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Factors of university–industry collaboration affecting university innovation performance

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Abstract   The rapid development of technology and knowledge-based economies has drawn attention to the linkage between academic institutions and private industries. Universities are a major source of knowledge creation; different industries are increasingly recognizing the importance of scientific knowledge creation and seeking alliances with universities to not only enhance their knowledge base but also gain a competitive advantage. To facilitate university–industry collaborations (UICs), financial support from governments and industries is necessary for resource allocation. This study investigates the effects of UIC funding on universities' technology innovation performance in Taiwan. The Taiwanese government has implemented a variety of policies and programs to enhance the research innovation capability of universities and bridge the gap between academic research and industrial application. Three fundamental factors of UIC environments within universities—namely, management mechanism, innovation climate, and reward system— are identified as critical antecedents of UIC funding and universities' technology innovation performance. The results reveal that UIC funding is directly instrumental to universities' technology innovation. The UIC management mechanism and innovation climate within universities support diverse UIC funding. In addition, mechanism incentives affect directly and moderately university researchers' involvement in and contribution to technology innovation.

Keywords   University–industry collaboration · UIC funding · Universities' technology innovation performance · UIC management mechanism · Universities' innovative climate · UIC reward

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1 Introduction

With the rapid development of knowledge-based economies, universities have become a crucial source of knowledge flow in national innovation systems (Hu and Mathews 2009); they provide vital infrastructure for scientific research and the accomplishment of technology innovation (Nelson 1993). In addition to academic research quality, the concept of an "entrepreneurial university" is emphasized to facilitate the commercialization of universities' technology innovation (Rothaermel et al. 2007). Private companies in various industries have increasingly recognized the importance of scientific knowledge creation and technological opportunities, seeking alliances with universities to enhance their knowledge base and competitive advantage in specific areas (Hewitt-Dundas 2013; Perkmann et al. 2011). Consequently, universities have reinforced their industry collaborations with firm sponsors and created strategic advantages in technology diffusion processes (Chen et al. 2013; Kim 2013). Therefore, universities' involvement with industries is critical for the development of industries' technological capabilities (Boardman 2009). Several studies have indicated that university–industry collaborations (UICs) contribute to firms' technological performance by providing technology licensing and more patents of higher quality. For example, Mindruta (2013) argued that UICs promote innovative product development and considerable sales growth in the market. Guerrero et al. (2014) identified three types of UIC outcomes in terms of human capital, knowledge capital, and entrepreneurship capital, all of which promote technological growth and contribute to economic value.

Because of the influence of commercialized academic research results on nationwide technology innovation, governments have formulated subsidy policies to facilitate opportunities for UICs and encourage knowledge transfer from universities to industries (Van Looy et al. 2004). To facilitate universities' scientific research and its industrial application, the government should provide financial support for research projects to ensure the allocation of necessary resources. An increasing portion of research funding from private industries has enabled universities to meet their financial needs (Kaymaz and Eryiğit 2011). Governments attempt to establish a close "triple helix" relationship with universities and industries in terms of funding allocation and legislation (Etzkowitz and Leydesdorff 2000) by increasing innovation-related benefits for both industries and institutions of higher education (Mowery 2011). In recent years, university–industry interactions have also reflected a proliferation of government and industrial funding for research activities. Generally, government funding is allocated on a research-oriented basis, whereas a mission-oriented and contract-based approach has been adopted for the strategic allocation of industrial funding.

The 2013 World Academic Summit Innovation Index, released by *Times Higher Education*, indicated that university-based scientific researchers from many Asian nations including Korea, Singapore, Taiwan, China, and India were attracting substantially more industry funding per researcher than their American counterparts. Similarly, Taiwanese government has guaranteed increased science and technology funding because scientific and technological innovations are crucial for national competitiveness. The government's nationwide R&D expenditure has increased steadily from NT$331.8 billion in 2007 to NT$483.5 billion in 2014. R&D expenditure, as a percentage of GDP, increased steadily from 2.47% in 2007 to 3.00% in 2014. Several government agencies such as the Ministry of Education (MOE), Ministry of Science and Technology (MOSTO), and Ministry of Economic Affairs (MOEA) have actively promoted UICs. It is expected that R&D capabilities in universities

will improve the quality and quantity of industrial innovation, increase the practical value of academic research, and enhance business and national competitiveness (Ho et al. 2016; Huang and Chen 2016).

