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How can academic innovation performance in university–industry collaboration be improved?

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ABSTRACT

As universities gradually become the center of society's knowledge production system, their role in innovation becomes more diverse. In the pursuit of such a role, universities are encouraged to establish a university–industry collaboration (UIC) context that supports faculties and students to engage in entrepreneurial activities. On the basis of the organizational control perspective, we investigated how UIC factors, namely implementing a formal UIC management mechanism, implementing UIC regulations, and supporting an innovative climate, influence the academic innovation performance of universities. The results of partial least squares analysis of 141 Taiwanese universities showed that UIC-subsidized universities have more advantages for developing their UIC environment and improving academic innovation performance. We found that a formal UIC management mechanism might be the most essential factor for enhancing the academic innovation performance of non-UIC-subsidized universities. Furthermore, the innovation climate was found to moderate the relationship between formal UIC management mechanisms and academic innovation performance.

1. Introduction

In the knowledge economy era, universities are vital in the innovation system for contributing to the economic development of a nation (Etzkowitz et al., 2000; Florida and Choen, 1999; Phillips and Eto, 1998; Laredo and Mustar, 2001) through activities such as developing skilled human capital, transferring knowledge and technology to industry, and becoming the seedbed of new enterprises (Lazzeroni and Piccaluga, 2003). This indicates that university roles in knowledge and technology innovation tend to become more diverse (Godin and Gingras, 2000).

The traditional missions of a university are teaching, research, and service to industry. Scholars have claimed that a new aim of universities is to become entrepreneurial universities that contribute to national economic development and that attain a financial advantage through the commercial and industrial application of research (Etzkowitz et al., 2000; Martin, 2003). Currently, universities are implementing various mechanisms for encouraging faculties and students to engage in entrepreneurial activities (Tornatzky et al., 2002).

The ability of a university to engage in entrepreneurial activities is affected by its context, resource-based capability, and capacity (Williams and Kitaev, 2005). Where a university develops its university–industry collaboration (UIC) context influences its ability to become a successful entrepreneurial university; furthermore, an appropriate combination of entrepreneurial activities can maximize its contribution to society. To more clearly understand how academic innovation performance in UIC can be improved, this study investigated the influence of UIC context on academic innovation performance in 141 Taiwanese universities. Three facets of UIC context were investigated: formal UIC management mechanisms, implementation of UIC regulations, and support for an innovative climate.

Prior studies have indicated that collaboration among three institutional spheres, namely industry, academia, and government, can be a critical factor for success in improving regional and national innovation systems (Etzkowitz et al., 2000; Motohashi, 2005; Gibbson et al., 2006). To improve academic innovation, the Taiwan government encourages universities to engage in UIC with industry. Most Taiwanese universities have their own UIC program. Every year, the National Science Council (NSC) of Taiwan calls for UIC proposals from academia and provides financial support to selected universities. We investigated and compared the academic innovation performance of universities with and without government funding from the NSC UIC program in order to determine the effectiveness of the funding. In this paper, "UIC-subsidized" indicates universities whose UIC activity is subsidized by the NSC UIC program, whereas "non-UIC-subsidized" refers to universities that run their UIC program without NSC subsidization.

The remainder of this paper is organized as follows. First, we review the literature related to the academic innovation performance of universities and four hypotheses. Second, we present our data analyses, which are conducted by performing structural equation modeling

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(SEM) through partial least squares (PLS), which is regarded as one of the most appropriate techniques available for analyzing our type of research model (Chin, 2003). Finally, we discuss our results and provide several implications for UIC research and practice.

2. Literature review and hypotheses

2.1. Academic innovation performance of universities

Under the framework of the National Innovation System, "innovation" signifies the creation of knowledge or technology (Metcalfe and Ramlogan, 2005). Prior studies have suggested that papers (Rosenberg and Nelson, 1994; Nelson and Rosenberg, 1998) and patents (Pouris and Pouris, 2009) are direct indicators for evaluating knowledge accumulation. For example, Rosenberg and Nelson (1994, 1998) have suggested that papers are critical for industrial technology development. Scientific papers are the only medium of reporting scientific achievements (Wouters, 1998), and citation patterns can also be used for examining knowledge exchange among scientists and interdependencies among disciplines (Small and Garfield, 1985).

