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Application of a static game of complete information: economic behaviors of professors and students

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Abstract

The economic behaviors manifested between professors and students may be viewed as a game, with both behaviors endogenously correlated. In this paper, a static game is applied to address this behavior and determine the Nash equilibrium. Both professors and students choose their best strategies (i.e., optimal efforts) to maximize their payoffs. Consequently, theoretical analysis suggests that professor's evaluation and student's grade are endogenously correlated. More importantly, an innovation is offered here that is useful in constructing empirical models for the further investigation of this issue.

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I. Introduction

Since both professors and students are economic individuals, their responses to each other manifest as economic behavior. For example, students need good grades from professors and professors need good evaluations from students. These types of economic behaviors are endogenously correlated. Taken further, the economic behavior between professors and students may be viewed as a game.

A number of studies have theoretically and empirically examined the relationship between student evaluations of teaching and students' grades. Most of these studies have been done empirically (e.g., Voeks and French, 1960; Kelly, 1972; Nichols and Soper, 1972; Soper, 1973; Mirus, 1973; Tuckman, 1975; Danielsen and White, 1976; Dilts, 1980; Marlin and Niss, 1980; Seiver, 1983; Nelson and Lynch, 1984; Aigner and Thum, 1986; Mason, Steagall, and Fabritius, 1995; Krautmann and Sander, 1997; Becker and Watts, 1999; Grimes, Millea, and Woodruff, 2004; Isely and Singh, 2005; McPherson, 2006). Many have concluded that students' reported grade expectations are positively and significantly associated with students' overall evaluations of teachers. The theoretical framework for this subject has not been significant (e.g., Kelly, 1975; McKenzie, 1975; Lichty, Vose and Peterson, 1978; Needham, 1978). The theoretical work started by Kelly (1975) and McKenzie (1975) viewed students as a utility maximizer and focused on the potential influences of grades and grading structures on student evaluations of teachers. In 1978, Lichty, Vose and Peterson extended the theoretical work of Kelly (1975a) and McKenzie (1975) and examined McKenzie's hypothesis (1975) that many instructors might attempt to inflate students' grades in order to maintain or enhance the evaluations of their teaching.

Although a fair number of previous researchers have investigated and discussed this issue, I attempt to adopt an alternative approach here by applying game theory to address the economic behavior that occurs between professors and students and determine the Nash equilibrium. Thus, this paper extends the literature on student evaluations used in higher education. More importantly, it offers an interesting innovation that will be useful in constructing empirical models for further investigation of this issue. These are this paper's primary contributions.

This paper is organized as follows. First, a theoretical model is developed. Second, a static game is applied to address the economic behavior between professors and students, and the Nash equilibrium is determined. Concluding comments may be found in the final section.

II. The Theoretical Model

Suppose a student (say, student *j*) wishes to produce an education product (e.g., knowledge of economics). However, without a professor, student *j* cannot produce the education product independently. Thus, student *j* enrolls in professor *i*'s class so that student *j* and professor *i* can produce the education product (Y_{ij}) jointly and simultaneously. Professor *i* now has *n* students in a class ($j = 1 \ldots n$), and produces *n* different education products with *n* different students at the same time, which is $Y_{i1} \cdots Y_{ij} \cdots Y_{in}$. Therefore, the production function (Y_{ij}) of the education good consists of the following eight factors:

(1) Professor *i*'s efforts devoted to teaching the class (denoted as E_i). The efforts include those that occur inside and outside the classroom. For example, professor *i* needs to prepare the course, grade student *j*'s exam & homework assignments, and provides office hours to help the student manage term projects, homework assignments, and/or exams.

Note that if the professor has a high expectation standard for his or her students, the professor will devote more efforts to teaching the class and give more lectures.

(2) Professor i's human capital (denoted as H_i) at the time when he or she teaches the class. The professor's human capital reflects the professor's quality, which may be identified by the professor's highest education degree (e.g., Ph.D. in economics) and teaching experiences. Note that professor i's effective labor is $\left(H_i \cdot E_i\right)$, where H_i = professor i's human capital at the time that he/she teaches student j, and E_i = professor i's effort.

(3) Student j's efforts devoted to studying and learning (denoted as e_j). The efforts include those that occur inside and outside the classroom. For example, the student spends time studying for this class at home or in the library.

