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PACIS 2017 Proceedings

Pacific Asia Conference on Information Systems (PACIS)

Summer 7-19-2017

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Completed Research Paper

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Abstract

Massive Open Online Courses (MOOCs) have recently received a great deal of attention in higher education. MOOCs demonstrate universities' efforts in offering high-quality digital learning materials to everyone in the world, which should be encouraged. Nevertheless, as a MOOC platform must ensure its financial sustainability, it is questionable whether a platform's profit-seeking pricing strategy will hurt the diversity of courses, such as eliminating courses with low certificate purchasing rates. To address this question, we adopt a game-theoretic framework to model the interaction and strategic choices of a MOOC platform, learners, and universities. Based on the certificate prices and revenue sharing ratios chosen by the platform for courses with various certificate purchasing rates, universities consider the competition intensity and decide their course quality levels, to attract learners. We conclude that all types of course will exists in equilibrium throughout the lifecycle of a MOOC platform, regardless of the technology maturity and competition intensity. We also find that course qualities may decrease when MOOCs become more accessible to learners. Finally, qualities of courses with different certificate purchasing rates are compared.

Keywords: Massive Open Online Courses (MOOCs), Pricing, Diversification, Multi-sided Platforms, Game Theory

Introduction

E-learning is considered so important for higher education (Franceschi et al., 2013, Ilie and Pavel, 2008, Popescu, 2012) and corporate knowledge management (Chen and Edgington, 2005).

Massive Open Online Courses (MOOCs) have recently received a great deal of attention in higher education. It has grown into a thriving battleground for prestigious universities competing regarding reputation and course quality by putting elite courses on MOOC platforms. The rapid expansion of MOOCs has sparked considerable interest in the higher education market, leading to springing emergence of MOOC platform providers such as Coursera, edX, and Udacity.[1]

Coursera is one of the most popular MOOC platforms. As a for-profit company founded in 2012 by two Stanford Computer Science professors Daphne Koller and Andrew Ng, it currently has over 1600 courses from over 140 institutions in 10 fields, including computer science, mathematics, business, humanities, social science, medicine, and engineering. edX is a non-profit and open source MOOC platform founded by Massachusetts Institute of Technology and Harvard University in 2012. It offers online courses from worldwide universities and institutions. Currently, there are a total of 30 subjects and over 950 courses in computer science, biology, engineering, architecture, data science, literature, social science, and more from about 106 institutions. Udacity is another for-profit initiative founded by Sebastian Thrun, David Stavens, and Mike Sokolsky with investment from venture capital offering

[1] https://www.coursera.org/; https://www.edx.org/; https://www.udacity.com

computer science, programming, and related courses by industry giants Google, AT&T, Facebook, Salesforce, Cloudera, etc. Despite their different management types and course composition, these three platforms all provide free access or audit alternatives.

The most common revenue stream for a MOOC platform is to charge fees for certificates. Some other sources include selling student information to potential employers or advertisers, fee-based assignment grading, access to the social networks, etc. As for cooperating universities, they may receive a proportion of revenue from the certificate fees and other value-added services for students. For example, Young (2012) reports that Coursera shares 20% of gross revenue from certificates to partners. Partners may receive 6% to 15% of revenue for each career introduction by Coursera Career Services. edX also shares a proportion of revenue to their partners when total revenue goes beyond a threshold (Kolowich, 2013).

By November 2016, Coursera earned over 600 thousand course certificates, and edX reached over 840 thousand certificates.[2] However, the financial sustainability of this revenue models is yet to be confirmed. Most of these platforms currently still follow the common approach of Silicon Valley start-ups by receiving investment from venture capital. The sustainability issue and profit model are still big concerns for most MOOC platforms. These issues are not only critical for these platforms but also important for learners around the world. First, if this "free-enrollment-paid-certificate" model can be proved to be financially sustainable, learners will be able to access free high-quality courses from universities and institutes all over the world. This would help people spread education to everywhere in the world. Second, even if this model can be sufficiently profitable, it is possible that the platforms offer only courses with high conversion rates (proportion of enrolled learners paying for the certificates). Whether appropriate diversity among courses can still be achieved in the long run is worth of investigation.

As far as we know, there are quite a few studies discussing the business model of MOOCs, but rare of them adopt a theoretical framework to investigate the platform strategy. In this study, we present a game-theoretic model of the market for MOOCs. We assume that there are multiple types of course on the platform, some types are more attractive for students to buy certificates while some types are not. In other words, we assume that the conversion rates of some types are naturally higher than the conversion rate of low type. The conversion rate somehow implies the spirit of free access of MOOCs. The students do not need to pay for auditing the MOOCs, but only need to pay for the certificates. We also assume that there are several heterogeneous universities competing in offering MOOC courses. The platform decides the revenue sharing ratio and certificate price for each type of course. Universities then choose the quality of each type of course to maximize its utility. Under this setting, we investigate the platform's strategic pricing choice, platform's profit, and the induced course offering strategies of universities and course quality levels in equilibrium.

In the next section, we review some related works with respect to MOOCs, network externality, and market of higher education. In section "Model", we develop a game-theoretic model to describe the competitive relationship among universities. The platform's strategic choice of certificate prices and revenue sharing ratios are also formulated. Analysis and implications are presented in section "Analysis". The summary of this paper is in section "Conclusion". Due to the page limit, all proofs are omitted but can be requested from the authors.

Literature Review

Massive Open Online Courses (MOOCs) are online courses aiming at unlimited participation and open access via the web (Kaplan and Haenlein, 2016). Introduced in 2008 and emerged as a popular mode of learning in 2012, MOOCs have become a popular approach of learning nowadays. Yuan and Powell (2013) point out that the development of MOOCs is rooted within the ideals of openness in education, knowledge should be shared freely, and the desire to learn should be met without demographic, economic, and geographical constraints. There are several studies discussing the business models and value propositions of MOOCs. Baker and Passmore (2016) propose four pricing strategies: cross-subsidy, third-party, freemium, and nonmonetary. However, climate of cost-consciousness is still an issue. Belleflamme and Jacqmin (2016) propose five potential monetization strategies. The most sustainable approach seems to be the subcontractor model which allows MOOC platforms to deliver innovative education to universities, and sell made-to-measure training programs to private company. Burd et al. (2015) state that MOOCs potentially challenge the traditional dominance of higher education providers. It is said that prestigious universities will retain traditional degree and offer certificates on a

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[2] Coursera (2016); edX (2016)

course-by-course basis, while other universities will trade these certificates of completion for course credits in long-term survivability. The feasibility of monetization of MOOC business is still in the air where opportunities and challenges coexist.

