Universities as patent- and licensing income-generating institutions: a survey in Taiwan

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Abstract: This study examines the preliminary results of patenting and licensing activities in Taiwanese Higher Education Institutions (HEIs) from 1997 to 2001. We propose a framework to analyse the influence of a university’s internal Intellectual Property Right (IPR) management and external research partnerships on creating income through patenting and licensing. Through a postal questionnaire survey, all 122 HEIs in Taiwan were surveyed. The empirical results demonstrate that internalised IPR management capability and external research partnerships have substantially increased the amount of academic patents and licensing income. The paper reveals that the relation between external research partnership and patterns of academic licensing is moderated by industry research funding, towards more domestic and partner-oriented licensing. This has crucial policy implications for enhancing effective national triple-helix interactions.
1 Introduction

A main concern of government today is how to make best use of the academic knowledge base to foster innovation and economic competitiveness in a knowledge-based economy. Policy makers have asserted that the lag between the discovery of new knowledge at Higher Education Institutions (HEIs) and its use by companies could seriously impair a country’s economic growth. Therefore, changing the structure and function of HEIs has become a crucial task to facilitate knowledge flow into new sources of industrial innovation (Etzkowitz and Leydesdorff, 1997).

It has been acknowledged that HEIs produce numerous discoveries and inventions that show potential for commercialisation, especially in the science-based technologies. In order to reap the economic benefit, various institutional and organisational innovations have burgeoned in academies, such as the devolution of Intellectual Property Right (IPR), the establishment of technology transfer/license offices, incubator facilities, and spin-offs. Inspired by the US Bayh-Dole Act of 1980, Japan, Korea, and Taiwan enacted...
the Science and Technology Basic Law (STBL) in the late 1990s. The enactments allowed HEIs to own the patents that were generated from government research grants and removed the restrictions preventing a more decentralised licensing policy. It was expected that ownership and management of IPRs in academia would accelerate the commercialisation of new technologies and promote economic development and entrepreneurial activity.

Prior research tried to assess the impact of the Bayh-Dole Act on the changes of market-oriented research (Thursby and Thursby, 2002), academic patenting and licensing (Mowery et al., 2001), academic spin-offs (Gregorio and Shane, 2003; Shane and Stuart, 2002), and regional economy (Jaffe et al., 1993; Zucker et al., 1998). Most research supported the idea that the Bayh-Dole Act has contributed to the emergence of new high-technology firms and the high rate of growth in the US economy during the 1990s (Mowery and Ziedonis, 2002). However, previous studies focused on universities in the USA. Little research has been done to examine the preliminary results of patenting and licensing activities in the newly STBL-enacted economies. This research set out to bridge this gap by paying special attention to the academies in Taiwan.

The paper is organised as follows. The process of academic research commercialisation, the stages and supportive organisations involved in the process are discussed in Section 2.1. The evolving institutional, organisational and external partnership changes towards university research commercialisation are reviewed. Three main hypotheses and research framework are also drawn in Section 2. Questionnaire design, the survey scope and response rate measurement of variables, and statistics applied are discussed in Section 3. The results of regressions are shown in Section 4, while discussions are made and conclusions are drawn in Section 5.

## 2 Conceptual background

### 2.1 The process and supportive organisation of academic research commercialisation

Many supportive organisations are crucial in assisting academic researchers to transform their research discoveries into commercial ideas and products. In the beginning of research, academic researchers look for the sources of research funding from government, industry, and others (e.g., foreign units) to support their research. Under the support from research community and practitioners, academic researchers have increasingly gained a great impetus to protect their research discovery via invention disclosure in the beginning (Mowery and Ziedonis, 2002). Once the academic inventions have proven their novelty, originality and commercial value, academic researchers may pursue formal and legal way to protect their inventions, mostly in the form of patent.

However, applying for a patent is never costless. In the patent application stage, academic researchers may get some patent application subsidy from universities through the approval of the university patent committee. The committee will evaluate the quality and potential market value of patent application. For the case of university-subsidised patent application, generally speaking, the assignees of the patents will go to universities. Some universities outsource the works of patent application to external IPR agents to deal with governmental patent offices such as US Patent Office (USPTO), Europe Patent Offices (EPO), Taiwan Intellectual Property Office (TIPO). Generally speaking, it takes
one to two years from patent application to patent approval and the patent examination time varies by cases and countries. Consequently, there is a time delay effect between patent application and patent approval.

Subsequently, some firms and organisations may find academic patents useful for their new product/process development. Then they may be interested in getting licensing from academic patent owners. Academic patent owners often hand over the administrative and legal issues of licensing to the Technology Transfer Office (TTO), Technology Licensing Office (TLO) at campus rather than on their own. In some occasions, universities may invest their own venture funds by exploiting faculty patents with a promising market potential.

