Building an Economic Theoretical Framework to Link Quizzes, Effort Investment, and Learning Outcomes

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ABSTRACT. Using an economic theory (theory of producer choice), a basic theoretical model is constructed to illustrate how and why quizzes can affect a student's behavior in effort-investment and learning outcomes. The theoretical evidence demonstrated that quizzes can improve students' exam performance and enhance their investment in effort, and that unannounced-quizzes may most likely increase student in-class effort relative to announced-quizzes; while announced-quizzes may most likely enhance student out-of-class effort relative to unannounced-quizzes. In addition, this study looks at how different types of quizzes may serve as different effective instructional methods for student learning, and seeks to explain why student efforts are suboptimal absent a quiz. More importantly, this study frames an economic theoretical background for quizzes, which can be useful in constructing empirical models for further investigations of this issue. (A20; A22; D20; D21; I20)

I. Introduction

The topic of quizzes has been broadly investigated by a mass of researchers, many of whom are psychologists (e.g., Azorlosa and Renner, 2006; Wilder, Flood, and Stromsnes, 2001). The disciplines of psychology and economics both study human behavior, but with different analytical focuses. Psychologists focus on an individual's perception, cognition, emotion, motivation, etc.; while economists focus on how cost/benefit affect an individual behavior. For example, from the psychological perspective, quizzes motivate students to attend classes; while from the economic perspective, quizzes raise the opportunity cost of missing classes. In order to reduce cost, students attend classes. Although the analytical focuses differ, both predict the same result – students will attend classes more frequently when mandatory quizzes are part of the class plan.

A review of the literature on the extent to which announced versus

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unannounced class quizzes and quizzes versus no quizzes could influence examination results showed that a vast number of studies have been framed using behavioral theories of learning at the individual level, such as reinforcement learning theory or goal-setting theory (e.g., Haigh, 2007; Sansone, Fraughton, Zachary, Butner, and HeinerSelf, 2011; Tremblay, Gardner, and Heipel, 2000). Many recent studies also have specifically examined quizzes as a learning process and their influence on examination results and other learning outcomes (e.g., Landrum, 2000).

Obviously, psychologists have successfully used psychological theories (e.g., learning behavioral theories) at the individual level to frame their studies on the topic of quizzes. However, in designing and preparing for this study, we did not identify a literature that recounted efforts to use economic theories at the individual level to model class quizzes. For that reason, we attempted to use the theory of producer choice[1] to frame a model for quizzes that can be used to present how and why students' investment in efforts and education output would change by taking quizzes. The reason for using economic theory to model class quizzes is that the quiz is one of the factors that may influence a student's effort-investment and hence impact the student's learning outcome, and students can be regarded as producers who produce their knowledge. This idea inspired us to use economic theory to frame a theoretical background for quizzes and in turn to describe students' investment behavior in efforts to produce knowledge.

This issue is important because educators need to comprehend students' investment behavior in accumulating their human capital. A student's human capital investment not only includes monetary investment (e.g., tuition) but also includes effort investment (e.g., time devoted to studying for classes). Since quizzes are one of the important factors affecting a student's effort investment, this paper particularly focuses on a student's investment in effort. Therefore, we developed five research questions for this study: (1) Do quizzes enhance students' investment in effort? (2) Do quizzes improve students' learning outcomes? (3) Do different types of quizzes influence students' behavior differently in in/out-of-class effort investment? (4) Would different types of quizzes serve different effective instructional purposes in students' learning? (5) Why are student efforts suboptimal absent a quiz?

In short, the main contribution of this paper is that it offers the first descriptive look at the use of producer choice theory to model class quizzes, linking the economic relationship among quizzes and education output, in-class effort, and out-of-class effort, which may be useful in constructing empirical models for further investigations of this issue.

II. Brief Literature Review

As mentioned earlier, this paper recounts an economic theoretical study that is the first to use the theory of producer choice to frame the topic of class quizzes. No previous study directly relates to our present study. However, a vast number of previous empirical studies are indirectly related to our study. For that reason, in this section, we briefly review some selected previous empirical studies that are related to this topic. Our brief review focuses on the empirical results reported by those previous researchers. We are not able to review the methodology they used, since their studies did not involve an economic theoretical analysis.

According to our research, not all studies have shown that quizzes exert a positive and significant effect on exam performance (e.g., Lumsden, 1976; Conard, Spenser, and Semb, 1978; Beaulieu and Utecht, 1987; Beaulieu and Frost, 1989; Gurung, 2003; and Gaizzi, 2010), but a number have revealed that quizzes have positive and significant effects on exam performance and/or effort investment (e.g., Hovell, Williams and Semb, 1979; Wilder, Flood, and Stromnes, 2001; Azorlosa and Renner, 2006; Azorlosa, 2011 and 2012; Braun and Sellers, 2012; Rusico, 2001; Marchant, 2002; Turney, 1931; Geist and Soehren, 1997; Graham, 1999; Landrum, 2007; and Kamuche, 2005 and 2007).

In addition to exam performance, quizzes serve as an important instructional method for enhancing students' attendance (in-class effort). The studies done by Hovell, Williams and Semb (1979), Azorlosa and Renner (2006), and Braun and Sellers (2012) are examples of those that have shown positive relationships between frequent quizzes and high attendance, inferring that students' attendance is promoted by quizzes. That is, in order to reduce grade loss, students attend class more frequently. The results of Braun and Sellers' (2012) empirical survey even showed that daily quizzes motivated student participation in class discussions.

Moreover, quizzes serve as another important instructional method to augment students' preparation prior to exams (out-of-class effort). For example, Ruscio (2001), Marchant (2002), and Azorlosa and Renner (2006) all found that students in the quiz section would study a few more hours a week than students in the non-quiz section. In addition, Braun and Sellers (2012) revealed that daily quizzes increased students' reading prior to an exam. These examples demonstrated that students' out-of-class effort was improved by the inclusion of quizzes on the syllabus.

Furthermore, researchers even found that quizzes can serve as an effective feedback mechanism. For instance, both Metha (1995) and Bell (1996) showed that quizzes offered instructors instant responses from students. That is, instructors can instantly assess student learning from class quizzes.

