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Technological Forecasting & Social Change 73 (2006) 199–213

Technological Forecasting and Social Change

Managing academic innovation in Taiwan: Towards a 'scientific–economic' framework

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Received 17 May 2004; received in revised form 18 October 2004; accepted 19 October 2004

Abstract

Since the passage of the Science and Technology Basic Law in 1999, Taiwanese universities have taken a more "scientific–economic" approach to protect and commercialize their research. This research mainly examines innovation activities such as patenting, licensing, and incubated startups in the context of Taiwanese higher education institutions (HEIs). The "scientific–economic" framework used to analyze the strategic aspects influencing these academic innovations includes (1) intellectual property managerial capabilities, (2) the strength of external industrial partnerships, (3) the university entrepreneurial orientation, and (4) government research policy. Four hypotheses were developed. Data were collected via a questionnaire with all 122 HEIs in Taiwan surveyed.

The research reveals that the aspects of intellectual property managerial capability, HEI–industry partnerships, and academic entrepreneurial orientation are useful to distinguish the university's innovation performance on patent grants, licensing incomes, and firm incubation. Also, government support on research plays a moderating

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doi:10.1016/j.techfore.2004.10.004

role in academic innovation. Managerial and policy implications for managing innovation effectively in universities were drawn.

Keywords: Higher education institution; Academic innovation; Patenting and licensing; University–industry partnership; Firm incubation

1. Introduction

Changing the structure and function of the higher education institutes (HEIs) has become a crucial task in facilitating the flow of knowledge into new sources of industrial innovation [1,2]. In order to reap the economic benefit, various institutional and organizational innovations have burgeoned in academies including the devolution of intellectual property (IP), the establishment of technology transfer/licensing offices, incubator facilities, and spin-offs. There are increasing numbers of academic inventions that display immediate commercial potential, and the university knowledge base has become a new source of industrial innovation [3].

McKelvey [4] explains that the changing role of universities in knowledge-seeking activities using cognitive (scientific vs. technological) and institutional (market vs. government) environments is moving from a scientific–government (S–G) environment, or basic scientific environment to a scientific–economic (S–E) environment. In the S–G environment, research activities are designed to increase general knowledge. However, the S–E environment encourages scientific activities that have economic potential. The knowledge-seeking activities in the S–E environment are directed by the criteria of the diffusion of economic influence and scientific excellence.

Inspired by the U.S. *Bayh–Dole Act of 1980* and the U.K. *Patent Law* in 1978, many Asian economies (i.e., Japan, Korea, and Taiwan) adopted a *Science and Technology Basic Law* (STBL) during the late 1990s.[1] One of mandates in the STBL allows HEIs to own the patents that arise from government research grants. Presumably, these changes would give universities greater flexibility in negotiating licensing agreements, and firms would be better informed about academic inventions. Many governments expect that the increase in IP management capabilities of HEIs would accelerate the commercialization of new technologies and promote national/regional entrepreneurial and economic activities.

Although past research has attempted to assess the impact of the *Bayh–Dole Act* on technology transfer and commercialization in the U.S. universities [5–8], little research has been conducted to evaluate the preliminary impact on the newly STBL-enacted economies of Asia. Moreover, despite the rising importance of HEIs as sources of industrial innovation, the link between an HEI and its contribution to industrial innovation is not completely understood [9,10]. This study sets out to bridge this gap by evaluating the economic contribution of the HEIs' innovation in Taiwan.

This empirical study explores the innovative activities of Taiwanese HEIs in terms of patenting, licensing, and firm incubation. This article is structured as follows: Section 2 reviews the factors influencing a university's innovative performance. These four factors include intellectual property

[1] Japan adopted the law in 1995; Taiwan adopted in 1999, and Korea adopted in 2001.

management, external industrial partnerships, the university entrepreneurial orientation, and governmental research commitment. Section 3 describes the methodology employed in the research to gather data consisting of a postal questionnaire survey. Section 4 describes the data analysis and findings of the research. Sections 5 and 6 present the discussions and conclusions respectively.