Some past studies have addressed network externality issues. Network externality can be defined that there are many products for which the utility that a user derives from consumption of the good increases with the number of other agents consuming the good (Katz and Shapiro, 1985). In Armstrong (2006) and Rochet and Tirole (2006), we can see two forms of network externality: same-side and cross-side. Same-side network externality usually happens in a one-sided market where volume of transactions realized on the platform depends only on the aggregate price level. Cross-side network externality usually happens in a two-sided market as one in which the volume of transactions between groups depends not only on the overall price level but on the size of another group. Therefore, cross-side network externality is an important property of a two-sided market. Armstrong (2006) develops an optimal pricing function similar to the Lerner index in monopoly platform to depict how the price elasticity of demand and the network externality affect the platform's pricing strategy. Hagiu (2009) introduces the consumer preferences of variety and finds that higher consumer preferences of variety leads to less substitutable among producers and greater market power of producers. Jing (2007) discusses how network externality affects the pricing of monopoly platform regarding vertical differentiation in quality. Rochet and Tirole (2006) develop a mixed model for the two-sided market and find that the platform could maximize its profit by manipulating the prices for buyer and seller. Even though there are different conclusion regarding to different network externality settings, there is no doubt that network externality plays a crucial part to study the rapid proliferation of platform economy. To better clarify the competition between the types of course offered by two universities, we leverage network externality to explain universities' decisions in our study.

As for higher education issues, Arcidiacono (2005) addresses how changing the admission and financial aid rules at colleges affects future earnings. In the model, college quality serves as a consumption good so that high ability individuals may have preferences for particular majors independent of effort costs. The model also includes decisions by schools as to which students to accept and how much financial aid to offer. Epple et al. (2006) present an equilibrium model of the market for higher education. Their model gives rise to a strict hierarchy of colleges that differ by the educational quality provided to the students. In equilibrium, the reservation price functions of each college and their beliefs about student matriculation must be consistent with utility maximization and the actions of the other colleges. These studies have disclosed the decision procedure for higher education market, and the spirit of pursuit of quality is consistent throughout these papers. However, to the best of our knowledge, there is no research adopts a theoretic model to study the MOOC business. We plan to deliver new managerial insights to complement the study in the management of modern higher education.

Model

Players and decision sequence

Universities and courses. Consider a MOOC platform (it) and two heterogeneous universities (for each of them, she), university 1 and university 2, competing in offering MOOCs. We assume that there are two types of courses on the MOOC platform, the high type and low type, where the high-type one has higher conversion rate and the low-type one. The high and low type will also be denoted by type H and L, respectively. Both universities may offer both types of courses. To facilitate discussion, we will sometimes call the type-j course offered by university i the course (i, j), $i \in \{1,2\}$, $j \in \{\mathrm{H}, \mathrm{L}\}$. The two courses differ in their *conversion rate*, i.e., the proportion of auditing students that will purchase the certificate. We assume that the conversion rate of the type-j course is $a_j - b_j p_j$, where $a_j > 0$ and $b_j > 0$ are all exogenous parameters for $j \in \{\mathrm{H}, \mathrm{L}\}$, and p_j is the certificate price of the type-j course. We assume that under the same price, the conversion rate of the high-type course is higher than that of the low one, i.e., $a_{\mathrm{H}} - b_{\mathrm{H}} p > a_{\mathrm{L}} - b_{\mathrm{L}} p$ for all $p \geq 0$.

Universities' decisions. University i needs to determine the quality of its type-j course to find a balance between the benefit and cost. The benefit consists of two parts, the reputation earned from students who audit the course and revenue shared by the platform from students purchasing the certificate. We represent the reputation as $n_{ij} q_{ij}$, the number of auditing students n_{ij} times the course quality q_{ij}. This captures the fact that more reputation can be earned if more students audit the course, but the reputation is really high only if the course quality is high. The revenue earned by the platform is $(a_j - b_j p_j) p_j n_{ij}$, where p_j is the certificate price of the type-j course and $a_j - b_j p_j$ is the corresponding conversion rate. Given the revenue sharing ratio w_j set by the platform, the university's revenue from certificate sales is $(a_j - b_j p_j) p_j w_j n_{ij}$. Finally, as quality is costly, the university pays a cost $\alpha_{ij} q_{ij}^2/2$, where $\alpha_{ij} > 0$ is an exogenous parameter scaling the cost, and the quadratic form is chosen for tractability.[3] Collectively, the utility function of university i is

$$u_{ij}^{\mathrm{U}} = n_{ij} q_{ij} + \left(a_j - b_j p_j\right) p_j w_j \beta_i n_{ij} - \frac{\alpha_{ij} q_{ij}^2}{2},$$

where the parameter β_i adjusts how university i's weighs the reputation and revenue. Upon observing w_js and p_js, university i then chooses its course quality levels $q_{ij} \in [0, 1]$ to maximize its utility, where $q_{ij} = 0$ means not offering the course and $q_{ij} = 1$ means offering the best possible course. Note that as n_{ij} enters the benefit part of the utility function, it captures the positive cross-side network effect: the more students, the more incentive for a university to offer a course. To reduce tedious calculations and derivations that do not generate useful insights, we will assume that $\beta_1 = \beta_2$ throughout this paper.

Students' decisions. As different students (for each of them, he) may have different preferences over universities, we model the preference attitudes with a Hotelling line (Hotelling, 1929). Consider the courses of type L first. Let universities 1 and 2 locates at 0 and 1, the two endpoints of a line segment $[0, 1]$, and x_{L} be a student's location in respect to course j, his utility of taking course $(1, \mathrm{L})$ and $(2, \mathrm{L})$ are

$$u_{1\mathrm{L}}^{\mathrm{S}} = \theta_{1\mathrm{L}} q_{1\mathrm{L}} - t x_{\mathrm{L}} \quad \text{and} \quad u_{2\mathrm{L}}^{\mathrm{S}} = \theta_{2\mathrm{L}} q_{2\mathrm{L}} - t(1 - x_{\mathrm{L}}),$$

where $t > 0$ is the "transportation cost" in the Hotelling line model, measuring different students' preference over different universities, and $\theta_{i\mathrm{L}}$ is the students' willingness-to-pay for a unit of quality of the type-L course offered by university i. As higher $\theta_{i\mathrm{L}}$ makes course (i, L) attract more students, $\theta_{i\mathrm{L}}$ is also considered as university i's authority in the field of the course of type L. The type-x_{L} student will choose to audit course $(1, \mathrm{L})$, audit course $(2, \mathrm{L})$, and does not audit any type-L course to maximize his utility, where the utility of the last option is normalized to 0. For high-type courses, we adopt the same setting. We assume that a student will audit at most one course of each type and may audit two courses of different types simultaneously.