In addition to papers, patents have become a key indicator to assess invention performance, the diffusion of knowledge, and the internationalization of innovative activities at different levels (Pouris and Pouris, 2009). Patents have several advantages for use in policy making (earlier, Archibugi and Pianta, 1996); for example, they contain the direct outcome of inventions intended to be used commercially as well as information on the rate of inventive activities, and are easily accessible. Patents are a means of protecting original inventions, and patent data are readily available and operational tools. Thus, this study used the numbers of papers and patents to measure the academic innovation performance of universities.

2.2. Development of university–industry collaboration in universities

Organizational controls are the mechanisms utilized by managers to direct the attention and motivation of organization members to perform in desired manners for achieving an organization's objectives (Cardinal, 2001; Snell, 1992). Prior studies have adopted a more instructive viewpoint than the colloquial notion of "control" for explaining control theory; specifically, the studies have described the capabilities of establishing structures and rewards that motivate and influence organization members. For example, Owen-Smith (2001) proposed the notion of scientific skepticism as a form of organizational control in ambiguous managerial situations. This notion can further be categorized as a form of input control in which the professional etiquette and knowledge of actors within an innovative setting facilitate the development of management mechanisms that contribute to the success of the system. Different types of controls have been defined: structural control, also called bureaucratic or behavior control (Lebas and Weigenstein, 1986); input control (Mintzberg, 1983); output control (Jaworski, 1988); market control (Williamson, 1975); cultural control (Wanous, 1980); and integrative control (Roth et al., 1994). In this study, three facets of the control types, namely the formal UIC management mechanism, the implementation of UIC regulations, and the innovation climate, were investigated in the context of UIC development.

2.2.1. Formal UIC management mechanism

Formal UIC management mechanisms are beneficial for interorganizational collaborative relationships (Boardman, 2009; Thune and Gulbrandsen, 2011). Thune and Gulbrandsen (2011) argued that institutionalization facilitates improving the interaction between universities and industry. However, how the changes of formal UIC management mechanisms are implemented has seldom been addressed. The current study contends that implementing formal UIC management mechanisms within universities can facilitate UIC development. Formal UIC management mechanisms can be considered an arrangement for control and coordination in collaborative relationships (Ring and Van de Ven, 1994). Specifically, this study measured the formal UIC management mechanism by using the number of industry professionals employed by the university whose job is to find UIC partnerships and the number of university staff responsible for UIC services.

In research policy studies, Youtie et al. (2006) and Corley et al. (2006) have claimed that exploring collaborative relationships requires focusing on changes in mechanisms through which collaboration becomes more formal, standardized, and structured. In addition, formal UIC management mechanisms can be defined as a control process that permits the interorganizational relationship to be reproduced and perpetuated. Therefore, this study investigates the implementation and effects of formal UIC management mechanisms in universities.

Hypothesis 1. Implementing formal UIC management mechanisms in universities positively affects the academic innovation performance of universities.

2.2.2. UIC regulation implementation

Few studies have explored the influence of regulation implementation on the academic innovation performance of universities in the UIC context. From a behavior control perspective, the agency theory of the organization involves monitoring members' behaviors and then stipulating productive behaviors (Eisenhardt, 1985). Behavior control has a long research history and is usually associated with rules and regulations designed to ensure that the behavior of members aligns with the goals of managers. Feldman (1989) argued that innovation requires the simultaneous regulation of autonomy and control for promoting creativity. Cardinal (2001) performed an empirical investigation and found that regulation implementation may improve the outcomes of radical innovation ventures in the pharmaceutical industry. The current study contends that UIC regulation implementation in universities can motivate the development of UIC activities. Two regulations associated with UIC development were used for measuring UIC regulation implementation in universities, namely the perceived effectiveness of UIC management regulations in encouraging UIC-related activities and the perceived effectiveness of UIC outcome distribution regulations in encouraging teachers and students to participate in UIC projects, as assessed on a 5-point scale by university directors of UIC activities.

Hypothesis 2. UIC regulation implementation in universities positively affects the academic innovation performance of universities.

2.2.3. Innovation climate

A university's support for entrepreneurial activities is a key factor affecting its academic innovation performance (Clarysse et al., 2011). Developing an innovative climate in universities is a management practice that facilitates enterprise and benefits both entrepreneurs and universities. In this study, support for an innovative climate was considered to include a series of initiatives and actions taken for providing a support service by conducting UIC forums, holding entrepreneurial contests, and offering intellectual property courses. When faculties and students perceive that their university is supportive of entrepreneurial activities, they are more likely to perceive the organizational work environment as supportive and thus are highly motivated to demonstrate innovation performance. This study measured the innovation climate of a university according to the number of UIC conferences and forums held by the university, the average number of intellectual property-related courses offered by the university each academic year, and the average number of entrepreneurial contests and lectures held by the university each academic year.