2. The new governance of academic innovation: towards a "scientific–economic" regime

2.1. Intellectual property managerial capabilities

Conceptually, HEIs are asked to fulfill the responsibilities of education, research, and service. The purpose and function of the university have always been knowledge and wealth creation on behalf of the nation-state. Industrial economists have attempted to adopt the "market-oriented" model to analyze HEIs. The model regards academies as one of the major actors in the process of economic development. HEIs have to demonstrate the social and economic benefits of their research in order to compete for the diversified sources of funding available to them [4,11]. Nowadays, universities are much more likely to manage and patent the intellectual property created on their campuses than they were in earlier periods [12]. Thus, with maintaining the function of scholar training and theoretical development, many universities have increasingly paid attention to the function of wealth creation [2]. We argue the ongoing function of wealth creation not only directly enhance the overall welfare for state-nation, but also generate the incomes for respective universities.

Policymakers asserted that the lag between the discovery of knowledge at the university and its use by companies was seriously impairing the global competitiveness of American firms in such industries as steel, automobiles, televisions, and semiconductors [13]. Moreover, the direct management of government has been criticized as unable to enhance the economic effectiveness of HEIs. Some science and technology (S&T) policy researchers claimed that to adopt "new public management" increases the operational efficiency of public research institutes in generating knowledge and wealth [14,15]. Contracts, evaluation, and accountability have replaced direct management by the government ministries [16].

The National Science Council (NSC) used to be the sole government agency claiming IP rights on behalf of HEIs in Taiwan. In response to the changing environment, the Taiwanese government implemented the *Science and Technology Basic Law* in January of 1999 laying out the fundamental principles and direction for the country's technological development while providing for a sustained and balanced support of R&D. The law allows universities and research institutes to partially or fully claim and commercialize the titles of IPs derived from government-funded research and reap the economic benefits of such. The *Guidelines for Ownership and Utilization of S&T Research and Development Result of 2000* further specifies the distributing shares of licensing incomes among implementing institutes, inventors, government funding agencies as 40%, 40% and 20% respectively.

Furthermore, in order to integrate academic resources and effectively manage R&D results, the NSC implemented the *Subsidy Principles of Management and Promotion of Academia R&D Results* in 2002. This subsidy enables HEIs to receive reimbursement for patent filing and maintenance fees. The principles commit to reimburse HEIs up to 70% of the total patenting expenditures including patent application and maintenance fees. The reimbursing fees will be reduced to 50% in 2005. Table 1 shows increased efforts by HEIs to the potential economic benefits of research in terms of patenting and licensing.

Table 1
Patenting and licensing activities recorded in HEIs (1997–2001)

Unit: case

Year	HEIs		
	Patent applied	Patent issued	Licensing
1997	223	n/a	16
1998	215	178	10
1999	199	213	14
2000	189	129	19
2001	183	331	41
Total	1009	851	100

Source: adapted from the series of *National Science Council Annual Review* from 1998 to 2002.

More importantly, the recognition of the increasing importance of IP infrastructure is perceived by HEIs, and they have begun to established IP offices (IPOs), technology transfer offices (TTOs), and technology licensing offices (TLOs) that are in charge of internal IP protection, management, and exploitation. These offices are charged with facilitating and managing the invention disclosure, patenting and licensing with commercial potential [17,18]. Furthermore, in order to facilitate technological diffusion, the NSC is devoted to providing financial support for the establishment of an IP infrastructure in the HEIs. By 2003, ten HEIs having excellent patenting performances have established the technology transfer/license centers and received subsidies under the program. Also, incubator centers provide shelters for new venture businesses through the use of academic facilities and resources as consultants.[2]

This study suggests that the open environmental space in the early days of burgeoning entrepreneurial academia provided the opportunity for HEIs to enhance their IP managerial capabilities. A direct consequence of the policies granting universities title to inventions and enabling the exploitation of inventions has been the creation of IPOs, TTOs, TLOs or equivalent offices that commercialize their research results and facilitate technology transfer and utilization with third parties. Thus, we hypothesize:

Hypothesis 1A. Intellectual property managerial capability can enhance HEI's patent creation.

Hypothesis 1B. Intellectual property managerial capability can enhance HEI's licensing creation.

Hypothesis 1C. Intellectual property managerial capability can enhance HEI's firm incubation.