Platform's decision. To optimize its decision about the certificate prices p_js and revenue sharing ratios w_js, the platform must first conduct an equilibrium analysis to predict the consequence of its decision. After the prediction about the course qualities q_{ij} and student size n_{ij} is done, the platform's problem is to maximize its profit

$$\pi_j^P = \left(1 - w_j\right)\left(a_j - b_j p_j\right) p_j n_{ij},$$

subject to the constraints $w_j \in [0, 1]$ and $p_j \geq 0, j \in \{\mathrm{H}, \mathrm{L}\}$. Note that n_{ij} depends on the universities' choices of q_{ij}, which depends on the authority of universities θ_{ij}, the course development course α_{ij}, and competition intensity (the smaller the t, the stronger the competition), etc. The platform would take these factors into consideration to set the two pricing variables w_j and p_j to induce desirable equilibrium behaviors chosen by the universities.

Decision sequence. The sequence of events is as follows. First, the platform determines the revenue sharing ratio w_j and the certificate price p_j for the type-j course, $j \in \{\mathrm{H}, \mathrm{L}\}$ Second, the two universities act simultaneously, where university i observes p_j and w_j and chooses its $q_{i\mathrm{L}}$ and $q_{i\mathrm{H}}$. At the end, each student makes his course auditing choice, the sizes of students n_{ij} are realized, and the platform earns its profit.

Market segmentation and assumptions

Market segmentation. After the courses are offered by different universities at various quality levels, each student independently decides which course(s) to audit. In this subsection, we will derive the student size of course (i, j), n_{ij}, as a function of q_{ij}, θ_{ij}, and t.

Consider the type-j course. As a type-x_j student sees the two type-j courses, he will be willing to take course $(1, j)$ if $\theta_{1j} q_{1j} - t x_j \geq 0$, i.e., $x_j \leq \frac{\theta_{1j} q_{1j}}{t}$. Similarly, if $\theta_{2j} q_{2j} - t(1 - x_j) \geq 0$, i.e., $x_j \geq 1 - \frac{\theta_{2j} q_{2j}}{t}$, he

3 It can be shown that our major findings will be qualitatively unchanged as long as the cost is an increasing and convex function of q_{ij}.

will be willing to take course $(2, j)$. Let $\bar{x}_{1j} = \frac{\theta_{1j} q_{1j}}{t}$ and $\bar{x}_{2j} = 1 - \frac{\theta_{2j} q_{2j}}{t}$ be the two cutoff values, their relationship determines the equilibrium market segmentation. If $\bar{x}_{1j} < \bar{x}_{2j}$, the market is *partially covered*, some students do not take any type-j course, and $n_{ij} = \frac{\theta_{ij} q_{ij}}{t}$. See Figure 1 for a depiction. On the contrary, if $\bar{x}_{1j} \geq \bar{x}_{2j}$, the market is *fully covered*, all students take a type-j course from one university, and $n_{1j} = \bar{x}_{0j} = 1 - n_{2j}$, where the type-$\bar{x}_{0j}$ student is indifferent in taking the course from either university. It then follows that $\bar{x}_{0j}$ is the unique value satisfying $\theta_{1j} q_{1j} - t\bar{x}_{0j} = \theta_{2j} q_{2j} - t(1 - \bar{x}_{0j})$, i.e., $\bar{x}_{0j} = \frac{\theta_{1j} q_{1j} - \theta_{2j} q_{2j} + t}{2t}$. Figure 2 illustrates this scenario.

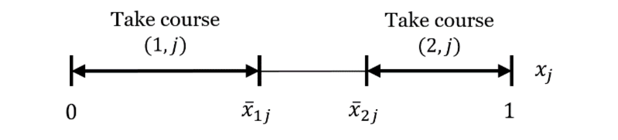

Figure 1. Market segmentation of partial coverage

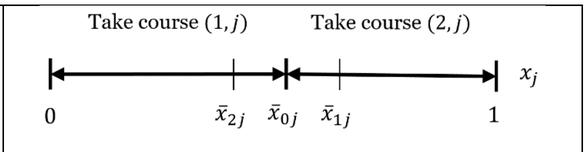

Figure 2. Market segmentation of full coverage

According to the derivations above, it can be observed that when the market will be partially or fully covered depends on the value of t. When t is large, which means the cost of taking a MOOC is high, it is more likely that the market will be partially covered. As technology improves and an MOOC platform is more accessible to students, t will become smaller, and it is more likely for the market to be fully covered. More precisely, the market is fully covered if and only if $\bar{x}_{1j} \geq \bar{x}_{2j}$, which is equivalent to $\theta_{1j} q_{1j} + \theta_{2j} q_{2j} \geq t$. Because $q_{ij} \leq 1$, if $\theta_{1j} + \theta_{2j} < t$, the market must be partially covered regardless of the course qualities; if $\theta_{1j} + \theta_{2j} \geq t$, it is then possible for the two universities to fully cover the market of the type-j course.

Assumptions. We consider both the full coverage and partial coverage scenarios under some mild assumptions. First, under partial coverage, we assume that none of the universities can take the whole market even with the best possible course ($q_{ij} = 1$). As $n_{ij} = \frac{\theta_{ij} q_{ij}}{t}$ under partial coverage, this means to assume $t > \max_{i,j}\{\theta_{ij}\}$. Second, as the providers of MOOCs are usually prestigious universities and institutions, the cost of offering a course is typically an insignificant part in their annual budgets. Moreover, modern technology has diminished the difficulties to digitalize a course, which also implies that the course development cost is low. As α_{ij} is believed to be small, we assume $\theta_{1j} + \theta_{2j} < \min\left\{\frac{\theta_{ij}}{\alpha_{ij}}\right\}$ to avoid tedious comparisons that do not generate useful managerial insights.

