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THE RELATIONSHIP BETWEEN HETEROGENEITY OF GRADUATE INSTITUTES AND INSTITUTE-INDUSTRY COLLABORATION EXPLAINED BY BLAU'S INDEX

Hung-Jen Weng[1] and Dian-Fu Chang[2,*]

[1]Doctoral Program of Educational Leadership and Technology Management
[2]Graduate Institute of Educational Policy and Leadership
Tamkang University
No. 151, Yingzhuan Rd., Tamsui Dist., New Taipei City 25137, Taiwan
andyw921@yahoo.com; *Corresponding author: 140626@mail.tku.edu.tw

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Abstract. *In this study, the organizational heterogeneity has been considered as a key factor influencing the effects of institute-industry cooperation in graduate institutes. We assumed that faculty position, faculty member nationality, and diversity of academic expertise are influencing indicators of heterogeneity to interpret the relationship with effect of institute-industry cooperation by using Blau's index. One-hundred graduate institutes with doctoral programs were selected from 881 graduate institutes offering doctoral programs in Taiwan as our example. Correlation analysis, regression analysis, and curve estimation were conducted to determine the effects of graduate institute heterogeneity on institute-industry collaboration. The results reveal that excessive or insufficient differentiation among faculty positions has an adverse effect on institute-industry collaboration, presenting both advantages and disadvantages in this case. A Blau's index value of 0.56 for faculty position differentiation indicated optimal performance in institute-industry collaboration. Heterogeneity in nationality positively influenced institute-industry collaboration.*

Keywords: Institute-industry collaboration, Higher education, Graduate institutes, Heterogeneity, Organization management

1. **Introduction.** Previous studies indicated that institute-industry collaboration positively influences academic research and economic development; therefore, both the higher education institutions and industry sectors are willing to undertake institute-industry collaboration [1,2]. Many scholars have provided various viewpoints and opinions on the effective models of institute-industry collaboration [3-5]. However, the outcomes of institute-industry collaboration do not always meet expectations [6]. In this study, we selected heterogeneity and diversity as influencing factors in organizations to disclose their relationships with the effect of institute-industry collaboration. This way can provide an alternative view to determine how the graduate institutes will increase the effect of institute-industry collaboration.

From the viewpoint of organizational management, both heterogeneity and diversity in organizations are crucial factors for discussing their influences on the institute-industry collaboration. Diversity will influence on the effectiveness of organizations. For example, in business management, the heterogeneity of top management team (TMT) has exerted its influence on organizational performance [7]. In addition, the heterogeneity of top management team will also influence the relationship of resource allocation and performance [8]. Previous studies have shown there are couple indicators using for evaluating the heterogeneity of organization, for instance, Blau's index, standard deviation, and coefficient of variation [9,10]. Numerous studies stand for economic viewpoint to promote the effect of institute-industry collaboration or create different models of cooperation [3,4]. We

hypothesized that the performance of graduate institutes in higher education regarding institute-industry collaboration is influenced by faculty position, nationality of faculty members, and diversity of academic expertise. Regression model and Blau's index can be used to uncover the problem of effectiveness of institute-industry collaboration. In this paper, we presents the method section, results, conclusions, and suggestions for further studies.

2. **Method.** Based on the assumption that heterogeneity of graduate institutes will influence on their effectiveness of institute-industry collaboration. The testing model will focus on faculty position, nationality of faculty members, and diversity of academic expertise based on the data set. The samples, research variables, and data collection are presented in the following sections.

2.1. **Samples.** In the present study, graduate institutes such as public and private colleges and vocational colleges in Taiwan were the research targets. Through stratified sampling, we recruited 100 graduate institutes from 881 departments offering doctoral programs. First, departments were selected according to the following inclusion criteria: the doctoral programs had been offered for more than 5 years, and the department had more than 10 faculty members. These departments were categorized into three categories: science and technology, financial management, and humanities. The samples comprised 38 science and technology departments, 33 financial management departments, and 29 humanities departments. Among the institutes in the sample, 66 were public colleges and 34 were private colleges. Regarding the type of institution, 78 were comprehensive universities, 15 were vocational colleges, and 7 were teachers' colleges. This distribution fits to the normal distribution of the current graduate institutes in the system.