2.2. External industrial partnership

Accompanied with more attentions being paid to the function of wealth creation in universities, distinct institutional boundaries have become blurred and replaced by a network of linkages with other actors [19]. HEIs are asked not only to more often reflect the scientific and technological needs of the society, but also to cooperate with firms by becoming the suppliers of an applied knowledge that can be readily transformed into innovation [20,21]. Also, due to scientific advancement and the rapid change in technology development, research equipment and facilities can easily become obsolete and difficult for a single entity to afford [22]. Thus, the funding from industry, foreign organizations and non-profit

[2] There are 67 incubator centers established by 2003 with 54 of them located at universities.

research organizations has become attractive alternatives to offset the decreasing amounts of governmental research funding (see Table 2).

Becoming less dependent upon the support of government funding will drive the HEI–industry collaborations into a more businesslike partnership. Both sides will seek out the industrial potential of research accompanied by expectations that a tangible product or service will be produced in return [17]. Thus, HEI have become entrepreneurial in nature through the external connections made with firms for research contracts and transfer of knowledge and technology [1]. Link et al. [23] argue that geographic the concentration and the co-location of university research and industrial R&D may enhance knowledge spillovers in the local region. The clustering effect is a main factor in the development of an incubator [24]. The more applied technology an HEI becomes involved with may attract a clustering of startups and in sharing knowledge spillovers. Furthermore, collective learning stimulates the ability to exchange, assemble, integrate, and deploy knowledge across organizational boundaries [25,26]. The interdependent network relations facilitate the identification of potential licensees for universities and the technological fitness for technology commercialization.

Except the universities in the U.S., the HEIs in other countries have historically maintained a stronger compartmentalization with industrial sector [27]. Universities differ on the degree to which their researchers focus on industrial problems. Some HEIs focus their research more on the needs of industry than do other HEIs [5]. We argue that external industrial partnerships broaden the HEIs' participation in the field of applied technology. Moreover, the economical and technological potentials of near-market technology do create more wealth and firm incubation for HEIs. Thus, we hypothesize:

Hypothesis 2A. The strength of an external industrial partnership can enhance the HEI's patent creation.

Hypothesis 2B. The strength of an external industrial partnership can enhance the HEI's licensing creation.

Hypothesis 2C. The strength of an external industrial partnership can enhance the HEI's firm incubation.

2.3. University's entrepreneurial orientation

The key "suppliers" in this process of innovation creation are faculty members who must disclose their inventions to the TTO in order for the university to generate an economic return from the transfer of the technology [28]. Based on the perspective of minimizing transactional cost, the faculty member's

Table 2
Sources of research funds for HEIs

Year	Industry (Million NT$)(A)	Percent (A/D)	Government (Million NT$)(B)	Percent (B/D)	Others[a] (C)	Percent (C/D)	Total (Million NT$)(D)
1997	448	2.4	17,351	94.7	529	2.9	18,328
1998	596	2.8	20,244	95.1	451	2.1	21,291
1999	1048	4.7	19,075	85.9	2081	9.4	22,204
2000	916	3.9	20,483	86.3	2340	9.9	23,740
2001	744	2.9	21,705	85.8	2843	11.3	25,292

Source: the series of *Indicators of Science and Technology, NSC (1998–2002)*.

[a] Others could be non-profit R&D organizations and foreign organizations.

choice of invention disclosure is made after considering the potential benefits and derivative costs. On the one hand, the tangible benefit is the share of licensing incomes and royalties while the intangible benefits are that the patenting achievement may influence his/her tenure decision and research project application. On the other hand, the tangible costs are the patent application fees and maintenance, while the intangible costs are that most university inventions may need further development and could take time away from their research.

Prior research [5,18,29] suggests that the entrepreneurial orientation of faculties is mainly influenced by the university policy that supports or impedes academic entrepreneurship. Universities typically earn revenues from their inventions through royalties on the gross sales from technology licensing. The distribution of royalty rates between inventor and the university could influence the propensity of entrepreneurs to exploit university inventions [5]. The university-wide policies for the shares of licensing incomes and/or sponsored research should be established [18]. University administration could provide incentives to enable the TTO and faculty members to allocate time and effort to applied research and consulting that may generate incomes for the researcher and the university [29].

