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Strategies for Construction of Majors in Universities with Different Characteristic Based on Social Needs

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Abstract We used the basic principles of game theory to investigate development strategies for standards of professional competence in universities in the same geographic area, under conditions of non-uniform distribution of social demand preference. The results revealed that, under various conditions in our model, different approaches for differential strategies were selected by university U_2 compared with university U_1. Specifically, in the competition between U_1 and U_2, there is a differential strategy compression point of U_2 to U_1; When U_2 universities choose the biggest differentiation strategy, university U_1 also have differentiated strategy control points. Arbitrary decision-making of university U_1 in relation to university U_2 was based on the requirements of professional competence standards, according to the change of the social demand for professional competency standard, universities U_2 will adopt the strategy of "no difference", "maximum differentiation" and "comprehensive intermediate strategy", respectively. The current results have theoretical implications for the selection of professional development and professional competence development strategies in asymmetric universities operating in the same geographic area.

Keywords heterogeneous preferences; specialty construction; game analysis

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1 Introduction

Specialty construction is not only a need of local universities, but is also an important factor for effective allocation of social education resources. Professional construction, particularly the determination and development of professional competency standards, is valuable for local universities and academics. Three major factors influencing the specialty construction of local universities are social demand, the regulation of local education administrative departments, and the internal motivational force of the university's own resource advantages in relation to professional competency construction.

Many previous studies have examined decision-making in the context of specialty construction in local universities, particularly the influence of decision-makers' internal factors and their behaviors on decision-making. Ma emphasized the importance of establishing decision-making processes in education[1], whereas Dowling-Hetherington investigated the influence of teachers in decision-making about specialty construction in colleges and universities[2]. In addition, Philip examined the role of students in university decision-making[3]. From the perspective of knowledge transfer, Tan, et al. built a multi-objective scheduling model for new product development projects, and proposed a multi-attribute decision-making method based on priority rules[4]. Yang proposed a new product development plan selection method based on the preferences of decision-makers[5]. Bulmus constructed a two-stage game model of an original equipment manufacturer (OEM) and remanufacturers to analyze the OEM's optimal decision-making and remanufacturing profitability[6]. From the manufacturer's point of view, in which the level of product quality is treated as an endogenous variable, Xie developed a strategy for optimal manufacturing and remanufacturing[7]. Pu examined the effects of retailer preference on promotion behavior and supply chain efficiency in a two-phase supply chain with manufacturing as its core. Although these researchers took internal factors and the effects of policy-makers' behavior on decision-making into account, they did not consider the role of consumer preferences[8].

In addition, the influence of external environmental factors on the development of university professional competency standards is an important factor to consider. Previous studies have proposed that external environmental factors are particularly important in decision-making in the context of educational projects. Wang examined the impact of big data on education project decision-making[9]. Zhou emphasized the benefits of evidence-based decision-making, defined as a combination of professional wisdom, practical experience and evidence from various methods and channels, proposing that it is the wisest method of decision-making in education[10]. Using system theory and synergetics, Li integrated educational research, educational decision-making and educational practice to create synergies among the three, with effective internal controls and external interventions[11]. Maniu explored the impact of market competition on operating modes for higher education programs[12]. Moreover, Zhai investigated the optimal pricing and rationing decisions of retailers in the presale environment, under conditions of uncertainty regarding consumer valuation and consumer search cost[13]. Because there is little correlation between external factors and consumer preferences, these studies have faced difficulties in applying their findings to real-world situations.

Consumer demand operates directly as an external variable in decision-making about university professional program construction, and has been investigated in a number of previous studies. For example, Liu, et al. focused on multi-channel product quality and pricing decisions by extending Salop's circular city model from the perspective of consumer utility theory[14]. Considering uncertainties in the market and technology in the development of new products, Liu, et al. used the degree of innovation of research and the importance of customer knowledge in research and development as indicators, and elucidated the conditions for selecting appropriate customer engagement strategies for a particular enterprise[15]. Based on Bayesian decision theory and its related mathematical models, Yang, et al. explored the future market demand for venture capital for new product development, the risk tendencies of investment decision-makers and the impact of intelligence costs on investment decisions[16]. Chen, et al. constructed the Graphical Evaluation and Review Technique (GERT) network model, combined with Bayesian decision theory, and studied the relationship between market demand, new product development costs and success rates. To adapt to the changing needs of the market, innovative product design can be based on a hybrid cross product development model using informed construction theory[17]. These models are informed by consumers' preferences to pay for functional quality and environmental quality[18]. Chen established a double-channel closed-loop supply chain decision model and analyzed the influence of consumer preferences and government subsidies on supply chain decision-making[19]. Xie, et al. constructed a two-cycle and indefinite output and price decision model for producers, and analyzed the influence of consumer preference coefficients on producers' production decision-making[20]. Based on the research described above, the market demand factor is typically regarded as an important condition for the development decisions of a project (or new product), and thus closely related to decision-making practice.