III. The Model

3.1. The Knowledge/Grade Production Function

In this study we assumed that each student is a knowledge maximizer. Consider that a student pursues knowledge (denoted by Q). The knowledge production function includes three factors: the student's lecture attendance (i.e., in-class effort, denoted by E), and his/her study outside the classroom (i.e., out-of-class effort, denoted by S), and the instructor's instructional skills/school environment (denoted by I). Both lecture attendance (E) and study outside the classroom (S) are factors that can be determined by the student; thus, these two factors are endogenous variables. Teacher's instructional skills/school environment (I) is the factor that cannot be determined by the student, so this factor is an exogenous variable. Therefore, the knowledge production function can be expressed as: $Q = Q(E,S; I)$, and Q_E, $Q_S > 0$; Q_{EE}, $Q_{SS} < 0$; and $Q_{ES} = Q_{SE} > 0$. Suppose that professors do not inflate students' grades; hence, the level of knowledge acquired is positively reflected in students' grades.[2] In other words, without grade inflation, professors give students grades based upon how much knowledge they acquire.[3] For that reason, a knowledge maximizer can be regarded as a grade maximizer. Therefore, grade (denoted by G) is a function of knowledge, i.e., $G = G(Q)$, and $\frac{dG}{dQ} > 0$. The grade function now is written as: $G = G(E,S; I)$, and G_E, $G_S > 0$; G_{EE}, $G_{SS} < 0$; and $G_{ES} = G_{SE} > 0$.

3.2. The Price Function of In-Class Effort

An opportunity cost of devoting effort to the classroom is the price of attending class (i.e., the price of in-class effort, denoted by P_E). The price of attending class is influenced by the percentage of the course grade for each quiz (denoted by q). When more weight is given to each quiz (say from 0% to 5%) by the professor, if students miss a quiz due to skipping the class, they will lose 5% on their final course grades. Therefore, the opportunity cost of missing class becomes more expensive. Since "missing class" is the opposite of "attending class", the opportunity cost of attending class becomes cheaper $(i.e., \frac{dP_E}{dq} < 0)$. An alternative explanation is that as the weight given to each quiz increases from 0% to 5%, in order not to lose 5% on his/her final course grade, students will attend class more frequently. This implies that the price of attending class becomes cheaper so that students can employ more "attendance" due to the greater weight given to each quiz.

The price of attending class is also influenced by uncertainty (denoted by u), such as an unannounced-quiz. Unannounced-quizzes are short tests given without prior warning or announcement; absent students cannot take unannounced-quizzes later no matter what their reasons for missing class.[4] Hence, when the degree of uncertainty is higher (say from announced to unannounced), if students miss a quiz due to absence, they will lose 5% on their final course grades (assume each unannounced-quiz also = 5% of final course grade). As a result, the opportunity cost of missing class becomes more expensive, implying that the opportunity cost of attending class becomes cheaper $(i.e., \frac{dP_E}{d\theta} < 0)$. An alternative explanation can be expressed as shown below. When the degree of uncertainty given to each quiz increases from announced to unannounced, in order not to lose 5% on his/her final course grade, students will attend class more often. This infers that the price of attending class drops so that students can employ more "attendance" because of the higher degree of uncertainty ascribed to quizzes.

Moreover, the price of attending class can be affected by a student's quality (denoted by θ). The higher the student's quality, the lower the opportunity cost of devoting effort toward the classroom $(i.e., \frac{dP_E}{d\theta} < 0)$. A higher-quality student normally grasps lectures in class more quickly than a lower-quality student. For example, a higher-quality student understands 100% of the lecture in class (say in an hour), while a lower-quality student understands only 50% of the lecture in class. If we quantify the knowledge, then the higher-quality student produces one unit of knowledge in an hour, while the lower-quality student only produces one-half unit of knowledge in an hour. In order to produce one unit of knowledge, the lower-quality student needs double the time to produce it. Suppose that the price of one unit of time is \$10—it will cost \$20 for the lower-quality student to produce one unit of knowledge, which raises the cost. Therefore, the lower-quality student has a higher opportunity cost of devoting effort in the classroom than the higher-quality student does.

The price of attending class also can be affected by a student's motivation to learn and interest in the class (denoted by λ). The greater the student's motivation to learn and be interested in the class, the lower the opportunity cost of attending class $(i.e., \frac{dP_E}{d\lambda} < 0)$. If a student is very interested in the class and is more motivated to learn the course since he/she plans to go to graduate school, the student usually will grasp lectures in class more quickly than a student who is not interested in the class and is less motivated to learn the course since he/she just wants to pass the class and get a degree. This is because the more motivated student will always concentrate in class and take good notes; while the less motivated student may be frequently distracted in class (e.g., falling asleep or texting in class) and never take good notes. As a result, based upon the reason expressed above for the influence of student quality on price, the opportunity cost of devoting effort in the classroom is relatively lower for the highly motivated student than for the one lacking interest in the class and having a lower motivation to learn the course material.

Moreover, whether or not a student's employment hours (denoted by h) may affect his/her attendance is debatable. People who support the no influence on attendance argument believe that if the student can enroll in the class, then the student's work schedule does not conflict with the class schedule. Thus, work hours will not affect the price of attending class. On the other hand, people who support an influence on attendance argument indicate that the more work hours the student works for pay, the less time the student has for travel to campus and for rest, so that the student may skip class more often. Therefore, they believe that the more hours the student works for pay, the higher the price of attending class and the more the student will pay $\left(i.e., \frac{dP_E}{dh} > 0\right)$. In this study, we chose the latter argument.

In summary, the price of in-class effort is a function of the percentage of the course grade for quizzes (q), uncertainty (u), student quality (θ), motivation to learn and interest in the class (λ), and employment hours (h). That is, $P_E = P_E\left(\bar{q}, \bar{u}, \bar{\theta}, \bar{\lambda}, \overset{+}{h}\right)$.

3.3. The Price Function of Out-of-Class Effort

Similarly, there also is an opportunity cost of devoting effort outside the classroom, which is the price of studying outside the classroom (i.e., the price of out-of-class effort, denoted by P_S). The price of out-of-class effort can be impacted by a student's employment hours (denoted by h). The greater the number of work hours, the higher the opportunity cost of devoting effort outside the classroom $\left(i.e., \frac{dP_S}{dh} > 0\right)$. For instance, a student (say Student A) who has a 40-hour/week job may have less time than a student (say Student B) who has a 20-hour/week job to study for the course. Assuming that these two students are of the same quality and if we can quantify the knowledge, Student A may produce fewer units of knowledge than Student B does. In order to produce the same units of knowledge as Student B does, Student A will need to reduce some of his/her leisure time (e.g., sleeping time), which raises the cost.

In addition, the price of out-of-class effort is affected by a student's quality. The higher the student's quality, the lower the opportunity cost of devoting effort outside the classroom $\left(i.e., \frac{dP_S}{d\theta} < 0\right)$. A higher-quality student usually grasps the content of the textbook, lecture notes, and other references more quickly than a lower-quality student. The example and explanation can be referred to the impact of a student's quality on the price of attending class in Section 3.2. As a result, the lower-quality student has the higher opportunity cost of devoting effort outside the classroom than the higher-quality student does.