The entrepreneurial orientation of faculty could also influence the cost of startup activities. Most university technologies are embryonic and tacit and further inventor cooperation in commercialization is necessary before they can be sold in the market place [30]. The faculties with stronger entrepreneurial minds are more likely to assist startups in exploiting their inventions than those with less entrepreneurial intentions. Incubators allow entrepreneurial faculty members to provide further inputs to “ripen” technologies in close proximity to entrepreneurs in startups [5]. Moreover, better researchers are more likely to be found in the more eminent universities. Universities with higher academic rankings for their faculty have a higher proportion of disclosures licensed in the proof of concept stage [18]. Indeed, investors often make their evaluation of entrepreneurs and their ideas on the basis of the intellectual eminence of the researchers and the institution spawning the venture [31]. Startups could enhance their legitimacy by their location at elite research universities [32].

With the establishment of realistic royalty sharing, a subsidy plan, and patenting incentives, faculty members can engage in disclosing, transferring, and commercializing their intellectual capital into material forms.

Hypothesis 3A. The entrepreneurial orientation of a university can enhance an HEI’s patent creation.

Hypothesis 3B. The entrepreneurial orientation of a university can enhance an HEI’s licensing creation.

Hypothesis 3C. The entrepreneurial orientation of a university can enhance an HEI’s firm incubation.

2.4. Government research commitment

HEIs have recently experienced funding cuts or are only maintaining current levels of support from national or regional government sources [20]. The transition to less dependence upon government support occurred most significantly in the UK during the 1980s and can also be seen in the US [33]. HEI administrators may search for other supplemental support to relax their budget constraint by enabling university researchers to augment their incomes [29]. Similarly, this trend has pushed Taiwanese HEIs to diversify their funding sources to replace the declining funding share from government (Table 2). Even though the importance of industrial funding has been noticed, the governmental research funding is the major source of an HEI’s research funding.

It has been well documented that not only university management, but also academic researchers are responsible for patenting, licensing, and incubating activities. Duke [34] argues that it needs both the innovator and laboratory management (e.g., TTO) to be interested, organizational resources will be allocated to commercializing the idea. Patents are often the major laboratory criteria used to determine whether or not laboratory funds are to be used for continued development of an innovation. Resource availability, mostly derived from government funds, is therefore an important determinant for academic researchers to disclose and commercialize their research result. As Shane [35] suggests, the availability of organizational resources and technical systems is surely the valuable assets an intra-entrepreneur can count on. Moreover, the use of public sector investments fulfils a very critical role in assisting technology-based firms in the building up their credibility on the market [36]. Industrial partner or tenant firm tends to consider the capacity of government funding owned by a university in determining whom and in what form (e.g., research, incubating) to cooperate with [37].

The commercial orientation of university research is reflected in the source of funding for that research [5]. Government research commitment varies annually and largely depends on types of HEIs such as general universities, science and technology universities and colleges. Arguably, the study hypothesizes that government research funding plays a moderate role in stimulating academic innovation.

Hypothesis 4A. The governmental research commitment moderates the influence of intellectual property managerial capability on an HEI's innovative performance.

Hypothesis 4B. The governmental research commitment on funding moderates the influence of external industrial partnership on an HEI's innovative performance.

Hypothesis 4C. The governmental research commitment moderates the influence entrepreneurial orientation of a university on an HEI's innovative performance.

The conceptual framework of the paper is shown in Fig. 1.

