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Driving factors of external funding and funding effects on academic innovation performance in university–industry–government linkages

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Abstract This study focuses on analyzing the driving factors of government and industry funding and the effects of such funding on academic innovation performance in the Taiwan's university–industry–government (UIG) collaboration system. This research defines the relationships of the triple helix in the UIG collaboration system as a complex intertwined combination that covers demography, financial support, and innovation performance. These relationships are simultaneously modeled by a multivariate technique, structural equation modeling, to investigate the causal-effect relationship among the antecedent factors on the subsequent ones. This model will enable us to investigate three questions: (1) Is government funding or industry funding tied to university demography, to university innovation performance, or to both? (2) Does government funding lead industry funding? (3) Is government funding or industry funding conducive to more university innovation performance? In addition to verifying the model against all participating universities in the UIG collaboration, we also categorize them into two tiers in terms of whether or not universities have been selected for the incentive programs of UIG collaboration so as to explore groups' differences.

Keywords University–industry–government collaboration · Triple helix · Structural equation modeling · Partial least squares estimation

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Introduction

Since the passage of the Bayh–Dole Act in 1980, the triple helix (TH)—universities, industries, and government (UIG)—has collaborated to transfer research output from universities to industries (Mowery and Sampat 2005). This partnership has turned out an impressive list of innovative products and has led to the belief that basic research from universities supporting innovative activities can help maintain their competitiveness (Severson 2004). Encouraging such partnerships and the successful commercialization of university inventions have since become major policy goals. Governments across the world play the role of positively cooperating partners, providing incentives for researchers to engage in research partnerships with industry, to undertake projects with greater commercial prospects, and to patent scientific research (Meissner 2010).

The TH model, developed by Etzkowitz and Leydesdorff (2000), is an important tool for building policies by considering bilateral and trilateral interactions among the UIG. Taking into account the present tendency to integrate the policies of science and technology within the context of the industrial policy, mixed economy, and international economic competition, this change in terms of understanding the policies has also affected the connections among these components. They have taken the roles of the other components, for example, industries which conduct research, universities which managing companies, etc. (Etzkowitz 1994; Priego 2003). The TH model has already been applied in many developed or developing countries to explore how to develop their national innovation systems or regional socio-economic systems. It has recently prompted a flurry of empirical work in the Asian region (Khan and Park 2012).

Over the past two decades, the application and management of those rich achievements have been actively enhanced by Taiwan's government in order to increase competitiveness in states and industries. The Science and Technology Basic Act was one of the most well established incentive programs in Taiwan during 1999. Universities were allowed to claim and partially or fully commercialize intellectual property rights that were derived from external funding in order to gain profit. It has attempted to boost the fashion that the universities have changed from "theory-orientated" education to "application-orientated". For example, Neihu, Hsinchu, and central or southern Taiwan science-based industrial parks house the providers or makers of information communication, semi-conductors, opto-electronic and precision machinery respectively and continue to attract increasing numbers of other high tech firms. Activities in those parks are linked to nearby universities as well as the government's leading science research institutes (Mathews and Hu 2007; Hu and Mathews 2009). In 2006, the Executive Yuan of the Republic of China proposed an incentive program, inter-ministerial project, to boost the country's economic development. This project spans three phases during 2007–2015. One of the policy purposes is to further improve the UIG collaboration.

Taiwan was selected for the study because UIG relations have been gradually emphasized. In the past decade, Taiwan's government has promoted many national incentive programs to activate a climate of collaboration among UIG. As shown in Fig. 1, during the recent years in Taiwan, the government and industry funding for UIG collaboration account for more and more portions of universities' total budgets. Especially in 2009, the percentage of government funding increased dramatically. It means that UIG pointed to the emergence of the overlaid activities among them and had received positive achievements. With the effort of Taiwan's government, the "triplet" has engaged in a variety of productive relationships that have provided benefits to universities through commercial expanded research results, opportunities for students, budgets for research

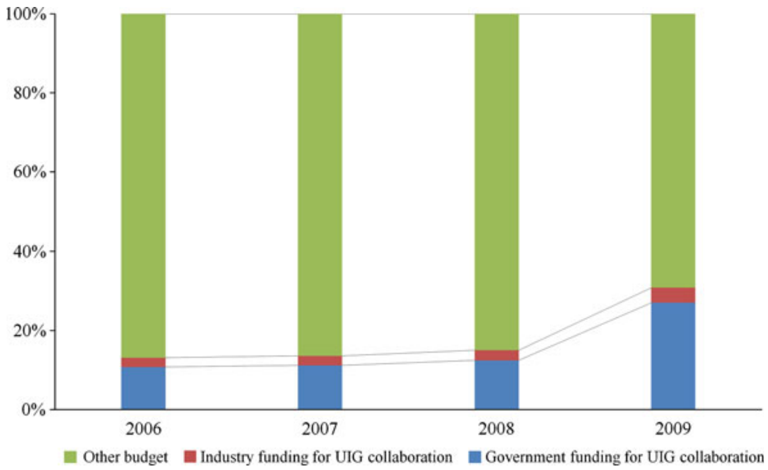

Fig. 1 The percentages of government and industry funding for UIG collaboration with respective to the universities' total budgets in Taiwan

equipment, and revenue that can support their academic missions. Government catalyzes the partnership between industries and the academic community. It directs academic R&D energy to industries to establish a high-quality talent bank, drives the industrial economy toward knowledge and innovation, and enhances the nation's competitive advantage. Industries, other than the government, can offer additional funding resources which are always more flexible than government grants. Industries have benefit from the access to specialized programs, the ability to work with faculty or others with expertise in a specialized area of research, and access ideas and discoveries that can enrich their product development.

Increasingly, analysts have embarked on efforts to address issues related to the TH (Leydesdorff and Meyer 2003). The TH unites different types of research on the interaction of university, industry, and government. In general, this relationship can be measured through items such as budgets, collaborations, concurrences, and citations, or can be considered as a complex and adaptive network of communication. Unlike those works, this study is partly motivated by the discussion of Hu and Mathews (2009), Hu (2009), and Jerome and Jordan (2010) in regard to the theoretical development of the UIG relationship. We assert that the roles and interests of UIG collaboration have become increasingly intertwined in a complex combination of demography, financial support, and innovation performance relationships. After collecting the empirical data from universities that are carried out UIG collaborative activities in Taiwan, this study analyzes the driving reasons of external funding resources in university systems and funding's effects on academic innovation performance. The five constructions of university demography, previous university innovation performance, government funding, industry funding, and university innovation performance have been established, and the causal links among the constructions are developed on the basis of theories or previous research conclusions. Three key research questions are addressed in this study. The first concerns the funding base of government or industry allocations to universities: Are the funds tied to university output of innovation performance, to university demographic input, or both? The second question relates to the issue of the degree of government-orientation in industry funding arrangements: Does government funding tend to be the pilot of industry funding? The last question looks at the effect of funding on university innovation performance: Does government funding or industry funding result in higher university innovation performance? That is, who is the driver of innovation output? Although mutual interactions between the double helices have been partly discussed in previous literatures, no studies have attempted to address these research problems at the conceptual level and integrate all the issues into one model. Structural equation modeling (SEM) with partial least squares (PLS) estimator is applied in this study to investigate the causal relationship between the antecedent factors and the subsequent ones described above. In addition to verifying the model with all the universities participating in UIG collaboration (a model with full samples), we also divide them into two tiers, groups of universities who were selected to take part in the incentive programs of UIG collaboration (the Tier 1 model) and groups of those that were not (the Tier 2 model), in order to explore their similarities and dissimilarities.

The rest of this paper is organized as follows. In "Theory and research hypotheses", we review the literature and provide justifications for the conceptual framework and the related research hypotheses. In "Methodologies", we describe the research methodologies. In "Results and discussion", we depict the experimental environments and present the results and findings. Our concluding remarks and further suggestions are discussed in "Conclusions and further studies".