Hypothesis 3. The innovation climate in universities positively affects the academic innovation performance of the respective universities.

Furthermore, the innovation climate in universities can be considered a contextual variable that moderates the influence of formal UIC management mechanisms on academic innovation performance. In general, individuals may not directly perceive the innovation climate in universities because such support is considered a university-wide contextual factor that interacts with other supportive mechanisms influencing academic innovation performance. We expect that faculties and students demonstrate a high level of academic innovation performance after perceiving a high level of support for an innovative climate.

Hypothesis 4. The innovation climate in universities moderates the association between formal UIC management mechanisms and the academic innovation performance of universities.

3. Methods

3.1. Research context and data collection

3.1.1. Innovation activities in Taiwan

Innovation activities in East Asian countries mainly focus on technology diffusion and knowledge spillovers, which drive the formation of national innovation systems (Hu and Mathews, 2005). Over the past two decades, the Taiwan government has established a qualified R&D environment and infrastructure. Taiwan has been successful in establishing science-based industrial parks and public research institutions for promoting and encouraging innovation activities (Mathews and Hu, 2007).

The Taiwan government implemented the Science and Technology Basic Act in 1999 in response to the changing environment. Under this act, universities and public research institutions can partially or fully claim and commercialize intellectual property rights derived from government-funded research in order to obtain economic benefits, resulting in a considerable increase in the number of patents granted by the Industrial Technology Research Institute of Taiwan (Hu and Mathews, 2009). The Science and Technology Advisory Group of the Executive Yuan (Cabinet) of Taiwan launched the Inter-Ministerial Project for Academic–Industry Collaboration in 2007 for integrating the resources from relevant departments more efficiently. The Ministry of Education, National Science Council, and Ministry of Economic Affairs are responsible for promoting UIC; higher education institutes were asked to fulfill the responsibilities of education, research, and industrial innovation.

Because universities are nonprofit institutions, the government provides adequate financial aid for research, which strengthens the partnership between industry and academia and facilitates the growth of this partnership and key technological innovations. In this study, we focused on the association between academic innovation performance and UIC developments to elucidate the complementary system that makes the financial aid more effective.

Specifically, we examined the effects on academic innovation performance of three facets of UIC development within universities, namely the formal UIC management mechanism, regulation implementation, and the innovation climate.

3.1.2. Data collection

This study identified 163 universities and colleges from the Directory of Higher Education Institutions of the Ministry of Education. Surveys were sent to the schools, with most addressed to the director of the UIC center, technology transfer center, or incubation center, or to the director whose business was mainly related to UIC, such as R&D department directors. In total, 163 questionnaires were distributed, and 141 complete and useable questionnaires were returned (response rate = 86.5%). Of the 141 higher education institutes from which valid questionnaires were returned, 31 were UIC-subsidized universities and 110 were non-UIC-subsidized universities. As mentioned, UIC-subsidized universities are defined in this study as universities that receive special government funding to promote UIC.

The descriptive analysis results for the two types of higher education institutions, shown in Table 1, reveal several notable findings. First, most UIC-subsidized universities (approximately 65%) had established an UIC center as their official office for implementing a formal UIC management mechanism of university–industry collaboration. However, most of the non-UIC-subsidized universities (approximately 90%) relied on their R&D department to conduct UIC-related business. This means that most non-UIC-subsidized universities did not have specific units for managing UIC. Second, 87% of the UIC-subsidized universities (n = 27) had more than 7 years of experience in UIC, compared with only 65% (n = 74) of the non-UIC-subsidized universities. Third, the average number of UIC professionals employed in the UIC-subsidized universities was 3.6, which was higher than the approximately 0.27 professionals employed by the non-UIC-subsidized universities. Finally, the UIC-subsidized universities exhibited superior performance in establishing UIC regulations, regulating UIC implementation, and average number of start-ups resulting from UIC. These results indicated that the status of formal UIC management mechanisms and UIC regulation implementation development differ between UIC-subsidized and non-UIC-subsidized universities.

3.2. Instruments

Formal UIC management mechanisms reflect the arrangement for control and coordination in collaborative relationships (Ring and Van de Ven, 1994); we measured this construct by using two indicators: the number of industry professionals employed by the university whose job is to identify and develop UIC partnerships and the number of university staff responsible for UIC services.