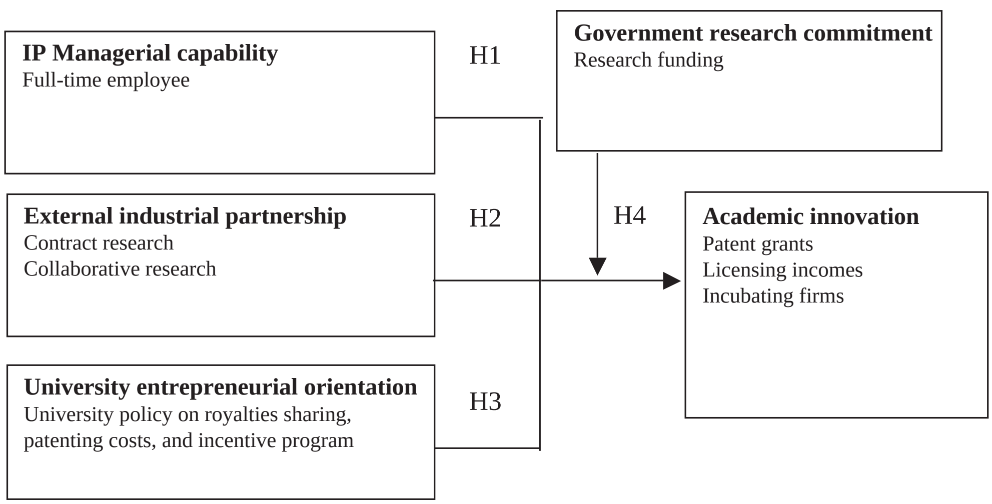

Fig. 1. Conceptual framework: a 'scientific–economic' regime.

3. Methodology

3.1. Questionnaire design

The content of the questionnaire consists of fours parts: (1) IP managerial capability, (2) industrial partnerships, (3) university entrepreneurial orientation, (4) government research funding, and (5) innovative performance in HEIs. Some questions in the survey are adapted from Bordt and Read [9] and Howells et al. [38].

The questionnaire was pre-tested by mailing the questionnaire to 10 HEI IP administrators and conducting follow-up interviews with them. Based on the pre-test feedback, the questionnaire was modified to clarify the questions that were difficult to understand or interpret.

3.2. Survey scope and response rate

Since this research focused on the study of innovation management in Taiwanese HEIs, the researchers utilized the list of universities and colleges in the *Directory of Higher Education Institutions, Ministry of Education* to identify participants. Due to inconsistent usage of HEI IP authorities in this infant stage, telephone inquiries were applied in order to construct a complete survey list. Ultimately, the study surveyed 122 HEIs including 56 universities and 66 colleges. The questionnaires were most often addressed to the director/chief of the R&D offices or of the Technological Cooperation offices at the HEIs.

Questionnaires were mailed a second and third time to non-respondents. Four investigators were designated for following up on the returned questionnaires. In order to reduce non-respondent bias and increase the response rate, the third wave of questionnaires were sent by express delivery to the non-respondents who ranked in the top ten HEIs in patenting activities according to the statistics of the NSC. Missing values in the questionnaires were filled through telephone interviews and email contacts. Ultimately, 60 questionnaires were received, 2 were non-usable, and 58 were valid. The overall response rate of the survey was 48%.

This study used Cronbach's alpha coefficient to evaluate the reliability of the questionnaire. The Alpha coefficient ranged from 0.81 for contract research to 0.92 for university entrepreneurial orientation showing that the questionnaire was reliable.

3.3. Analysis on data

This study deploys the main technology transferring and commercializing activities of HEIs between 1997 and 2001. Descriptive statistics were analyzed for each variable. Due to the early stage of development, Taiwanese HEIs generally do not operate spin-offs or startups. Therefore, the research focused on the patenting, licensing, and firm incubating serving as proxies for innovative performance. An OLS regression was run to model the influential factors of innovation performance.

3.3.1. Innovation performance

Patent grants were the primary concern of this study because this is the category of IP that has been the target of the most recent policy reforms aimed at fostering greater commercialization by HEIs. The number of domestic and foreign patent grants was calculated as the first dependent variable. Licensing was used as a proxy for technology commercialization. The data measured by the natural logarithm of licensing incomes and royalties were calculated as the second dependent variable. Firm incubation was measured by the number of new-entered incubating firms in each sample year and calculated as the third dependent variable.

3.3.2. IP managerial capability

The variable was measured as the number of full-time employees in TTOs, IPOs, and incubators or equivalent units.

3.3.3. Industrial partnership

Research partnerships between HEIs and industry were often divided into short-term and long-term orientations [38]. The research investigated the links of contract research and collaborative research serving as proxies for the short-term and long-term external industrial partnerships respectively.

3.3.4. Entrepreneurial orientation

The university policies on royalty sharing, payment of patenting costs, and incentive programs are scaled and measured as the proxy of the entrepreneurial orientation of the university.