Theory and research hypotheses

Literature reviews

Relationships within the TH

The TH model presents an integrated pattern of university, industry, and government. It postulates that UIG interaction is the key to improving the conditions for innovation in knowledge-based society. The roles of the three helices are: industry operates as the locus of production realization; government represents a guider of relations that guarantee interactions and exchanges; and university acts as a source of the generative knowledge and technologies (Etzkowitz 2003, 2008). In the last decade, measuring the underlying structure and strength of the relationship among the three main components has attracted considerable attention. Leydesdorff (2003) and Park et al. (2005) measured UIG relations on the internet, and publications/patents in terms of the occurrences and co-occurrences of the words "university", "industry", and "government" and the co-authorship of documents. Meyer et al. (2003) combined patent data with an inventor survey to relate academic patents further to their TH environment. Leydesdorff and Sun (2009), Park and Leydesdorff (2010), Hossain et al. (2012), Kim et al. (2012), Kwon et al. (2012), Lei et al. (2012), and Shin et al. (2012) used co-authored publications/patents across sectors as indicators of the TH model. Khan and Park (2011), (2012) considered various internet resources, content analysis, and co-word analysis techniques to ascertain longitudinal trends in the UIG relationship. Khan et al. (2012) extended the TH model, together with webometric, to the musical industry so as to explore the performance of social hubs from the perspective of entropy and the web. Recently, the traditional TH indicator is extended to measure the evolving network of co-occurrence or co-authorship relations. There is also a trend toward comparing the TH behaviors of subareas (regions, countries, cities, etc.) to reveal their commonalities and differences. In our opinion, the majority of the literature in this field is limited because the UIG relationship has typically used patentometrics, scientometrics or webometrics. Only the co-occurrence or co-authorship behaviors between double helix or among TH were explored.

Different from previous studies, Hu and Mathews (2009) explored the UIG linkages and the influence on innovation in Taiwan. Hu (2009) investigated the funding sources available to universities and their significance in defining the essentials of operating entrepreneurial universities. Jerome and Jordan (2010) hypothesized the relationships among inputs, outputs, and impacts in UIG collaborative models for six locales in the Pacific region. They offered different collaborative opportunities from a perspective of various dimensions (such as financial, intellectual, personal, performance, and legal) within novel interfaces in the theoretical development of UIG relationships. This study is partly motivated by their discussion and claims that the roles and interests of UIG collaboration have increasingly intertwined in a complex combination of demography, financial support and innovation performance relationships.

The causal-effect of funding allocation

It is very critical for each university to understand the driving factors of the funding and realize a more efficient funding source to pursue being outstanding. The universities are non-profit institutions, so most of UIG collaboration initiatives are subsidized by the government or by the industries. Especially in Taiwan, she is one of the countries with highest higher education density of a university per 219 km. There is a funding struggle among universities under the situation of limited resources. The recent landscape of the funding allocation in Taiwan is shown in Fig. 2. It reflects the fact that the amount of external funding is highly skewed and most of the funding goes to the top one-fifth of universities. Even though this phenomenon slows down in 2009, funding of UIG collaboration is still in a status of unequal distribution. If a university earns few subsidies, it would be difficult to start collaboration activities as they require a number of expenditures. Funding cannot be earned unless the crucial actions are taken.

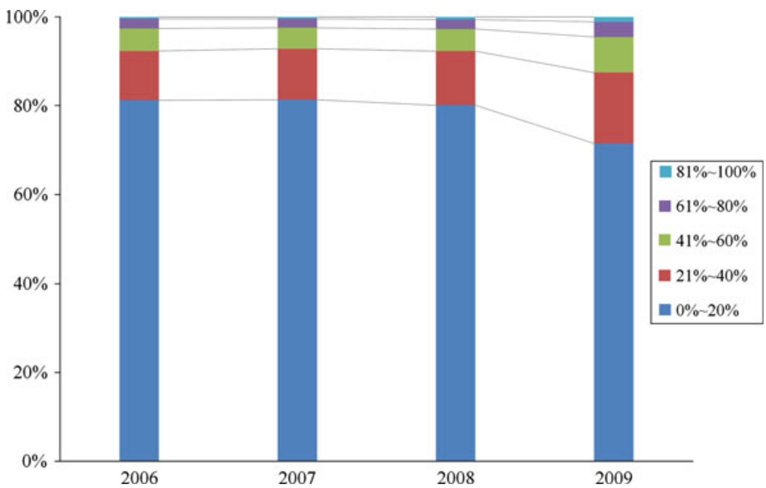

Fig. 2 The landscape of the funding allocation in Taiwanese universities

In this section, we address three research questions that relate to the causal or effect of funding allocation among the triplet. Also, we summarize relevant literatures to reveal the existing findings.

The funding mechanisms of universities The sources of financial aid for UIG cooperation projects considered in this analysis were primarily from government or industries. In terms of the indications of Liu (2003) and Jongbloed (2008), policy-makers have to take either an "input-oriented" approach if the budgets are driven by the demography of an institution, an "output-oriented" approach if the budgets are tied to specific research outcomes of the institutions' activities, or both approaches in funding the defined intervention. To our knowledge, some studies regard input criterion as more commonly used (Kaiser et al. 2001; Miroiu and Aligica 2003), whereas others believe that funding on the basis of output has increased because it contains more incentives for efficient behavior (Liu 2003; Jongbloed 2008; Himanen et al. 2009). This discrepancy encourages us to ask whether government or industry funding is driven by university demography, benefits derived from innovation performance, or both?

Effect of government funding on private industrial funding How government funding affects industry funding behavior is another concern of this study. Few studies provide econometric analysis of industry funding as a function of government funding. To our knowledge, Jensen et al. (2010), Thursby and Thursby (2011) provided two models by the parameters of two funding sources that could be simultaneously determined. The government funding equation includes the current level of industry funding and the industry funding equation the current level of government funding. They found that government and industry funding for university research act as strategic complements, rather than substitutes or evidence of the ability of universities to leverage their research infrastructure to attract research funding. However, our study argues that government funding will influence the attitude and willingness of industry involvement in UIG cooperation.

Effect of external funding on universities' innovation performance R&D expenditure includes equipment, manpower, and miscellaneous materials. It seems almost self-evident that researchers with external funding are more productive than colleagues with no such funding (Gulbrandsen and Smeby 2005). Adams and Griliches (1998), Payne and Siow (2003), Huang et al. (2005), and Goldfarb (2008) have examined the relationship between research funding and academic achievement. They concluded that there is a positive correlation between research outcome and government research funding. On the other hand, private firms are playing a growing role in funding university research. Blumenthal et al. (1996), Godin (1998), Gulbrandsen and Smeby (2005), and Cherchye and Vanden Abeele (2005) found that university researchers receiving funding from and collaborating with industry are more academically or commercially prolific than those who were not receiving funding. That is to say, financial support through funding exerts a larger degree of positive influence on research performance. In addition to single funding sources as described above, research performance was also regarded as a function of both funding channels in the study of Thursby and Thursby (2011).