Figure 1 The process and supportive organisations involved in academic research commercialization

<table>
<thead>
<tr>
<th>Research commercialised process</th>
<th>Supportive organisations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sources of research funding</td>
<td>Governments, industry and others</td>
</tr>
<tr>
<td>Academic research discovery</td>
<td>Research community and practices</td>
</tr>
<tr>
<td>Invention disclosure</td>
<td>University patent committees and patent offices</td>
</tr>
<tr>
<td>Patent application</td>
<td>IP agencies, Governmental Patent offices (e.g., TIPO, USPTO)</td>
</tr>
<tr>
<td>Patent approval</td>
<td>University technology transfer offices</td>
</tr>
<tr>
<td>Spin-offs</td>
<td>University venture funds</td>
</tr>
<tr>
<td>Licensed</td>
<td>Domestic licensing vs. foreign licensing</td>
</tr>
<tr>
<td></td>
<td>Cooperator/Sponsor licensing vs. others licensing</td>
</tr>
</tbody>
</table>
Regarding the patterns of academic licensing, most academic research is funded by governmental research funding agencies such as the National Science Council, Ministry of Economic Affairs in Taiwan. Taiwanese government tends to encourage university faculty to do domestic licensing rather than foreign licensing in order to support indigenous technological development (NSC, 2002). Besides, a cooperator or sponsor of the academic-based discovery, firms or nonprofit organisations may have better positions to evaluate more precisely the academic partner technology and eventually becomes its licensee (Thursby and Thursby, 2002). Prior research has shown that research scientists without entrepreneurial training and experience, while competent to be the initial technology champion, are often not well suited as entrepreneurs (Gregorio and Shane, 2003; Zucker et al., 1998). In order to maintain an organisational momentum, senior faculties in a venturing team are typically compelled to remove themselves from the bench to devote virtually full time to entrepreneurial tasks (Etzkowitz, 2003). Finally, a comprehensive process and supportive organisations of academic-based discovery commercialisation are shown in Figure 1.

2.2 Towards a new HEI regime

Traditionally, HEIs are asked to fulfil the responsibility of education, training, and fundamental research. Recently, the HEIs have experienced funding cuts or maintained status quo in terms of national or regional government sources, especially in Europe (Geuna, 1999). This also has motivated Taiwanese HEIs since 1999 to diversify their funding sources to replace the declining funding share from government (Table 1). It is worth noting that HEIs received a significant increase of funding from non-profit R&D organisations (e.g., Industrial Technology Research Institute) after the STBL was enacted. Moreover, with the establishment of an incentive and subsidy system in HEIs, faculty members engaged more frequently in disclosing, protecting, and commercialising their intellectual capital into material forms, such as patents and licenses (Table 2).

<table>
<thead>
<tr>
<th>Year</th>
<th>1997</th>
<th>1998</th>
<th>1999</th>
<th>2000</th>
<th>2001</th>
</tr>
</thead>
<tbody>
<tr>
<td>Industry (Million NTS) (A)</td>
<td>448</td>
<td>596</td>
<td>1048</td>
<td>916</td>
<td>744</td>
</tr>
<tr>
<td>Percentage (%) (A/D)</td>
<td>2.4</td>
<td>2.8</td>
<td>4.7</td>
<td>3.9</td>
<td>2.9</td>
</tr>
<tr>
<td>Government (Million NTS) (B)</td>
<td>17,351</td>
<td>20,244</td>
<td>19,075</td>
<td>20,483</td>
<td>21,705</td>
</tr>
<tr>
<td>Percentage (%) (B/D)</td>
<td>94.7</td>
<td>95.1</td>
<td>85.9</td>
<td>86.3</td>
<td>85.8</td>
</tr>
<tr>
<td>Others* (C)</td>
<td>529</td>
<td>451</td>
<td>2081</td>
<td>2340</td>
<td>2843</td>
</tr>
<tr>
<td>Percentage (%) (C/D)</td>
<td>2.9</td>
<td>2.1</td>
<td>9.4</td>
<td>9.9</td>
<td>11.3</td>
</tr>
<tr>
<td>Total (Million NTS) (D)</td>
<td>18,328</td>
<td>21,291</td>
<td>22,204</td>
<td>23,740</td>
<td>25,292</td>
</tr>
</tbody>
</table>

Note: Others could be non-profit R&D organisations and foreign organisations.