Moreover, the price of out-of-class effort can be influenced by a student's motivation to learn and interest in the class (denoted by λ). The greater the student's motivation to learn and be interested in the class, the lower the opportunity cost of studying for the class $(i.e., \frac{dP_S}{d\lambda} < 0)$. The example can be referred to as the impact of a student's motivation to learn and interest in the class on the price of attending class (see section 3.2). The more motivated student will always concentrate on studying; while the less motivated student may be frequently distracted during studying (e.g., checking the Internet or texting while studying). Consequently, the opportunity cost of devoting effort outside the classroom is relatively lower for the highly motivated student than for the one lacking interest in the class who is less motivated to study the course material.

In short, the price of out-of-class effort is a function of employment hours (*h*), student quality (θ), and motivation to learn and interest in the class (λ). That is, $P_S = P_S\left(\overset{+}{h}, \overset{-}{\theta}, \overset{-}{\lambda}\right)$.

3.4 Iso-Cost Line

Furthermore, every student has maximum ability[5] that can be brought to bear on learning opportunity cost (denoted by Ψ). A student's maximum ability (Ψ) is affected by his/her quality. Thus, the higher the student's quality, the higher his/her available maximum ability to take on the learning opportunity cost $(i.e., \frac{d\Psi}{d\theta} > 0)$. A higher-quality student normally grasps lectures in class, the content of the textbook, lecture notes, and other references more quickly than a lower-quality student, implying that the higher-quality student is more productive in constructing knowledge than the lower-quality student.

In addition, a student's maximum ability is influenced by his/her interest in the class and motivation to learn. The greater a student's motivation to learn and interest in the class, the greater will be that student's ability to make maximum effort toward the learning opportunity cost $(i.e., \frac{d\Psi}{d\lambda} > 0)$. The explanation is as offered in the reason illustrated above.

Moreover, a student's maximum ability can be influenced by his/her work hours for pay. The greater the number of work hours for pay, the lower will be the student's maximum ability toward the learning opportunity cost $(i.e., \frac{d\Psi}{dh} < 0)$. For example, a student (Student A) who works at a job forty hours a week will have less time than a student (Student B) who works twenty hours a week to study for the course. Thus, Student A will have lower maximum ability for the learning opportunity cost than Student B.

Above all, maximum ability is a function of student quality (θ), motivation to learn and interest in the class (λ), and employment hours (h). That is, $\Psi = \Psi\left(\overset{+}{\theta}, \overset{+}{\lambda}, \bar{h}\right)$. Furthermore, the student's available maximum ability (Ψ) should be equal to his/her maximum affordable learning opportunity cost (denoted by C). A student's maximum ability that can be brought to bear on the learning opportunity cost to produce the knowledge can be regarded as a producer's maximum asset that can exert an impact on the production cost of developing a product. Thus, the higher the producer's asset, the higher the production cost that is affordable to the producer. For example, if the producer's maximum asset is $1,000,000, then the producer's maximum production cost must be equal to $1,000,000.

Similarly, if a student works 60 hours a week for pay, then the student's opportunity cost of being a full-time student in school must be very high. If the student cannot afford this opportunity cost, the student would either withdraw from the school or be a part-time student (e.g., taking one class). This implies that the maximum ability for the student to continue the class should be equal to the maximum affordable learning opportunity cost (C) for the student. Hence, $\Psi = C = C\left(\overset{+}{\theta}, \overset{+}{\lambda}, \bar{h}\right)$. Thus, the student's iso-cost line[6] can be expressed as: $P_E(q,u,\theta,\lambda,h) \cdot E + P_S(h,\theta) \cdot S = C(\theta,\lambda,h)$.

3.5 Equilibrium

Choosing E and S can solve the student's optimization problem, which maximizes $G = G(E,S;I)$ subject to $P_E(q,u,\theta,\lambda) \cdot E + P_S(h,\theta) \cdot S = C(\theta,\lambda,h)$. The Lagrangian expression is set up as follows:

$$L = G(E,S;I) + \delta\,[C(\theta,\lambda,h) - P_E(q,u,\theta,\lambda) \cdot E - P_S(h,\theta) \cdot S],$$

where δ stands for the Lagrangian multiplier or a shadow price. Meanwhile, the Lagrangian expression yields the following first-order conditions for the constrained maximum:

$$\frac{G_E}{P_E} = \frac{G_S}{P_S} \tag{1}$$

$$C = P_E E + P_S S \tag{2}$$

According to Equations (1) and (2), we can solve the equilibriums of these two efforts:

$E^*\left(P_E(q,u,\theta,\lambda,h), P_S(h,\theta,\lambda), C(\theta,\lambda,h)\right) = E^*\left(q,u,\theta,\lambda,h\right)$ and
$S^*\left(P_E(q,u,\theta,\lambda,h), P_S(h,\theta,\lambda), C(\theta,\lambda,h)\right) = S^*\left(q,u,\theta,\lambda,h\right)$.

We then aubatitute $E^*(q,u,\theta,\lambda,h)$ and $S^*(q,u,\theta,\lambda,h)$ into the grade function (G), which can be solved as:

$$G^*\left(P_E(q,u,\theta,\lambda,h), P_S(h,\theta,\lambda), C(\theta,\lambda,h); I\right) = G^*\left(q,u,\theta,\lambda,h; I\right).$$

IV. Comparative Static Analysis and Specification

In this section, we offer the comparative static analysis. First, we further totally differentiate Equations (1) and (2) and obtain:

$$\begin{bmatrix} G_{EE}P_S - G_{SE}P_E & G_{ES}P_S - G_{SS}P_E \\ -P_E & -P_S \end{bmatrix} \begin{bmatrix} dE \\ dS \end{bmatrix} = \begin{bmatrix} G_S & -G_E & 0 \\ E & S & -1 \end{bmatrix} \begin{bmatrix} dP_E \\ dP_S \\ dC \end{bmatrix}$$