Moreover, in Taiwan, diverse sources of governmental funding have developed various strategies to support UIC activities. For example, MOE focuses on specific educational issues such as the implementation of remedial instruction or the Higher Education Sprout Project to reinforce university quality standards and enhance international competitiveness. UIC in MOE projects aims to establish a learning environment that links students, academia, and industries. Moreover, the MOST and MOEA require early participation and specific commitments from industries and universities, including industrial funding support and revenue allocation agreements before providing public funding for these projects. Because of regulations imposed by the Taiwanese Government, the obligations and expenditure of UIC funding are controlled to allocate resources and sustain innovation performance.

This study examines the relationship between UIC funding and universities' technology innovation in Taiwan. Although various studies have explored the funding sources for UICs, few studies have examined the organizational factors that facilitate UIC funding and the role of UIC rewards in universities' technology innovation in the Taiwanese context. Because funding is imperative to universities, the present study endeavors to integrate the governmental and industrial sources of UIC funding to investigate its effects on universities' technology innovation performance. In this study, UIC is evaluated from the viewpoint of universities. Two concerns are addressed to examine the aforementioned effect and to identify the fundamental factors that might explain the extent of UIC funding.

2 Theoretical background and hypotheses

2.1 Universities' technology innovation performance

Universities are expected to not only create knowledge but also achieve social and economic targets through knowledge creation (Laredo 2007). Changing the function of universities has become a crucial task in enhancing knowledge of new sources of industrial innovation (Herlitschka 2009). Owen-Smith (2003) proposed a hybrid system linking scientific and technological success to show that academic success drives technology innovation. Several studies have indicated that the publication of research papers is not merely an academic output; rather, it is critical to industrial technology development (Ho et al. 2016; Nelson and Rosenberg 1998). Researchers usually present new ideas, applications, and findings in their publications. Research publications can be considered an important channel for university–industry interactions to discuss and develop the implementation of the results of academic innovation (Chang 2012; Huang 2009; Mowery 2011).

In addition to publications, patents can be used to represent technology innovation in universities. According to Goldfarb (2008), academic publications and the commercialized output of UICs are two complementary aspects of performance concerning universities' fundamental and utilitarian contributions. Archibugi and Planta (1996) explained the advantages of using patents in policymaking, revealing that patents are direct outcomes of inventions intended for commercial use. Patents in the context of science and technology can be used to measure technology innovation performance. To use patent-protected technologies, a technology licensing agreement with universities is necessary (Agrawal 2006).

The recognition of intellectual property has led to universities establishing intellectual property offices, technology transfer offices, and technology licensing offices to protect, manage, and utilize internal intellectual property (Sine et al. 2003). Patents and technology licenses issued by universities generate substantial economic value for academic institutions (Lach and Schankerman 2004). A growing trend among universities, therefore, is to pursue technology transfer by forming start-up companies or issuing licenses to young firms. Mowery (2011) argued that UIC facilitates business incubation in universities to support academic invention for commercialization.

2.2 UIC funding

Recently, the creation of new UIC channels has granted strategic advantages to universities, primarily because of their potential as external funding sources. Several empirical works (e.g., Gulbrandsen et al. 2011) have investigated the drivers of UICs and business funding for universities. Financial support for a university can be internal or external (Irvine et al. 1990). Specifically, government grants are typically viewed as external funding; universities receive these grants according to their technological capabilities and performance. Since the 1980s, governments have increased funding support options for universities. For example, many European governments pressured universities to derive research funding from industries and contribute to industrial innovation (Herlitschka 2009). Auranen and Nieminen (2010) compared the funding sources of universities in eight countries and investigated whether more competitive funding sources results in a higher number of scientific papers. The research results demonstrated that external funding incentives for universities generate more technological output than do competition-based incentives.

University research funding derived from private industries and the government refers to the additional incentives provided to academics (Goldfarb 2008) and is critical in the R&D measure of a nation's technological capability (Hu and Mathews 2009). To raise Taiwan's academic and research status in the world, the Taiwanese government has implemented a variety of policies and programs to improve the research environment in the universities and bridge the gap between academic research and industrial application. For example, in accordance with the Fundamental Science and Technology Act, the Ministry of Science and Technology amended the Government Scientific and Technological Research and Development Results Ownership and Utilization Regulations in 2012 to designate universities' obligation to establish managerial mechanisms to create, maintain, and utilize the UIC results. Meanwhile, the Ministry of Economic Affairs has worked with the Ministry of Science and Technology, Ministry of Culture, Council of Agriculture, and Ministry of Education to propose the Intellectual Property Strategy Program, which addresses IP circulation and protection (Ministry of Education 2017; Ministry of Culture 2015; Ministry of Science and Technology 2016). These strategies and resource planning programs are expected to foster the accumulation of scientific and technological capacity as well as increase industrial competitiveness.