3.3.5. Governmental research commitment

The research funding of Taiwanese HEIs originated from two main sources: the annual budgetary allocation of the Ministry of Education (MOE) and the R&D grants from the NSC. The amount of the MOE funding allocation and the NSC research funding were aggregated and calculated by use of a natural logarithm, representative of the level of governmental commitment.

3.3.6. Control variables

In considering the influence of organizational practices on the university's innovative performance, the attributes of an HEI (public or private school) and the presence of a medical school or engineering school were a crucial organizational factor [8,18,28]. Here dummy variables were represented as “1” if an HEI owns the specific schools; and “0” if did not.

4. Results

Table 3 reports means, standard deviations, and the inter-correlations for all variables used in the study. The results of a modified Kolmogorov–Smirnov Goodness-of-Fit test support the validity of the univariate normality assumption. Moreover, the correlations among the independent variables and other diagnostic tests conducted suggest no problem of multicollinearity ($VIF < 1.76$).

Table 4 presents the results of the regression analyses for hypotheses testing. Models 1, 3, and 5 are the examination of the main effects of IP managerial capability, industrial partnership, and entrepreneurial orientation on innovative performance. Model 1 shows there is a positive, no statistically significant relationship between IP managerial capability and patent creation, thereby Hypothesis 1A was rejected. Contract research and collaborative research have different outcomes for their effect on patent creation. Only collaborative research was statistically significant. Contract research was not found to be statistically significant. A positive coefficient provides evidence that the two types of research links have

Table 3
Means, standard deviations, and correlations[a]

Variable	Mean	S.D.	1	2	3	4	5	6	7	8	9	10
1. Patent grants	2.14	6.22										
2. Licensing	0.83	3.24	0.22**									
3. Firm incubating	2.22	4.53	0.30**	0.24**								
4. Managerial capability	4.21	4.32	0.29**	0.41**	0.44**							
5. Contract research	4.89	2.65	0.15	0.33**	0.10	0.07						
6. Collaborative research	4.76	20.64	0.15*	0.11	0.13	0.16*	0.14					
7. Entrepren. Orientation	1.71	2.24	0.50**	0.46**	0.31**	0.36**	0.12	0.27**				
8. Gov. commitment	21.65	1.35	0.20**	0.37**	0.23**	0.24**	0.34**	0.27**	0.33**			
9. Public school	0.29	0.46	0.01	0.26**	0.29**	0.07	0.28**	0.25**	0.06	0.38**		
10. Medical school	0.07	0.25	0.09	0.31**	0.06	0.22**	0.13	0.41**	0.37**	0.21**	0.12	
11. Engineering school	0.55	0.50	0.27**	0.23**	0.31**	0.44**	0.26**	0.16*	0.40**	0.30**	0.05	0.03

[a] $N=174$ (58 cases multiplied by three periods).
* $p<0.05$.
** $p<0.01$.

a different association with patent creation, thereby partially supporting Hypothesis 2A. The statistically significant, positive coefficient associated with university entrepreneurial orientation provides support for Hypothesis 3A.

Table 4
Effects of IP managerial capability, industrial partnership, and entrepreneurial orientation on innovation management[a]

Independent Variables	Patent creation		Licensing creation		Firm incubation	
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Main effects						
IP managerial capability	0.07	0.20	0.17*	0.02	0.32***	0.01*
Contract research	0.11	0.01+	0.19**	0.07	0.02	0.01
Collaborative research	0.17*	0.15+	0.23**	0.01*	0.05	0.05
Entrepreneurship orientation	0.53***	0.35***	0.28***	0.14*	0.17*	0.16+
Moderated effects						
Government Commitment ×						
IP managerial capability		0.17		0.15		0.37*
Contract research		0.12+		0.17*		0.09
Collaborative research		0.39***		0.26**		0.04
Entrepreneurial orientation		0.19*		0.16*		0.01+
Controls						
Public university	0.12+	0.10	0.09	0.10+	0.18*	0.17*
Medical school	0.17*	0.10*	0.06	0.11+	0.08	0.07
Engineering school	0.02	0.05	0.07	0.03	0.15+	0.15+
F	13.63***	14.73***	19.18***	17.34***	8.91***	6.44***
Adjusted R^2	0.34	0.47	0.43	0.51	0.24	0.26

[a] For all models, $n=174$ (58 cases multiple by three years). Standardized coefficients are shown.
+ $p<0.10$.
* $p<0.05$.
** $p<0.01$.
*** $p<0.001$.