In addition, a number of studies have examined the importance of specialty construction to serve the local community, considering both schools and enterprises, highlighting several important characteristics. Kim seung studied the relationship between the expansion of university autonomy and the marketization of higher education[21]. Although these previous studies are part of mainstream research into professional construction in universities, it has been difficult to examine the cooperative development of local universities because research has been limited to the relationships between universities and society, universities and enterprises, universities and governments, and between universities, parents and students. Thus, previous studies have rarely investigated the interactions between local universities in the construction of specialized education, and it is difficult to solve the problem of coordinated development of professional construction and optimal allocation of educational resources in local universities.

To address the shortcomings of previous research on the basis of societal preferences regarding the standards of professional competence in universities, the current study examined the development strategies of professional competence standards in local asymmetrical universities. We extended the scope of previous studies, hypothesizing that consumer preference needn't obey a uniform distribution in Hotelling's model to bring it closer to actual decision-making situations. The Hoteling model is extended in the method. It is not necessary to obey the uniform distribution of consumer preferences, which makes the model more close to the actual decision-making situation.

2 Problem Description

To facilitate the definition of the scope of the current study, we implemented four assumptions:

Assumption 1 The model contains two universities in one geographic area, both of which are seeking to develop a professional program M, according to societal needs. Each university is able to design talent-cultivating objectives and professional programs according to different types of professional competency standards, ranging from applied competencies to research-based competencies.

Assumption 2 $[0, 2]$ is adopted to represent the competency standards of a professional program M. A horizontal value of 0 indicates that the competency standard of professional program M is purely applied. A horizontal value of 2 indicates that the competency standard of professional program M is purely research-based. A horizontal value of 1 indicates that the competency standard of professional program M is comprehensive. The closer the horizontal value is to 0, the more applied the competency standards of professional program M; in contrast, the closer the horizontal value is to 2, the more research-based the professional standards of professional program M. a_i $(i = 1, 2)$ is used to represent the competency standards of professional program M, determined by U_i $(i = 1, 2)$ in the two universities. Without losing generality, suppose $a_1 < a_2$.

Assumption 3 The preference θ of social demand for the competency standards of professional program M is a random variable with an interval $[0, 2]$, but does not obey a uniform distribution, and its distribution density is

$$p(\theta) = \begin{cases} r, & \theta \in [0, 1], \\ 1 - r, & \theta \in (1, 2], \\ 0, & \theta \in (-\infty, 0) \cup (2, +\infty). \end{cases}$$

When a student S chooses a value of $a_i (i = 1, 2)$, the total payment is composed of two parts: 1) The price of the tuition fee paid by the student S is p_i $(i = 1, 2)$. Without losing generality, suppose $p_1 < p_2$. 2) The deviation cost is $[t(h - a_i)]^2$ $(i = 1, 2)$ of the student S's choice, a_i $(i = 1, 2)$. t is the deviation cost rate.

The deviation cost is the loss incurred when the student S chooses a professional program M with a bit value of a_i $(i = 1, 2)$, which differs from their own preference θ. The higher the deviation rate t, the more sensitive the deviation is to the loss. Therefore, if the student S selects a professional program M with a bit value of a_i $(i = 1, 2)$, then their total payment is $W_i = p_i + [t(\theta - a_i)]^2$ $(i = 1, 2)$.

Assumption 4 According to the requirements of local government regarding the development of the university, the competency standard of professional program M is set to meet $1/2 \sum_{i=1}^{2} a_i \geq 1$ by the U_i $(i = 1, 2)$. Let $W_1 = W_2$, and $\theta^* = \frac{a_1+a_2}{2} + \frac{1}{2t(a_2-a_1)}(p_1 - p_2)$ can be calculated. Let $\bar{a} = \frac{a_1+a_2}{2}$, $\Delta a = a_2 - a_1$, then $\theta^* = \bar{a} + \frac{1}{2t\Delta a}(p_2 - p_1)$.