2.2. **Research variables.** In this study, the heterogeneity among graduate institutes was the independent variable, comprising three dimensions: faculty position, nationality of faculty members, and diversity of academic expertise. Typically, these three factors are the key components of the graduate institutes. Faculty position was classified into four categories: professor, associate professor, assistant professor, and others (expert or lecturer). This classification accords with the current status of most higher education institutions in Taiwan. Regarding the nationality of faculty members, because only a few foreign faculty members work in higher education institutes in Taiwan, faculty members were categorized as either nationals or non-nationals. Regarding the diversity of academic expertise, faculty' expertise was categorized according to whether their highest level of educational attainment was related to the graduate institutes where they worked; accordingly, it was categorized as either relevant or irrelevant. According to the formula for calculating Blau's index and the standardization procedure, a standardized heterogeneity index was obtained.

In the present study, the number of cases in which the graduate institutes have successfully applied for subsidies for institute-industry collaboration or conducted similar research projects from Ministry of Science and Technology (MOST) was the dependent variable. At the R&D stage of institute-industry collaboration, most higher education institutions in Taiwan apply for grants from MOST and then commercialize their research results by transferring ownership to related industries. This is the most common model of current institute-industry collaboration in our target group. Therefore, the number of cases in which graduate institutes applied for grants from MOST and conducted the projects was used as an indicator of institute-industry collaboration.

2.3. **Verifying by statistics.** In this study, SPSS (statistical package of social science) was used to transform the data by using correlation and regression analysis. In correlation and regression models, faculty position, nationality of faculty members, and diversity of

academic expertise are verified by their relationships with the effect of institute-industry collaboration.

In addition, the curve estimation method was employed to identify the optimal values of various heterogeneity indices and to further interpret the data. The curve estimation could be defined by a second-order polynomial curve, a cubic or a quadratic curve to fit the model. Blau's index was commonly used to assess organizational heterogeneity based on the curve estimation. The standardized Blau's index is defined as follows [10]:

$$H = 1 - \sum_{i=1}^{n} s_i^2 \tag{1}$$

where n represents the number of categories, and s_i denotes the proportion of organizational members in a category i. A high index value indicates a high degree of heterogeneity; theoretically, the minimum value is 0 and the maximum value, which depends on the number of categories, is calculated as $(n-1)/n$. For example, the gender variable has two categories ($n = 2$), which implies that the maximum heterogeneity index is 0.5; similarly, when a variable has five categories ($n = 5$), the maximum heterogeneity index is 0.80. To further compare the degree of heterogeneity among multiple variables without the results being influenced by the number of categories, standardization is necessary to normalize the heterogeneity index. To standardize, the value of the heterogeneity index of a variable is divided by its maximum value such that the adjusted value of the heterogeneity index of the variable is between 0 and 1 [11]. The standardized Blau's index was used as an indicator of heterogeneity in this study.

3. **Results.** First, the sample of 100 graduate institutes was analyzed by their institute-industry collaboration based on the transform of Blau's index. The successful cases of institute-industry collaboration among these graduate institutes are from 70 to zero (Figure 1). This figure indicates that the variation of institute-industry collaboration is quite significant in current graduate institutes.

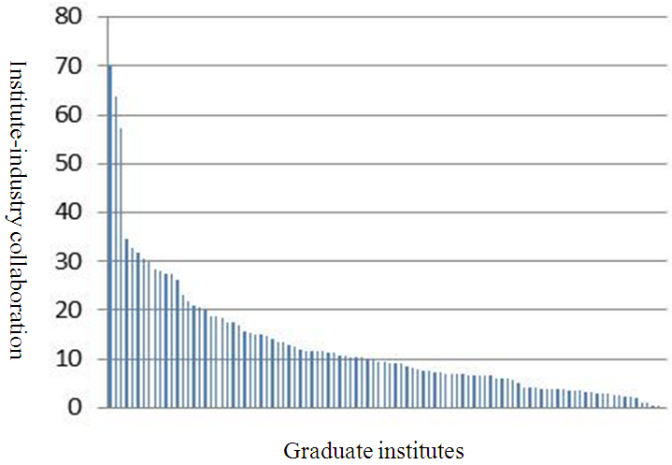

FIGURE 1. Differences of institute-industry collaboration in selected graduate institutes

3.1. **Correlation and regression analysis.** For the correlation analysis, the Pearson's correlation coefficients between institute-industry collaboration and faculty position, nationality of faculty members, and diversity in faculty expertise were -0.217 ($p = .030$), 0.215 ($p = .031$), and 0.300 ($p = .002$), respectively, all of which were significantly correlated. Thus, the results support our hypothesis that faculty position, the nationality of faculty members, and the diversity of faculty expertise are correlated with the effectiveness of institute-industry collaboration.