In summary, universities' UIC funding considered in the study is derived from the government and industries. Huang et al. (2005) and Goldfarb (2008) have identified a positive correlation between UIC funding and scientific productivity (number of publications, patents, and royalty sharing). Gulbrandsen and Smeby (2005) concluded that a significant relationship exists between industry funding and research performance, implying that researchers with industry funding are more productive compared with their colleagues

with no such funding. Boardman (2009) also demonstrated that government- and industry-sponsored UIC funding positively affect universities' industrial involvement and innovation performance. Evidence suggests a close relationship between funding and innovation performance within universities. This study examines whether increased UIC funding helps build a suitable UIC environment within universities and enhances technology innovation performance. The first hypothesis is proposed as follows:

H1   UIC funding positively influences universities' technology innovation performance.

2.3 Fundamental factors of UIC environments within universities

2.3.1 UIC management mechanism

A formal UIC management mechanism can be defined as controlled standardizations that are stabilized in the operation of UICs as well as an activator for collaborative relationships (Boardman 2009; Perkmann et al. 2011). In the framework of knowledge production function, knowledge inputs (such as R&D expenditures) are expected to contribute to technology innovation output (such as the number of patents or new products) (Goldfarb 2008). However, innovation remains various problems and risks that are expected to be encountered in the UIC process (Kaymaz and Eryiğit 2011). Formal structure is required in university–industry relationships to control and coordinate the process of R&D input, behavior, and innovative outcomes (Thune and Gulbrandsen 2011). Guerrero et al. (2014) argued that internal management structure and decision-making mechanisms provide a supportive environment where teaching and research activities can be transformed into social and economic outputs. Meanwhile, government agencies delegate responsibilities to universities to support academics in understanding the needs of industry, preparing UIC proposals, earning public or industrial funding, and facilitating the commercial exploitation of research outputs (Meyer et al. 2013; Weckowska 2015). Careful and effective management, including administrative support and human capital, is crucial to improving the quality of the UIC process and outcomes (Wong 2013), The results of research by Huang and Chen (2016) revealed that the number of employees supporting the UIC service and the number of industry professionals hired by a university are two critical managerial factors that facilitate academic innovation performance. Therefore, this study argues that an effective management mechanism in universities represents well-established links between academia, industry, and government and further increases UIC funding. The second hypothesis is proposed as follows:

H2   Effective UIC management mechanisms positively influence UIC funding.

2.3.2 Universities' innovation climate

Universities' innovation climate refers to the supportive activities taken for encouraging UIC interaction and motivating technological innovation. Drawn upon the perspective of organizational climate, the common values, shared beliefs, authority systems, and norms is established and maintained within an organization, which essentially motivate organizational members to share and create knowledge (Chen and Huang 2007; Tesluk et al. 1997). According to Bock et al. (2005) and Chen et al. (2012), innovation climate is a type of organizational climate within which information flows openly and freely through social

interaction and ideas for new opportunities to emerge. Shirahada and Hamazaki (2013) further argued that an innovation climate in R&D settings facilitates creative behaviors and innovative performance. However, conflicts exist between universities and their industrial partners. The possibility of cooperation between universities and industry being considered "someone else's business" and being affected by "not-invented-here syndrome" also inhibits technology transfer activity in academia (Khadhraoui et al. 2016). To facilitate the discussion and sharing of technological knowledge in UIC projects, an innovation climate encourages positive interactions among partners (Bruneel et al. 2010). Universities with innovation climates have vigorously established programs, courses, or workshops in entrepreneurship and sponsored venture competitions to not only demonstrate their technological capabilities but also encourage more participation in UIC projects. Huang and Chen (2016) reported that constructing a support system from a series of UIC forums, entrepreneurial contests, and innovation-related courses is significantly correlated with the innovation climates in universities. UIC participants exchange ideas and shape norms, understanding, and identities that help decrease the uncertainty of technological innovation (O'Kane et al. 2015). Therefore, we argue that a more positive UIC innovation climate generates higher external funding and greater UIC financial support. The third hypothesis is proposed as follows:

H3 UIC innovation climate positively influences UIC funding.