Model 3 shows there is a positive, statistically significant relationship between IP managerial capability and licensing creation, thereby supporting Hypothesis 1B. Industrial partnerships, whether contract or collaborative research, has a statistically significant, positive coefficient supporting Hypothesis 2B. The statistically significant, positive coefficient associated with university entrepreneurial orientation provides support for Hypothesis 3B.

Model 5 shows there is a positive, statistically significant relationship between IP managerial capability and firm incubation, thereby supporting Hypothesis 1C. Industrial partnerships, whether contract or collaborative research, had positive, but not a statistically significant coefficient so that Hypothesis 2C is rejected. The statistically significant, positive coefficient associated with university entrepreneurship orientation provides support for Hypothesis 3C.

Models 2, 4, and 6 show the interaction effect of government research commitment and the main independent variables on innovative performance. Model 2 shows that moderated effects are important, in that accounts for 47% of the variance in patent creation (Δ adjusted $R^2=0.13$, $p<0.001$). Similarly, in Model 4 and Model 6, the moderated effect accounts for 51 and 26% of the variance in licensing creation (Δ adjusted $R^2=0.08$, $p<0.001$) and firm incubating (Δ adjusted $R^2=0.02$, $p<0.001$). It suggests that government research commitment variable acts as a meaningful moderator. Overall, the lower explanatory power of Model 5 and Model 6 clarifies the fact that not every university has an incubator facility. Moreover, universities and faculties in Taiwan tend to play the role of technical advisors without getting involved with daily operation within the tenant firms.

The interactions of IP managerial capability and government research commitment indicate that only the parameter in Model 6 reaches a statistically significant level, thereby cannot support Hypothesis 4A. The results suggest that government funding has limited influences on the university's patenting and licensing. Furthermore, the interactions of industrial partnerships and government research commitment suggest that only the parameters in Model 6 do not reach the statistically significant level, thereby conditionally supporting Hypothesis 4B. The findings imply that HEIs with substantial research links with industry and adequate governmental supports can enhance innovative performance. Overall, the interactions of academic university entrepreneurship orientation and government research commitment are associated with a statistically significant, positive coefficient, thereby supporting Hypothesis 4C. The positive signs suggest that the universities with solid innovative policies and adequate government funding do enhance their entrepreneurial performance.

5. Discussions

In the paper, internal IP managerial capability, measured by the number of full-time staff in the IP management/transfer office and incubator, has positive and statistical significant effect on licensing creation and firm incubation. However, the hypothesis that larger IP managerial capability would yield greater patent creation was not supported. These results emphasize that there is a functional heterogeneity of the organizational objectives in IP generation and exploitation. The generation of IPs is derived form the awareness and willingness of faculties. Consistent with the finding of Lehrer and Asakawa [27], technology managers and employees in TTOs or equivalent offices are being asked for the outcomes of number of licenses and royalties, with less attention been paid to patents and sponsored research agreements.

External industrial partnerships are derived from the number of contract research and collaborative research projects. The empirical results show that collaborative research can bring the HEIs more patent creation than contract research. The reason may result from the fact that most contract research is intended to solve a specific technical problem of the industrial sector bringing only short-term and limited knowledge development for industrial partners. Moreover, both research partnerships have positive and statistical significance for licensing creation, especially collaborative research that contributes more substantial economic incomes. However, they do not present significant effects in stimulating firm creation showing that incubators may play a supplementary role in providing industry technical service. Echoing the argument of Shane [7], private firms can appropriate the returns of university-generated technology through directly engagement in research development or the incorporation of the new technology in their products or services.

The university entrepreneurial orientation was measured from the extent of university policies in supporting the faculties' IP generation and exploitation. In the study, the variable was consistently positive and had statistically significant effect on three aspects of innovative performance. The empirical result is consistent with the works of prior research [8,27]. For example, Thursby and Thursby [8] found that "increased licensing is due primarily to an increased willingness of faculty and administrators to license and increased business reliance on external R&D." Similarly, Siegel et al. [28] argued "the most critical organizational factors are likely to be reward systems and compensation practices for faculty, and actions taken by administrators to extirpate informational and cultural barriers between universities and firms." Universities allocating a higher percentage of royalty payments to faculty members tend to be more efficient in technology transfer activities.