Source: The series of Indicators of Science and Technology from 1998–2002
Table 2  Patenting and licensing activities recorded in HEIs (1997–2001)\(^a\)

<table>
<thead>
<tr>
<th>Year</th>
<th>Patent applied</th>
<th>Patent issued</th>
<th>Licensing</th>
</tr>
</thead>
<tbody>
<tr>
<td>1997</td>
<td>223</td>
<td>n/a</td>
<td>16</td>
</tr>
<tr>
<td>1998</td>
<td>215</td>
<td>178</td>
<td>10</td>
</tr>
<tr>
<td>1999</td>
<td>199</td>
<td>213</td>
<td>14</td>
</tr>
<tr>
<td>2000</td>
<td>283</td>
<td>193</td>
<td>28</td>
</tr>
<tr>
<td>2001</td>
<td>89</td>
<td>267</td>
<td>32</td>
</tr>
<tr>
<td>Total</td>
<td>1009</td>
<td>851</td>
<td>100</td>
</tr>
</tbody>
</table>

Notes:  
\(^a\) The government account calendar was adjusted in the year 2000. The year 2000 includes the second half of 1999, while the year 2001 presents the first half of year 2001.  
\(^b\) The data is collected from the series of National Science Council Annual Review from 1998 to 2002.

Sociologists of science had analysed the social functions of universities and identified that functions have shifted from scholar training and theoretical development, the endless knowledge frontier and application relevance, to wealth creation (Etzkowitz and Leydesdorff, 1997). HEIs now play a tangled role intertwined with teaching, research, service, and innovation. The knowledge-generating process of universities is becoming interdisciplinary, cross-institutional, and application-oriented in nature (Gibbons et al., 1994). The study of McKelvey (1997) suggests that the changing role of universities in knowledge-seeking activities is moving from a scientific-government environment, or basic scientific environment, to a scientific-economic environment.

Industrial economists attempted to adopt the ‘market-oriented’ model to analyse HEIs. The market model regards academies as one of the major actors in the process of economic development. Therefore, HEIs not only have to reflect the scientific and technological needs of the society, but also have to cooperate with firms by becoming the suppliers of an applied knowledge that can be readily transformed into innovation (Geuna, 1999). Furthermore, the market model urges that the government should not be the only sponsor of HEIs. Universities are encouraged to actively search for funding from different sources in the competitive contract research and technology market (Howells, 1999). Therefore, it has become crucial for HEIs to demonstrate the social and economic benefits of their research in order to compete for diversified sources of funding.

2.3  The establishment of IPR management infrastructure

Many governments now devolve IPRs derived from government-funded research to HEIs on the assumption that the technology development gap can be filled. Some science and technology (S&T) policy researchers claim to have adopted a ‘new public management’ that increases the efficiency of the HEIs’ operation and economic effectiveness (Cox et al., 1999). Consequently, many universities have established internal IPR management infrastructure to file patents and to deal with licensing agreements of third parties (Mowery et al., 2001; Henderson et al., 1998).
During the pre-STBL period, the National Science Council (NSC) was the sole government agency claiming IPRs on behalf of HEIs in Taiwan. The passage of the STBL in 1999 laid out the fundamental principles and directions for the country’s technological development. Specifically, Article 6 allowed universities and research institutes to fully or partially claim and commercialise the titles of IPRs derived from government-funded research. The Guidelines for Ownership and Utilisation of S&T Research and Development Result of 2000 further specified that the share of licensing revenues among implementing institutes, inventors, and government funding agencies be distributed in the amount of 40%, 40% and 20% respectively.

In order to encourage HEIs to get involved in patenting activities, the NSC implemented the Subsidy Principles of Management and Promotion of Academia R&D Results in 2002. With the financial support of $NT27.9 million from the NSC, nine universities and the Academia Sinica have established IPR or technology transfer offices since 1999 including National Taiwan University, National Chiao-Tung University, National Tsing-Hua University, Feng-Chia University and Kaohsiung Medical University. The Subsidy Principles reimburse HEIs 80% of the patent application and maintenance fees.

We argue that the open environmental space in the early days of the burgeoning entrepreneurial HEIs provided the opportunity for HEIs to adjust organisational structure and functions that proved beneficial for economic creation, and assisted faculty members in the disclosure and protection of research results. A direct consequence of policies that grant universities titles to inventions and requirements for disclosure and exploitation has been the creation of the TTO or equivalent offices that file patents and deal with licensing agreements of third parties. Thus:

**Hypothesis 1A** The internal IPR managerial capacity is positively associated with the HEI’s patent creation.

**Hypothesis 1B** The internal IPR managerial capacity is positively associated with the HEI’s licensing income creation.

### 2.4 The establishment of university-industry research partnerships

The shifting function of universities towards economic creation has caused the distinct blurring of institutional boundaries to be replaced by a network of linkages with other actors. Furthermore, due to the complexity of scientific advancement and technology development, equipment and facilities are usually too expensive for any single party to afford (Druilhe and Garnsey, 2001). In responding to these transformations, the university-industry interaction orientation has changed from a previous arm’s-length, short-term, informal transaction to an institutional, long-term, and formal partnership orientation (Geisler and Rubenstein, 1989).