Thus, when the student S has a preference of θ^*, the total income obtained from choosing a university with a bit value of a_1 is equal to that obtained through selecting a university with a bit value of a_2. Thus there is no difference when the student S chooses a university with the bit value of a_1 or a_2. θ^* is called the indifference preference of the student S.

We examined the competitive strategies of two universities, U_i $(i=1,2)$, when the probability distribution of the preference θ of the student S to the competency standards of professional program M is $p(\theta)$.

3 Equilibrium Analysis

$x_i(a_1,a_2,p_1,p_2)$ $(i=1,2)$ is defined as the demand function of the social market of professional program M with a bit value of $a_i(i=1,2)$. Then,

$$\begin{cases} x_1(a_1,a_2,p_1,p_2)=p(\theta\le\theta^*)=F(\theta^*)=\displaystyle\int_0^{\theta^*}p(\theta)\mathrm{d}\theta, \\ x_2(a_1,a_2,p_1,p_2)=p(\theta\ge\theta^*)=1-F(\theta^*)=1-\displaystyle\int_0^{\theta^*}p(\theta)\mathrm{d}\theta. \end{cases} \tag{1}$$

The function of $\theta^*\ge\bar{a}\in[1,2]$ can be defined by Assumption 3 and Assumption 4, and the demand functions of U_i $(i=1,2)$, respectively, are:

$$\begin{cases} x_1(a_1,a_2,p_1,p_2)=\displaystyle\int_0^1 r\mathrm{d}\theta+\int_1^{\theta^*}(1-r)\mathrm{d}\theta=(1-r)\theta^*+2r-1, \\ x_2(a_1,a_2,p_1,p_2)=1-x_1(a_1,a_2,p_1,p_2)=(1-r)(2-\theta^*). \end{cases} \tag{2}$$

The profit functions of the two universities $U_i(i=1,2)$, respectively, are:

$$\pi_i(a_1,a_2,p_1,p_2)=(p_i-c)x_i(a_1,a_2,p_1,p_2),\quad i=1,2. \tag{3}$$

To obtain the maximum profit, the two universities U_i $(i=1,2)$ enter into a two-stage game: In the first phase, the two universities U_i $(i=1,2)$ simultaneously choose their own bit value a_i $(i=1,2)$ for the competency standards of professional program M. In the second phase, U_i $(i=1,2)$ competes with the tuition standard (i.e., the price of professional program M) around the position of professional program M determined by each university. The backward induction method can be used to solve the subgame perfect Nash equilibrium of the model.

In the second phase, the two universities U_i $(i=1,2)$ have already seen the bit value of professional program M a_i $(i=1,2)$ of both sides. At the same time, they choose their own price p_i $(i=1,2)$, to maximize their own income function. For the sake of discussion, i^- $(i=1,2)$ is an agreed participant other than i $(i=1,2)$, namely $1^-=2$, $2^-=1$.

$$\max_{p_i}\pi_i(a_1,a_2,p_1,p_2)=(p_i-c)x_i(a_1,a_2,p_1,p_2),\quad i=1,2. \tag{4}$$

The tuition price response function of the professional program M in the two universities U_i $(i=1,2)$ can be respectively obtained by the first order condition of formula (4):

$$\begin{cases} p_1=p_1^R(p_2)=\dfrac{1}{2}\left[p_2+c+2t\Delta a\left(\dfrac{r}{1-r}-1+\bar{a}\right)\right], \\ p_2=p_2^R(p_1)=\dfrac{1}{2}[p_1+c+2t(2-\bar{a})\Delta a]. \end{cases} \tag{5}$$

The intersection point of the two reaction curves can be obtained by formula (5), and the

Bertrand-Nash equilibrium of the subgames starting from (a_1, a_2) is given by

$$\begin{cases} p_1^B = p_1^B(a_1, a_2) = c + \dfrac{2}{t} t\Delta a\left(\dfrac{1}{1-r} + \bar{a} - 2\right), \\ p_2^B = p_2^B(a_1, a_2) = c + \dfrac{2}{t} t\Delta a\left(\dfrac{2}{1-r} - \bar{a} + 2\right). \end{cases} \tag{6}$$