TABLE 1. Summary of regression analysis for institute-industry collaboration ($N = 100$)

Variables	B	SE (B)	β	t	Sig. (p)
Heterogeneity of faculty position	−19.315	9.250	−.200*	−2.088	.039
Heterogeneity of nationality of faculty	8.157	8.636	.104	.944	.347
Heterogeneity of diversity of expertise	8.165	3.915	.231*	2.085	.040

$R^2 = .135$ in regression model, * $p < .05$

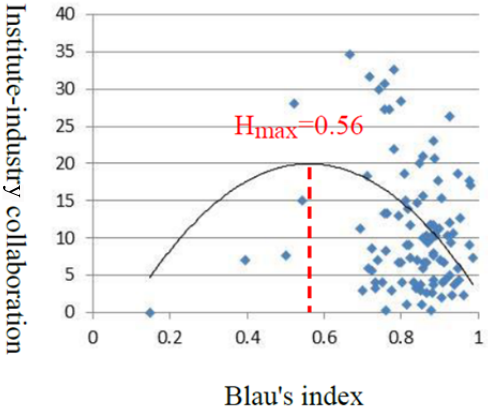

FIGURE 2. Heterogeneity of faculty position

According to the regression coefficient t test results, faculty position and diversity of academic expertise significantly influenced institute-industry collaboration (Table 1). By comparing the standardized beta coefficients, we found that the heterogeneity in diversity of faculty expertise had the strong positive influence on institute-industry collaboration, while faculty position exerted strong negative influence. The regression model showed that the heterogeneity in the nationality of faculty members was non-significant; hence, the influence of heterogeneity in the nationality of faculty members on institute-industry collaboration cannot be counted in this model. However, the heterogeneity in the nationality of faculty members correlated positively with institute-industry collaboration. Both the correlation and regression analysis presented a little different picture in this stage. Therefore, the curve estimation was adopted to further identify the optimal degree of heterogeneity in faculty position, nationality of faculty members, and diversity of faculty expertise.

3.2. **Heterogeneity of faculty position.**

3.2.1. *Optimization for heterogeneity of faculty position.* A scatter diagram was plotted with institute-industry collaboration along the vertical axis and Blau's index for faculty position along the horizontal axis. Second-order polynomial curves were fit to the diagram and revealed that when the heterogeneity index for faculty position was 0.56, institute-industry collaboration performance had a maximum value, as shown in Figure 2. These results indicated that excessively high or low faculty position heterogeneity was detrimental to institute-industry collaboration; however, when the heterogeneity index of faculty position was 0.56, institute-industry collaboration performance was optimal.

3.2.2. *Optimization for the proportion of faculty position construction.* In higher education institutions in Taiwan, faculty members include professors, associate professors, assistant professors, lecturers, research assistants, and administrative staff. Figure 3 shows a scatter diagram, in which institute-industry collaboration is plotted against the proportion of professors in a higher education institution. The average proportions of professors,

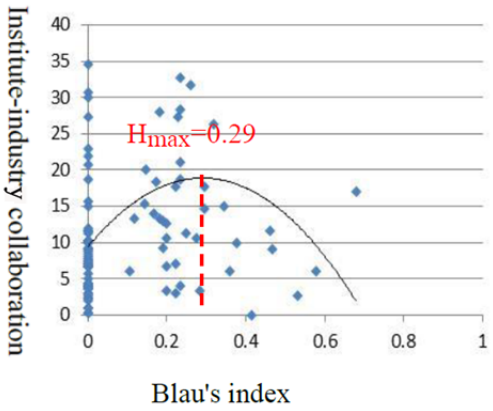

FIGURE 3. Heterogeneity of nationality of faculty

associate professors, and assistant professors were 0.42 ($SD = 0.17$), 0.32 ($SD = 0.11$), and 0.21 ($SD = 0.14$), respectively. To optimize the proportions of the various faculty positions, a cubic estimation method was adopted because it provides a more favorable fit than quadratic curve estimation methods do (i.e., the cubic estimation yields a smaller residual sum of squares).