The main purpose of university-industry collaboration is to pursue economic returns that cannot be attained by a single party. Etzkowitz (2003) suggests that academia has become entrepreneurial in its inner dynamic as well as in its external connections with business firms for research contracts and transfer of knowledge and technology.
The motives of the university-industry links from the HEI perspective are different from those of industries outside the university. Moreover, the motives for corresponding to a particular market environment are slightly distinct. The reasons that British universities become involved in university-industry links are:

- accessing industrial funding
- conforming to the requirements of university policy
- exploiting research capabilities
- contributing to the local economy
- accessing complementary expertise (Howells et al., 1998).

However, the Taiwanese universities involved in industry-university links intend to commercialise university research, participate in the real world, access industrial funds, provide students with employment opportunities, and access equipment and facilities (Wu, 2000).

Two main perspectives concerning university-industry collaboration mechanisms can be found in prior research. The first approach is based on the configuration of collaboration, in that five formal collaboration mechanisms are identified as:

1. Short-term contract research – academia provides consultation and training programmes and industry offers research sponsorship
2. Long-term collaborative research – academia and industry jointly operate research equipment and facilities
3. Research venturing – academia and industry set up a cooperative platform, drawing together research groups from firms and universities to address interdisciplinary problems, i.e., research centres, research consortia or spin-offs
4. Intermediary services – academia sets up an IPR authority, i.e., the TTO is established to provide industry with technical services and patent licensing
5. Physical infrastructure – industry and academia set up a research or science park (Howells et al., 1998; Stankiewicz, 1986).

The second approach is focused on research flow in that four HEI-industry collaboration mechanisms can be classified as:

1. Part-time staffs transfer – faculty member offers on-plant research/experiment, education and training within a firm
2. University equity holdings, i.e., a university takes an equity interest in a company in exchange for providing the company the right to use university IPRs
3. Industry commercialises university-generated research results

Not only do university-industry links augment research capacity that is beneficial for patent creation, but also HEIs play an assistant role in promoting the firms’ legitimacy. Several studies indicate that budding firms attempted to enhance their legitimacy by identifying themselves with elite research universities (Radosevich, 1995).
Firms engaged in university-industry collaborations can incorporate the skills and knowledge needed into academic curricula; therefore, the legitimacy of the firms and the technologies is heightened. Moreover, firms that cooperate with HEIs capitalise on their advantages in low-cost and flexible production (Feldman et al., 2002).

Despite the rising importance of HEIs as a source of industrial innovation, the linkages between university-industry cooperation and their contributions to national economies are not well understood. The transition to less dependence upon government funding support will drive the HEIs’ relationship with industry to be more like a business partnership that seeks out the industrial potential of research. This paper argues that the establishment of university-industry collaborations broadens the HEIs’ participations in the fields of applied technology, and the economic potentials of near-market technology brings the HEIs more licensing income. Thus, we hypothesise:

**Hypothesis 2A** The external research partnership strength is positively associated with the HEI’s patent creation.

**Hypothesis 2B** The external research partnership strength is positively associated with the HEI’s licensing income creation.

### 2.5 Pattern of academic licensing

Once the patent has been awarded, the HEI may focus on identifying, negotiating, and marketing the IPR with potential licensees. However, the external partners and sponsors of academic research (e.g., governments, industry, and non-profit organisations) may affect and constrain the HEI’s licensing decision. The relation between sources of research funding and patterns of licensing also was illustrated in the Figure 1. The resource dependence theory points out that no organisation is self-sufficient and the need to acquire resources in order to develop its activities creates dependence between the organisation and a number of external actors (Pfeffer and Salancik, 1978). The nature and extent of this dependence is determined by the volume of the resources required for what constitutes the core activity of the institute and by the relative abundance of these resources (Sanz-Menéndez and Cruz-Castrol, 2003). According to recent statistics, the share of industry research funding to total research funding has been steadily enhanced for academic institutions in Taiwan (NSC, 2002). We expect that industry funding will play a crucial role in determining the development and utilisation of academic research portfolios.

The other sociological perspective builds on the network theory – specifically, the influence of social networks on organisational activities. Fundamental to this perspective is the notion that an organisation’s economic actions are embedded in social networks, where the embeddedness refers to the extent that economic actions are informed, influenced, and enabled by the network of accumulated stable and preferential social relations (Granovetter, 1985). The triple helix regime modelled from the relations of university – industry-government explains that university, industry, and government are the important actors in research networks. There is a new balance between structural integration and functional differentiation in which university, industry, and government are relatively autonomous but overlapping, with each taking the
role of the other (Etzkowitz and Leydesdorff, 1997; Etzkowitz, 2002). The research networks of university, industry, and government tend to alter the pattern of academic research activities.