2.3.3 UIC rewards

In general, universities seldom directly manufacture or commercialize products based on their inventions by themselves. Through the UIC agreement, technology transfer from universities to private firms according to agreements on licensing fees, royalty sharing, publications, and consulting has created a significant economic phenomenon in universities and contributed to product innovations in the market (Agrawal 2006; Sine et al. 2003). According to the economic exchange perspective, an incentive mechanism reflects extrinsic rewards including pay increases, bonuses or promotion and is vital to the success of knowledge management (Bock and Kim 2002). The results of Lach and Schankerman (2004) revealed that monetary rewards attract more productive researchers and are positively associated with inventive output. Similarly, Khadhraoui et al. (2016) argued that incentives for UIC activities or successful technology transfer can act as a driving force for greater innovation in universities. In Taiwan, many universities have established UIC-related regulations to specify the distribution percentage of shared incomes among universities, industries, and government sectors. The present study defines the concept of UIC rewards as monetary incentives to foster higher technological productivity in UIC projects. Meanwhile, we argue that the reward mechanism in UIC regulation motivates faculty members and students to participate in UIC projects and enhances the university's technology innovation performance. Hence, the following hypothesis is proposed:

H4 UIC rewards positively influence universities' technology innovation performance.

Previous studies (e.g., Boardman 2009; Gulbrandsen and Smeby 2005) have claimed that UIC funding is used to foster both academic and industrial innovation performance. However, there is little empirical evidence of the impact of UIC rewards on the relationship between UIC funding and performance. The problem of "not-invented-here syndrome"

or uncertainty regarding commercial exploitation may prevent academics from publicizing their UIC innovation (Khadhraoui et al. 2016). UIC rewards are therefore designed to arouse enthusiasm and stimulate joint research ventures with industries. Our study examines the positive moderating effect of reward systems on the relationship between UIC funding and universities' technology innovation performance by proposing the following hypothesis:

H5 The direct effect of UIC funding on universities' technology innovation performance is positively moderated by UIC rewards.

Based on the hypothesized relationships among the constructs, the research model is presented in Fig. 1.

3 Research design

3.1 Participants and data collection

In this study, empirical research was conducted in the form of a mail survey to collect and analyze primary data from universities in Taiwan. Two datasets were combined to avoid bias that can occur if multiple data come from the same source. First, a questionnaire was conducted to collect perceptual evaluations of the UIC management mechanism, innovation climate, and rewards. A total of 163 surveys were delivered to all officially recognized Taiwanese universities and 145 responses were received, yielding a response rate of 88.96%. Respondents rated the overall statuses of their universities on a 5-point Likert scale (1 = highly inappropriate, 5 = highly appropriate). According to Buchanan and Bryman (2009), a survey's response rate is a critical indicator of data quality. In general, a high response rate (80% or higher) is preferable and confers greater credibility on survey results, as well as less response bias (Fincham 2008). Second, this study used the UIC database to extract data on the governmental funding, industrial funding, and innovation performance of the 145 universities that responded. The development of this database was supported by
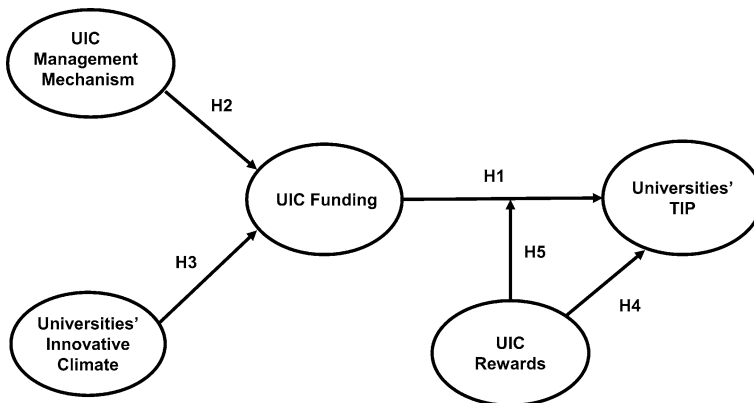
Fig. 1 Research model

a research grant from the MOE in Taiwan, which annually investigates the status of UIC in universities.

Because of the high skewness of UIC funding and performance measurements, the collected data were normalized using Z transformation to reduce the dynamic range and avoid the problem of scale dominance. The Z scores were transformed again using the log-sigmoid function, with the number of relatively high and low values approaching one and zero, respectively, after being repressed. Finally, Rosin's thresholding was employed to determine the corner points of the exponential histogram of each indicator based on the maximum distance between the line (from the peak to the end of the histogram) and corner point. The threshold point is not predetermined but dynamically serves as a useful application to obtain the higher and lower intensity of the histogram for noise/signal classification (Rosin 2001, 2002). The thresholding technique in this study identified eight universities with no significant UIC funding or performance as noise to be filtered out for further analysis.

3.2 Measurement instrument

According to the literature review, five constructs are developed in the research model: namely, "universities' technology innovation performance," "UIC funding," "UIC management mechanism," "universities' innovation climate," and "UIC reward" to assess the relationship between UIC funding and universities' technology innovation performance. The operational definitions and measurement items of each construct are presented in Table 1.