Correspondingly, the demand of consumers for professional program M in the two universities U_i $(i = 1, 2)$ is, respectively:

$$\begin{cases} x_1^B(a_1, a_2) = \dfrac{1}{3}[\bar{a} + (2 - \bar{a})r], \\ \\ x_1^B(a_1, a_2) = \dfrac{1}{3}[3 - \bar{a} + (2 - \bar{a})r]. \end{cases} \tag{7}$$

The reduced order income function can be obtained by substituting formula (6) and (7) into formula (3):

$$\begin{cases} \pi_1^B(a_1, a_2) = (p_1^B - c)x_1^B, \\ \pi_2^B(a_1, a_2) = (p_2^B - c)x_2^B. \end{cases} \tag{8}$$

In the first phase, the two universities U_i $(i = 1, 2)$ can predict the price p_i^B $(i = 1, 2)$ and $\pi_i^B(a_1, a_2)$ $(i = 1, 2)$. At the same time, they choose the bit value a_i $(i = 1, 2)$ of their own professional program M to maximize its reduced order income function. For the two universities U_i $(i = 1, 2)$, the maximization problem can be solved as follows:

$$\max_{a_i} \pi_i^B(a_1, a_2) = (p_i^B - c)x_i^B. \tag{9}$$

1. U_1 decision-making is performed by solving the maximization problem: $\max_{a_1} \pi_1^B(a_1, a_2) = (p_1^B - c)x_1^B$.

Let $\frac{\partial \pi_1^B(a_1,a_2)}{\partial(a_1)} = Q(a_1, a_2)$, with no difficulty verifying, $\frac{\partial Q(a_1,a_2)}{\partial(a_1)} < 0$, $\frac{\partial Q(a_1,a_2)}{(\partial(a_2)} > 0$, so $Q(a_1, a_2)$ is a decreasing function of a_1 and an increasing function of a_2 within the interval $[0, 2]$.

The following definitions are given for the convenience of the subsequent discussion:

Definition 1 For university U_1 (U_2), if there is a bit value $a_2' \in [0, 2]$ $(a_1' \in [0, 2])$, when U_2's (or U_1's) strategy bit value of the professional program M meets $a_2 < a_2'$ $(a_1 > a_1')$, U_1 (U_2) will automatically select the maximum differentiation strategy. Hence, $a_2' \in [1, 2]$ $(a_1' \in [0, 2])$ is the differential strategy compression point of U_2 (U_1) to U_1 (U_2).

Proposition 1 *In the competition between U_1 and U_2, if $r \neq 1$, there is a differential strategy compression point of U_2 to U_1.*

Proof Let $a_1 = 0$, $Q(t, r, 0, a_2) = \frac{1}{2}(1 - r)^2 a_2^2 - \frac{8tr^2}{9(1-r)} = 0$. Then, $a_2 = \frac{4r}{(3(1-r)}\sqrt{\frac{t}{1-r}} = a_2'$ can be calculated, and $Q(t, r, 0, a_2') = 0$. Because $Q(t, r, 0, a_2)$ is an increasing function of a_2 within the interval $[0, 2]$, when $a_2 < a_2'$, we have $Q(t, r, 0, a_2) < 0$. In addition, $Q(t, r, a_1, a_2)$ is a decreasing function of a_1 within the interval $[0, 2]$, so when $a_2 < a_2'$, $\forall a_1 \in [0, 2], a_1 \leq a_2$, we have $Q(t, r, a_1, a_2) < 0$. That is, $\frac{\partial \pi_1^B(t,r,a_1,a_2)}{\partial(a_1)} < 0$. Thus, U_1 should attempt to implement different differentiation strategies in relation to U_2, and gradually reduce the bit value until $a_1 = 0$ to achieve the maximum differentiation strategy. Therefore, a_2' is the compression point of the differential strategy of U_2 for U_1 (QED).