As institutional reforms tend to stimulate collaborative research between university and industry, the enactment of the STBL empowers the HEIs to make decisions on licensing and licensee according to their own judgment. We argue that university-industry links provide the industrial partner the priority to acquire the license they demand. Ownership of the patented invention remains with the HEI while the firm funding the research retains the right (or option) to license the patent on a precedent basis. Thus, we hypothesise:

**Hypothesis 3A**  Industry research funding positively moderates the external research partnership strength on the HEI’s cooperator/sponsor licensing.

The critical role that HEIs play in regional economies has been observed since the 1990s. Collective learning in regional development is similar to the concept of knowledge sharing in industry networks referring to the ability to exchange, assemble, integrate, and deploy knowledge across organisational boundaries.

Results from the current knowledge spillover research show that the innovative activities of businesses tend to occur in the proximity of research institutes. Jaffe et al. (1993) investigated the citations of university patents and found that citations tended to come from localised firms as evidence of the extent to which knowledge spillovers are geographically localised. Zucker et al. (1998) stated that a connection exists between intellectual human capital created by frontier research and the founding of firms in high-tech industry. The regional impact of research institutes depend on whether these institutions can provide complementary knowledge input to the internal innovation efforts of businesses (Henderson et al., 1998).

Under the development of a knowledge-based economy, the academia, especially research universities, are being asked to be responsible actors for regional economic development and employment creation (Diez, 2000; Chrisman et al., 1995). The OECD survey shows that European public research institutions tended to file most of their patents in their home country and that fewer academic patents were filed at the European level or overseas (OECD, 2003). Furthermore, the MOEA enacted the S&T Research Development Project Plan of 1990 that required that research results generated from university-industry cooperations should be directed to the local market. Once the HEIs are integrated into the regional economy as one of the key drivers, we expect that the academic licensee tends to be domestic rather than foreign. Moreover, the higher cost and insufficient understanding of foreign patent application also limits the geographical scope of academic licensees. Thus:

**Hypothesis 3B**  Industry research funding positively moderates the external research partnership strength on the HEI’s domestic licensing.

In Figure 1, we have illustrated the important roles of university IPR management offices, venture funds, and related research funding providers in supporting the process of academia-based discovery commercialisation. Therefore, we suggest that the internal IPR managerial capacity and external research partnership have positive impacts on university
patent creation and license income creation. Moreover, the extent of the research funding from local industrial partners can shape the patterns of technology transfer and formation of industrial clusters, via domestic and partner and sponsor licensing. The conceptual framework of the paper is shown in Figure 2.

**Figure 2** The influence of internal IPR management and external research partnership on HEI’s patenting and licensing: a conceptual framework

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### 3 Methodology

#### 3.1 Questionnaire design

We developed a questionnaire based on previous research to test our hypothesis. The contents of the questionnaire consisted of four parts:

1. IPR management infrastructure
2. Industrial funding
3. University-industry research linkages
4. Patenting and licensing activities in HEIs.

Some questions in the survey were adapted from Howells et al. (1998) and Bordt and Read (1999).

The questionnaire was pre-tested with IPR administrators in ten different HEIs by mail and respondents were interviewed to clarify questions on the instrument. Based on the feedback from the pre-test, we modified the questionnaire to clarify and improve understanding of the questions that were difficult to understand or interpret.

#### 3.2 Survey scope and response rate

Since this research focused on the study of the economic potential embodied in Taiwanese HEIs, we used universities and colleges listed in the Directory of Higher Education Institutions, Ministry of Education. Due to the inconsistent use of academic IPR authorities by universities in the developing stage, telephone inquiries were done in order to construct a complete survey list. Ultimately, 122 HEIs including 56 universities and 66 colleges were surveyed. The questionnaires were addressed to the director/chief of R&D offices or of technological cooperative offices in HEIs.
Three waves of the surveys were delivered and four investigators were designated for follow up. In order to reduce non-respondent bias and to increase 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 completed through telephone interviews and e-mail contacts. Ultimately, 60 questionnaires were received; two were non-useable and 58 were valid. The overall response rate of the survey was 48%.

This study used the alpha coefficient promoted by Cronbach to evaluate the reliability of the questionnaire. The Alpha coefficient ranged from 0.79 for collaborative research centres to 0.86 for co-research projects, showing that the questionnaire is reliable.