The proposed model

In this section, we conduct an empirical analysis by SEM to explore the causal-effect of funding allocation among the UIG in Taiwan. SEM incorporates both indicators and latent

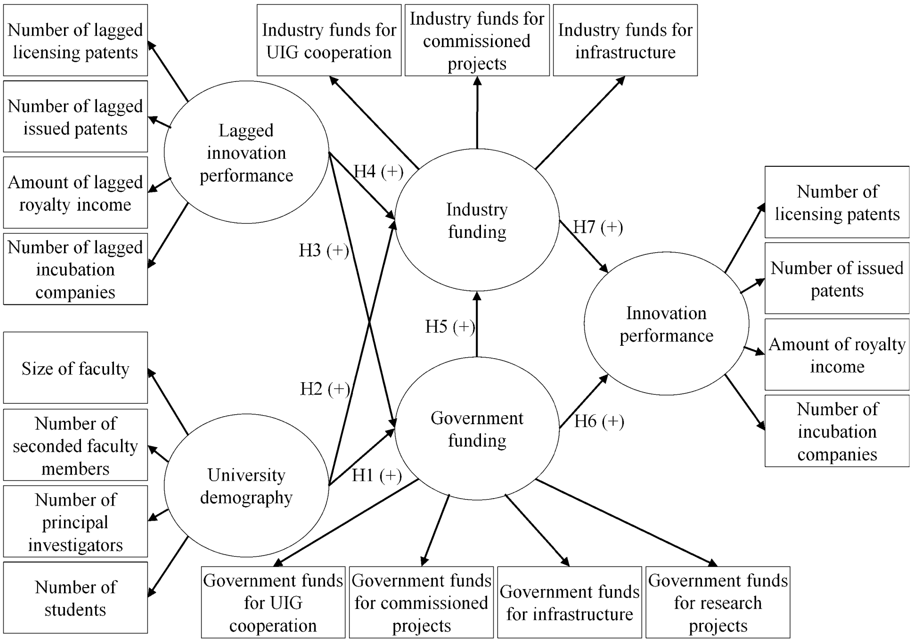

Fig. 3 Path diagram representing the hypothesized relationship among UIG in collaborative research model

variables into measurement models (or constructs) and then integrates them through causal links to build a structural model. It not only addresses the reliability and validity of a construct, but also specifies the direct and indirect relations between the constructs (Yue and Wilson 2004). The path diagram is presented in Fig. 3. Following the convention of SmartPLS analysis (Ringle et al. 2005), indicators are represented by squares while latent variables are represented by circles. A straight arrow pointing from a latent variable to an indicator or another latent variable indicates the causal-effect.

The constructs

The detailed explanations of the latent variables and the corresponding indicators are listed as follows:

1. University demography (UD): an input-orientated concept which describes the basic and historical attributes of a particular university (Kaiser et al. 2001; Miroiu and Aligica 2003; Jongbloed 2008). The fundamental demographic data includes:
   - Size of faculty (FAC): the number of university faculty members.
   - Number of seconded faculty members (SFAC): the number of faculty members transferred temporarily to industry.
   - Number of principal investigators (PI): the number of principal investigators in the projects related to UIG cooperation.
   - Number of students (STU): the number of students at a university.
2. University innovation performance (UIP): in the area of measuring the research activities, the indicators of innovation results could be as follows (Kivistö 2005; Geuna and Nesta 2006; Breschi et al. 2008).

- Number of licensing patents (LP): the number of patents which licensors over which exploitation rights have been granted to licensees.
- Number of issued patents (IP): the number of patents issued in Taiwan, the United States (U.S.), or other countries.
- Amount of royalty income (RI): the amount of income drawn from all sorts of intellectual property right.
- Number of incubation companies (IC): the number of newly established companies that acknowledge transferring technologies.

When the data of such constructs is extended to the prior year, the construct could be renamed previous university innovation performance (PreUIP), and the term "previous" could also be added to other corresponding indicators. An output-orientated concept which describes the past benefits can be derived from the innovation performance of a particular university.

3. Government funding (GF): the funding that universities receive from the government. Sources of funding include:
    - Government funds for UIG cooperation ($F_{\mathrm{UIG,G}}$): the funding for UIG cooperation projects which are supported by the government.
    - Government funds for commissioned projects ($F_{\mathrm{CP,G}}$): the funding from the government used for conducting continuing education, vocational or practical training, discussion panels, and other commissioned activities.
    - Government funds for infrastructure ($F_{\mathrm{INF,G}}$): the funding from the government for the construction of basic physical and organizational structures needed for UIG cooperation.
    - Government funds for research projects ($F_{\mathrm{RP,G}}$): the funding for use in academically oriented research.
4. Industry funding (IF): the funding that universities receive from industry. Usually government funding is limited and there is increasing competition for funds, therefore, the maintenance of financial independence is vitally important as academic institutions seek funds from different sources (Zajkowski 2003). The sources of funds are basically the same as the sources of governmental funds in our dataset, except for the funds for academic research projects.
    - Industry funds for UIG cooperation ($F_{\mathrm{UIG,I}}$): the funding for UIG cooperation projects which are supported by industry.
    - Industry funds for commissioned projects ($F_{\mathrm{CP,I}}$): the funding from industries used for conducting commissioned activities as described above.
    - Industry funds for infrastructure ($F_{\mathrm{INF,I}}$): the funding from industries for the construction of basic physical and organizational structures needed for UIG cooperation.

The hypotheses

Three main questions and the corresponding hypotheses are developed on the basis of theoretical works or previous empirical findings so as to form the causal-effect relationships in the UIG funding allocation model.

Question 1 Which kind of funding mechanism does the external funding tie to?

Referring to "The funding mechanisms of universities", both input and output criteria will be simultaneously adopted in this study and four hypotheses (H1–H4) are presented as below. That is, current government and industry funding could be modeled as functions of current university demography and innovation performance in the prior year. Our estimation is that either university demography or past outputs of innovation performance will have a positive effect on research funding from the government and industry.

Hypothesis 1 The demography of universities will positively affect incentive funding from the government.

Hypothesis 2 The demography of universities will positively affect incentive funding from industry.

Hypothesis 3 The previous innovation performance of universities will positively affect incentive funding from the government.

Hypothesis 4 The previous innovation performance of universities will positively affect incentive funding from industry.

Question 2 Does the government play the role of funding guider?

Referring to the "Effect of government funding on private industrial funding", pursuing how industry involvement in UIG cooperation is stimulated by government might also be a meaningful path in SEM. This hypothesis (H5) is shown below, and we expect that government funding has a positive effect on industry funding.

Hypothesis 5 The government funding will positively affect incentive funding from industry.

Question 3 Which kind of external funding is the output exciter?

Referring to the "Effect of external funding on universities' innovation performance", we would like to realize that external funding, whether from government or from industry, positively affects universities' innovation performance. That is, current innovation performance could be modeled as functions of current government and industry funding. The claim serves as two of our hypotheses (H6, H7) for exploring in this study:

Hypothesis 6 Government funding will positively affect the incentive innovation performance of the university.

Hypothesis 7 Industry funding will positively affect the incentive innovation performance of the university.

Methodologies

Data collection and preprocessing

The original data of universities were collected by conducting an online questionnaire administered by the Higher Education Evaluation and Accreditation Council of Taiwan in the years 2008 and 2009. University-related entries included demography, external funding, and innovation performance. We find that each indicator related to the external funding is highly skewed, taking an exponential shape, which means that the majority of external funding goes to just a few universities. Samples of universities should be included if their indicators of industry and government constructs are relatively active at the same time. Indicators are first normalized by *Z* transformation to reduce the dynamic range and avoid the problem of scale dominance. Then *Z* scores are transformed again via log-sigmoid function. After repressing, the number of relatively large and small values will approach one and zero respectively. Finally, Rosin thresholding, which originated in image processing, will be used to automatically determine a corner point of the exponential histogram of each indicator that can preserve dominant samples while weak ones are filtered out (Perng and Chen 2011; Chen et al. 2012).

Evaluation procedure of the model quality

Instead of using co-variance based on SEM methods such as the maximum-likelihood and generalized least squares, we chose the PLS estimator as it is suitable for testing exploratory models in earlier stages of theoretical development (Jöreskog and Wold 1982; Chin 1998). The PLS, introduced by Wold (1975), focuses on maximizing the variance of the endogenous variables that explained by the exogenous ones. Such as other estimation methods of SEM, a PLS model is composed of a structural model, which specifies the direct and indirect relations among the latent variables and a measurement mode. It addresses how the latent variables and their indicators relate to each other. Evidences from simple simulations to real-world data, PLS has been regarded as a powerful tool to deal with multiple regression problems where the data distribution is non-normal, sample size is limited, missing data are numerous, or the correlations between the variables are high, i.e., multicollinearity (Sambamurthy and Chin 1994; Grewal et al. 2004; Pirouz 2006; Götz et al. 2010).