From Proposition 1, it can be seen that, as long as U_2 chooses the bit value $a_2 \leq a_2'$ of professional program M, U_1 will select the maximum differential value. That is, $a_1 = 0$, and the compression point a_2' of U_2 to U_1 are affected by r and t. As shown in Figure 1, the smaller t is, the greater the influence of r on a_2'. After t is determined, when r increases to a certain extent, the compression point of U_2 to U_1 will appear. With decreasing r, there will be a smaller bit value of the compression point of U_2 to U_1, so the degree of pressure of U_2 on U_1 will be greater. In contrast, the bigger r is, the greater the bit value of the compression point of U_2 to U_1, so the compression degree of U_2 to U_1 is smaller. As long as U_2 selects $a_2 > a_2'$, U_1 does not necessarily choose $a_1 = 0$. That is, U_1 does not necessarily choose the maximum differentiation strategy, which can converge to a certain degree with the U_2 strategy.

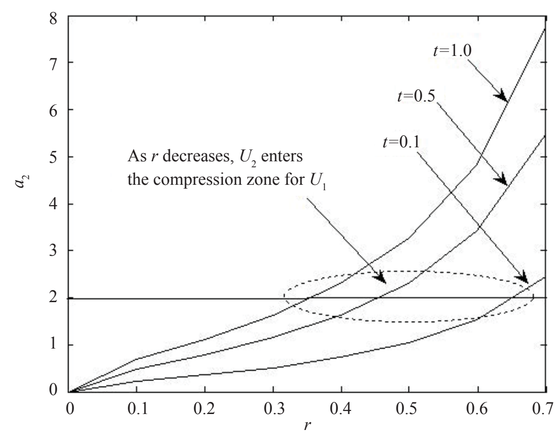

Figure 1 The compression curve of U_2 to U_1 under the condition $t = 0.1, 0.5, 1.0$

Definition 2 For university U_i $(i = 1, 2)$, if the bit value $a_i' \in [0, 2]$, U_i will automatically adjust its policy to reduce the bit value to a_i' when the strategy bit value of U_i satisfies $a_i > a_i'$. In addition, when $a_i < a_i'$ holds, U_i will automatically adjust the strategy to increase its bit value to a_i'. The bit value a_i' is called the automatic control point of the differentiation strategy of U_i.

Proposition 2 *In competition between U_1 and U_2, if U_2 chooses the maximum differentiation strategy, there must be a differentiation strategy control point of U_1.*

Proof U_2 chooses the greatest differentiation strategy, so $a_2 = 2$. It can be proven that, as long as r and t satisfy $r^2 + (16t - 90)r + 54 = 0$, then $Q(t, r, 0, 2) = Q(t, r, 2, 2)$. From Rolle's theorem, it can be determined that $Q(t, r, a_1, 2) = 0$ has at least one root in the interval $[0, 2]$. That is, $a_1' \in [0, 2]$ exists, making $Q(t, r, a_1', 2) = 0$. Because $Q(t, r, a_1, a_2)$ is a decreasing function of a_1 in the interval $[0, 2]$, when $a_1 > a_1'$, $Q(t, r, a_1, 2) < 0$. That is, $\frac{\partial_1(t,r,a_1,2)}{\partial(a_1)} < 0$. Therefore, a_1 will reduce to a_1' when $a_1 > a_1'$. In addition, when $a_1 < a_1'$, $Q(t, r, a_1, 2) > 0$, i.e., $\frac{\partial\pi_1(t,r,a_1,2)}{\partial(a_1)} > 0$. When $a_1 < a_1'$, a_1 goes up to a_1'. Thus, a_1' is the differentiated strategy automatic control point of U_1 (QED).

In two cases (numerical simulation of Proposition 2): Take $t = 0.05, 0.20, 0.08, 1.10$, simulate $Q(t, r, a_1, 2) = 0$ using Matlab 7.1 to analyze four different cases of t to lead to the movement law of U_1 with a differential automatic control point with r increasing (Figure 2).