UIC regulation implementation reflects regulation implementation for R&D management and UIC development. Two regulations associated with UIC development were used for measuring regulation implementation for UIC in universities: the perceived effectiveness of UIC management regulations in encouraging UIC-related activities and the perceived effectiveness of UIC outcome distribution regulations on encouraging teachers and students to participate in UIC projects, as assessed on a 5-point scale by university directors of UIC activities.

Table 1
Characteristics of respondent universities (N = 141).

Characteristic variables	UIC-subsidized universities (N = 31)	Non-UIC-subsidized universities (N = 110)
Official unit		
University–Industry Collaboration Center	20 (65%)	10(8.8%)
Technology Transfer Center	6 (19%)	14(12%)
Incubation Center	2 (6.5%)	6 (5.3%)
Subject to R&D Department	9 (29%)	90 (79%)
Years		
Under 1 year	0 (0%)	3 (3%)
1–3 years	0 (0%)	11 (10%)
4–6 years	4 (13%)	26 (23%)
7–10 years	8 (26%)	32 (28%)
Over 11 years	19 (61%)	42 (37%)
Professional engagement		
Already engaged professionals	24 (77%)	22 (19%)
Average number of professionals employed	3.6	0.27
UIC management regulation		
Setup the regulation	31 (100%)	84 (68%)
UIC outcome distribution regulation		
Only setup the regulation	14 (45%)	13 (11%)
Regulation implementation	13 (93%)	9 (69%)
Average number of start-ups	6	5

Table 2
Loadings of reflective indicators.

Variable	Indicator	Loadings	*t*-Value	Composite reliability	
				Composite reliability	AVE
Formal UIC management mechanisms	ORGM	0.92	28.761*	0.87	0.76
	PRO	0.83	10.436*		
UIC regulation implementation	UCA	0.81	10.066*	0.73	0.58
	UCRD	0.72	6.413*		
Innovation climate	UIC_F	0.80	12.642*	0.85	0.74
	UIC_CON	0.45	4.366*		
	UIC_IPCLS	0.89	33.346*		
Academic innovation performance	PACNT	0.94	37.337*	0.95	0.91
	PATCNT	0.97	92.265*		

* $P < 0.001$.

The *innovation climate* construct comprises three dimensions representing a university's support for entrepreneurial activities, namely the number of UIC conferences and forums held by the university, the average number of intellectual property-related courses offered by the university each academic year, and the average number of entrepreneurial contests and lectures held by the university each academic year.

Academic innovation performance reflects the number of papers published between 2010 and 2014 and the total number of patents authorized by the U.S. Patent and Trademark Office and Intellectual Property Office of Taiwan between 2010 and 2014.

SEM was conducted using PLS for examining the reliability and convergent validity of each measurement model (Chin, 1998). The coefficients of all measurement models are presented in Table 2. All factor loadings were higher than the threshold value of 0.6 (Fornell and Lacker, 1981), and the average variance extracted for the constructs exceeded the threshold level of 0.5 (Chin, 1998). Thus, the validity of instruments was confirmed. Furthermore, the composite reliability values were higher than the threshold value of 0.7 (Chin, 1998).

4. Results

4.1. Direct effect

The hypotheses were evaluated using PLS regression analyses. The explanatory power of the structural model was evaluated using the R squared value. To determine whether each hypothesis was supported, we used the *t* test to derive the standardized path coefficients. Following the method proposed by Chin (1998), bootstrapping (with 300 resamples) was performed to obtain the standard error estimates for testing the statistical significance of the path coefficients.

First, we examined the association between formal UIC management mechanisms and academic innovation performance. As shown in Table 3, formal UIC management mechanisms had a significant influence on the academic innovation performance of the universities ($\beta = 0.625$, $t = 5.711$, $P < 0.001$), supporting Hypothesis 1. However, the influence of regulation implementation ($\beta = 0.049$, $t = 1.356$, n.s.) and the innovation climate ($\beta = 0.053$, $t = 0.430$, n.s.) on academic innovation performance were both nonsignificant. Therefore, Hypotheses 2 and 3 were rejected.

These results revealed that implementing a formal UIC management mechanism significantly influences the academic innovation performance of Taiwanese universities, but that UIC regulation implementation and innovation climate had no such influence. The R squared values showed that our research model explained 44.8% of the variance in academic innovation performance, and the formal UIC management mechanism explained a larger proportion of the variance.