Applying the PLS method requires a multi-level process to check the model quality covering the evaluations of the measurement models and the structural equation model. A measurement model specifies the relationship between indicators and the underlying latent variable. In this context, the investigation of suitable indicators is an important step with regard to the operationalization of such a construct (Churchill 1979). Several evaluation types can be differentiated:

- Indicator reliability: it specifies which part of an indicator's variance can be explained by the corresponding latent variables. It is usually assessed by examining the factor loadings and their statistical significance through *t* values (Dunn et al. 1994). Weak loadings are frequently observed in empirical research, especially when newly developed scales are used. However, indicators should be eliminated from the latent variable if their loadings are smaller than 0.4 (Hulland 1999; Götz et al. 2010) or their *t* values do not exceed 1.96.
- Construct reliability: it is estimated to assess whether the specified indicators sufficiently stand for the corresponding latent variable or not. Composition reliability (CR) is one of the approaches measuring the degree of the multi-indicators that share the same measurement within a construct. The larger the CR value is, the higher the inter-correlatedness between the indicators with respect to the latent variable will be. CR values larger than 0.6 are frequently judged as acceptable (Fornell and Larcker 1981). Average variance extracted (AVE) is another common measure of construct reliability of SEM. AVE measures the amount of variance in the multi-indicators accounted for by the specified latent variable. The larger the AVE value is, the higher the representativeness of multi-indicators with respect to the latent variable will be. AVE values of less than 0.4 are considered insufficient (Diamantopoulos and Siguaw 2000).

- Discriminant validity: it refers to the distinctiveness of the constructs as measured by different sets of indicators. It can be assured by cross-loading (Chin and Dibbern 2010) and the magnitudes of the correlations between the latent variables. If the cross-loadings of the indicators on other latent variables are relatively low and none of the estimated correlations between the latent variables exceeds 0.85 (Kline 1998), then the discriminate validity can be guaranteed.

On the other hands, the structural model covers the relationships among constructs. In this context, the investigations of suitable relationships among latent variables are the top missions. Several criteria can be used:

- Determination coefficient: it is usually named R^2 and is used to reflect the explained variance level of the latent variable. The larger R^2 is, the larger the percentage of variance explained. According to Pirouz (2006), variance explained for endogenous variables should be larger than 0.1.
- Goodness-of-fit (GoF): the non-parametrical global criterion of goodness-of-fit measure was suggested by Tenenhaus et al. (2005). It was defined as the geometric mean of the average communality and average R square. The cutoff 0.36 may serve as baseline values for validating the PLS model globally (Wetzels et al. 2009).
- Path coefficient: it represents individual path coefficients resulting from the estimation. Paths that are insignificant, or show signs contrary to the hypothesized direction, do not support a prior hypothesis, while significant paths showing the hypothesized direction empirically support the proposed causal relationship (Götz et al. 2010). Because the distribution of PLS is unknown, there is no conventional significance test. To test whether the path coefficients differ significantly from zero, t values are calculated via various re-sampling procedures such as jackknifing and bootstrapping (Chatelin et al. 2002; Garson 2007). In this study, bootstrapping is chosen to estimate the precision of PLS estimation as it is deemed more efficient than jackknifing (Chin 1998). In order to get more stable estimation results, the parameters setting of bootstrapping are based on the suggestion of Zhang (2009) in which the case size is set equal to the number of collected samples and the re-sampled times reach 500.

Results and discussion

After the original data of 165 universities were collected, each indicator related to the external funding was preprocessed by functions of Z transformation and log-sigmoid and then the corresponding Rosin threshold was yielded. Table 1 lists the average values, corresponding real values of Rosin thresholds, and corresponding percentages of samples with the values greater than the threshold in each indicator. As shown in Fig. 4, the number of qualified samples monotonically decreases with the growing requirement on the number of active indicators. Then we used majority vote to identify about one-third of the universities that participated in UIG collaboration, i.e., only 52 samples were put to subsequent analysis.

PLS estimation was conducted with the help of SmartPLS (Ringle et al. 2005) using the bootstrapping procedure. In contrast to the defaults of 100 cases and 100 samples in SmartPLS, the case size and re-sampled times were set equal to 52 and 500. The final coefficients are shown in Tables 2, 3 and 4. Then, we established indicator reliability, construct reliability and discriminant validity to validate the five constructs: UD, PreUIP,

Table 1 Summarization of each fund-related indicator (U.S. $)

Item	Indicator						
	$F_{UIG,G}$	$F_{CP,G}$	$F_{INF,G}$	$F_{RP,G}$	$F_{UIG,I}$	$F_{CP,I}$	$F_{INF,I}$
Average value	1,900,445	221,179	219,146	5,383,836	1,280,559	36,932	153,998
Threshold value	1,050,568	76,987	20,000	1,517,924	969,461	8,040	77,067
Percentage of samples with values greater than the threshold (%)	29	37	49	41	27	8	34

Please see "The constructs" to consult the full-length terms of those abbreviations

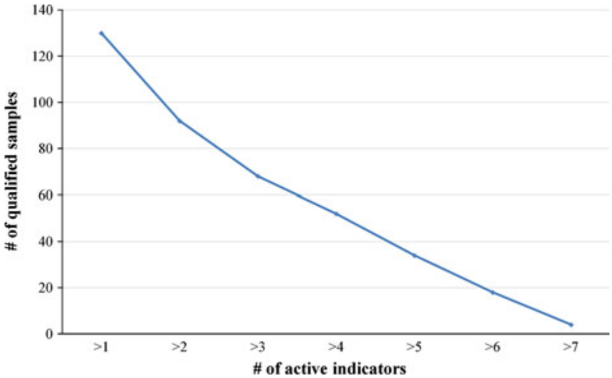

Fig. 4 Relationship between number of active indicators and qualified samples

GF, IF and UIP. Additionally, the fitness of the overall model was also examined. Table 2 shows that all factor loadings exhibit values greater than 0.4, and the bootstrapping *t* value of each indicator exceeds 1.96. That not only means no indicators should be eliminated from the construct and verifies the posited relationship among the multi-indicators and the underlying constructs. Table 2 also shows the fact that the lowest CR among five latent variables is 0.656, which exceeds the recommended level of 0.60 and the lowest AVE among the five constructs is 0.415, which is higher than the minimum of recommended level of 0.40. Those mean the indicators sufficiently stand for the corresponding constructs. In addition, as shown in Table 3, the crossing loadings are presented and the loadings on their respective constructs are bold-faced. The rows in Table 3 show that cross-loadings of the indicators on other constructs are relatively low. And, none of the estimated correlations between the constructs exceeds 0.85 in Table 4. Thus we can deduce that there exists discriminant validity between the likeability and the competence components. Finally, according to Table 2, each of the *R* squared value or variance explained for endogenous constructs is larger than 0.1, which indicates significant influencing power between constructs. Furthermore, the GoF for PLS path modeling is equal to 0.702, which well exceeds 0.36, indicating excellent model fit. To sum up, the proposed model exhibits a fit value exceeding the recommended threshold for the respective indices. In other words, the proposed model fits the collected data reasonably.

We also tested the hypotheses based on the proposed model which were summarized in Fig. 5 and Table 5. Referring to hypotheses H1 to H4 in Table 5, the specified