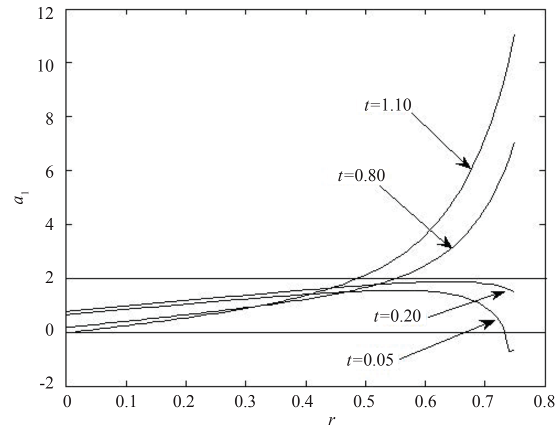

Figure 2 The differential control curve of U_1 under the condition $t = 0.05, 0.20, 0.08, 1.10$

1) At the time of $r = 0$, the probability of social demand for applied professional competency standards is 0. In this situation, the strategy of selecting competency standards for university U_1 should tend to the applied-type standard when the student chooses deviation from cost $t < 1.257$ of the competency standard of professional program M. The strategy of selecting competency standards for university U_1 should be $a_1 = 1$. Thus, the strategy indicates the intermediate standard type, which is a comprehensive professional competency standard, when the student chooses deviation from cost $t = 1.257$ of the competency standard of professional program M. The strategy for selecting the competency standard for university U_1 should tend to the research-type when the student chooses deviation from cost $t > 1.257$ of the competency standard of professional program M (Figure 3).

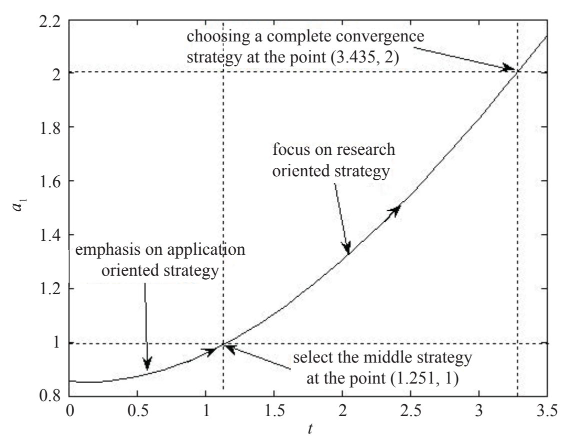

Figure 3 The impact of t on U_1 decision making in the case of $r = 0$

2) In the case of $t = 0.05$ and $t = 0.20$, the deviation from the cost of the competency standard of the professional program M is lower. At this time, with the gradual increase of the demand probability r of the applied-type professional competency standard, the differential control point $a_1 = a_1'$ of university U_1 began to increase, but when r increased to a certain

extent, university U_1's differential control point $a_1 = a_1'$ declined rapidly to the maximum differential regression.

3) In the case of $t = 0.80$ and $t = 1.10$, the deviation from the cost of the competency standard to the professional program M is higher for the student. With the gradual increase of the demand probability r of the applied-type professional competency standard, the differential control point $a_1 = a_1'$ of university U_1 began to slowly increase. However, when r increased to a certain extent, the difference in the automatic control point $a_1 = a_1'$ of U_1 increased rapidly to $a_1 = 2$, suggesting the adoption of a strategy of professional competency standard selection that is completely convergent with that of university U_2.

2. The decision of U_2 is the solution to the maximization problem: $\max_{a_2} \pi_2^B(a_1, a_2) = (p_2^B - c)x_2^B \max(a_2)$. Let $R(t, r, a_1, a_2) = \frac{\partial(\pi_2^B)}{\partial a_2}$. Then, the decision curve of U_2 is: $R(t, r, a_1, a_2) = 0$. By substituting any given $a_1 = a_1' \in [0, 2]$ into $\frac{\partial(\pi_2^B)}{\partial a_2} = R(t, r, a_1, a_2) = 0$, we can get the decision curve family $R(t, r, a_1', a_2) = 0$ of U_2's probability r, according to social needs under circumstances $a_1 = a_1'$. Then, when $a_2 = 0$ and $a_2 = 2$ are substituted into $R(t, r, a_1', a_2) = 0$, we can obtain the probability $r_2^{(0)}$ and $r_2^{(2)}$ of social demand corresponding to situations in which $a_2 = 0$ and $a_2 = 2$. That is, $R(t, r^{(0)}, a_1', 0) = 0$ and $R(t, r^{(2)}, a_1', 2) = 0$. Thus, there are the following propositions:

Proposition 3 *For an arbitrary decision value $a_1 = a_1' \in [0, 2]$ of U_1, the decision of U_2 for $r = r' \in [0, 1]$ is:* (i) *If $0 < r' < r^{(2)}$, then U_2 selects the no differentiation strategy.* (ii) *If $r^{(2)} < r' < r^{(0)}$, then the optimal decision value of U_2 is obtained in the interval* $[0, 2]$. (iii) *If $r^{(0)} < r' < 1$, then U_2 selects the maximum differentiation strategy.*

Proof First, it can be calculated that: $\frac{\partial R(t,r,a_1',0)}{\partial r} < 0$, $\frac{\partial R(t,r,a_1',0)}{\partial a_2} < 0$.