Let $|D|$ be the determinant of the pre-multiplied matrix of vector [dE dS], which can be shown to be positive. Second, using Cramer's rule, the straightforward comparative static analysis yields:

$$\frac{dE}{dP_E} = \frac{\begin{vmatrix} G_S & G_{ES}P_S - G_{SS}P_E \\ E & -P_S \end{vmatrix}}{|D|} < 0 \tag{3}$$

$$\frac{dE}{dP_S} = \frac{\begin{vmatrix} G_E & G_{ES}P_S - G_{SS}P_E \\ S & -P_S \end{vmatrix}}{|D|} >= or < 0 \tag{4}$$

$$\frac{dE}{dC} = \frac{\begin{vmatrix} 0 & G_{ES}P_S - G_{SS}P_E \\ -1 & -P_S \end{vmatrix}}{|D|} > 0 \tag{5}$$

$$\frac{dS}{dP_E} = \frac{\begin{vmatrix} G_{EE}P_S - G_{SE}P_E & G_S \\ -P_E & E \end{vmatrix}}{|D|} >= or < 0 \tag{6}$$

$$\frac{dS}{dP_S} = \frac{\begin{vmatrix} G_{EE}P_S - G_{SE}P_E & -G_E \\ -P_E & S \end{vmatrix}}{|D|} < 0 \tag{7}$$

$$\frac{dS}{dC} = \frac{\begin{vmatrix} G_{EE}P_S - G_{SE}P_E & 0 \\ -P_E & -1 \end{vmatrix}}{|D|} > 0 \tag{8}$$

Intuitively, as Equations (3) and (6) show, a rise in the price of in-class effort discourages a student's demand for in-class effort investment, but does not provide consistent information about out-of-class effort investment. Similarly, as Equations (4) and (7) show, an increase in the price of out-of-class effort lowers demand for out-of-class effort investment and uncertainty about in-class effort investment. Finally, as Equations (5) and (8) show, a student's maximum affordable learning opportunity cost enhancement increases demands for both in-class and out-of-class effort investment.

We now connect the comparative static analysis shown above with the price functions of in-class and out-of-class efforts ($i.e., P_E = P_E\left(\overset{-}{q}, \overset{-}{u}, \overset{-}{\theta}, \overset{-}{\lambda}, \overset{+}{h}\right)$ and $P_S = P_S\left(\overset{+}{h}, \overset{-}{\theta}, \overset{-}{\lambda}\right)$). The summary is shown below:

1. $\frac{dP_E}{dq} < 0 \text{ and } \frac{dE}{dP_E} < 0 \Rightarrow \frac{dE}{dq} > 0$

2. $\frac{dP_E}{du} < 0 \text{ and } \frac{dE}{dP_E} < 0 \Rightarrow \frac{dE}{du} > 0$

3. $\frac{dP_E}{d\theta} < 0 \text{ and } \frac{dE}{dP_E} < 0 \Rightarrow \frac{dE}{d\theta} > 0$

4. $\frac{dP_E}{d\lambda} < 0 \text{ and } \frac{dE}{dP_E} < 0 \Rightarrow \frac{dE}{d\lambda} > 0$

5. $\frac{dP_E}{dh} > 0 \text{ and } \frac{dE}{dP_E} < 0 \Rightarrow \frac{dE}{dh} < 0$

6. $\frac{dP_S}{dh} > 0 \text{ and } \frac{dS}{dP_S} < 0 \Rightarrow \frac{dS}{dh} < 0$

7. $\frac{dP_S}{d\theta} < 0 \text{ and } \frac{dS}{dP_S} < 0 \Rightarrow \frac{dS}{d\theta} > 0$

8. $\frac{dP_S}{d\lambda} < 0 \text{ and } \frac{dS}{dP_S} < 0 \Rightarrow \frac{dS}{d\lambda} > 0$

Based upon the theoretical framework, each student will choose his or her optimal combination of in-class and out-of-class efforts (*E** and *S**) to maximize his or her grade at the *G** level (see Figure 1).

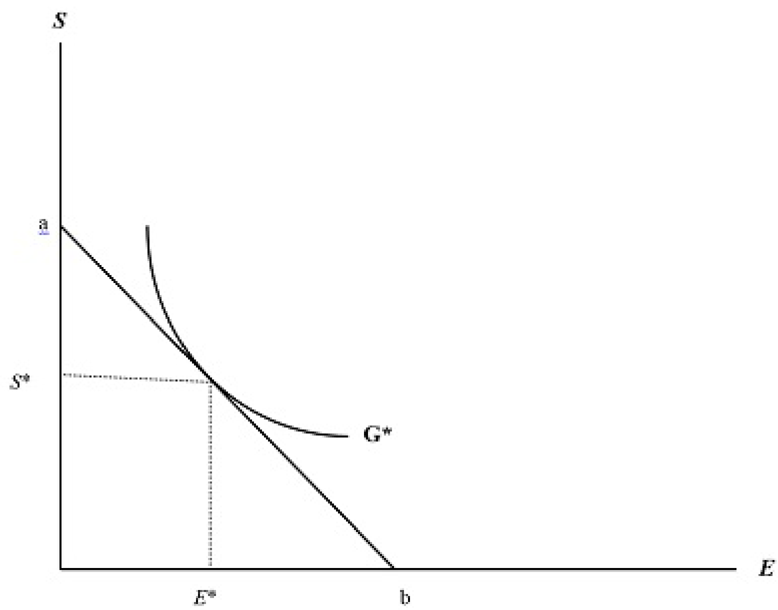

Figure 1. Students' Optimal In-class and Out-of-class Efforts

Therefore, both of these two equilibrium efforts (*E** and *S**) are related to percentage of course grade for quizzes (q), uncertainty (u), student's quality (θ), student's interest in the class and motivation to learn (λ), and student's employment hours per week (h); while a student's equilibrium grade (G^*) is related to percentage of course grade for quizzes (q), uncertainty (u), student's quality (θ), student's interest in the class and motivation to learn (λ), student's employment hours per week (h), and instructor's instructional skills/school environment (I). That is:

$$E^*\left(\overset{-}{P}_E\left(\overset{-}{q},\overset{-}{u},\overset{-}{\theta},\overset{-}{\lambda},\overset{+}{h}\right),\overset{?-}{P}_S\left(\overset{+}{h},\overset{-}{\theta},\overset{-}{\lambda}\right),\overset{+}{C}\left(\overset{+}{\theta},\overset{+}{\lambda}\overset{-}{h}\right)\right)=E^*\left(\overset{+}{q},\overset{+}{u},\overset{+}{\theta},\overset{+}{\lambda},\overset{-}{h}\right),$$

$$S^*\left(\overset{?}{P}_E\left(\overset{-}{q},\overset{-}{u},\overset{-}{\theta},\overset{-}{\lambda},\overset{+}{h}\right),\overset{-}{P}_S\left(\overset{+}{h},\overset{-}{\theta},\overset{-}{\lambda}\right),\overset{+}{C}\left(\overset{+}{\theta},\overset{+}{\lambda}\overset{-}{h}\right)\right)=S^*\left(\overset{?}{q},\overset{?}{u},\overset{+}{\theta},\overset{+}{\lambda},\overset{-}{h}\right),\text{and}$$

$$G^*\left(\overset{-}{P}_E\left(\overset{-}{q},\overset{-}{u},\overset{-}{\theta},\overset{-}{\lambda},\overset{+}{h}\right),\overset{-}{P}_S\left(\overset{-}{\overset{+}{h}},\overset{-}{\theta},\overset{-}{\lambda}\right),\overset{+}{C}\left(\overset{+}{\theta},\overset{+}{\lambda}\overset{-}{h}\right);\overset{+}{I}\right)=G^*\left(\overset{+}{q},\overset{+}{u},\overset{+}{\theta},\overset{+}{\lambda},\overset{-}{h};\overset{+}{I}\right).$$