(4) Student j's human capital (denoted as h_j) at the time when he or she takes the class. The student's human capital implies the student's quality, which can be identified through his or her SAT or ACT scores, high-school GPA, and cumulative GPA to date at the university. For example, economics classes (micro and macro) require high school math skills. A student who did very well in high school math will probably have an easier time studying economics. Note that student j's effective labor is $\left(h_j \cdot e_j\right)$, where h_j = student j's human capital at the time when he/she enrolls in professor j's class, e_j = student j's effort.

(5) Teaching/learning environment and supplemental resources (denoted as A). This factor identifies the quality of the classroom (e.g., air conditioning, chalkboard, lights, high-tech technology, overhead projectors, and chairs) and teaching assistants. For example, many professors in research institutes have teaching assistants (i.e., Ph.D. students) to help them with teaching. The responsibilities of a teaching assistant are to grade students' homework assignments/exams, give students a review class weekly, and hold office hours. Such assistance will substantially improve students' learning and studying, and thus increase education output.

(6) Professor i's teaching attitude (denoted as δ_i). This factor identifies the professor's courtesy and respect in class. A good teaching attitude will enhance students' willingness to learn because professors who treat students the same way they wish to be treated themselves increase education output.

(7) Professor i's communication skill (denoted as ϕ_i). This factor indicates whether the professor's speech is clear, understandable, and interesting. A clear, understandable, and interesting speech will stimulate students' interest in learning. Seiver (1983) showed that this factor is helpful in students' learning, implying that it will improve education output.

(8) Student j's interest in the class (η_j). This factor identifies the student's willingness to learn. For example, if the student is interested in the class, he or she will be willing to learn and attend the class all the time or very often and study for the class regularly.

Based on these eight factors, it is assumed that the output function of education product, Y_{ij}, may be displayed as the Cobb-Douglas form, which is:

$$Y_{ij} = B_{ij}\left(h_j e_j\right)^{\alpha}\left(H_i E_i\right)^{\beta}, \tag{1}$$

where $B_{ij} = A\delta_i\phi_i\eta_j$; and $0<\alpha,\beta<1$, and $\alpha+\beta<1$ (so that the first-order conditions can be sufficient for a maximum effect). In all, α and β are constant parameters and shares of the student *j*'s effective labor (i.e., $\left(h_j \cdot e_j\right)$) and the professor *i*'s effective labor (i.e., $\left(H_i \cdot E_i\right)$) in this output function, respectively. The reason for displaying the output function of the education product in the Cobb-Douglas form is that the education product (Y_{ij}) is created by both professor *i* and student *j* jointly and simultaneously. If either professor *i* or student *j* makes zero efforts (i.e., $E_i = 0$ or $e_i = 0$), the education output will be zero. Since the Cobb-Douglas form can satisfy the assumption, it is the most appropriate form for displaying the output function of the education product. The other forms, such as the CES and linear forms, cannot satisfy the assumption. Therefore, the Cobb-Douglas form was chosen for this study.

In addition, professor *i* has a cost of teaching the class ($C_{P,i}$), which can be illustrated as follows:

$$C_{P,i} = c_{P,i} \cdot E_i\,, \tag{2}$$

where $c_{P,i} > 0$ is professor *i*'s marginal cost of effort (i.e., opportunity cost per unit effort devoted to teaching). Note that if professor *i* has more research requirements and/or other activities, such as services or consulting, the professor's marginal cost of effort ($c_{P,i}$) will increase. This is because the professor's maximum feasible efforts are fixed. Thus, the fact of a greater number of research requirements and other activities implies a higher opportunity cost per unit effort devoted to teaching. Meanwhile, student *j* also has a cost of taking and studying for the class ($C_{S,j}$), which can be written as follows:

$$C_{S,j} = c_{S,j} \cdot e_j\,, \tag{3}$$

where $c_{S,j} > 0$ is student *j*'s marginal cost of effort (i.e., opportunity cost per unit effort devoted to learning and studying). Note that if student *j*'s working hours increase and/or professor *i* raises the grading standard and expectation, the student's marginal cost of effort ($c_{S,j}$) will increase. This is because the student's maximum feasible efforts are also fixed. Thus, more working hours and higher grading standards and expectations imply a higher opportunity cost per unit effort devoted to learning and studying.