Faculty quality is believed to affect the innovative performance of universities. The empirical results show that public universities outperform private ones in patent creation and startups incubation. Public universities in Taiwan have traditionally been endowed with adequate research resource and government funding. Therefore, they have higher social legitimacy to attract more star researchers and industrial interests in incubation. This result can also be explained with the findings that higher faculty quality tends to produce greater inventions with potential viability [39,40]. Moreover, there is no significant difference for public universities with respect to licensing creation. This is consistent with the arguments of past research at western HEIs where private schools are more flexible and less bureaucratic than public schools, and should be more efficient on technology transferring [28,40].

The influence of having a medical/or engineering school may work through generating more funded research, thereby increasing the number of patent grants or the patents for licensing by the university [5,41]. The results suggest that the medical research fields (e.g., life science, biotechnology) generate patent grants and the engineering research fields (e.g., information and communication technology) generate firm incubations for a university. However, empirical results found that licensing incomes do not come naturally through a medical school or an engineering school establishment although they have the expected positive sign. Buyers are unwilling to purchase knowledge if they cannot verify its value, and sellers are unwilling to disclose the value of knowledge for fear that buyers will not pay once the knowledge is disclosed [7]. Also, having a medical school has limited effect on incubating firms although it has the expected positive sign. The startups in the engineering field are more interested in locating at a university's incubator, especially in their early development stage. The results are similar to the finding of Hsu et al. [24] who suggested that the co-location of university research and industrial R&D is pretty intensified in the field of engineering in Taiwan, which becomes a main factor in the development of an incubator facility.

Investigating the moderated effect of government research funding, the study has shown that government research commitment has the most positive impact on the relations of industrial partnership and patent creation, and less impact on the relation of IP managerial capability and patent creation. Government research funding stimulates the involvement of the industrial sector and the faculties' willingness to be involved in patent creation. Consistent with a study of Klofsten et al. [36], the use of public sector early stage investments fulfils a very important and critical role in assisting technology-based firms in building up their credibility on the market. Simultaneously, highly committed government research funding plays a critical role in facilitating TTO staffs, industrial partners, and faculty members to reach a licensing agreement. Moreover, government research funding enhances the conditions of an incubating seedbed that sustains the relationships of IPs management staffs or faculty members with startup involvements. However, government research commitment does not affect the importance of contract research and collaborative research even though incubators can provide supplementary technical services.

6. Conclusions

University-generated knowledge has been recognized as an important source of industrial innovation. Taiwanese Universities have established internal IP management capabilities, external industrial partnerships, and incentive entrepreneurial mechanisms to foster commercialization of academic research results. This study explores the new governance of academic innovation and identifies four key 'scientific–economic' aspects influencing the performance of academic innovation.

The study concludes that the proposed 'scientific–economic' framework is useful to distinguish from the university's innovation performance on patent grants, licensing incomes, and firm incubation. However, patenting is costly and thereby universities need to be more concerned about the quality of patents rather than the quantity of patents. Collaborative HEI–industry partnerships have better ability to increase patent grants and licensing incomes than what contract partnerships do. University entrepreneurship policies are the most determinant factors influencing university innovative performance, not only in patenting and licensing but also in firm incubation. However, the framework catching limited effect on firm incubation (adjusted R^2 ranges from 0.26 to 0.28) suggests that a further study needs to take other factors into consideration in the firm incubation system such as organizational and managerial capabilities of campus incubator centers. Moreover, government commitment on HEI's research remains still indispensable even towards a more scientific–economic regime of academic innovation.

Acknowledgements

The authors would like to thank Professors Yee-Yeen Chu, Shih-Chang Hung, Bou-Wen Lin, Chung-Yao Huang, Feng-Shang Wu and Dr. Shin-Horng Chen and two anonymous reviewers for their insightful comments on this paper. The financial support from APEC-STPRC, Taiwan, is gratefully acknowledged (project No: APEC-STPRC-2002-06-14-B1).

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