The purpose of this study was to link quizzes, effort investment, and learning outcomes; thus, we focus our explanation on these relationships: $\frac{dE^*}{dq}>0$, $\frac{dE^*}{du}>0$, $\frac{dS^*}{dq}>=or<0$, $\frac{dS^*}{du}>=or<0$, $\frac{dG^*}{dq}>0$, and $\frac{dG^*}{du}>0$. As shown above, the effects of quizzes (q) and uncertainty (u) on out-of-class effort are ambiguous, implying that there are three different possible cases. To explain these uncertain relationships, we rely on the analysis of the substitution and income effects.

In this paper, the substitution effect means that when the price of in-class effort decreases, the price of out-of-class effort becomes relatively more expensive. Given the same grade, the student is willing to substitute greater employment of in-class effort for out-of-class effort. Therefore, the student will employ more units of in-class effort and fewer units of out-of-class effort. On the other hand, the income effect means that when the price of in-class effort decreases, the student's real maximum ability that can be brought to bear on learning opportunity cost will increase. Hence, the student will employ more units of both in-class and out-of-class efforts. Consequently, in-class effort must increase while out-class-effort is uncertain depending on which effect is dominant. If the income effect outweighs the substitution effect, then out-of-class effort will increase; if the substitution effect exceeds the income effect, then out-of-class effort will decrease; and if these two effects are equal, then out-of-class effort will remain the same. Below, we summarize these results in Table 1:

TABLE 1–Substitution, Income and Total Effects

When P_E ↓	Substitution Effect (S.E.)	Income Effect (I.E.)	Total Effect (Price Effect)
In-Class Effort (E)	↑	↑	↑
Out-of-Class Effort (S)	↓	↑	If S.E. < I.E. ⇒↑ If S.E. = I.E. ⇒ $\bar{S}$ If S.E. > I.E. ⇒ ↓

When quizzes (either announced or unannounced) are given to students by the professor, as explained earlier, the price of attending class will decrease (i.e., P_E ↓, that is, the opportunity cost of missing class increases); thus, the student's iso-cost line will shift from *ab* to *ac* (as shown in Figures 2–4). Therefore, there are three possible cases:

(1) Substitution effect < *income effect*: $\frac{dE^*}{dq} > 0, \frac{dE^*}{du} > 0; \frac{dS^*}{dq} > 0, \frac{dS^*}{du} > 0;$ and $\frac{dG^*}{dq} > 0, \frac{dG^*}{du} > 0.$

As Figure 2 shows, due to the substitution effect, the student's out-of-class effort decreases from $S1^*$ to $S2$, while the in-class effort increases from $E1^*$ to $E2$. On the other hand, due to the income effect, the student's out-of-class effort increases from $S2$ to $S2^*$, while the in-class effort increases from $E2$ to $E2^*$. In-class effort must increase, but out-of-class effort is uncertain. Since the substitution effect is less than the income effect, the out-of-class effort ultimately will increase. Therefore, the student will choose optimal efforts $E2^*$ (> $E1^*$) and $S2^*$ (> $S1^*$). As a result, the student attends class more often and studies harder outside the classroom, and eventually achieves at the $G2$ level ($G2 > G1$) and receives a better grade.

(2) Substitution effect = *income effect*:

$$\frac{dE^*}{dq} > 0, \frac{dE^*}{du} > 0; \frac{dS^*}{dq} = 0, \frac{dS^*}{du} = 0; \text{ and } \frac{dG^*}{dq} > 0, \frac{dG^*}{du} > 0.$$

As shown in Figure 3, due to the substitution effect, the student's out-of-class effort drops from S1* to S2, while the in-class effort rises from *E*1* to *E*2. However, because of the income effect, the student's out-of-class effort rises from *S*2 to *S*3*, while the in-class effort rises from *E*2 to *E*3*. In-class effort definitely increases, but out-of-class effort remains uncertain. The substitution effect is now equal to the income effect; hence, the out-of-class effort ultimately does not change. Consequently, the student will choose optimal efforts *E*3* (> *E*2* > *E*1*) and *S*3* (= *S*1* < *S*2*). As a result, the student attends class more frequently but studies outside the classroom as hard as before when quizzes were not given. However, the student eventually still achieves at a higher level, say the *G*3 level (*G*3 > *G*1), and receives a better grade.

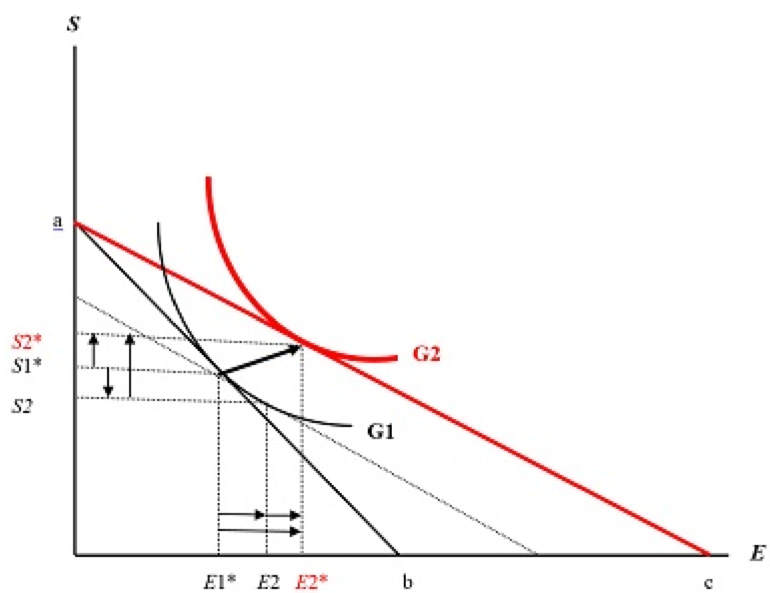

Figure 2. Students' New Optimal In-class and Out-of-class Efforts When Faced with Quizzes: Income Effect Dominates Substitution Effect