As a result, professor *i* has payoff ($\pi_{P,i}$) from producing Y_{ij} with student *j*, which represents student *j*'s overall evaluation of professor *i*, which can be specified as follows:

$$\pi_{P,i} = B_{ij}\left(h_j e_j\right)^{\alpha}\left(H_i E_i\right)^{\beta} - c_{P,i} E_i\ . \tag{4}$$

Similarly, student *j* also has payoff ($\pi_{S,j}$) from producing Y_{ij} with professor *i*, which represents student *j*'s final grade as given by professor *i*. This can be specified as follows:

$$\pi_{S,j} = B_{ij}\left(h_j e_j\right)^{\alpha}\left(H_i E_i\right)^{\beta} - c_{S,j} e_j\ . \tag{5}$$

It should be pointed out that the payoffs for professors and students are not necessarily monetary. They also can include a person's achievement and/or well-being (i.e., utility). A professor who receives good evaluations from students will feel that he or she is a successful teacher. The achievement and/or well-being indirectly represent the professor's payoff. The same can be applied to the student's payoff. In addition, when specifying professor *i*'s and student *j*'s payoff functions, the education outputs are the same for both professor *i* and student *j* – only costs differ. This is because the education output (Y_{ij}), shown in Equation (1), is produced by both professor *i* and student *j* jointly and simultaneously. In other words, Y_{ij} is an output between professor i and student j, not between professor i and other students, although professor i will produce n different outputs ($Y_{i1} \cdots Y_{ij} \cdots Y_{in}$) with different n students at the same time in one class.

III. The Nash Equilibrium

Since professors and students are economic individuals, the economic behavior between professors and students can be viewed as a game. Thus, game theory is applied in this study. Both professor i and student j will play the game and choose their best strategies (i.e., the player's best response to the strategies specified by the other player) to receive their best payoffs. Professor i needs a good evaluation from student j, which represents professor i's payoff. Similarly, student j needs a good grade from professor i, which represents student j's payoff. Student j fills out the evaluation before he/she knows his/her final grade. Certainly, professor i gives student j a final grade before he/she knows the result of student j's evaluation of his/her teaching. Both players (professor i and student j) simultaneously choose actions. Therefore, this game may be viewed as a static game of complete information (i.e., a simultaneous-move game).

In the game, both players (professor i and student j) choose their best strategies (i.e., their efforts, E_i and e_j). The strategies available to each player are their different efforts. It is assumed that effort is continuously divisible. Naturally, negative efforts are not feasible. Hence, each player's strategy space can be represented as $S_i = \left[0, \Omega_i\right]$ and $S_j = \left[0, \Omega_j\right]$, where Ω_i and Ω_j are the maximum number of feasible efforts for professor i and student j, respectively. Thus, in the model, the efforts pair $\left(E_i^*, e_j^*\right)$ is a Nash equilibrium if, for the professor, e_j^* solves:

$$\max_{0 \le E_i < \infty} \pi_{P,i}\left(e_j^*, E_i\right) = \max_{0 \le E_i < \infty} B_{ij}\left(h_j e_j^*\right)^{\alpha}\left(H_i E_i\right)^{\beta} - c_{P,i} E_i$$

Thus, the first-order condition for the professor's optimization problem is both necessary and sufficient; it yields:

$$\frac{\partial \pi_{P,i}}{\partial E_i} = 0 \Rightarrow E_i^* = \left(\frac{c_{P,i}}{B_{ij} h_j^{\alpha}\left(e_j^*\right)^{\alpha} H_i^{\beta} \beta}\right)^{\frac{1}{\beta-1}}. \tag{6}$$

Similarly, for the student, E_i^* solves:

$$\max_{0 \le e_j < \infty} \pi_{S,j}\left(e_j, E_i^*\right) = \max_{0 \le e_j < \infty} B_{ij}\left(h_j e_j\right)^{\alpha}\left(H_i E_i^*\right)^{\beta} - c_{S,j} e_j$$

Hence, the first-order condition for the student's optimization problem is also both necessary and sufficient; it yields:

$$\frac{\partial \pi_{S,j}}{\partial e_j} = 0 \Rightarrow e_j^* = \left(\frac{c_{S,j}}{B_{ij} \alpha h_j^{\alpha} H_i^{\beta}\left(E_i^*\right)^{\beta}}\right)^{\frac{1}{\alpha-1}}. \tag{7}$$