Table 2 Factor loading and composite reliability

Construct	Indicator	Loading	t value	CR	AVE	R^2
UD	FAC	0.894	21.154	0.884	0.657	–
	SFAC	0.834	24.557			
	PI	0.775	19.909			
	STU	0.729	9.859			
PreUIP	PreLP	0.840	6.161	0.900	0.693	–
	PreIP	0.799	6.402			
	PreRI	0.863	6.669			
	PreIC	0.827	11.572			
GF	$F_{\text{UIG,G}}$	0.929	54.903	0.826	0.558	0.724
	$F_{\text{CP,G}}$	0.587	4.332			
	$F_{\text{INF,G}}$	0.514	5.976			
	$F_{\text{RP,G}}$	0.871	30.281			
IF	$F_{\text{UIG,I}}$	0.904	25.596	0.656	0.415	0.524
	$F_{\text{CP,I}}$	0.472	2.579			
	$F_{\text{INF,I}}$	0.452	2.622			
UIP	LP	0.828	30.308	0.895	0.682	0.698
	IP	0.903	37.563			
	RI	0.864	35.004			
	IC	0.693	10.269			

relationships between input and output criteria and two kinds of external funds, both input and output criteria are found to have significant effects on the level of government or industry funding. That is, government and industry funding are driven by both the impetus of university's demography and performance. This result confirms that historically, based on an input orientation, the government or industry funding system today is also partially based on the output criterion related to past innovation performance. However, the path weight from UD to GF or IF is much higher than that from PreUIP to GF or IF, which reveals that the system of government or industry funding is still very input-oriented in Taiwan. Reliable arguments have suggested that input-based funding entails a more limited set of incentives for an efficient operation, and was gradually replaced by output criterion in most developed countries (Miroiu and Aligica 2003; Jongbloed 2008). However, input criterion is still dominant in Taiwan. Referring to the hypothesis H5 in Table 5, government funding is found to have a significant effect on the level of industry funding, which means industry funding is positively related to government funding. In Taiwan, the government can be regarded as playing the role of a mediator that sets the pace to stimulate the participation of industries. Meanwhile, industries observe trends and seize the best investing opportunities in UIG collaboration to reduce costs and maximize commercial profit. Referring to the hypotheses H6 and H7 in Table 5, both funding sources were found to have positive relationships with university innovation performance. Industry funding may be conducive to a higher level of university innovation performance. This reflects that universities funded by industry were more likely to report positive commercial output than those funded through government. One possible reason is that input–output performance is the main concern of industries, making a better use of limited funds and frequently communicating with partners to create win–win situations.

Table 3 PLS cross-loading

Indicator	Construct				
	UD	PreUIP	GF	IF	UIP
FAC	**0.894**	−0.051	0.671	0.558	0.546
SFAC	**0.834**	0.172	0.727	0.662	0.564
PI	**0.775**	0.094	0.747	0.516	0.693
STU	**0.729**	−0.179	0.391	0.226	0.297
PreLP	−0.027	**0.840**	0.206	0.156	0.183
PreIP	−0.157	**0.799**	0.087	0.101	0.108
PreRI	−0.046	**0.863**	0.151	0.170	0.221
PreIC	0.169	**0.827**	0.308	0.395	0.421
$F_{UIG,G}$	0.792	0.222	**0.930**	0.625	0.680
$F_{CP,G}$	0.490	0.027	**0.587**	0.233	0.179
$F_{INF,G}$	0.353	0.241	**0.514**	0.310	0.388
$F_{RP,G}$	0.713	0.269	**0.871**	0.682	0.801
$F_{UIG,I}$	0.613	0.265	0.665	**0.904**	0.753
$F_{CP,I}$	0.328	0.261	0.250	**0.472**	0.217
$F_{INF,I}$	0.208	0.069	0.250	**0.453**	0.348
LP	0.563	0.357	0.601	0.544	**0.829**
IP	0.570	0.278	0.654	0.681	**0.903**
RI	0.656	0.254	0.754	0.747	**0.864**
IC	0.436	0.275	0.465	0.533	**0.693**

Table 4 PLS construct correlations

Construct	UD	PreUIP	GF	IF	UIP
UD	1.000				
PreUIP	0.050	1.000			
GF	0.819	0.272	1.000		
IF	0.649	0.311	0.679	1.000	
UIP	0.682	0.346	0.762	0.769	1.000

Notice that, it is interesting to compare differences of TH between Taiwan and the U.S. We found that their UIG's funding allocation behavior is quite similar to that in previous literature. Firstly, the input criterion in the U.S. is more important than the output one. Only a small part of the public fund is allocated on an output basis (Kaiser et al., 2001). Secondly, the U.S. government funding had a positive influence on industry funding (Thursby and Thursby 2011). Thirdly, industry funding was more conducive to innovation output of the U.S. universities when compared with the government funding (Thursby and Thursby 2011).

In addition to the analysis of the model with 52 samples who actively participated in UIG collaboration in Taiwan described above, we further divided them into two tiers in according to whether or not the universities were subsidized by the incentive programs of Ministry of Education, Taiwan. Such analyzes are also interesting due to the potential for

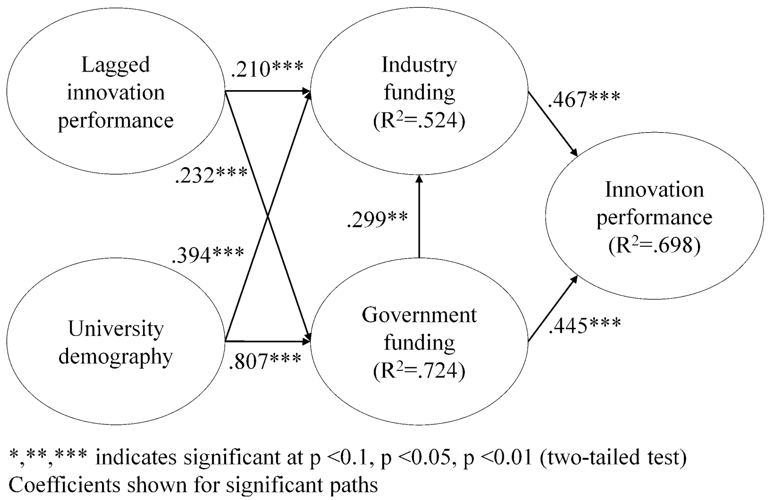

Fig. 5 Path weights and significant tests among UIG in collaborative research model

Table 5 Detailed PLS hypothesis testing among UIG in collaborative research model

Hypothesis	Path	Estimation	Sample mean	Standard error	*t* value	Result
H1 (+)	UD → GF	0.807	0.807	0.031	25.910***	Support
H2 (+)	UD → IF	0.394	0.368	0.118	3.337***	Support
H3 (+)	PreUIP → GF	0.232	0.229	0.047	4.930***	Support
H4 (+)	PreUIP → IF	0.210	0.210	0.071	2.948***	Support
H5 (+)	GF → IF	0.299	0.332	0.144	2.072**	Support
H6 (+)	GF → UIP	0.445	0.435	0.100	4.451***	Support
H7 (+)	IF → UIP	0.467	0.477	0.098	4.740***	Support

Significant at * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$ respectively (two-tailed test)

officials to realize the current priorities they should follow in order to activate more funding support and produce more innovation output. Tier 1 is the group of subsidized universities, consisting of 28 samples, and the remaining unsubsidized universities are grouped into Tier 2. The group members of Tier 1 and Tier 2 are listed in "Appendix", Table 7. The estimated results of PLS in the structural model for Tier 1 and Tier 2 are shown and explained as follows. As shown in Fig. 6a and Table 6, the relative strengths of path weights of Tier 1 model are partially distinct from the full model in Table 5. In addition to government funding, industry funding is also positively affected by the demography of the universities in Tier 1. However, the two funding sources are independent of the past innovation performance of the universities in Tier 1. These subsidized universities send out the most outstanding image with regard to teaching, research, and development in Taiwan. This kind of image impresses not only government but also industries, resulting in the allocation of funding without taking past innovation performance into account. That is, the input criterion plays an important role in Tier 1 model. Furthermore, government funding plays the role of dominator in university innovation

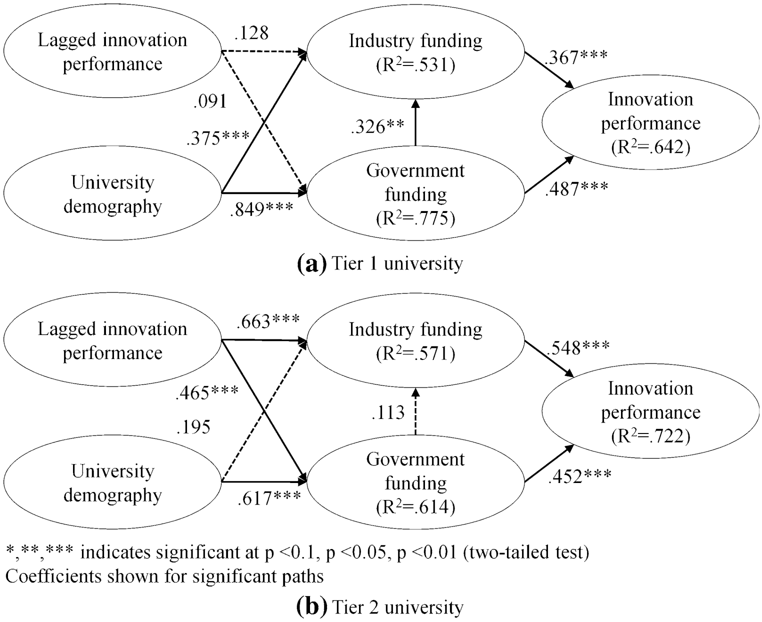

Fig. 6 Path weights and significant tests among UIG in collaborative research model of the two tiers

performance. The government funding to these universities in UIG collaboration is extremely abundant, bringing greater influence to the innovation outputs, which might be the possible reason.