(i) If $0 < r' < r^{(2)}$, the following inequality can be derived by $\frac{\partial R(t,r,a_1',0)}{\partial r} < 0$, $\frac{\partial R(t,r,a_1',0)}{\partial a_2} < 0$: $R(t, 0, a_1', a_2) > R(t, r', a_1', a_2) > R(t, r', a_1', 2) > R(t, r^{(2)}, a_1', 2) = 0$.

The above inequality indicates that, when $0 < r' < r^{(2)}$ and $a_1 = a_1'$ are determined, for any $a_2 \in [0, 2]$, it has $R(t, r', a_1', a_2) > 0$. That is, $\frac{\partial(\pi_2^B)}{\partial a_2} > 0$. Then, a_2 has been increased to $a_2 = 2$, meaning that U_2 chooses the minimum differentiation (complete convergence) strategy.

(ii) If $r^{(2)} < r' < r^{(0)}$, it can be inferred by $\frac{\partial R(t,r,a_1',0)}{\partial r} < 0$ that $R(t, r(0), a_1', a_2) < R(t, r', a_1', a_2) < R(t, r^{(2)}, a_1', a_2)$. That is, when a_2 changes within the interval $[0, 2]$, the decision curve $R(t, r', a_1', a_2) = 0$ of the probability r' for U_2's social demand is always between the two decision curves of $R(t, r^{(0)}, a_1', a_2) = 0$, and $(t, r^{(2)}, a_1', a_2) = 0$. In addition, because $R(t, r', a_1', a_2) > R(t, r^{(0)}, a_1', a_2') = 0$, $R(t, r', a_1', 2) < R(t, r^{(2)}, a_1', 2) = 0$ and $\frac{\partial R(t,r,a_1',0)}{\partial a_2} < 0$, from the zero point theorem, it can be determined that $a_2' \in (0, 2)$, which makes $R(t, r', a_1', a_2') = 0$. When $a_2 < a_2'$, because $R(t, r', a_1', a_2) < R(t, r', a_1', a_2') = 0$, U_2 will gradually increase a_2 to make it close to a_2'. In addition, when $a_2 > a_2'$, because $R(t, r', a_1', a_2) < R(t, r', a_1', a_2') = 0$, U_2 will gradually decrease a_2 to make it close to a_2'. Thus, a_2' is the optimal decision of U_2 for $r = r'$ under the condition of $a_1 = a_1'$.

(iii) For any given $a_1 = a_1' \in [0, 2]$ and $r = r' \in [0, 1]$, when $r^{(0)} < r' < 1$, the following inequality can be derived by $\frac{\partial R(t,r,a_1',0)}{\partial r} < 0$, $\frac{\partial R(t,r,a_1',0)}{\partial a_2} < 0$, $R(t, 1, a_1', a_2) < R(t, r', a_1', a_2) < R(t, r', a_1', 0) < R(t, r^{(0)}, a_1', 0) = 0$.

The above inequality indicates that, when $r^{(0)} < r' < 1)$ and $a_1 = a_1'$ are determined, for any $a_2 \in [0, 2]$, it has $R(t, r', a_1', a_2) < 0$, that is $\frac{\partial(\pi_2^B)}{\partial a_2} < 0$. Thus, a_2 has been decreased to

$a_2 = 0$, meaning that U_2 chooses the maximum differentiation strategy (QED).

Example 3 (numerical simulation of Proposition 3): Analysis of the decision curve $R(r, a_1, a_2) = 0$ of U_2 under condition $a_1 = 1$ is shown in Figure 4.