3.3 Analysis on data

This research deployed the main technology protection and utilisation of HEIs between 1997 and 2001. Since the technology is still in its early stage of development, Taiwanese HEIs generally did not operate spinoffs or startups. We focused on patenting and licensing in the process of academic-based technology commercialisation. The approaches of internal and external technology networks were evaluated to gather data on their effects on technology protection and utilisation. To better evaluate the level of internal IPR management, this research used the size of the IPR infrastructure as proxy to the IPR management capacity. Even though the types of university-industry research partnership were clarified earlier, the research omitted the research consortium link since the mechanism is rarely used in Taiwanese academies. The detailed operational definition of the investigated variables is as follows:

- **Patent creation**
  
  The application of research results is often regarded in terms of how HEIs embody and utilise their knowledge base (Howells, 1999; Bordt and Read, 1999; Siegel et al., 2003). Patent grant is the primary concern because this is the category of IPRs that has been the target of the most recent policy reforms aimed at fostering greater commercialisation by HEIs. The number of domestic and foreign patent grants was calculated as the first dependent variable.

- **Pattern of academic license**
  
  Based on the identity of the licensee, the patterns of academic licenses were subdivided into cooperator/sponsor licenses and domestic licenses respectively. Moreover, the number of cooperator/sponsor licenses and the number of domestic licenses was calculated as the measurements in the sample period. It is necessary to note that the patent number and the license number could vary in a specific period of time. This delay effect can be found in Table 2 where the number of patent grants was 213 in 1999, which is more than 199, the number of patent application in 1999. This is due to the fact that the patents granted 1999 could have been for applications in 1997, 1998, 1999 or even earlier. Additionally, not all patents turned out being licensed. On average, about 10% of academic patents were licensed during 1998–2001.
Licensing income creation

Prior research has evaluated academic-based technology commercialisation through the performance of licensing income (Mowery et al., 2001; Henderson et al., 1998). Specifically in Taiwan, licensing incomes and royalties are the most common ways for the faculty members to exploit their research results (Sanz-Menéndez and Cruz-Castrol, 2003). Therefore, licensing incomes and royalties are used as a proxy for technology commercialisation of Taiwanese HEIs. The data measured by the natural logarithm of license incomes and royalties was calculated as the second dependent variable.

Internal IPR management

Internal IPR management is measured in terms of the size of the TTO or equivalent technology transferring office in the sample period. Here the number of full-time employees is calculated as the size of the IPR infrastructure, representative of the IPR management capacity.

External research partnership

The research measured the major university-industry research links in Taiwan including contract research, co-research projects, and research centre engagement. The number of each partnership was calculated as the measurement in the sample period.

Industry funding

The value of research funds, research equipment and facility donations received from the industrial sector was collected and calculated by the natural logarithm, representative of the level of industrial interference.

Control variables

In considering the influence of organisational practices on the performance of TTOs, the presence of a medical school may be a crucial organisational factor (Siegel et al., 2003). We also argue that the presence of a business school may help HEIs in evaluating the potential value of research results. Here a dummy variable was used represented as ‘1’ if a HEI owned the specific school; and ‘0’ if it did not.

HEI ownership

The ownership status of the HEI may affect organisational entrepreneurial behaviours (Siegel et al., 2003). Here a dummy variable was used represented as ‘1’ if the HEI was a state-owned HEI; and ‘0’ if the HEI was a private HEI.

HEI type

HEI type is defined by a dummy variable coded ‘1’ for universities (including institutes of technology) and ‘0’ for colleges.

OLS regression was used so that we could model the factors influencing the creation of income from licensing and granting of patent. Additionally, we used industrial funding as a moderator to test the effect of external research partnerships on the pattern of academic license.
4 Results

The average, standard deviation, and correlation coefficient for each variable in a three-year period are shown in Table 3. The table shows that the average natural logarithm of licensing income was 1.22 roughly equal to $NT 377 thousand. The average case of a patent grant was 2.14, and the average person in an IPR management infrastructure was 2.86. Also, the average number of contract research, co-research projects, and research centres was 4.45, 4.76, and 0.74 respectively. The average natural logarithm of industry funding was 12.67 roughly equal to $NT 9,336. The average number of cooperator license and the average number of domestic license was 0.17 and 0.37, respectively.

The results of a modified Kolmogorov-Smirnov Goodness-of-Fit test supported the validity of the univariate normality assumption. The variables of IPR management, contract research, co-research projects, and research centres were significantly correlated with licensing income creation (p < 0.05). The variables of IPR management, co-research projects, and research centres were significantly correlated with patent creation (p < 0.05). Moreover, the establishment of a medical school was significantly correlated with licensing income creation (p < 0.01). The source of research funding from the industry sector was significantly correlated with licensing income creation and patent creation (p < 0.01). The state-owned HEI was significantly correlated with licensing income creation (p < 0.05), while the university-type HEIs were significantly correlated with licensing income creation and patent creation (p < 0.01).