First, universities' technology innovation performance is defined as the output of the technology innovation achievements in a university, which is measured by the numbers of research publications and issued patents, amount of royalty income from technology licensing, and extent of business incubation in the university. The number of research publications is measured by counting the number of articles published in journals from the Social Science Citation Index, Engineering Index, and Arts and Humanities Citation Index. These indices have been used by the Ministry of Education (MOE) to determine the research innovation capability of universities in Taiwan. The number of issued patents is measured by counting the patents issued by the United States Patent and Trademark Office. U.S. patents are the most reliable proxy for innovation quality and an adequate indicator of the economic importance of patents. Income from technology licensing is measured by the number of patents licensed to firms. The number of business incubations refers to the number of newly established firms with universities' assistance services in the form of consulting, mentoring, or technology transfer.

Second, UIC funding is defined as financial support for UIC programs or the construction of UIC infrastructure within universities. UIC funding can be derived from either government or industry sources. Industrial UIC funding provides financial assistance to obtain the research equipment required to undertake technology innovation activities. Moreover, to encourage universities to cooperate with industries, the Taiwanese government vigorously subsidizes universities' implementation of UIC programs and construction of UIC infrastructure.

Finally, the three fundamental factors of UIC environments within universities are UIC management mechanism, universities' innovation climate, and UIC rewards. UIC management mechanism is defined as the degree of a university's ability to conduct UIC activities and is measured by UIC organization level and professional engagement. Innovation climate is defined as the degree to which innovative activities are supported within

Table 1 Operational definitions of constructs and measurement items

Universities' technology innovation performance: output of the technology innovation achievements in the university

P1	The number of licensing patents (licensors have granted exploitation rights to licensees)
P2	The number of issued patents (patents issued in Taiwan, the United States, or other countries)
P3	The amount of royalty income (the amount of income drawn from all types of intellectual property rights)
P4	The number of business incubations (newly established companies with university assistance)

(Source: Agrawal 2006; Chang 2012; Ho et al. 2016)

UIC funding: financial support for UIC programs or the construction of UIC infrastructure within universities

F1	The amount of governmental funding for UIC
F2	The amount of governmental funding for UIC infrastructure
F3	The amount of governmental funding for research projects
F4	The amount of industrial funding for UIC
F5	The amount of industrial funding for UIC infrastructure

(Source: Goldfarb 2008; Gulbrandsen et al. 2011)

UIC management mechanism: the degree of a university's ability to conduct UIC activities

M1	The number of employee in charge with UIC affairs in the university
M2	The number of staff whose business is to establish links between universities and industries

(Source: Huang and Chen 2016; Meyer et al. 2013; Wong 2013)

Universities' innovation climate: the degree of to which innovative activities are supported within universities

C1	The degree of UIC forums exhibited
C2	The degree of entrepreneurial contests or forums exhibited
C3	The degree of intellectual property courses offered

(Source: Huang and Chen 2016; Khadhraoui et al. 2016)

UIC rewards: monetary incentives to foster more productivity in UIC projects

R1	The appropriateness of achievement distribution in UIC for encouraging teachers and students to join in UIC
R2	The appropriateness of intellectual property (technology transfer) income planning for encouraging university academics to engage in technology transfer activities

(Source: Khadhraoui et al. 2016; Lach and Schankerman 2004)

universities and measured by the degree of UIC forums and entrepreneurial contests exhibited and the degree of intellectual property courses offered. UIC rewards refer to the monetary incentives to foster more productivity in UIC projects. Two items are measured in the form of shared income from UIC output and technology licensing.

This study adopts five constructs from the literature review: management mechanism, innovation climate, reward, UIC funding, and innovation performance. The operational definitions and measurement items of each construct are presented in Table 1.

4 Data analysis and results

4.1 Measurement reliability and validity

Partial least squares (PLS) regression was used in this study to test the research hypotheses. The first step in PLS regression is to test item reliability and construct validity through confirmatory factor analysis (CFA). As shown in Table 2, the Cronbach's alpha value of most constructs exceeded 0.6, indicating that the reliability was acceptable (Cronbach 1951). Although the Cronbach's alpha values of universities' innovation climate and UIC rewards were less than 0.4, the factor loading of measurement items exceeded 0.5 and unidimensionality was satisfied (Davis et al. 1992; Steenkamp and van Trijp 1991). Moreover, composite reliability (CR) was calculated to determine the internal consistency of the measurements. The results revealed that all the obtained values exceeded the generally recommended threshold value of 0.6 (Fornell and Larcker 1981; Nunnally and Bernstein 1994). Convergent validity, referring to the degree to which different measures indicate the same meaning as the construct (Hair et al. 2010), was significant when the factor loadings for each item exceeded 0.5 (Steenkamp and van Trijp 1991). Following Chin (1998), the discriminant validity—the square root of average variance extracted—was compared with the correlations among constructs. As demonstrated in Table 3, all square roots of the average variance extracted (AVE) values were higher than the correlations between pairs of constructs. In summary, all the constructs and items satisfied the requirements of reliability, convergent validity, and discriminant validity.