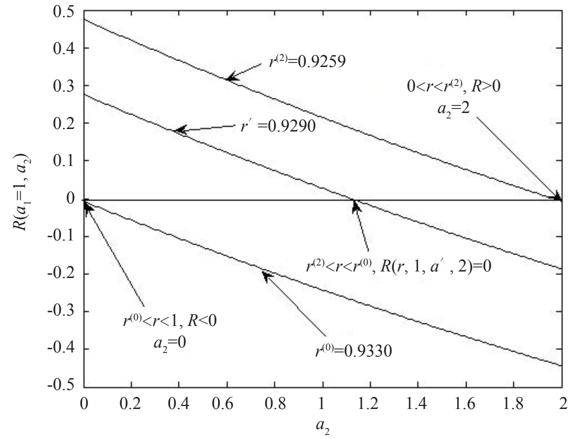

Figure 4 $r^{(0)}$ and $r^{(2)}$ form the decision boundary of U_2

Substitute $a_2 = 0$, $a_2 = 2$ respectively into $R(r, 1, a_2) = 0$, and $a_2 = 0$, $a_2 = 2$ can be calculated respectively, corresponding to the social demand probability $r^{(0)} = 0.9330$ and $r^{(2)} = 0.9259$ using Matlab 7.1. From proposition 3, it is known that:

1) When $r \in [0, r^{(2)}]$, $R(r, 1, a_2) > 0$, that is $\frac{\partial(\pi_2^B)}{\partial a_2} > 0$, U_2 selects the value $a_2 = 2$ of the professional competency threshold. That is, U_2 chooses the largest differentiation strategy.

2) When $r \in (r^{(2)}, r^{(0)})$, $a_2 = a_2' \in (0, 2)$, and $R(r, 1, a_2') = 0$, at this point, the value $a_2 = a_2'$ is selected by the optimal decision for the selection of professional competency for U_2. This relates to an intermediate comprehensive strategy.

3) When $r \in [r^{(0)}, 1]$, $R(r, 1, a_2) < 0$, that is, $\frac{\partial(\pi_2^B)}{\partial a_2} < 0$, the value $a_2 = 0$ is selected by the optimal decision for the selection of professional competency of U_2 (i.e., the choice of maximum convergence).

4 Conclusions

Four main conclusions can be drawn from the current findings:

1) In terms of social needs, there is a non-uniform preference for particular professional competency standards among local universities. University U_1 derived the following strategies from proposition 1: As long as the demand probability of sociology for professional application competency standards was not 1, then there was a differential strategy compression point for university U_2 for the applied-type of competence standard. Therefore, university U_1 must pay attention to the coercion strategy of U_2. When the bit value of university U_2 was close to that of U_1, U_1 was required to choose a maximum differentiation strategy.

2) It can be shown from Proposition 2 that there is a non-uniform preference for particular professional competency standards at local universities. Under conditions in which university U_1 was able to adopt a strategy similar to that of university U_2 after U_2 had chosen the maximum differentiation strategy, the research-type of professional competency standards was selected.

Thus, on the basis of adhering to the standards of the applied-type professional competency, university U_1 could appropriately strengthen its research standard, within appropriate limits.

3) It can also be shown from Proposition 2 that, when the probability of social demand for applied professional competency standards was 0, the strategy of selecting competency standards for university U_1 tended to the applied-type when students chose deviation from reduced cost ($t < 1.257$) of the competency standard of professional program M. Thus, the strategy for selecting competency standards for university U_1 should be $a_1 = 1$. This standard type belonged to the intermediate category, reflecting a comprehensive professional competency standard, which considers both applied learning and research-based learning, when students chose to exhibit moderate deviation of the cost ($t = 1.257$) of the competency standard of professional program M. In contrast, the strategy for selecting competency standards for university U_1 tended to the research-type when students chose deviation from cost ($t > 1.257$) of the competency standard of professional program M.

4) It can be shown from proposition 3 that, in view of the arbitrary strategy for university U_1 in determining professional competency standards, university U_2 adopted different coping strategies according to the size of the demand probability r for professional applied competency standards in society. That is, if $0 < r < r^{(2)}$, the applied-type professional competency standard would be chosen as if $r^{(2)} < r < r^{(0)}$, meaning that the comprehensive type of professional competency standard would be chosen, and, if $r^{(0)} < r < 1$, the research-type of professional competency standard would be chosen.

In the current study, we did not consider cost differences between the two universities, potentially limiting the applicability of the current findings to real-world situations. Further studies will be required to address this limitation.

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