As shown in Fig. 6b and Table 6, the relative strengths of path weights of the Tier 2 model are also partially distinct from the full model in Table 5. In addition to the weight path from UD to IF, government and industry funding are positively affected by the demography and past innovation performance of the universities in Tier 2. The output criterion occupies a decisive position in funding allocation. This may cause by a relative lack of confidence in Tier 2 university among financial supporters. They fear that their investment might be a drain on UIG collaboration, and so commercial potential becomes a critical consideration. Additionally, the government funding is without significant effect on the level of industry funding. These signify that the amount of government financial support is not one of the concerns when industries decide to participate in UIG collaboration with a given university in Tier 2.

In sum, in querying the funding basis of government or industry allocations to universities, both external funding forms are highly input-oriented in Tier 1, whereas the output criterion becomes very important in Tier 2. With regard to government funding piloting, this hypothesis holds for Tier 1, but not for Tier 2. With regard to exciters of innovation output, government and industry play the important roles in Tier 1 and Tier 2 respectively. These results then demonstrate the differences in behaviors of the two tiers.

By the same token, we could conceptually and qualitatively map the above results of the UIG relationship to the tri-lateral model of Etzkowitz and Leydesdorff (2000) where each sector takes the role of the other at the interface. Universities attract external funding and innovate something; government allocates funds to universities based on input and output criteria, motivating industries to follow up, and exciting universities to create innovation. Industries allocate funds to universities based on input and output criteria as well as

Table 6 Detailed PLS hypothesis testing among UIG in collaborative research model of the two tiers

Hypothesis	Path	Tier 1 ($n = 28$)			Tier 2 ($n = 24$)		
		Estimation	t value	Result	Estimation	t value	Result
H1 (+)	UD → GF	0.849	26.373***	Support	0.617	5.100***	Support
H2 (+)	UD → IF	0.375	2.618***	Support	0.195	0.990	Not significant
H3 (+)	PreUIP → GF	0.091	0.940	Not significant	0.465	3.962***	Support
H4 (+)	PreUIP → IF	0.128	1.236	Not significant	0.663	5.848***	Support
H5 (+)	GF → IF	0.326	1.957**	Support	0.113	0.492	Not significant
H6 (+)	GF → UIP	0.487	3.584***	Support	0.452	4.518***	Support
H7 (+)	IF → UIP	0.367	2.855***	Support	0.548	3.913***	Support

Significant at * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$ respectively (two-tailed test)

government funding policy, and excite universities to create innovation. The estimation results of the model with full samples are regarded as the base coefficients in order to present the differences between Tier 1 and Tier 2 universities. The overlapping regions among the triplet are all set equal to one-third circle area, where the sum of the base coefficients for the hypotheses "1, 3, 6", "2, 4, 7", and "5", respectively exhibits the interaction levels between sectors of government–university, industry–university, and government–industry. With the above-mentioned settings, we summed up the coefficients of each sector in the Tier 1 and Tier 2 models and divided the value by triple of the corresponding sum of the base coefficient. In this way, the interaction levels between sectors of the Tier 1 and Tier 2 models could be determined.

In the Tier 1 model, as shown in Fig. 7a, the government overlaps significantly with university and industry and directs the relations between them. Universities' demographics are the primary factor in attracting external funding. Government funding not only leads industry funding, but also stimulates more innovation within universities, whereas the relationship between industry and university is relatively weak. As a member of this group, ingratiating oneself to the government through the maintenance or improvement of their demography is a top priority.

In the Tier 2 model, as shown in Fig. 7b, the overlapping region between government and industry is relatively small, since government funding does not significantly lead industry funding. However, the overlapping region between university and industry is relatively large, since funding from the industry can excite more innovation than that from the government. As member of this group, innovation performance becomes an important factor in attracting external funding, so demonstrating innovation performance is a way of life. With such efforts, a successful performance leads to a more desired commercial result in the long run.

Conclusions and further studies

The commercial prospects of university research have been a major focus of government policy. Academic research is no longer undertaken for creating knowledge alone, but

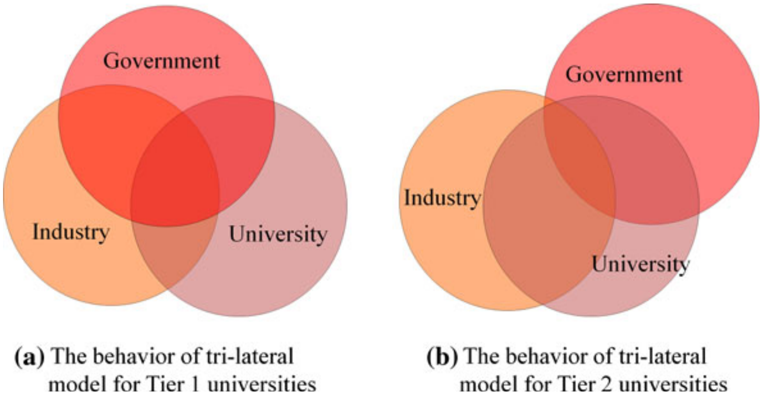

Fig. 7 Triple helix interaction model

increasingly driven by the needs of industry and its market value (Severson 2004). Thus it is important that universities, government and industry continue to work together to assure the university mission and provide the outcomes desired by government and industry. Analysts have taken lots of efforts to address issues related to interaction of the TH. Conventionally, the forerunners such as Leydesdorff, Etzkowitz, and Park, etc., investigated the UIG relationship using the co-authorship or co-occurrence analysis of patentometrics, scientometrics, or webometrics. Unlike the classic works, this study explored such relationship through the cause-effect of funding allocation using the SEM which offered a novel interface in the theoretical development among the triplets. The proposed model enabled us to understand the status of the funding mechanism, the government's capacity of funding guide, and the role of innovation output exciter. To our best knowledge, the model is distinct and contributive due to the fact that each question described above was only partly discussed in previous literature. No studies have attempted to integrate all the research questions into one model. Two experiments were conducted for which the samples were Taiwan's universities:

The first experiment covered all the universities with UIG collaboration in order to explore the cause-effect of funding allocation in Taiwan. The analytic results and the finding related to existing studies are summarized. Corresponding to the first question, we conclude that government funding and industry funding are rationed in terms of the combination of input and output criteria. However, the input criterion is dominant. The funding mechanism of Taiwan is still under development and is to be improved since the effects of increase output-orientation on several developed countries can be seen (Jongbloed 2008; Himanen et al. 2009). Corresponding to the second question, we conclude that in addition to demography or innovation performance, industry funding is also stimulated by the amount of government funding. It indicates that Taiwan's government is the funding guider and the amount of funding will influence the attitude and willingness of industry involvement in UIG collaboration. Corresponding to the third question, we conclude that government funding as well as industry funding simultaneously affect the incentive innovation performance of the university. This finding resonates with the conclusions of various studies such as Huang et al. (2005), Gulbrandsen and Smeby (2005), Cherchye and Vanden Abeele (2005), and Goldfarb (2008). We also find that industry funding is more conducive to innovation output, when compared with the government funding in Taiwan. This finding is agreed with that of Thursby and Thursby (2011), who suggest that industries perform as the role of output exciter in UIG collaboration in Taiwan.