4.2 Hypotheses testing

After the validity and reliability of measurements satisfactorily exceeded the threshold values, PLS regression was used to test the hypotheses by measuring the relationships between constructs. Structural equation modeling—PLS analysis—is an applicable technique to analyze nonnormal data or small sample sizes and is used in this study to test the

Table 2 CFA results for the reliability and validity of the measurement items

| Construct	Item	Factor loading	AVE	CR	Cronbach's α
Universities' technology innovation performance	P1	0.847	0.773	0.931	0.901
	P2	0.931			
	P3	0.878			
	P4	0.857			
UIC funding	F1	0.852	0.768	0.908	0.850
	F3	0.864			
	F4	0.911			
UIC management mechanism	M1	0.906	0.765	0.867	0.697
	M2	0.842			
Universities' innovation climate	C1	0.812	0.442	0.696	0.398
	C2	0.512			
	C3	0.637			
UIC rewards	R1	0.765	0.620	0.765	0.388
	R2	0.809			

Table 3 Discriminant validity for the research constructs

	Technology innovation performance	UIC funding	UIC management mechanism	Innovation climate	UIC reward
Universities' technology innovation performance	0.879				
UIC funding	0.828	0.876			
UIC management mechanism	0.585	0.510	0.875		
Universities' innovation climate	0.554	0.476	0.510	0.665	
UIC rewards	0.423	0.423	0.184	0.375	0.787

Diagonal entries represent the square root of the AVE for each construct; off-diagonal entries represent the correlations among the constructs

research hypotheses. PLS analysis has been widely used in various research areas to not only confirm theories but also suggest exploratory propositions for further testing (Chin 1998; Gefen et al. 2000). As shown in Fig. 2, the path coefficient of each hypothesis was significant. The results revealed that UIC funding plays a significant role in universities' technology innovation performance (H1, $\beta = 0.897$, $p < 0.001$). UIC management mechanism (H2, $\beta = 0.380$, $p < 0.001$) and innovation climate of universities (H3, $\beta = 0.308$, $p < 0.001$) significantly influenced UIC funding. The direct effect of UIC management mechanism on UIC funding was stronger than that of innovation climate. Regarding UIC rewards, the design of shared income from UIC output and technology transfer had a direct and positive influence on universities' technology innovation performance (H4, $\beta = 0.105$, $p < 0.001$). Moreover, UIC rewards moderated the relationship between UIC funding and universities' technology innovation performance (H5, $\beta = 0.154$, $p < 0.001$).

According to Hair et al. (2010), the predictive quality of a research model can be assessed according to the percentage of total variance it explains (R^2). The results of this study revealed that UIC management mechanism and innovation climate accounted for
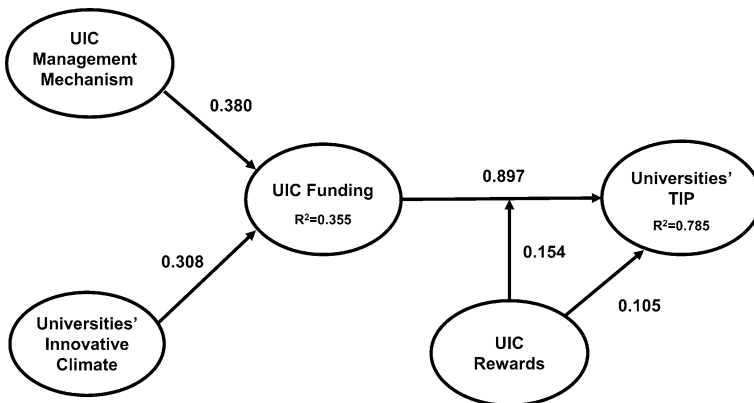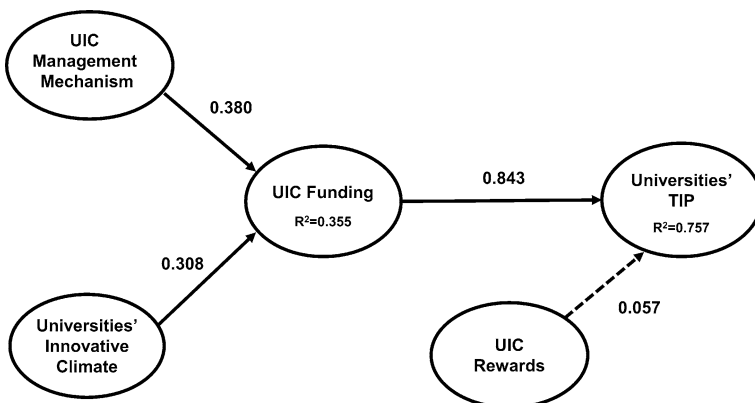