Lifecycle of MOOCs and the four periods

As we mentioned above, the relationship between t and $\theta_{1j} + \theta_{2j}$ has an impact on the equilibrium market segmentation. Moreover, the value of t also determines whether a university's utility function with respect to a course is convex or concave (to be detailed below). These two factors drive us to divide the lifecycle of MOOCs into four periods depending on the value of t (cf. Figure 3):

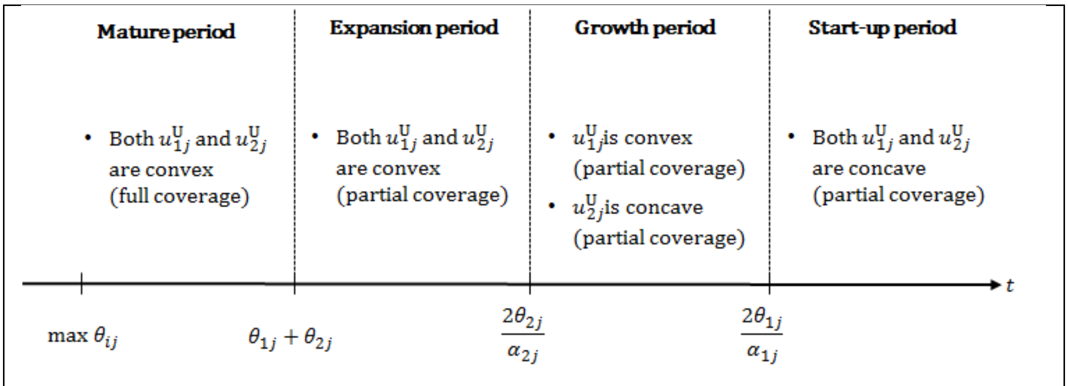

Figure 3. Lifecycle of MOOCs for the type-j course assuming $\theta_{1j}\alpha_{2j} > \theta_{2j}\alpha_{1j}$

- In the *start-up* period, we have $\max\left\{\frac{2\theta_{ij}}{\alpha_{ij}}\right\} < t$: The cost of taking a MOOC is quite large, both universities find their utility functions concave (and thus are less willing to offer the course to the highest possible quality level by setting $q_{ij} = 1$), and the market is partially covered.
- In the *growth* period, we have $\min\left\{\frac{2\theta_{ij}}{\alpha_{ij}}\right\} < t \leq \max\left\{\frac{2\theta_{ij}}{\alpha_{ij}}\right\}$: The cost is still high, but one of the university's utility function becomes convex. This university will either offer the best possible course ($q_{ij} = 1$) or offer nothing. The market is still partially covered.
- In the *expansion* period, we have $\theta_{1\mathrm{j}} + \theta_{2\mathrm{j}} < t \leq \min\left\{\frac{2\theta_{ij}}{\alpha_{ij}}\right\}$: The cost becomes lower, MOOCs are accessible to more students, and both universities find their utility functions convex. However, the market is still partially covered.
- In the *mature* period, we have $t \leq \theta_{1\mathrm{j}} + \theta_{2\mathrm{j}}$: The technology is well developed, platform is robust enough, and universities may attract students easily. Both universities have convex utility functions, and it is possible for the market to be fully covered.

Obviously, the platform's optimal pricing decisions may be different from period to period. Therefore, the platform needs to conduct a separate equilibrium analysis for each of the four periods. In the next section, we will first analyze the platform's pricing decisions in the four periods and then characterize the equilibrium certificate prices, revenue sharing ratios, and course qualities. We then combine the analyses for the four periods to deliver our main messages.

Table 1. List of decision variables and parameters

Decision variables	
p_j	The certificate price of the type-j course determined by the platform
q_{ij}	The course quality of the type-j course determined by the university i
w_j	The revenue sharing ratio of the type-j course determined by the platform
Parameters	
θ_{ij}	The students' willingness-to-pay for a unit of quality of the type-j course offered by university i
t	The transportation cost to the course on the platform
n_{ij}	The number of students auditing the type-j course offered by university i
a_j	An exogenous parameter regarding the conversion rate of the type-j course
b_j	An exogenous parameter regarding the conversion rate of the type-j course
α_j	An exogenous parameter regarding the cost of the type-j course
β_j	An exogenous parameter regarding how university i's weighs the reputation and revenue

Analysis

We characterize the quality pair (q_{1j}, q_{2j}), revenue sharing ratio w_j, certificate price p_j, and profit of the platform π_j^{P} in equilibrium under the four periods for each $j \in \{\mathrm{H}, \mathrm{L}\}$. We investigate the transportation cost cut-offs between the high- and low-type courses and their respective quality levels. The implications about market equilibrium and the platform's strategic choice will then be drawn.

As we mentioned in the model, the utility of student taking university 1 and university 2 can be formulated as $u_{1j}^{\mathrm{S}} = \theta_{1j}q_{1j} - tx_j$ and $u_{2j}^{\mathrm{S}} = \theta_{2j}q_{2j} - tx_j$. Under partial market coverage, the size of the student taking universities 1 and 2 can be calculated as $n_{1j} = \frac{\theta_{1j}q_{1j}}{t}$ and $n_{2j} = \frac{\theta_{2j}q_{2j}}{t}$, respectively. Therefore, the utilities of university 1 and university 2 can be formulated as

$$u_{1j}^{\mathrm{U}} = q_{1j}^2\left(\frac{\theta_{1j}}{t} - \frac{\alpha_{1j}}{2}\right) + q_{1j}\left(\frac{(a_j - b_j p_j)p_j w_j \beta_1 \theta_{1j}}{t}\right) \text{ and } u_{2j}^{\mathrm{U}} = q_{2j}^2\left(\frac{\theta_{2j}}{t} - \frac{\alpha_{2j}}{2}\right) + q_{2j}\left(\frac{(a_j - b_j p_j)p_j w_j \beta_2 \theta_{2j}}{t}\right).$$

If $2\theta_{ij} - \alpha_{ij}t > 0$, the utility function is convex; if $2\theta_{ij} - \alpha_{ij}t < 0$, the utility function is concave. Under full market coverage, the size of the student taking university 1 and university 2 can be calculated as