Concerning the implication of this study, a group difference analysis provides a possible way for university officials to learn what current priorities they should follow so as to gain more funding subsidies and create more innovation output. As for the Tier 1 model, the subsidized universities send out an outstanding image which encourages both governments and industries to allocate funding without taking past innovation performance into account. Besides, the government funding to these universities is abundant, bringing about greater influence to the innovation output. Therefore, for members in Tier 1, keeping up their demography to please the government was a primary concern. As for the Tier 2 model, unsubsidized universities are suggested to improve the innovation performance to demonstrate R&D ability so as to attract industry investment. With such efforts, self-propagating advantageous situations in which a successful performance led to a desired innovation result would occur. This virtuous circle is the chief attraction of the collaboration system.

There are two limitations that need to be addressed regarding the present study. The first limitation has something to do with the extent to which the proposed model can be generalized beyond the Taiwan's case study. Further empirical evaluations are encouraged to replicate the proposed model in different contexts and surroundings. The second limitation concerns the static nature of this study due to the fact that the analysis is only limited to a specific snapshot. If time series datasets are available, each dataset can be repeatedly inputted into the proposed model over time. Longitudinal analysis of dynamic changes in the relationships among the TH of a country remains a subject for further investigation.

Appendix

See Table 7.

Table 7 The lists of university names of groups Tier 1 and Tier 2

Tier 1	Tier 2
Chang Gung University,	Chaoyang University of Technology,
Cheng Shiu University,	Chinese Culture University,
China Medical University,	China University of Technology,
Chung Hua University,	Chung Shan Medical University,
Chung Yuan Christian University,	Da-Yeh University,
Far East University,	Fu Jen Catholic University,
Feng Chia University,	Hungkuang University,
I-Shou University,	Ming Chuan University,
Kaohsiung Medical University,	National Central University,
Kun Shan University,	National Chengchi University,
National Cheng Kung University,	National Chiayi University,
National Chiao Tung University,	National Chung Cheng University,
National Chung Hsing University,	National Taiwan Normal University,
National Formosa University,	National United University,
National Ilan University,	National University of Kaohsiung,
National Kaohsiung First University of Science and Technology,	National University of Tainan,
National Kaohsiung University of Applied Sciences,	National Yang-Ming University,
National Pingtung University of Science and Technology,	Shih Hsin University,
National Sun Yat-Sen University,	Soochow University,

Table 7 continued

Tier 1	Tier 2
National Taipei University of Technology University,	Tajen University,
National Taiwan Ocean University,	Tamkang University,
National Taiwan University,	Tatung University,
National Taiwan University of Science and Technology,	Tunghai University, and
National Tsing Hua University,	Yuan Ze University.
National Yunlin University of Science and Technology,	
Taipei Medical University,	
Shu-Te University, and	
Southern Taiwan University of Science and Technology.	

References

Adams, J. D., & Griliches, Z. (1998). Research productivity in a system of universities. *Annales d'Economie et de Statisque, 49*(50), 127–162.

Blumenthal, D., Campbell, E. G., Causino, N., & Louis, K. S. (1996). Participation of life-science faculty in research relationships with industry. *New England Journal of Medicine, 335*(23), 1734–1739.

Breschi, S., Lissoni, F., & Montobbio, F. (2008). University patenting and scientific productivity: a quantitative study of Italian academic inventors. *European Management Review, 5*(2), 91–110.

Chatelin, Y. M., Vinzi, V. E., Tenenhaus, M. (2002). State-of-art on PLS modeling through the available software. Working paper 764/2002, Haute Études Commerciales Graduate Business School, Jouy en Josas.

Chen, S. H., Huang, M. H., & Chen, D. Z. (2012). Identifying and visualizing technology evolution: a case study of smart grid technology. *Technological Forecasting and Social Change, 79*(6), 1099–1110.

Cherchye, L., & Vanden Abeele, P. (2005). On research efficiency: a micro-analysis of Dutch university research in economics and business management. *Research Policy, 34*(4), 495–516.

Chin, W. W. (1998). The partial least squares approach for structural equation modeling. In G. A. Marcoulides (Ed.), *Modern methods for business research* (pp. 295–336). London: Lawrence Erbaum Associates.

Chin, W. W., & Dibbern, J. D. (2010). An introduction to a permutation based procedure for multi-group PLS analysis: Results of tests of differences on simulated data and a cross cultural analysis of the sourcing of information system services between Germany and the USA. In V. E. Vinzi, W. W. Chin, J. Henseler, & H. Wang (Eds.), *Handbook of partial least squares: concepts, methods and applications in marketing and related fields* (pp. 171–193). Berlin-Heidelberg: Springer.

Churchill, G. A. (1979). A paradigm for developing better measures of marketing constructs. *Journal of Marketing Research, 16*(1), 64–73.

Diamantopoulos, A. D., & Siguaw, J. A. (2000). *Introducing LISREL*. London: Sage Publications.

Dunn, S. C., Seaker, R. F., & Waller, M. A. (1994). Latent variables in business logistics research: scale development and validation. *Journal Business Logistics, 15*(2), 145–172.

Etzkowitz, H. (1994). Technology centers and industrial policy: the emergence of the interventionist state in the USA. *Science and Public Policy, 21*(2), 79–87.

Etzkowitz, H. (2003). Research groups as 'quasi-firms': the invention of the entrepreneurial university. *Research Policy, 32*(1), 109–121.

Etzkowitz, H. (2008). *Triple helix innovation: industry, university, and government in action*. London: Routledge.

Etzkowitz, H., & Leydesdorff, L. (2000). The dynamics of innovation: from national systems and "mode 2" to a triple helix of university-industry government relations. *Research Policy, 29*(2), 109–123.

Fornell, C., & Larcker, D. (1981). Structural equation models with unobservable variables and measurement error. *Journal of Marketing Research, 18*(1), 39–50.

Garson, D. (2007). Structural Equation Modeling. Working paper. http://faculty.chass.ncsu.edu/garson/PA765/structur.htm. Accessed 5 December 2011.

Geuna, A., & Nesta, L. (2006). University patenting and its effects on academic research: the emerging European evidence. *Research Policy, 35*(6), 790–807.

Godin, B. (1998). Writing performative history: the new New Atlantis? *Social Studies of Science, 28*(3), 465–483.

Goldfarb, B. (2008). The effect of government contracting on academic research: does the source of funding affect scientific output? *Research Policy, 37*(1), 41–58.

Götz, O., Liehr-Gobbers, K., & Krafft, M. (2010). Evaluation of structural equation models using the partial least squares (PLS) approach. In V. E. Vinzi, W. W. Chin, J. Henseler, & H. Wang (Eds.), *Handbook of partial least squares: concepts, methods and applications in marketing and related fields* (pp. 691–711). Berlin-Heidelberg: Springer.

Grewal, R., Cote, J. A., & Baumgartner, H. (2004). Multicollinearity and measurement error in structural equation models: implications for theory testing. *Marketing Science, 23*(4), 519–529.

Gulbrandsen, M., & Smeby, J. C. (2005). Industry funding and university professors' research performance. *Research Policy, 34*(6), 932–950.

Himanen, L., Auranen, O., Hanna-Mari, P., & Mika, N. (2009). Influence of research funding and science policy on university research performance: a comparison of five countries. *Science and Public Policy, 36*(6), 419–430.

Hossain, M. D., Moon, J., Kang, H. G., Lee, S. C., & Choe, Y. C. (2012). Mapping the dynamics of knowledge base of innovations of R&D in Bangladesh: triple helix perspective. *Scientometrics, 90*(1), 57–83.

Hu, M. C. (2009). Developing entrepreneurial universities in Taiwan: the effects of research funding sources. *Science, Technology & Society, 14*(1), 35–57.

Hu, M. C., & Mathews, J. A. (2009). Estimating the innovation effects of university-industry-government linkages: the case of Taiwan. *Journal of Management & Organization, 15*(2), 138–154.

Huang, Z., Chen, H., Yan, L., & Roco, M. C. (2005). Longitudinal nanotechnology development (1991–2002): national science foundation funding and its impact on patents. *Journal of Nanoparticle Research, 7*(4–5), 343–376.