If the efforts pair $\left(E_i^*, e_j^*\right)$ is to be a Nash equilibrium, the players' effort choices must satisfy both equations (6) and (7). Therefore, solving this pair of equations (6) and (7) yields[1]:

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[1] Substituting equation (7) into equation (6) yields equation (8). And then substituting equation (8) into equation (7) yields equation (9).

$$E_i^* = \left(\beta B_{ij}^{\frac{1}{1-\alpha}} \alpha^{\frac{\alpha}{1-\alpha}} h_j^{\frac{\alpha}{1-\alpha}} H_i^{\frac{\beta}{1-\alpha}} c_{S,j}^{\frac{-\alpha}{1-\alpha}} c_{P,i}^{-1} \right)^{\frac{1-\alpha}{1-(\alpha+\beta)}} \tag{8}$$

and

$$e_j^* = \left(\alpha B_{ij}^{\frac{1}{1-\beta}} h_j^{\frac{\alpha}{1-\beta}} H_i^{\frac{\beta}{1-\beta}} \beta^{\frac{\beta}{1-\beta}} c_{P,i}^{\frac{-\beta}{1-\beta}} c_{S,j}^{-1} \right)^{\frac{1-\beta}{1-(\alpha+\beta)}} . \tag{9}$$

The efforts pair $\left(E_i^*, e_j^*\right)$ is the Nash equilibrium. As shown in equations (8) and (9), $\partial E_i^* / \partial B_{ij} > 0$, $\partial E_i^* / \partial h_j > 0$, $\partial E_i^* / \partial H_i > 0$, $\partial E_i^* / \partial c_{S,j} < 0$, $\partial E_i^* / \partial c_{P,i} < 0$, $\partial e_j^* / \partial B_{ij} > 0$, $\partial e_j^* / \partial h_j > 0$, $\partial e_j^* / \partial H_i > 0$, $\partial e_j^* / \partial c_{S,j} < 0$, and $\partial e_j^* / \partial c_{P,i} < 0$. Substituting equations (8) and (9) into equations (4) and (5) yields $\pi_{P,i}^*$ and $\pi_{S,j}^*$, which are professor *i*'s and student *j*'s payoffs, respectively. Therefore:

$$\pi_{P,i}^* = \left(\phi_i \eta_j \delta_i A \alpha^{\alpha} \beta h_j^{\alpha} H_i^{\beta} c_{P,i}^{-\beta} c_{S,j}^{-\alpha} \right)^{\frac{1}{1-(\alpha+\beta)}} \left(\beta^{\beta} - \beta^{1-\alpha} \right) , \tag{10}$$

and

$$\pi_{S,j}^* = \left(\phi_i \eta_j \delta_i A \alpha \beta^{\beta} h_j^{\alpha} H_i^{\beta} c_{P,i}^{-\beta} c_{S,j}^{-\alpha} \right)^{\frac{1}{1-(\alpha+\beta)}} \left(\alpha^{\alpha} - \alpha^{1-\beta} \right). \tag{11}$$

Note that $0 < \alpha, \beta < 1$ and $\alpha + \beta < 1$, so $(\beta^{\beta} - \beta^{1-\alpha}) > 0$ and $(\alpha^{\alpha} - \alpha^{1-\beta}) > 0$. Therefore, $\pi_{P,i}^* > 0$ and $\pi_{S,j}^* > 0$. The effects of exogenous variables (i.e., ϕ_i, η_j, δ_i, *A*, h_j, H_i, $c_{P,i}$, and $c_{S,j}$) on $\pi_{P,i}^*$ and $\pi_{S,j}^*$ can be illustrated as follows:

1. $\partial \pi_{P,i}^* / \partial \phi_i > 0$ and $\partial \pi_{S,j}^* / \partial \phi_j > 0$. A professor's communication skill is very important because a clearer and more understandable speech pattern will enable students to understand the class material more easily and help them to do better in the subject. Students who do well will be happier to give the professor a better evaluation. Seiver (1983) showed empirically that communication skill and students' overall evaluation of teachers are positively and significantly correlated. This is one reason for the slightly lower student evaluations of non-native English-speaking professors – their accent may make them more difficult to understand. If students find it difficult to follow the professor's lectures due to his/her accent and become frustrated, they may express those feelings via the evaluation.
2. $\partial \pi_{P,i}^* / \partial \eta_j > 0$ and $\partial \pi_{S,j}^* / \partial \eta_j > 0$. A student who is interested in the class will be more willing to learn and hence will give his/her professors a better evaluation. Such a student is more serious about and will study harder for the class. As long as the student is serious and does well, he/she will be more confident about the class and satisfied with the professor's teaching. Ultimately, he/she will give the professor a better evaluation. Certainly, the student will also receive a good grade from the professor.
3. $\partial \pi_{P,i}^* / \partial \delta_i > 0$ and $\partial \pi_{S,j}^* / \partial \delta_i > 0$. If the professor treats his/her students in the same way he/she wishes to be treated, the professor will receive more respect and better evaluations from students, because students will appreciate the professor's respect and courtesy. Of course, the professor who treats students respectfully will also be more generous in giving students better grades.

4. $\partial\pi^*_{P,i}/\partial A > 0$ and $\partial\pi^*_{S,j}/\partial A > 0$. A better teaching-learning environment and supplemental resources improve both the student evaluation of teaching and the student's grade. For example, if the professor has a very responsible teaching assistant who substantially helps the student, the student will do a good job on the midterm exam and receive a good grade. This student will be more satisfied with and interested in the class, and thus will give the professor a better evaluation at the end of the semester.
5. $\partial\pi^*_{P,i}/\partial h_j > 0$ and $\partial\pi^*_{S,j}/\partial h_j > 0$. A student who has a better quality educational experience will receive a better grade from the professor and offer a better evaluation of the professor. The quality will stem from the understandability of the professor's lecture, which will enable the student to do better in class. Students who easily understand the professor will be more confident in the class and give the professor a better evaluation.
6. $\partial\pi^*_{P,i}/\partial H_i > 0$ and $\partial\pi^*_{S,j}/\partial H_i > 0$. A professor who is very knowledgeable and has plenty of teaching experience will benefit students, who will subsequently do well in the class. Students then will be satisfied and give the professor a better evaluation.
7. $\partial\pi^*_{P,i}/\partial c_{P,i} < 0$ and $\partial\pi^*_{S,j}/\partial c_{P,i} < 0$. If a professor's marginal cost of efforts is higher due to greater research requirements or service work, both the professor and the student will receive lower payoffs. For example, if the professor is extremely busy with work other than teaching, he/she may cancel the class and/or office hours often because his/her opportunity costs of teaching this class are very expensive, which may lead him/her to reduce efforts on teaching. This will lead students to learn less and become frustrated with the professor because they do not understand the class and thus cannot do well in it. The result will be a bad evaluation.
8. $\partial\pi^*_{P,i}/\partial c_{S,j} < 0$ and $\partial\pi^*_{S,j}/\partial c_{S,j} < 0$. If a student's marginal cost of efforts is higher due to more working hours or higher grading standards and expectations from the professor, both the professor and the student will receive lower payoffs. For example, if the student is working 40 or more hours a week while enrolled as a full-time student, the student may skip the class quite often and never study/review after class because his/her opportunity costs of taking the class are expensive, which may cause him/her to reduce class-related efforts. Hence, the student will not understand the professor in class and will not do well. The result may be frustration and a poor evaluation. In addition, if the professor raises grading standards and expectations, the student may not receive a good grade. Thus, the student will have to devote more efforts to studying and may not necessarily receive a good grade, resulting in a worse evaluation of the professor. This is why many professors elect to improve their evaluations by grading more liberally. As shown by prior researchers, including Seiver (1983), Krautmann and Sander (1999), Lichty, Vose, and Peterson (1978), Nelson and Lynch (1984), Kelly (1972), McKenzie (1975), and Mirus (1973).

One may argue that the explanations for the partial derivatives (shown above) appear a bit simplistic in interpretation because students have varying learning styles and thus may behave in varying ways to the same stimulus. I agree with the argument and acknowledge that an empirical investigation is warranted. However, the main objective of this study was to provide a new approach to the further, empirical investigation of this issue.

IV. Conclusion

In this paper, I applied a static game to address the economic behavior that occurs between professors and students. Both professors and students choose their best strategies (i.e., their optimal efforts) to maximize their payoffs. The theoretical analysis suggests that professor's evaluation and student's grade are endogenously correlated. More importantly, an innovative method was offered here that may be useful in constructing empirical models for further investigations of this issue.

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