$n_{1j} = \frac{\theta_{1j}q_{1j}-\theta_{2j}q_{2j}+t}{t}$ and $n_{2j} = \frac{\theta_{2j}q_{2j}-\theta_{1j}q_{1j}+t}{t}$, respectively. Therefore, the utility of university 1 and university 2 can be formulated as

$$u_{1j}^{\mathrm{U}} = q_{1j}^2\left(\frac{\theta_{1j}}{2t} - \frac{\alpha_{1j}}{2}\right) + q_{1j}\left(\frac{t-\theta_{2j}q_{2j}+(a_j-b_jp_j)p_jw_j\beta_1\theta_{1j}+(t-\theta_{2j}q_{2j})(a_j-b_jp_j)p_jw_j\beta_1}{2t}\right)$$

and

$$u_{2j}^{\mathrm{U}} = q_{2j}^2\left(\frac{\theta_{2j}}{2t} - \frac{\alpha_{2j}}{2}\right) + q_{1j}\left(\frac{t-\theta_{1j}q_{1j}+(a_j-b_jp_j)p_jw_j\beta_2\theta_{2j}+(t-\theta_{1j}q_{1j})(a_j-b_jp_j)p_jw_j\beta_2}{2t}\right).$$

If $\theta_{ij}-\alpha_{ij}t > 0$, the utility function is convex; if $\theta_{ij}-\alpha_{ij}t < 0$, the utility function is concave.

Since that the profit function of the platform is $\pi_j^P = (1-w_j)(a_j - b_jp_j)p_jn_{ij}$, the optimal p_j can be derived as $\frac{a_j}{2b_j}$, and $(a_j - b_jp_j)p_j$ is always $\frac{a_j^2}{4b_j}$. For the platform, the more challenging decision to consider is the revenue sharing ratio w_j, which will be explicitly characterized for each of the four periods below.

Equilibrium Analysis

Start-up period

In the start-up period, the transportation cost is so high ($t > \max\left\{\frac{2\theta_{ij}}{\alpha_{ij}}\right\}$) that the student base does not contribute too much for the university. The market is partial covered. The utility function of each university is concave, and the first-order condition leads to the optimal course quality

$$q_{ij}^*(w_j) = \max\left\{\frac{(a_j - b_jp_j)p_jw_j\beta_i\theta_{ij}}{\alpha_{ij}t - 2\theta_{ij}}, 1\right\}$$

As a function of the revenue sharing ratio. Then, the size of students n_{ij} can be calculated. The platform's problem is to maximize its profit by determining w_j. Since that $q_{ij} \in [0,1]$, we can find out the constraints of $w_j \in [0,1]$ accordingly in equilibrium.

Lemma 1. *Consider the type-j course. In the start-up period, let* $\frac{\theta_{1j}}{\alpha_{1j}} > \frac{\theta_{2j}}{\alpha_{2j}}$ *without loss of generality, and let* $B_1 = \frac{\alpha_{1j}t-2\theta_{1j}}{(a_j-b_jp_j)p_j\beta_1\theta_{1j}}$ *and* $B_2 = \frac{\alpha_{2j}t-2\theta_{2j}}{(a_j-b_jp_j)p_j\beta_2\theta_{2j}}$. *We have*

$$w_j^* = \begin{cases} \frac{1}{2} & if\ \frac{1}{2} < B_1 \\ B_1 & if\ \frac{1}{2} - \frac{\theta_{1j}B_2}{2\theta_{2j}} < B_1 \le \frac{1}{2} \\ \frac{1}{2} - \frac{\theta_{1j}B_2}{2\theta_{2j}} & if\ B_1 \le \frac{1}{2} - \frac{\theta_{1j}B_2}{2\theta_{2j}} \end{cases}$$

as the platform's optimal revenue sharing ratio. The equilibrium qualities are

$$(q_{1j}^*, q_{2j}^*) = \begin{cases} \left(q_{1j}^*\left(\frac{1}{2}\right), q_{2j}^*\left(\frac{1}{2}\right)\right) & if\ \frac{1}{2} < B_1 \\ \left(1, q_{2j}^*(B_1)\right) & if\ \frac{1}{2} - \frac{\theta_{1j}B_2}{2\theta_{2j}} < B_1 \le \frac{1}{2} \\ \left(1, q_{2j}^*\left(\frac{1}{2} - \frac{\theta_{1j}B_2}{2\theta_{2j}}\right)\right) & if\ B_1 \le \frac{1}{2} - \frac{\theta_{1j}B_2}{2\theta_{2j}} \end{cases}$$

where $q_{2j}^* < 1$ *in all three cases and* $q_{1j}^* < 1$ *if* $B_1 > \frac{1}{2}$.

As not many learners have adopted MOOCs (t is large), the platform should always choose a positive revenue sharing ratio w_j to encourage the universities to participate in the market in the start-up period. In fact, in this period the demand is so small so that the platform's optimal revenue sharing ratio is definitely higher than $\frac{1}{2}$. More than half of the revenues must be given to the universities. We may also observe that it is impossible for both universities to offer the courses to the highest possible quality. Fortunately, none of them will quit and offer nothing. The concavity of their utility function drives them to offer a course, even if the optimal quality is low.

Growth period

In the growth period, t locates between $\min\left\{\frac{2\theta_{ij}}{\alpha_{ij}}\right\}$ and $\max\left\{\frac{2\theta_{ij}}{\alpha_{ij}}\right\}$. The market is partial covered. Suppose that $\frac{\theta_{1j}}{\alpha_{1j}} > \frac{\theta_{2j}}{\alpha_{2j}}$, the utility function of university 1 will be convex and that of university 2 will be concave. We can identify optimal q_{1j} and q_{2j} and the constraints of w_j.