4.2. Results for UIC-subsidized and non-UIC-subsidized universities

As stated previously, UIC subsidized universities are defined as universities that receive special funding from the government for promoting UIC activities; other universities that do not receive this special funding are categorized as non-UIC-subsidized universities. Based on this categorization, we distinguished the selected universities into UIC subsidized and non-UIC-subsidized categories and then evaluated our hypotheses by using submodels (see Table 4). First, the findings of the UIC-subsidized university model supported all hypotheses. In addition, it explained 39.1% of the variance in academic innovation performance, and formal UIC management mechanisms explained a larger proportion of the variance. The results implied that formal UIC management mechanisms had a strong influence on academic innovation performance in the UIC-subsidized universities. Moreover, the results suggested that the UIC-subsidized universities had more advantages for developing their UIC programs and thus improving their academic innovation performance.

According to the non-UIC-subsidized model, only formal UIC management mechanisms exerted a significant effect on academic innovation performance ($\beta = 0.468$, $t = 3.191$, $P < 0.01$), whereas the effects of UIC regulation implementation ($\beta = 0.130$, $t = 0.693$, n.s.) and innovation climate ($\beta = -0.279$, $t = 0.893$, n.s.) were nonsignificant. The non-UIC-subsidized model explained 28.4% of the variance in academic innovation performance, with formal UIC management mechanisms explaining most of the variance. The results of these two submodels revealed that government funding for UIC activities significant influences UIC regulation implementation and support for an innovative climate. We also found that the development of a formal UIC management mechanism has a stronger influence on academic innovation performance in non-UIC-subsidized universities. This might be because for universities that cannot obtain government funding, a formal UIC management mechanism facilitates using limited resources more effectively. Thus, for enhancing academic innovation performance, a formal UIC management mechanism is the most crucial factor. In addition, the average size of the non-UIC-subsidized universities was smaller than that of the UIC-subsidized universities, and it is easier for a smaller university to show the UIC effectiveness in a short time after the UIC is applied.

4.3. Moderating effect

In the case of the non-UIC-subsidized universities, we also examined whether support for an innovative climate moderated the association between formal UIC management mechanisms and academic innovation performance. Our results (Fig. 1) indicated that non-UIC-subsidized universities with high support for an innovative climate have a stronger association between formal UIC management mechanisms and academic innovation performance than do those with low

Table 3
PLS results of hypotheses testing.

Hypotheses	β	*t*-Value	Results
H1: Formal UIC management mechanisms → academic innovation performance	0.625	5.711*	Support
H2: UIC regulation implementation → academic innovation performance	0.049	1.356	Not support
H3: Innovation climate → academic innovation performance	0.053	0.430	Not support

* Indicates significance at $P < 0.001$ (two-tailed test).

Table 4
PLS results of UIC-subsidized and non-UIC-subsidized models.

Hypotheses	UIC-subsidized model			Non-UIC-subsidized model		
	β	*t*-Value	Results	β	*t*-Value	Results
H1: Formal UIC management mechanism → academic innovation performance	0.266	2.708**	Support	0.468	3.191***	Support
H2: UIC regulation implementation → academic innovation performance	0.206	2.294**	Support	0.130	0.693	Not support
H3: Innovation climate → academic innovation performance	0.236	2.815**	Support	−0.279	0.893	Not support

** Indicates significance at $P < 0.05$ (two-tailed test).
*** Indicates significance at $P < 0.01$ (two-tailed test).

support for an innovative climate. The explanatory power of our structural model increased from 28.4% to 47.7%, constituting the highest explanatory power among all the models and supporting Hypothesis 4. These results imply that, for non-UIC-subsidized universities, support for an innovative climate is critical for enhancing the strength of formal UIC management mechanisms and thus improving academic innovation performance.

5. Conclusion

Becoming an entrepreneurial university is the new mission of most universities. According to organizational control theory, this study explored how three facets of UIC development within universities (the formal management mechanism of UIC projects, the implementation of UIC regulations, and the innovation climate) may affect the academic innovation performance of universities, as indicated by their numbers of papers and patent publications.

The results of the scientometric analyses indicated that UIC-subsidized universities have more advantages in developing their UIC context and improving academic innovation performance. Specifically, for the non-UIC-subsidized universities, a formal UIC management mechanism was the most crucial factor for enhancing academic innovation performance. Furthermore, we found that the innovation climate moderated the association between formal UIC management mechanisms and academic innovation performance, such that universities with high support for an innovative climate exhibited a stronger association than did universities with low support for an innovative climate. On the basis of these results, several implications are discussed as follows.