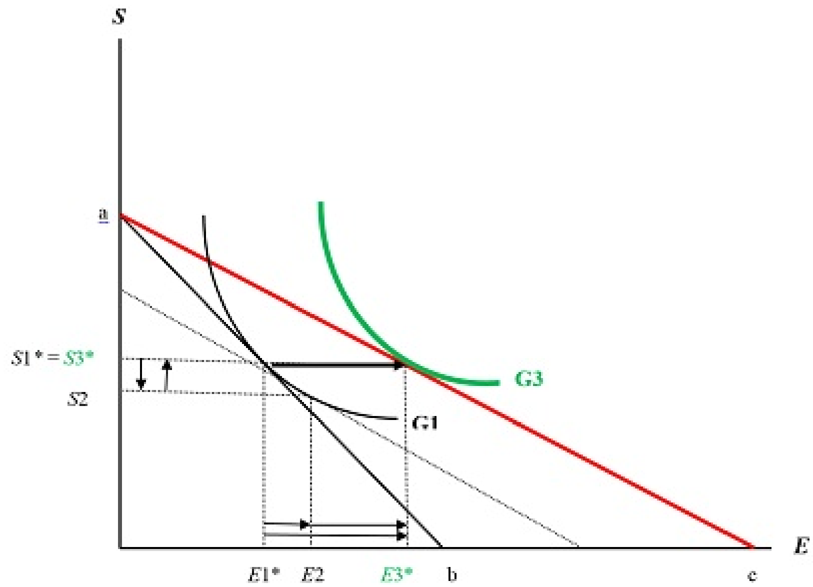

Figure 3. Students' New Optimal In-class and Out-of-class Efforts When Faced with Quizzes: Substitution Effect Equals Income Effect

(3) Substitution effect > *income effect*: $\frac{dE^*}{dq} > 0, \frac{dE^*}{du} > 0; \frac{dS^*}{dq} < 0, \frac{dS^*}{du} < 0;$ and $\frac{dG^*}{dq} > 0, \frac{dG^*}{du} > 0.$ As Figure 4 shows, due to the substitution effect, the student's out-of-class effort reduces from *S*1* to *S*2, while the in-class effort is enhanced from *E*1* to *E*2. Due to the income effect, the student's out-of-class effort improves from *S*2 to *S*4*, while the in-class effort improves from *E*2 to *E*4*. In-class effort must improve, but out-of-class effort is not certain. Since the substitution effect dominates the income effect, the out-of-class effort ultimately will decrease. For that reason, the student will choose optimal efforts *E*4* (> *E*3* > *E*2* > *E*1*) and *S*4* (< *S*1* = *S*3* < *S*2*). Accordingly, while the student attends class much more often, he/she studies slightly less hard outside the classroom. Nevertheless, the student eventually still achieves at a higher level, say the *G*4 level (*G*4 > *G*1), and receives a better grade.

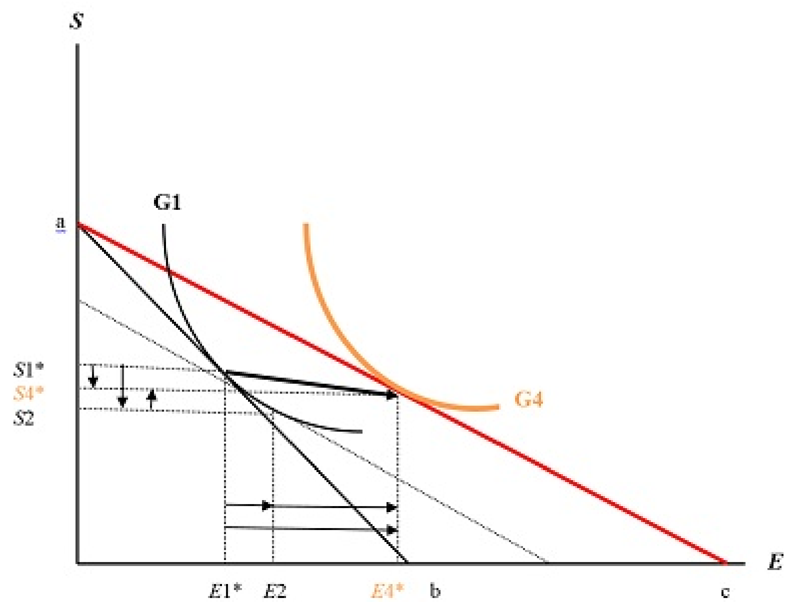

Figure 4. Students' New Optimal In-class and Out-of-class Efforts When Faced with Quizzes: Substitution Effect Dominates Income Effect

In summary, Case 1 would most likely occur in the announced-quiz system; while Cases 2 and 3 would most likely occur in the unannounced-quiz system. This is because students in the announced-quiz system know the schedule of quizzes and the materials covered for quizzes. In order not to lose points from quizzes, students will study ahead of time prior to taking quizzes and attend classes, especially when quizzes are scheduled. However, it is possible that under the announced-quiz system students might not attend class as often. Some students may just attend classes when quizzes and exams are scheduled. On the other hand, students in the unannounced-quiz system do not know the schedule for and materials to be covered on quizzes. For that reason, they might not study ahead of time prior to attending the next class. Nevertheless, due to uncertainty in the unannounced-quiz system, students may choose to attend class more frequently in order to minimize grade loss due to absence. This explains why in-class effort is lower in Case 1 than in Cases 2 and 3, but out-of-class effort is greater in Case 1 than in Cases 2 and 3. This implies that the announced-quiz system would be most likely to increase students' out-of-class effort relative to the unannounced-quiz system; while the unannounced-quiz system would be most likely to enhance students' in-class effort relative to the announced-quiz system.

V. Discussion

We are left with two more issues that need to be further discussed: (1) would different types of quizzes serve different effective instructional purposes in students' learning? (2) Why are student efforts suboptimal absent a quiz?

5.1. Issue 1

Under the announced-quiz system, there is no uncertainty so there is no risk; while under the unannounced-quiz system, there is uncertainty so there is risk. This implies that uncertainty and risk are positively correlated – the greater the uncertainty, the higher the risk. The degree of uncertainty/risk for a student depends on how much the student cares about his/her course grade (i.e., how much the course grade important to the student). If the student thinks that the course grade is extremely important to him/her, the student will feel the risk for him/her is very high. That is, the more the student cares about his/her grade, the higher the level of risk experienced by the student. In addition, when the student cares more about his/her course grade, the student will be more risk-averse, because the student does not want to lose points due to risk/uncertainty. Therefore, the greater the student's experienced level of risk, the more risk-averse the student will be. As a result, the more risk-averse the student is, the higher the student's level of uncertainty.