Fig. 2 Research results

35.5% of the variance in UIC funding. Finally, UIC funding and UIC rewards explained 78.5% of the variance in universities' technology innovation performance. The R^2 values indicated the importance of the relationships among UIC management mechanism, innovation climate, UIC rewards, UIC funding, and universities' technology innovation performance. When the path coefficients are compared, the results indicate that UIC management mechanism has a stronger influence on UIC funding than universities' innovative climate. In addition, UIC funding has a much greater influence on universities' technology innovation performance than either the direct or moderating effects UIC rewards.

To further examine the moderating effect of UIC rewards, this study analyzed the structure model without H5. The results are demonstrated in Fig. 3 and indicate that the direct effect of UIC rewards on universities' technology innovation performance is not significant. As shown in Fig. 2, both the moderating and direct effects of UIC rewards ($\beta = 0.105$ and $\beta = 0.154$, respectively) were supported. The relationship between UIC funding and academic output was also enhanced (namely, the path coefficient was increased from 0.843 to 0.897). Finally, the variance of universities' technology innovation performance was increased from 78.5 to 75.7%, reflecting the significant influence of UIC rewards as the moderating variable.

To determine the association among UIC funding, rewards, and universities' technology innovation performance, we conducted an item–test correlation analysis, as demonstrated in Table 4. The coefficients of item pairs between UIC funding and UIC rewards were approximately 0.3, indicating a weak relationship and insufficient conditions for causality (Hair et al. 2010).

5 Discussion and conclusion

With the rapid development of technology and global competitiveness, innovation has become a critical concern, attracting considerable attention from academics, industries, and governments and compelling them to collaborate with one another. Universities explore, create, and diffuse knowledge or inventions and industries apply these academic outcomes in the practical world. Government interventions, such as legal regulations and research funding, are also important factors in fostering the alliance and knowledge-based economy

Fig. 3 Research results without moderating effect of UIC rewards

Table 4 Correlation matrix of UIC funding, rewards, and technology innovation performance

	F1	F2	F3	F4	F5	R1	R2	P1	P2	P3	P4
F1	1										
F2	0.454**	1									
F3	0.618**	0.359**	1								
F4	0.663**	0.445**	0.680**	1							
F5	0.277**	0.450**	0.288**	0.377**	1						
R1	0.243**	0.205*	0.314**	0.246**	0.188*	1					
R2	0.272**	0.190*	0.199*	0.445**	0.231**	0.241**	1				
P1	0.475**	0.435**	0.541**	0.677**	0.372**	0.201*	0.232**	1			
P2	0.557**	0.525**	0.608**	0.772**	0.479**	0.348**	0.289**	0.807**	1		
P3	0.594**	0.452**	0.669**	0.806**	0.443**	0.335**	0.431**	0.607**	0.743**	1	
P4	0.564**	0.604**	0.571**	0.700**	0.478**	0.221**	0.259**	0.601**	0.723**	0.693**	1

*Denotes significance at the < 0.05 level

**Denotes significance at the < 0.01 level

(Hu and Mathews 2009; Kaymaz and Eryiğit 2011). In relation to the university–industry relationships and emerging entrepreneurship activities (Agrawal 2006; Mindruta 2013), the study confirms that UIC funding significantly influences the construction of well-developed UIC environments within universities and the enhancement of technology innovation performance (H1). Universities and industries participate in technology innovation fields to not only develop technologies with strong potential for significant economic benefits but also collaborate and ultimately increase industrial competitiveness. In Taiwan, UIC funding has dramatically increased since 2007. For example, the MOEA has established many programs, including the "Small Business Innovation Research Promoting Program" and the "Information Technology Applications Promotion Project," to directly support UIC activities and innovation-related activities.

