'currently existing ownership policy,' and 'compensation policy', we developed the following hypotheses: (H1) the relationship between academic patent ownership and research motivation affects the preference of students in relation to inter-organization aspects of academic patent ownership; and IP ownership policies within university; (H2) the factors influencing technology commercialization or the creation of spin-offs affects the preference of students in relation to inter-organization aspects of academic patent ownership; and IP ownership policies within university. Our hypotheses are tested by using the survey data of Korean engineering graduate students.

According to the result of classification tree analysis for the first target variable, "the relationship between conflicts over ownership rights and discouragement of research motivation," "sponsor organization," and "possibilities of expansion to various technology sectors" influence students' preference with regard to inter-organization aspects of academic patent ownership. Next, in the result of classification tree analysis for the second target variable, "time needed for the sponsor to agree to a modified contract," "mode of technology commercialization," and "technology market" affect the preference of students in relation to IP ownership policies within university. The results of two classification tree analyses confirmed our two hypotheses.

The majority of engineering graduate students thought that patent ownership conflicts decrease their motivation to carry out future research. Of these students, those who had the support of the university or a commercial firm preferred to own their academic patents. In addition, among respondents who thought that ownership conflicts had a negative effect on research motivation, those who had government support or no sponsor; and thought there was an above-average chance that the technology would have applications in other fields preferred to own their academic patents. Several studies on academic patent ownership pointed out that the university ownership model is not optimal for technology commercialization (Kenney and Patton 2009), especially, when the academic inventor has a high reputation and connection with industry (Sterzi 2013). In Korea, universities own academic patents, however, most university technology licensing offices have not been successful in commercializing academic patents or encouraging entrepreneurship. Thereby, most of academic patents are under-utilized. Accordingly, engineering graduate students preferred to own academic patents over their research outcomes. In contrast, students who had the support of the government or no sponsor; and felt that there was little chance that the technology would have applications in other fields preferred to let the university own academic patents. In case of academic patents with a low possibility of application in other fields, universities do not want to own these patents because it can be difficult to

commercialize these inventions and generate the profit from them. Although universities own these patents, universities do not want to own them any more when there is no active transfer activity until the first renewal fee should be paid. In this case, eventually, the rights are transferred to graduate students. But they do not do much with those patents. Therefore further efforts are needed to explore the application fields of invention or to improve invention quality.

Next, we investigated what kind of university patent management policy the engineering graduate students preferred. Most of graduate students wanted the researcher to own the right of academic patent and entrust its management to the university or technology transfer organization. However, if the sponsor took less than 6 months to agree to a modified contract, students who chose technology transfer or a spin-off as the mode of patent commercialization and should create a new market, wanted the university to own all patents created by students as well as faculty members.

In sum, it is very difficult for graduate students to look for potential licensee or assignee, start business based on the academic patents, and conduct their academic work at the same time. Accordingly, students preferred to entrust patent management to the university or technology transfer organization. We regard that faculties also prefer to entrust patent management to the university or technology transfer organization because they should conduct many academic works. If graduate student owns academic patent and entrust its management to the university or technology transfer organization, it can be inefficient and inconvenient because university or technology transfer organization needs the approval of owners whenever they license or sell academic patents. Therefore, we suggest the followings:

(a) If students want to own their academic patents and entrust its management university or technology transfer organization, then they should be given option to choose the consignment organization which is expected to stimulate technology commercialization and entrepreneurship. In this case, for efficient technology transfer, graduate students should assign the right of their academic patents, and negotiate with the consignment organization for financial reward. The option to choose the consignment organization is needed to facilitate the exploitation of research outcomes. Because some universities lack the capability to evaluate the value of the academic inventions and commercialize them, the academic patents can be under-utilized. However, universities may not want that students choose other universities or technology transfer organizations as the consignment organization because they provide students with resources required to conduct R&D. However, if university technology licensing office has own specialty area, students belong to corresponding university as well as other universities choose this university as the consignment organization.

(b) If students want their university to own all patents created by all students, the university own and manage academic patents by providing the students with adequate compensation according to patent value. In Korea, university IP ownership policies is commensurate with the initial evaluation of invention. In the initial evaluation process, the information for academic patent valuation is insufficient, accordingly the result of initial evaluation of invention can be inaccurate. Therefore, the evaluation of invention needs to be conducted by considering various indicators which can measure time-varying patent value. Our study is expected to be useful in improving the efficiency of university intellectual property management policies because they take into consideration the view of graduate students who will lead

innovation in the near future. Lastly, additional study is needed to compare views among graduate students, professors, universities, industrial sponsors, and the government. These are areas for further research that could be productively explored to develop more effective and acceptable patent ownership policies.

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Appendix

See Table 6.