Thus, the opportunity cost of missing class for a more risk-averse student is higher than the opportunity cost of missing class for a less risk-averse student under the unannounced-quiz system. This is because the uncertainty for the more risk-averse student is higher than for the less risk-averse student. For that reason, given that other factors are unchanged, the price of attending class (i.e., the price of in-class effort) is lower for the more risk-averse student than for the less risk-averse student. Hence, the more risk-averse student will demand more efforts than will the less risk-averse student. That is, the more risk-averse student will attend class more frequently and preview class more regularly than will the less risk-averse student. As a result, the more risk-averse student will likely receive a better grade than the less risk-averse student.

We now compare announced-quiz with unannounced-quiz for more/less risk-averse students. Suppose that a student (say, Student A) is more risk-averse. Under the announced-quiz system, there is no uncertainty/risk; under the unannounced-quiz system, there is uncertainty/risk. Since Student A is more risk-averse, the opportunity cost of missing class for Student A will be a little higher in the unannounced-quiz system than in the announced-quiz system. That is, given that other factors are unchanged, the price of attending class will be a little lower in the unannounced-quiz system than in the announced-quiz system. This is because a more risk-averse student cares more about his/her course grade, implying that uncertainty/risk will lead Student A to choose a more conservative way to invest his/her efforts (such as attending class more frequently and increasing textbook reading prior to class). For that reason, as shown in Figure 5, Student A's iso-cost line will be *ah*, indicating that s/he is choosing optimal efforts $E5^*$ and $S5^*$ under the unannounced-quiz system; while the student's iso-cost line will be *ac,* indicating that s/he is choosing optimal efforts $E2^*$ and $S2^*$ under the announced-quiz system. As a result, the student will attend the class more often and study harder outside the classroom in the unannounced-quiz system than in the announced-quiz system, and eventually achieve at the $G5$ level ($G5 > G2$) and receive a better grade in the unannounced-quiz system than in the announced-quiz system.

On the other hand, if a student (say Student B) is less risk-averse, under the unannounced-quiz system the opportunity cost of missing class for Student B may be a little lower than the opportunity cost of missing class for students in the announced-quiz system. That is, given that other factors are unchanged, the price of attending class will be a little higher in the unannounced-quiz system than in the announced-quiz system. This is because a less risk-averse student cares less about his/her course grade, implying that uncertainty/risk will not lead Student B to choose a more conservative way to invest his/her efforts or perhaps to choose a less conservative way to invest his/her efforts (such as attending class less frequently and decreasing textbook reading prior to class). Therefore, as shown in Figure 6, Student B's iso-cost line will be *mn,* indicating that s/he is choosing optimal efforts $E6^*$ and $S6^*$ under the announced-quiz system; while the student's iso-cost line will be *mi,* indicating that s/he is choosing optimal efforts $E7^*$ and $S7^*$ under the unannounced-quiz system.

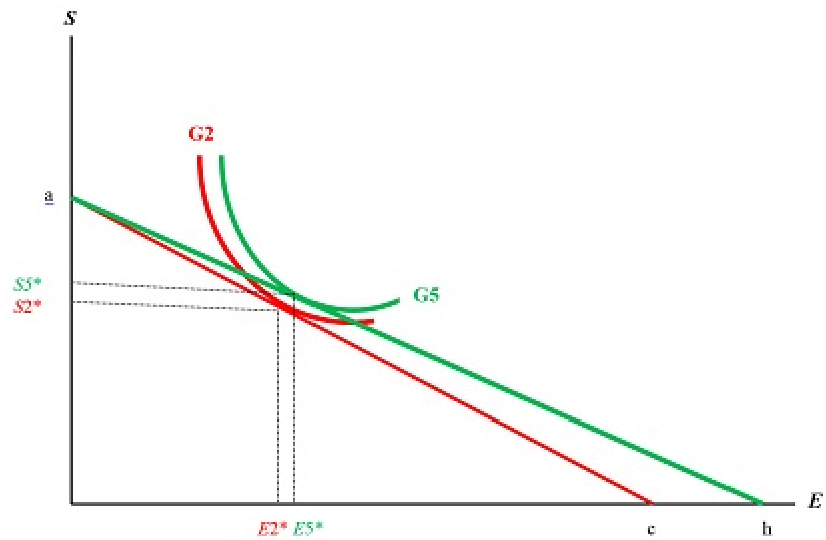

Figure 5.Comparison of Announced-Quiz and Unannounced-Quiz
If the Student is More Risk-Averse

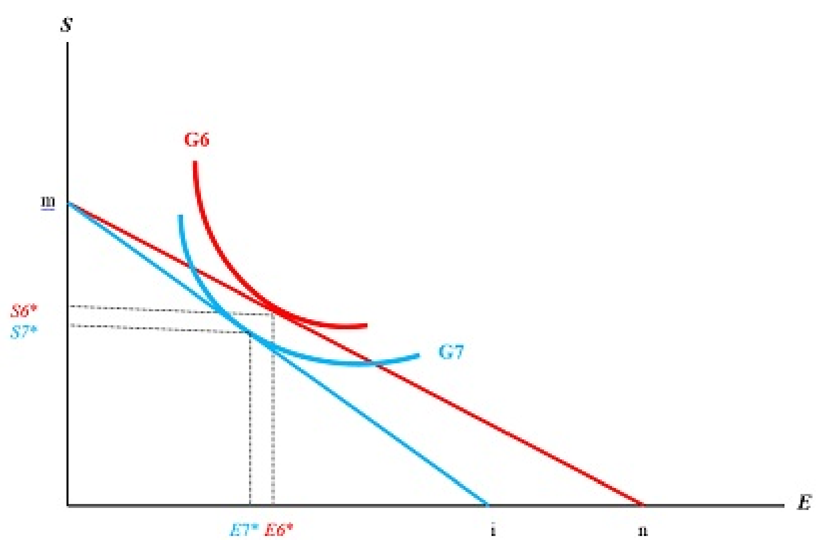

Figure 6. Comparison of Announced-Quiz and Unannounced-Quiz
If the Student is Less Risk-Averse

As a result, the student may attend the class less often and study less hard outside the classroom in the unannounced-quiz system than in the announced-quiz system, and eventually achieve at the $G7$ level ($G7 < G6$) and receive a lower grade in the unannounced-quiz system than in the announced-quiz system.

Based upon the theoretical analysis expressed above, we may conclude that the unannounced-quiz system will serve as a more effective instructional method for more risk-averse students' learning; while the announced-quiz system will serve as a more effective instructional method for less risk-averse students' learning.