First, the results of the full structural model showed that formal UIC management mechanisms had significant effects on the academic innovation performance of universities. Formal UIC management mechanisms reflect the arrangement for control and coordination in collaborative relationships (Ring and Van de Ven, 1994). Universities hiring more industry experts to seek potential partners for UIC might facilitate more interaction between universities and industry, thereby contributing to the creation of more UIC partnerships. Combined with more staff dedicated to UIC services, management mechanisms may stimulate more UIC activities in universities and lead to improved academic innovation. The results of this study further enrich our understanding of the UIC context by demonstrating that the formal UIC management mechanism has a strong influence on the academic innovation performance of universities, which has been seldom examined by prior research.

Second, the comparison between UIC-subsidized and non-UIC-subsidized universities further supports the aforementioned findings. The results for the UIC-subsidized university model showed that these universities had more advantages in developing their UIC context on all three dimensions and thus can publish more papers and patents. However, the results of the non-UIC-subsidized university model showed that only the formal UIC management mechanism has a significant effect on the academic innovation performance of the universities. The resulting differences between the two groups suggest that government funding for UIC may have significant impact on the implementation of UIC regulations and the support for an innovative climate in universities. For universities that do not receive UIC subsidies, implementing a formal UIC management mechanism (such as employing professionals to seek UIC partnerships and hiring staff for UIC services) might be the most crucial factor for enhancing academic innovation performance.

Third, in the case of non-UIC-subsidized universities, we examined whether the innovation climate had a moderating effect between the formal UIC management mechanism and academic innovation performance. The results showed that when UIC activities in universities are not subsidized by the government, supporting an innovative climate can moderate the enhancement of academic innovation performance. Moreover, universities with high support for an innovative climate have a stronger association between formal UIC management mechanisms and academic innovation performance than do universities with low support for an innovative climate. This means that the creation of an innovative climate through various activities (such as conducting UIC forums, holding entrepreneurial contests, and offering intellectual

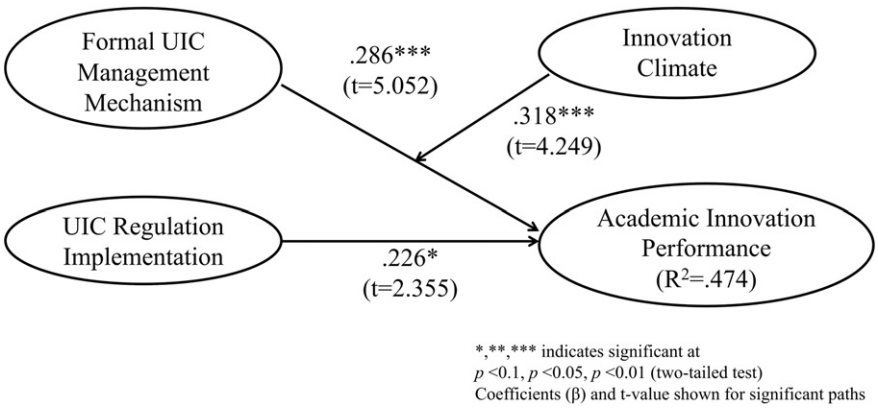

Fig. 1. Moderating effect of innovation climate in the non-UIC-subsidized model.

property courses) may enhance the influence of formal UIC management mechanisms on academic innovation performance. For faculties and students, such activities may increase their awareness of current UIC initiatives as well as potential UIC partners and services offered by the university. Therefore, supporting an innovative climate may encourage participation in UIC projects, thus enhancing the influence of formal UIC management mechanisms on the academic innovation performance of universities. We investigated the association between UIC development and the academic innovation performance of universities by using structural models according to specific conditions. Strengthening the formal UIC management mechanism, that is, employing more industrial professionals who are involved in UIC matchmaking activities and hiring more university staff responsible for UIC services, might be a critical factor for enhancing the academic innovation performance of non-UIC-subsidized universities. Moreover, support for an innovative climate may be a moderator in improving academic innovation performance in non-UIC-subsidized universities. Our results can guide universities in UIC development. Finally, our study has limitations because the structural model was evaluated only for Taiwanese universities. In the future, we expect to expand and test the research scope of our results by involving other fields or countries and thus improving the generalizability of our research framework.

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