Lemma 2. *Consider the type-j course. In the growth period, let* $\frac{\theta_{1j}}{\alpha_{1j}} > \frac{\theta_{2j}}{\alpha_{2j}}$ *without loss of generality, and let* $C_1 = \frac{\alpha_{1j}t - 2\theta_{1j}}{(a_j - b_j p_j)p_j \beta_1 \theta_{1j}}$ *and* $C_2 = \frac{\alpha_{2j}t - 2\theta_{2j}}{(a_j - b_j p_j)p_j \beta_2 \theta_{2j}}$. *We have*

$$w_j^* = \begin{cases} \frac{1}{2} - \frac{\theta_{2j}C_2}{2\theta_{1j}} & if\ \frac{1}{2} - \frac{\theta_{2j}C_2}{2\theta_{1j}} < C_2 \\ C_2 & if\ C_2 \le \frac{1}{2} - \frac{\theta_{2j}C_2}{2\theta_{1j}} \end{cases}$$

and

$$(q_{1j}^*, q_{2j}^*) = \begin{cases} \left(1, q_{2j}^*\left(\frac{1}{2} - \frac{\theta_{2j}C_2}{2\theta_{1j}}\right)\right) & if\ \frac{1}{2} - \frac{\theta_{2j}C_2}{2\theta_{1j}} < C_2 \\ (1,1) & if\ C_2 \le \frac{1}{2} - \frac{\theta_{2j}C_2}{2\theta_{1j}} \end{cases}$$

where $q_{2j}^* < 1$ *if* $\frac{1}{2} - \frac{\theta_{2j}C_2}{2\theta_{1j}} < C_2$. *Because* $t \in \left(min\left\{\frac{2\theta_{ij}}{\alpha_{ij}}\right\}, max\left\{\frac{2\theta_{ij}}{\alpha_{ij}}\right\}\right)$ *implies* $0 < C_2 < \frac{8b_j(\theta_{1j}\alpha_{2j} - \theta_{2j}\alpha_{1j})}{a_j^2 \beta_2 \theta_{2j} \alpha_{1j}}$, *the optimal quality pair* $(1,1)$ *exists if and only if* $\frac{8b_j(\theta_{1j}\alpha_{2j} - \theta_{2j}\alpha_{1j})}{a_j^2 \beta_2 \theta_{2j} \alpha_{1j}} < \frac{1}{2} - \frac{\theta_{2j}C_2}{2\theta_{1j}}$.

According to Lemma 2, the platform will still set a positive revenue sharing ratio w_j^* to stimulate the participation of the university. Compared to the optimal ratio in the start-up period, we may find that in the growth period, the optimal ratio may be lower than $\frac{1}{2}$, which is impossible in the start-up period. It is still possible that it is too expensive for the platform to make all the universities set their qualities to 1, if t is large enough. However, university 1, the university with convex utility, finds it optimal to maximize the course quality.

Expansion period

In the expansion period, the transportation cost becomes smaller, though the market is still partial covered. Both universities' utility functions are convex in this period. Therefore, each university will only consider the corner solutions $q_{ij} \in \{0,1\}$ in course offering. It can be proved that in equilibrium (q_1, q_2) can be neither $(1,0)$ nor $(0,1)$: As long as one university finds it profitable to offer the course, the other would also benefit from offering a course. $(1,1)$ is the unique equilibrium. This is summarized in Lemma 3.

Lemma 3. *Consider the type-j course. In expansion period, we have* $w_j^* = 0$ *and* $\left(q_{1j}^*, q_{2j}^*\right) = (1,1)$ *if* $w_j \ge 0$ *for all* $j \in \{L, H\}$.

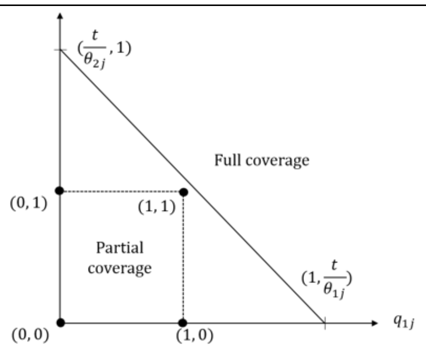

Figure 4. Corner solutions in expansion period

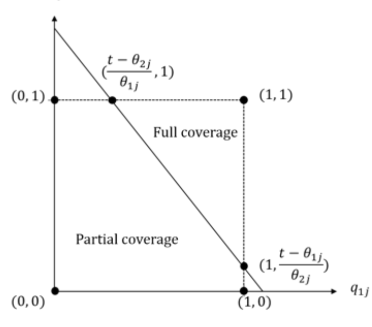

Figure 5. Corner solutions in mature period

In Lemma 3, even though the platform set the optimal revenue sharing ratio w_j^* to zero, both universities will offer the qualities to one because the transportation cost t is at the best region: it is low so that it is easy for a university to offer a course to attract many students, and it is high enough so that the two universities' courses are not really in a competition. This may be the case, e.g., that all people in the world have high-speed free Internet access, and the concept of MOOCs has been widely adopted, but the technology of automatic translation is still imperfect. Therefore, a university may easily attract a lot of students in its own language, and the threat from a course using a foreign language is weak. Each university will drive itself to offer the best course regardless of the revenue sharing ratio, and the platform takes away all the certificate revenues. The universities are comfortable with having no certificate income because the high reputation earned through course offering is good enough.

Mature period

In the mature period, the utility function of the university is convex. Moreover, now t is so small that if both universities offer their courses to the highest possible quality level, the market will be fully covered. In other words, in such a $(q_1, q_2) = (1, 1)$ situation, the two universities really compete in qualities to win students. We can identify six corner solutions (cf. Figure 5), i.e., three full coverage solution $(1, 1)$, $\left(1, \frac{t-\theta_{1j}}{\theta_{2j}}\right)$, and $\left(\frac{t-\theta_{2j}}{\theta_{1j}}, 1\right)$ and three partial coverage solutions $(0, 0)$, $(0, 1)$, and $(1, 0)$. We investigate the equilibrium by examining that there is no player can be better off by a unilateral change, and figure out the constraints of w_j.

Lemma 4. *Consider the type-j course. In the mature period, we have $w_j^* = 0$ and $\left(q_{1j}^*, q_{2j}^*\right) \in \left\{\left(1, \frac{t-\theta_{1j}}{\theta_{2j}}\right), \left(\frac{t-\theta_{2j}}{\theta_{1j}}, 1\right)\right\}$ if $w_j \geq 0$ for all $j \in \{L, H\}$. It can be verified that all the solutions along the line between $\left(1, \frac{t-\theta_{1j}}{\theta_{2j}}\right)$ and $\left(\frac{t-\theta_{2j}}{\theta_{1j}}, 1\right)$ for all $j \in \{L, H\}$ are not equilibria.*

Lemma 4 shows that the universities would set their quality so that the market is exactly full covered. The fact is that both universities find it beneficial to offer high-quality courses. However, as long as one university has set its quality to 1, the other university will find it not worthwhile to also set the quality to 1 due to the competition. The convexity of the utility function would then suggest the university to set the quality to exactly the level that attracts all the remaining learners. Interestingly, we have no idea which university will get the chance to be the one offering the course of higher quality, as there exist two equilibria in this case. Despite of this, both equilibria yield the same profit to the platform.