Hulland, J. (1999). Use of partial least squares (PLS) in strategic management research: a review of four recent studies. *Strategic Management Journal, 20*(2), 195–204.

Jensen, R., Thursby, J., & Thursby, M. (2010). University-industry spillovers: the government funding and industrial consulting. NBER Working paper 15732.

Jerome, L. W., & Jordan, P. J. (2010). Building an institute for triple-helix research innovation. Working paper. http://www.triplehelixinstitute.org/thi/ithi_drupal/sites/default/files/uploaded/documents/TripleHelix_BuildingAnInstitute.pdf. Accessed 16 December 2011.

Jongbloed, B. (2008). Funding higher education: a view from Europe. seminar on funding higher education: a comparative overview. http://www.utwente.nl/mb/cheps/summer_school/Literature/Brazil%20funding%20vs2.pdf. Accessed 16 December 2011.

Jöreskog, K. G., & Wold, H. (1982). The ML and PLS techniques for modeling with latent variables: Historical and comparative aspects. In H. Wold, & K. G. Jöreskog (Eds.), *Systems under indirect observation: causality, structure, prediction*. Amsterdam: North-Holland.

Kaiser, F., Vossensteyn, H., & Koelman, J. (2001). Public funding of higher education: a comparative study of funding mechanisms in ten countries. Working paper, Enschede: Center for Higher Education Policy Studies.

Khan, G. F., Cho, S. E., & Park, H. W. (2012). A comparison of the Daegu and Edinburgh musical industries: a triple helix approach. *Scientometrics, 90*(1), 85–99.

Khan, G. F., & Park, H. W. (2011). Measuring the triple helix on the web: longitudinal trends in the university–industry–government relationship in Korea. *Journal of the American Society for Information Science and Technology, 65*(12), 2443–2455.

Khan, G. F., & Park, H. W. (2012). Editorial: triple-helix and innovation in Asia using scientometrics, webometrics, and informetrics. *Scientometrics, 90*(1), 1–7.

Kim, H., Huang, M., Jin, F., Bodoff, D., Moon, J., & Choe, Y. C. (2012). Triple helix in the agricultural sector of Northeast Asian countries: a comparative study between Korea and China. *Scientometrics, 90*(1), 101–120.

Kivistö, J. (2005). The government-higher education institution relationship: theoretical considerations from the perspective of agency theory. *Tertiary Education and Management, 11*(1), 1–17.

Kline, R. B. (1998). *Principles and practice of structural equation modeling*. New York: The Guilford Press.

Kwon, K. S., Park, H. W., So, M., & Leydesdorff, L. (2012). Has globalization strengthened South Korea's national research system? National and international dynamics of the triple helix of scientific co-authorship relationships in South Korea. *Scientometrics, 90*(1), 163–176.

Lei, X. P., Zhao, Z. Y., Zhang, X., Chen, D. Z., Huang, M. H., & Zhao, Y. H. (2012). The inventive activities and collaboration pattern of university–industry–government in China based on patent analysis. *Scientometrics, 90*(1), 231–251.

Leydesdorff, L. (2003). The mutual information of university–industry–government relations: an indicator of the triple helix dynamics. *Scientometrics, 58*(2), 445–467.

Leydesdorff, L., & Meyer, M. (2003). The triple helix of university–industry–government relations. *Scientometrics, 58*(2), 191–203.

Leydesdorff, L., & Sun, Y. (2009). National and international dimensions of the triple helix in Japan: university–industry–government versus international coauthorship relations. *Journal of the American Society for Information Science and Technology, 60*(4), 778–788.

Liu, X. (2003). *Policy tools for allocative efficiency of health services*. Geneva, Switzerland: WHO.

Mathews, J. A., & Hu, M. C. (2007). Universities and public research institutions as drivers of economic development in Asia. In S. Yusuf, & K. Nabeshima (Eds.), *How universities promote economic growth* (pp. 91–109). Washington, D.C.: The World Bank.

Meissner, C. (2010). *University research and industry involvement. Three essays on the effects and determinants of industry collaboration and commercialization in academia.* Dissertation, Department of Economics, City University, London.

Meyer, M., Siniläinen, T., & Utecht, J. T. (2003). Towards hybrid triple helix indicators: a study of university-related patents and a survey of academic inventors. *Scientometrics, 58*(2), 321–350.

Miroiu, A., & Aligica, P. D. (2003). Public higher education financing: a comparison of the historical and formula-based mechanism. Working paper. http://unpan1.un.org/intradoc/groups/public/documents/NISPAcee/UNPAN009148.pdf. Accessed 14 January 2012.

Mowery, D., & Sampat, B. (2005). The Bayh-Dole Act of 1980 and university-industry technology transfer: a model for other OECD governments? *Essays in Honor of Edwin Mansfield, 4*, 233–245.

Park, H. W., Hong, H. D., & Leydesdorff, L. (2005). A comparison of the knowledge-based innovation systems in the economies of South Korea and the Netherlands using triple helix indicators. *Scientometrics, 65*(1), 3–27.

Park, H. W., & Leydesdorff, L. (2010). Longitudinal trends in networks of university–industry–government relations in South Korea: the role of programmatic incentives. *Research Policy, 39*(5), 640–649.

Payne, A. A., & Siow, A. (2003). Does federal research funding increase university research output? *Advances in Economic Analysis & Policy, 3*(1), Article 1.

Perng, D. B., & Chen, S. H. (2011). Directional textures auto-inspection using discrete cosine transform. *International Journal of Production Research, 49*(23), 7171–7187.

Pirouz, D. M. (2006). An overview of partial least squares. Working paper. http://www.merage.uci.edu/~dpirouz04/research/pls/PLS.pdf. Accessed 10 June 2011.

Priego, J. L. O. (2003). A vector space model as a methodological approach to the triple helix dimensionality: a comparative study of biology and biomedicine centres of two European national research councils from a webometric view. *Scientometrics, 58*(2), 429–443.

Ringle, C. M., Wende, S., & Will, A. (2005). SmartPLS-Version 2.0. Germany: university at Hamburg. http://www.smartpls.de. Accessed 5 September 2011.

Sambamurthy, V., & Chin, W. W. (1994). The effects of group attitudes toward alternative GDSS designs on the decision-making performance of computer-supported groups. *Decision Sciences, 25*, 215–241.

Severson, J. A. (2004). Models of university-industry cooperation. *Journal of Industry-Academia-Government Collaboration, 2*, 1–6.

Shin, J. C., Lee, S. J., & Kim, Y. (2012). Knowledge-based innovation and collaboration: a triple-helix approach in Saudi Arabia. *Scientometrics, 90*(1), 311–326.

Tenenhaus, M., Vinzi, V. E., Chatelin, Y. M., & Lauro, C. (2005). PLS path modeling. *Computational Statistics & Data Analysis, 48*(1), 159–205.

Thursby, J. G., & Thursby, M. C. (2011). Faculty participation in licensing: implications for research. *Research Policy, 40*(1), 20–29.

Wetzels, M., Odekerken-Schröder, G., & Van Oppen, C. (2009). Using PLS path modeling for assessing hierarchical construct models: guidelines and empirical illustration. *MIS Quarterly, 33*(1), 177–196.

Wold, H. (1975). Path models with latent variables: The NIPALS approach. In H. M. Blalock, A. Aganbegian, F. M. Borodkin, R. Boudon, & V. Capecchi (Eds.), *Quantitative sociology: International perspectives on mathematical and statistical modeling* (pp. 307–357). NewYork: Academic.

Yue, W., & Wilson, C. S. (2004). Measuring the citation impact of research journals in clinical neurology: a structural equation modeling analysis. *Scientometrics, 60*(3), 317–332.

Zajkowski, M. E. (2003). Institutional structure and the Australian research director: a qualitative study. *Journal of Higher Education Policy and Management, 25*(2), 203–212.

Zhang, Y. (2009). A study of corporate reputation's influence on customer loyalty based on PLS-SEM model. *International Business Research, 2*(3), 28–35.