Table 6 The explanatory variables

Class of variables	Variables		Level	References
Researcher and the environment for R&D	Gender	J1	1. Male 2. Female	Landry et al. (2006)
	Age	J2	Interval (age)	Audretsch (2000)
	Academic degrees	J3	1. Master's course student 2. Doctoral course student 3. Post-doctoral course	–
	Actual industry experience	J6	1. Yes 2. No	Audretsch (2000), Sohn and Moon (2003), Landry et al. (2006), Marion et al. (2012) and Sohn et al. (2013)
	Responsibility for research	E2	1. Yes 2. No	–
	Existence of research notes	E4	1. Yes 2. No	Chamas (2008) and Sohn et al. (2013)
	Domestic competitiveness of the laboratory	E3	1. Upper 10% 2. 10–25% 3. 25–50% 4. Lower 50%	Jaffe and Lerner (2001) and Sohn et al. (2013)
	Number of researchers in the laboratory	E1	Interval (persons)	Hall and Zeidonis (2001), Reitzig (2004), Harhoff and Hoisl (2007) and Sohn et al. (2013)

Table 6 continued

Class of variables	Variables		Level	References
Technology	Technology field	G2	1. Information technology 2. Biotechnology 3. Nanotechnology 4. Culture technology 5. Environmental technology 6. Space technology	Landry et al. (2006), O'Shea et al. (2008), Deng (2007), Harhoff and Hoisl (2007) and Sohn et al. (2013)
	Level of technology	F1	1. Copying level 2. Absorption level 3. Improvement level 4. Innovation level	Chiu and Chen (2007) and Sohn et al. (2013)
	Research experience in technology field	F2	Interval (years)	Lynskey (2006) and Sohn et al. (2013)
	Technical innovation in relation to existing technology	G3	1. Very low 2. Low originality, but efficient and with high applicability 3. High originality, but with low efficiency and applicability 4. Distinctive, low pioneering ability 5. Distinctive, high pioneering ability	Baark (1988) and Sohn et al. (2013)
	Life cycle of the technology	G4	1. Declining 2. Introductory 3. Maturing 4. Growing	Haupt et al. (2007) and Sohn et al. (2013)
	Possibility of applications in other fields	G7	1. No possibility 2. Low 3. Neutral 4. High possibility due to proximity to original technology 5. Very high	Long (1989), Sohn and Moon (2003) and Sohn et al. (2013)
	Market for the technology	G1	1. Existing market 2. New market 3. Converged market	Nerkar and Roberts (2004) and Sohn et al. (2013)

Table 6 continued

Class of variables	Variables		Level	References
Patenting activities	Burden of patent application and maintenance costs	B11	1. Sponsor 2. University 3. Researcher 4. Co-ownership (sponsor and university) 5. Co-ownership (sponsor and researcher)	–
	Mode of patent commercialization	H6	1. Technology transfer 2. Spin-off 3. Patent licensing 4. No experience of patent commercialization	Kollner and Dowing(2004) and Sohn et al. (2013)
Sponsor	Sponsoring organization	D1	1. Researcher (no sponsor) 2. University 3. Commercial firm 4. Government	–
	Type of research	B8	1. Contract (consigned) research 2. Joint research	–
	Period of sponsorship	D3	1. Under 6 months 2. 6 months–1 year 3. 1–2 years 4. 2–3 years 5. Over 3 years	Schwartz (2004) and Sohn et al. (2013)
	Time needed for the sponsor to agree to any contract modifications	A4	1. Under 1 month 2. 1–3 months 3. 3–6 months 4. Over 6 months 5. No modification 6. Contract cancellation	–
Currently existing ownership policy	The present patent owner	B9	1. Researcher 2. University 3. Sponsor 4. Co-ownership (sponsor and university) 5. Co-ownership (sponsor and researcher)	Reitzig (2004) and Sohn et al. (2013)

Table 6 continued

Class of variables	Variables		Level	References
	The present patent ownership policy within the university	B10	1. Management according to related laws and regulations 2. Goes to the principal research institution 3. Decided according to the particulars of the contract 4. Decided through arrangement	–
	Relationship between the conflict over patent ownership rights and research motivation	B12	1. Strongly agree 2. Agree 3. Neutral 4. Disagree 5. Strongly disagree	Reitzig (2004) and Sohn et al. (2013)
	Relationship between "professor's privilege" and the creation of added value	B17	1. Strongly disagree 2. Disagree 3. Neutral 4. Agree 5. Strongly agree	SOU 2005:95 (2005) and Sohn et al. (2013)
Compensation policy	Interest in the reward policy for employee inventions	B19	1. Strongly interested 2. Interested 3. Moderate 4. Not interested 5. Strongly not interested	–
	Internal regulations of the reward policy	B20	1. The method of reward is clearly stated in the internal regulations 2. Generally stated, but not in detail 3. Unstated, but a reward is given to a certain degree 4. Unstated and a reward is not given	–
	Desirable form of financial reward	B21	1. Bonus 2. Increase in research funding 3. Technology royalty	–
	Desirable form of non-financial reward	B22	1. Official commendation 2. Promotion 3. Discretionary power in choosing field of research 4. Sabbatical year	–
	Conflicts related to the distribution of technology royalties	B23	1. Almost never 2. Practical hold-ups (difficulties) 3. Conflicts that did not cause the contract to be cancelled 4. Conflicts that caused the contract to be cancelled	–

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