Discussions and Implications

Having the equilibrium qualities characterized in the previous section, we now examine the relationships between the transportation cost and the optimal qualities in each period.

Proposition 1. *In equilibrium, we have $q_{ij}^* > 0$ for all i, j, t. The optimal qualities of both high type and low type throughout the four periods are all positive in equilibrium.*

Our first finding is regarding whether the diversity of the courses exists throughout the four periods in equilibrium. As the low type course results in a low purchase conversion rate, and the high transportation cost in the initial period lowers the university's intention to offer the course, it seems that under some periods some types of course will not be offered. Somewhat surprisingly, we find out that both types of course exist throughout the four periods in equilibrium. This fact may be explained as follows. When t is small, even the low-type course may benefit a university by earning it reputation. When t is large, such a benefit does decrease, but the universities will at the same time find the competition between them become less intense. Given that the platform earns revenue only when universities offer courses, it will always adjust the revenue sharing proportion to induce course offering. It then follows that there is always enough incentives for both universities to offer both types of courses.

Below we discuss the equilibrium quality levels of courses. We are particularly interested in the number of "excellent courses," which are defined as courses whose quality levels are 1.

Proposition 2. *There is one excellent course in the mature period and two in the expansion period. In the growth period, if $\frac{8b_j(\theta_{1j}\alpha_{2j}-\theta_{2j}\alpha_{1j})}{a_j^2\beta_2\theta_{2j}\alpha_{1j}} < \frac{1}{2} - \frac{\theta_{2j}B_2}{2\theta_{1j}}$, there exists a sub-period such that there are two* *excellent courses; otherwise, there is only one throughout the growth period. In the start-up period, there is no excellent when* $t > \frac{a_j^2\beta_1\theta_{1j}+16b_j\theta_{1j}}{8b_j\alpha_{1j}}$*; otherwise, there is an excellent course.*

Somewhat surprisingly, it shows that the maximum number of excellent courses locates in expansion period rather than mature period. As aforementioned, due to the intense competition and limited number of learners, in the mature period one university will find it suboptimal to offer an excellent course. Note that, in growth period, the optimal quality pair $(1,1)$ exists if its w_j^* locates in growth period (cf. Figure 6). Otherwise, only $(1, q_{2j}^*)$ exists in the growth period (cf. Figure 7).

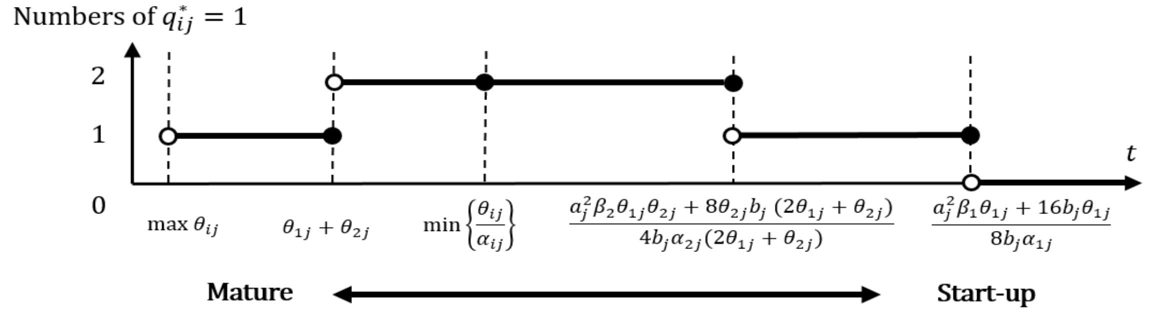

Figure 6. The change of numbers of $q_{ij}^* = 1$ in t if $\frac{8b_j(\theta_{1j}\alpha_{2j}-\theta_{2j}\alpha_{1j})}{(a_j^2\beta_2\theta_{2j}\alpha_{1j})} < \frac{1}{2} - \frac{a_j^2\theta_{2j}(2t-2\theta_{2j})}{8b_j\beta_2\theta_{1j}\theta_{2j}}$

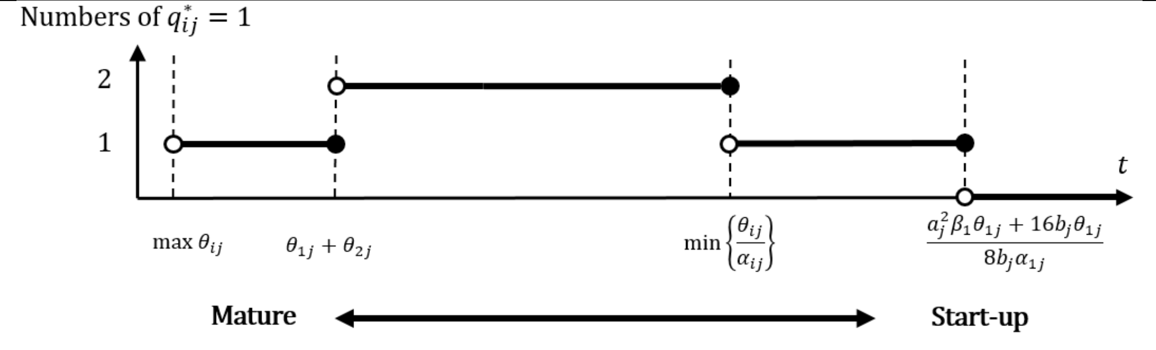

Figure 7. The change of numbers of $q_{ij}^* = 1$ in t if $\frac{8b_j(\theta_{1j}\alpha_{2j}-\theta_{2j}\alpha_{1j})}{(a_j^2\beta_2\theta_{2j}\alpha_{1j})} \geq \frac{1}{2} - \frac{a_j^2\theta_{2j}(2t-2\theta_{2j})}{8b_j\beta_2\theta_{1j}\theta_{2j}}$

We now move forward to compare the quality levels of the two types of courses. Is it always the case that the high-type courses will be offered at a higher quality level? Or is it possible for a low-type course to possess better quality? The two propositions below address these questions.