According to our analysis, the number of professors, associate professors, and assistant professors accounted for 70% ($S_{max} = 0.71$), 20% ($S_{max} = 0.16$), and 10% ($S_{max} = 0.11$) of the total number of teachers, respectively. To facilitate institute-industry collaboration, the proportions of the number of professors to the number of associate professors to the number of assistant professors should be 7 : 2 : 1.

3.3. **Heterogeneity of nationality of faculty.** According to Figure 3, the degree of heterogeneity in the nationality of faculty members tended to be low. The results indicated that faculty members in higher education institutions in Taiwan were mostly Taiwanese citizens. According to the curve estimate, the inverted U curve has been presented in Figure 3. When the value of the heterogeneity index was 0.29, institute-industry collaboration performance attained the maximum value.

3.4. **Heterogeneity of diversity of faculty expertise.** According to the curve estimate results, organizations with a high degree of heterogeneity in the diversity of faculty expertise attained high institute-industry performance, and the fit of the curve slightly concaved downward. The results indicated that diversity in faculty expertise increased the capacity for institute-industry collaboration. For the institutions with a low degree of heterogeneity in the diversity of faculty expertise, the effect of increasing the degree of institute-industry collaboration was favorable at the early stage; however, the rate of the increase in institute-industry collaboration reduced with increasing degree of heterogeneity.

3.5. **Comparison of the differences among correlation, regression and curve estimation model.** In correlation analysis, the Pearson's correlation coefficients between institute-industry collaboration and faculty position, nationality of faculty members, and diversity in faculty expertise are all significant. In the regression analysis, the heterogeneity in diversity of faculty expertise had the strong positive influence on institute-industry collaboration, while the faculty position exerted strong negative influence. The regression model showed that the heterogeneity in the nationality of faculty members was non-significant. The curve estimation demonstrated that faculty position and nationality of faculty members manifested a double-edged sword phenomenon in institute-industry collaboration and presented their optimal values in the model. Table 2 presents the effect of institute-industry collaboration among the three approaches with different variables.

TABLE 2. The different results of correlation, regression and curve estimation

Variables in model	*Correlation*	*Regression*	*Curve estimation*
Heterogeneity of faculty position	$\surd$	$\surd$	$\surd$
Heterogeneity of nationality of faculty	$\surd$	$\times$	$\surd$
Heterogeneity of diversity of expertise	$\surd$	$\surd$	$\times$

Note. $\surd$ represents significance in the model; $\times$ represents no significance

4. **Conclusions.** The present study found that the main factors influencing institute-industry collaboration were the degree of heterogeneity in faculty position and the diversity of faculty expertise in regression model. While the curve estimation demonstrates that faculty position manifested a double-edged sword phenomenon in institute-industry collaboration. An excessively high or low heterogeneity index for faculty position is disadvantageous to institute-industry collaboration. In the present study, when the value of the heterogeneity index for faculty position was 0.56, the institute-industry collaboration performance was optimal. By analyzing the heterogeneity of faculty position, we found that when the proportion of the number of professors to the number of associate professors to the number of assistant professors was 7 : 2 : 1, institute-industry collaboration yielded the most optimal outcomes in this setting.

In addition, employing faculty members of various nationalities may be an effective method for enhancing institute-industry collaboration. The results of this study may serve as a reference for institute-industry collaboration, human resource planning, and organizational management. The findings provide some specific strategies for graduate institutes to reallocate their human resources to optimize their performance. Basically, the higher the degree of heterogeneity in the diversity of faculty expertise is, the more favorable the institute-industry collaboration performance is. Hiring professors with various professional backgrounds might enhance the institute's capacity for institute-industry collaboration, while the optimal point is hard to estimate in this case.

Because of the limitation of samples, we cannot approach to the details of major differences among the selected graduate institutions of science and technology, financial management, and humanities. For further studies, we suggest to consider more wide scopes to determine the details of whole system's issues. Basically, to enhance the effect of institute-industry collaboration, this study provides an alternative way to test the influence of organizational heterogeneity and diversity. By using the Blau's index, the data transformation can be used to determine an optimal proportion of faculty numbers in graduate institutions, judge how many faculty members with different nationalities should be recruited, and verify the other diversities of the faculty which might impact on organizational performance.

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