Although a relationship exists between UIC funding and universities' innovation performance, few empirical studies have examined the antecedents of UIC funding and their influence on UIC activities. The results of this study reveal that both formal UIC management mechanism (H2) and universities' innovation climate implementation (H3) positively affect UIC funding. The involvement of management in UIC projects has a positive and considerable effect on all dimensions of innovation featured in this study, including not only the development of internal processes to support the R&D activities of universities but also collaborative connections among university researchers, industries, and government agencies (Khadhraoui et al. 2016). The UIC management mechanism is responsible for resource allocation, identifying collaborative partners, contract advice, intellectual property development, new venture funds, and even technological foresight and evaluation for future UIC opportunities (Meyer et al. 2013; O'Kane et al. 2015; Weckowska 2015). This implies that when a university invests more effort in developing its UIC management mechanism, such as by providing a higher-level organizational unit to deal with UIC affairs, it facilitates problem solving and risk management in the UIC process. Moreover, because of the importance of knowledge sharing and knowledge creation among universities and industries (Chen and Huang 2007), a free and innovative atmosphere is critical for encouraging UIC partners to exchange ideas openly through face-to-face and continuous interaction (Bruneel et al. 2010). The research results of this study verify that the UIC innovation climate is a catalyst for promoting technological innovation beyond universities, where varied experiences, ideas, and knowledge can be discussed under a common theme, as well as the shared interests of UIC partners. Consequently, the UIC innovation climate can generate long-term advantages in supporting peer-to-peer communication and facilitating substantial progress in competitive positioning.

In this study, UIC rewards are essential in directly and positively affecting universities' innovation performance (H4). Consistent with the results of Sine et al. (2003) and Lach and Schankerman (2004), the benefits of financial rewards is an incentive mechanism for increasing the motivation of university researchers and departments, resulting in improved technology innovation performance. UIC rewards not only exhibit a direct effect on universities' technology innovation performance but also moderate the relationship between UIC funding and academic output. In other words, UIC funding from government and industrial partners in combination with fair reward programs can facilitate stronger innovation performance in universities (H5). In Taiwan, incentives for academics to engage in university–industry technology transfer are provided after UIC partnerships have been established. Government agencies typically request that management mechanisms and an innovation climate be developed in advance by universities to foster these partnerships. Our research identified the two fundamental factors for attracting more UIC funding. The

implementation of UIC rewards is critical for increasing universities' technology innovation performance as well as opportunities for joint ventures with industries.

This study provides both theoretical and practical implications for UICs. Theoretically, we proposed an integrated research model to assess the relationship between UIC funding and universities' technological innovation performance. According to knowledge management perspectives, knowledge creation in organizations refers to the dynamic process of moving knowledge from individuals to groups and beyond the boundaries of the organization in question (Nonaka and Takeuchi 1995). This process not only facilitates problem-solving and new skill implementation; knowledge transfer and innovation can occur in a shared context (Leonard-Barton 1995). Choo (2006) asserted that managerial practices and values constitute the core capability to reinforce the diffusion and growth of knowledge. Our study demonstrated that specified knowledge required by a firm and subsequent technological innovation are products of organizational knowledge in UIC activities. To articulate the effect of knowledge transfer in relation to managerial practices and a culture of sharing, two organizational antecedents—the UIC management mechanism and universities' innovation climates—were included in the model to demonstrate their substantial influence on UIC funding. With respect to expected values, another organizational factor—UIC rewards—plays a vital, direct, and moderate role in technological output as a knowledge asset. From a practical perspective, these factors provide insight into how the academic achievements and technological capabilities of universities can facilitate industrial innovation and commercial advantages. The mutual benefits of UIC depend on not only research funding but also supportive factors such as managerial support, innovative organizational culture, and monetary incentive program. The study provides a useful guideline to develop organizational management and open channels of sharing for the success of UIC projects.

Although this study offers several insights into UICs, several limitations and suggestions for future research must be addressed. First, all data regarding UIC circumstances were collected from a single respondent by using perceptual measures. An adequate sampling technique and multiple respondents would be more appropriate for understanding the real circumstance of UICs. In addition, this study does not consider the type of university (i.e., private, technology, or public) or firm size, which may be correlated with possible resources and technological capabilities. Eventually, drawing upon the perspectives of universities' entrepreneurial economies (Guerrero et al. 2015; Lach and Schankerman 2004), more actual values will be required for further objective evaluation of economic performance derived from UICs, including royalty sharing, technology licensing, and commercialization. To expand the scope of research conducted by UIC, new research agendas should be established, including (1) the relationship between university characteristics (e.g., public or private, size, professional fields) and UIC funding amounts; (2) the degree of willingness for or participation in UIC and technology performance of various industries; (3) the influence of UIC on organizational changes in universities and industries; (4) the development of entrepreneurial activities in universities and the expected market value creation from such activities. The establishment of these agendas could lead to a more comprehensive understanding of the practice of UIC and to the successful implementation of our research findings.

Compliance with ethical standards

Conflict of interest   The authors declare that they have no conflict of interest.

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