Proposition 3. *If* $\theta_{ij} = \theta$ *for all* $i \in \{1,2\}$, $j \in \{L, H\}$ *and* $\alpha_{iL} > \alpha_{iH}$ *for* $i \in \{1,2\}$, *there exists* $t > \min_{i\in\{1,2\}}\left\{\frac{2\theta}{\alpha_{iL}}\right\}$ *such that* $q_{iH}^* \geq q_{iL}^*$ *for all* $i \in \{1,2\}$. *Moreover, if* $a_H > a_L$ *and* $b_H \leq b_L$, *there exists* $t > \frac{a_L^2\beta_1\theta_{1L}+16b_L\theta_{1L}}{8b_L\alpha_{1L}}$ *such that* $q_{iH}^* \geq q_{iL}^*$ *for all* $i \in \{1,2\}$.

The quality-gap periods of t mentioned in Proposition 3 are marked with grey color in Figure 8. If the effort cost of type L is larger than type H, and t locates in these quality-gap periods, then the optimal quality of type L is smaller than or equal to type H. Notice that the phenomenon might happen in start-up period or growth period. We suggest that the government and organization concerned should pay more attention to aid the university with higher effort cost to raise the quality in these early periods.

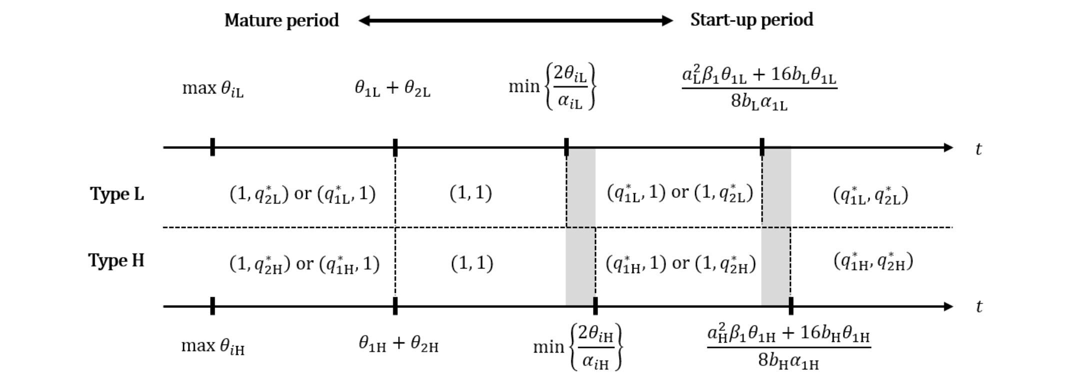

Figure 8. The gaps of optimal equilibrium between type H and L when $\alpha_{iL} > \alpha_{iH}$

Proposition 4. *If $\alpha_{ij} = \alpha$ for all $i \in \{1,2\}$, $j \in \{L,H\}$ and $\theta_{iH} > \theta_{iL}$ for $i \in \{1,2\}$, then for all $i \in \{1,2\}$, there exists $t > \theta_{1L} + \theta_{2L}$ such that $q_{iL}^* \geq q_{iH}^*$, and there exists $t > \min_{i\in\{1,2\}}\left\{\frac{2\theta}{\alpha_{iL}}\right\}$ such that $q_{iH}^* \geq q_{iL}^*$. Moreover, if $a_H > a_L$ and $b_H \leq b_L$, there exists $t > \frac{a_L^2\beta_1\theta_{1L}+16b_L\theta_{1L}}{8b_L\alpha_{1L}}$ such that $q_{iH}^* \geq q_{iL}^*$ for all $i \in \{1,2\}$.*

The quality-gap periods of t mentioned in Proposition 4 are marked with grey color in Figure 9. Surprisingly, if the reputation of type H is larger than type L, and t locates in the quality-gap period near $\theta_{1j} + \theta_{2j}$, then the optimal quality of type L is larger than or equal to type H because type H falls in mature period earlier than type L near this gap. The competition of type L is more intense in the quality-gap period near $\theta_{1j} + \theta_{2j}$. If t locates in the other two quality-gap periods, the optimal quality of type L is smaller than or equal to type H because the reputation of type H is larger than type L.

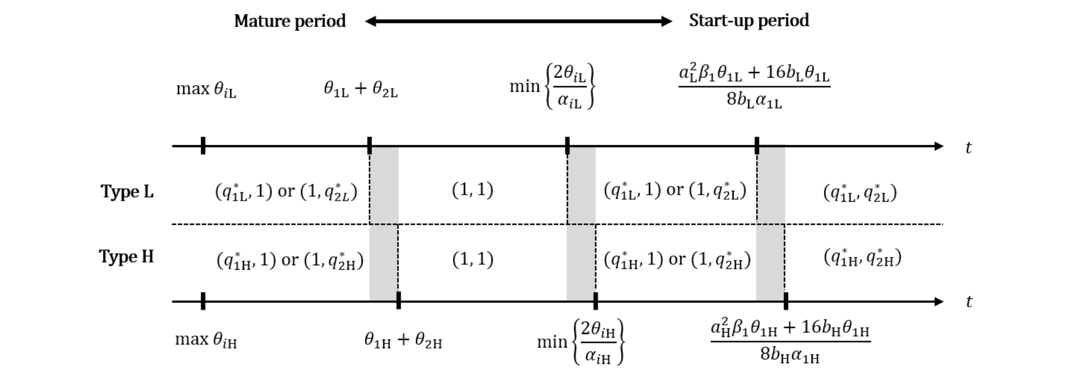

Figure 9. The gaps of optimal equilibrium between type H and L when $\theta_{iH} > \theta_{iL}$

Conclusion

In this paper, we adopt a theoretical framework to investigate an MOOC platform's strategic choice of the certificate prices and the revenue sharing ratios for coordinating supply and demand. By modelling the maximization problems of the platform's profit and the university's utility, the equilibrium quality levels and profits are then derived. Thus, the platform's optimal strategic pricing choice are determined.

In our opinion, we believe that diversity of course type make the world of MOOCs more colourful. Fortunately, we conclude that all types of course will exists in equilibrium throughout the lifecycle on the MOOC platform. We show that the number of courses of the highest possible quality may not always increase as technologies become more mature and MOOCs become more popular due to the potential competition among universities. Moreover, the difference in effort level and reputation between universities on the platform will lead to the gaps of optimal equilibrium between different types of course.

We may further extend our research into the following directions. First, we can change the time sequence and event so that the university controls the price, and the platform controls an overall revenue sharing ratio over different types of course. Second, it would be thorough to address the issue that a proportion of learners are not that free to study all types of course on the platform because of time constraints. A theoretical investigation on the impact of competition across different types of courses may contribute to the literature.

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