In testing Hypotheses 1 and 2, we regressed the management capacity of the IPR management, university-industry links, licensing income creation, and patent creation while adding control variables. Variance Inflation Factors (VIF) for all the models were within acceptable parameters (VIF < 1.76); thus, suggesting no problem of multicollinearity. Table 4 provides the standardised regression results. The regression results show that the management capacity of the IPR management had a positive and significant impact on HEIs’ licensing income creation and patent creation before (Model 1: $\beta$ = 0.19, p < 0.01; Model 4: $\beta$ = 0.11, p < 0.05) and after the entry of control variables (Model 2: $\beta$ = 0.21, p < 0.01; Model 3: $\beta$ = 0.17, p < 0.01; Model 5: $\beta$ = 0.08, p < 0.10; Model 6: $\beta$ = 0.07, p < 0.10). Hypotheses 1A and 1B are thus supported.

We then examined the impact of university-industry partnerships on licensing income creation and patent creation. Model 3 shows that research partnerships were more important to enhance licensing income creation ($F = 22.67$, adjusted $R^2 = 0.68$) than in Model 2 ($F = 18.95$, adjusted $R^2 = 0.60$). Co-research projects and research centre involvement have significantly positive influences on the creation of licensing income ($\beta$ = 0.14 and 0.30, respectively, p < 0.05). Contract research shows positive and insignificant influence on the creation of licensing income ($\beta$ = 0.03). Moreover, Model 6 shows that university-industry partnerships were more important to enhance patent creation ($F = 18.86$, adjusted $R^2 = 0.58$) than in Model 5 ($F = 9.65$, adjusted $R^2 = 0.35$). Co-research projects and research centre involvement have a significantly positive influence on patent creation ($\beta$ = 0.14 and 0.46 respectively, p < 0.05). Again, contract research shows positive and insignificant influence on creation of patent grants ($\beta$ = 0.06). These findings imply that HEIs with substantial research partnerships with industry create more opportunities for licensing and patenting. Hypotheses 2A and 2B are thus supported.
<table>
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<th>Variable</th>
<th>Mean</th>
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<td>0.05</td>
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<tr>
<td>5. Co-research project</td>
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<td>0.18*</td>
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<td>0.46***</td>
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<td>7. Medical school</td>
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<td>0.24**</td>
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<td>0.09</td>
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<td>9. Industry funding</td>
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<td>0.20*</td>
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<td>0.01</td>
<td>0.58***</td>
<td>0.57***</td>
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<td>12. Cooperator licensing</td>
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<td>0.16*</td>
<td>0.04</td>
<td>0.03</td>
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<td>0.12</td>
<td>-0.02</td>
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<td>13. Domestic licensing</td>
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<td>0.02</td>
<td>0.29**</td>
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<td>-0.01</td>
<td>0.01</td>
<td>0.01</td>
<td>0.51***</td>
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</table>

Notes: *N = 174 (58 cases multiplied by three periods)
* p < 0.05
** p < 0.01
*** p < 0.001
Table 4 Effects of IPR management and U-I links on economic creationa

<table>
<thead>
<tr>
<th>Variable</th>
<th>Licensing income creation</th>
<th>Patent creation</th>
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<tbody>
<tr>
<td></td>
<td>Model 1</td>
<td>Model 2</td>
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<td>Internal IPR management</td>
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<td>External partnership</td>
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<td>Research center</td>
<td>0.30***</td>
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<td>Controls variables</td>
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<td>Medical school</td>
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<td>Industry funding</td>
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<td>Model F</td>
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<td>Model $d f$</td>
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</table>

Notes: aFor all models, N = 174 (58 cases multiple by three periods), standardised coefficients are shown.
+ $p < 0.10$
* $p < 0.05$
** $p < 0.01$
*** $p < 0.001$

Concerning Hypotheses 3A and 3B, Table 5 reveals the influence of the university-industry partnerships on cooperator licenses and on domestic licenses. Model 1 suggests that university-industry partnerships have a positive and insignificant influence on cooperator/sponsor licenses. However, the interactions of industry research funding and contract research or research centre participation had a significantly positive impact on cooperator/sponsor licenses (Model 2: $F = 8.24$, $p < 0.05$), thus partially supporting Hypothesis 3A. Similarly, Model 3 suggests that all university-industry partnerships have a positive influence on domestic licenses, especially with the co-research project effect which was significant ($\beta = 0.71$, $p < 0.001$). Moreover, the interaction of industry research funding and co-research project had a significantly positive impact on domestic licenses (Model 4: $F = 17.92$, $p < 0.01$), thus partially supporting Hypothesis 3B.
5 Discussions and conclusions

The economic creation of HEIs has tended to be neglected and underestimated in the past. Although the idea that economic potential embodied in internalised IPR management and external research partnerships is hardly controversial, few scholars have taken on the challenge. This study, an initial step in this direction, indicates that the internal IPR management and external research partnerships of HEIs have increased since the passage of the STBL in 1999. The positive impacts on licensing income creation and patent creation through the commercialisation of research results support that HEIs are playing the more ‘scientific-economic’ role.

The establishment of IPR management authorities such as the TTO, Intellectual Property Offices (IPO), and TLO in HEIs is gradually being internalised and centralised. Not only do the establishment of IPR executive agencies, but also the organisational functions in technology transfer and licensing facilitate the utilisation of research results effectively and efficiently. The empirical results support the assumption that economic creation from the relevant IPR management infrastructures in HEIs were quite substantially.

More importantly, the development of IPR management and exploitation is no longer the privilege of some elite universities. Consistent with the condition of the US HEIs (Shane and Stuart, 2002; Siegel et al., 2003), the state-owned universities have no significant ability to create licensing income. Partially in contradiction to findings in the US HEIs (Siegel et al., 2003), the state-owned universities in Taiwan have a better research capacity to accomplish patent creation. The reason may result from the
allocation of Taiwan government funding which historically has tended to be concentrated in state-owned universities. And the reputation of state-owned universities is relatively attractive to star scientists. However, bureaucratic culture and organisational structure hinder the development of entrepreneurship. Furthermore, the study shows that HEIs that own medical or business schools have a greater chance to exploit the economic potential of intellectual capital, even without considering collaborative research links with the industry. Additionally, the HEI-type has a limited impact on economic creation. These findings suggest that HEIs should first look inward and build up a favourable organisational structure before they can become viable. With the establishment of a market-oriented regime, the research linkages to industrial partners can produce more complementary and valuable resources in research and economic returns.

The enactment of the STBL act as a catalyst for Taiwanese HEIs to conduct technology commercialisation and create economic benefits, and for industries to engage in high-risk venturing. The institutional environment in the post-STBL period has built up a preliminary cooperative platform that facilitates and supports research partnerships between university and industry. Achieving the legitimacy of IPR exploitation and infrastructure build-up, most Taiwanese HEIs now actively establish a reward system to encourage their faculty members to disclose, protect and exploit their inventions. Therefore, the traditional evaluation of faculty member based on research and publication needs to be reconsidered toward the efforts of patent application and research result protection. However, the expenditures of patent application and maintenance can be a heavy burden for HEIs. The accompanying challenge is how effectively the HEI manages its IPRs.

The most common university-industry partnership mechanism in Taiwan is contract research (84% of universities are very active here) followed by co-research projects (78%) and research centres (21%). The empirical results show that co-research projects and research centres bring HEIs higher licensing income and patent creation than those resulting from contract research. The reason can be traced to the fact that most contract research are intended to solve specific technical problems, which simply bring short-term and near-market research for HEIs. Similarly, the mission delegated to industrial partners limits knowledge diffusion in HEIs such as time delay for publication.

Moreover, the university-industry partnership alone cannot explain the licensing pattern in HEIs. The interaction effects of industry research funding and university-industry partnerships support the view that the level of industry research funding would moderate the patterns of academic licenses. Contract research in HEIs and a research centre’s involvement with high-industry research funding indeed create more licensing opportunities for their cooperators/sponsors. Most industrial research funding come from domestic firms that enable HEIs to create more domestic licenses from their co-research project. Therefore, the more industrial funding accumulated in a HEI, the more cooperator/sponsor and domestic licenses can be expected.

It may be too soon to jump into conclusion that the research partnerships between universities and industry alter or deter the base of fundamental research. However, the empirical results do suggest that research partnerships with a higher input of industry funding tend to enforce HEIs offering of more cooperator/sponsor licenses and domestic licenses. Therefore, the government policy makers need to be more aware of the trade-offs of cutting government research funding. We argue that the moderate decrease in government research funding drives the HEIs to cooperate more with other economic actors and enlarge the extent of research application on overall technology development.
and social welfare. However, the excessive shortage of government funding may incur an imbalance in public and private interests that put the national knowledge repository in jeopardy.

The study has expanded previous work on the link connecting institutional IPR management and economic potential to research networks of university, industry, and government. It highlights both internal and external technological ties as beneficial. In particular, the micro-macro link allows HEIs to conceptualise the opportunities in the pursuit of their social and economic goals. Moreover, it helps policy makers to realise the new balance of triple-helix interactions among university, industry, and government.

Acknowledgement

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