We raise one more inquiry: what kind of students would be more risk-averse? We hypothesize that high GPA students are likely to be more risk-averse since they would like to maintain their high GPAs. To determine whether our hypothesis is correct, we will need to conduct an empirical study on this topic in the future.

5.2 Issue 2

The theoretical analysis has demonstrated that quizzes (unannounced-quizzes or announced-quizzes) can promote student effort, especially in-class effort (attendance). However, some could argue that in reality students still skip class and miss scheduled quizzes under the announced-quiz without a makeup quiz policy, implying that quizzes cannot promote student effort, which conflicts with our model. In other words, their argument raises a question: why are student efforts suboptimal absent a quiz? Below, we provide our explanation.

We believe that there are negative externalities (such as employment hours) from knowledge acquisition in the model. Employment hours are believed to be a primary negative externality. According to the model, when a student's employment hours (*h*) increase, this will raise the opportunity cost of attending class (i.e., the price of in-class effort will increase, $P_E \uparrow$). While quizzes will lower the price of in-class effort, employment hours will raise the price of in-class effort. Therefore, the overall effect will depend on which effect is dominant. We specify three possible cases:

(1) If a student has a significantly large number of employment hours (e.g., 50 or more hours a week – the student works 2 or more jobs), then the increase in the price of in-class effort will outweigh the

decrease in the price of in-class effort. Thus, the price of in-class effort still increases eventually for the student. Consequently, the student will determine his/her suboptimal choice by opting to skip class and miss quizzes in order to keep his/her job(s); otherwise, the student may not be able to afford college.[7] The student may be still a grade maximizer; but under the suboptimal choice, the student's objective function may not be an A or a B grade. Instead, the student may just want to pursue a C or a passing grade (say D). This is because the student does face constraints in the form of an opportunity cost of time.

(2) If the increase in the price of in-class effort for the student due to employment hours is equal to the decrease in the price of in-class effort due to quizzes, then the price of in-class effort eventually will remain the same for the student. As a result, the student's investment in effort may not be influenced by quizzes. The student will not particularly increase/decrease his/her effort investment due to quizzes. That is, the positive effect due to quizzes would be completely offset by the negative effect due to employment hours.

(3) If the decrease in the price of in-class effort for the student due to quizzes exceeds the increase in the price of in-class effort due to employment hours (e.g., the student only works 20 or fewer hours a week), then the price of in-class effort eventually will decrease for the student. Therefore, the student will enhance his/her effort investment. This is because the positive effect due to quizzes dominates the negative effect due to employment hours.

In short, our model indeed does not conflict with the reality that students still skip class and miss quizzes. This is because negative externalities (such as employment hours) from knowledge acquisition exist in the model, which offsets the positive effect on effort investment from quizzes. On the other hand, the positive effect from quizzes may be offset by the negative effect from employment hours; without quizzes, the negative effect could be even bigger. Therefore, quizzes can be an effective instructional tool in promoting student effort when each quiz weights a significant percentage of the course grade, which may enlarge the positive effect and thus enhance the possibility of dominating the negative effect of negative externalities, such as employment hours.

VI. Conclusion

In this paper, using the theory of producer choice, a basic economic theoretical model was constructed to illustrate how quizzes (unannounced-quizzes or announced-quizzes) can affect a student's behavior in effort-investment and learning performance. The theoretical model mainly focuses on an economic perspective to explain the economic relationships between quizzes and education output (i.e., exam performance), in-class effort (i.e., attendance), and out-of-class effort.

In light of the theoretical results, five findings are offered:

1. When quizzes (unannounced-quiz or announced-quiz) are given to students before they take exams, students will perform better on exams.
2. Facing the possibility of quizzes (unannounced-quiz or announced-quiz), students will increase their in-class effort investment in order to minimize their grade loss from being absent, but not certainty about their out-of-class effort investment.
3. The unannounced-quiz system will most likely increase student in-class effort relative to the announced-quiz system; the announced-quiz system will most likely enhance student out-of-class effort relative to the unannounced-quiz system.
4. The unannounced-quiz system will serve as a more effective instructional method for more risk-averse students' learning; while the announced-quiz system will serve as a more effective instructional method for less risk-averse students' learning.
5. When a student has a significantly large number of employment hours, the negative effect from employment hours will likely dominate the positive effect from quizzes, and thus student efforts may be suboptimal absent a quiz.

In summary, the main purpose of this paper is to frame an economic theoretical background for quizzes, which can be useful in constructing empirical models for further investigations of this issue. Our theoretical analysis has demonstrated that quizzes improve student exam performance. Nevertheless, we still need a further empirical study and more data evidence to demonstrate whether quizzes can unambiguously improve students' exam performance in reality. We leave this topic for our future investigation.

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Endnotes

1. Whether students can be regarded as producers or consumers depends on analytical focuses. When students are viewed as consumers, the focus is on the demand side and thus the theory of consumer choice has to be used. On the other hand, when students are viewed as producers, the focus is on the supply side and hence the theory of producer choice has to be used. In this paper, students are regarded as producers because we focus on student knowledge production – students invest their efforts to produce their "*knowledge*", and the quiz is one of the factors that would affect a student's effort-investment decision and hence influences the student's knowledge production. Obviously, we focus on the supply side, so the theory of producer choice rather than the theory of consumer choice has to be used. A theoretical article on students as consumers that uses the theory of consumer choice is Lin (2009). An empirical article whose author demonstrates that students behave like producers is Lin (2013).
2. This is an assumption. In reality, it is possible that some professors may inflate students' grades, and thus the level of knowledge acquired cannot be precisely reflected in students' grades.

3. One may argue that it is possible for a bright student or one who for a variety of reasons may already have considerable knowledge of the material to likely get a good grade even if he/she does not gain much from the class. Our argument is that it does not matter whether or not the knowledge is gained from the class. The point is that the student does have that knowledge so that he/she can get a good grade. The bright student may spend more out-of-class effort to gain that knowledge. Therefore, it is reasonable to assume that grades are based upon the knowledge a student acquires without grade inflation.
4. It is necessary to assume that unannounced quizzes can be given without allowing make-ups under any circumstances. Without this assumption, the unannounced quizzes would become "announced quizzes" for absent students who are allowed to take make-ups, and thus the factor of "uncertainty" will not exist in the model.
5. "Maximum ability" refers to a student's ability to afford the maximum opportunity cost of learning the course in order to continue the class.
6. In the theory of producer choice, the iso-cost line is a line that shows the various combinations of labor and capital that the producer can hire or rent for the given total cost. In this paper, the iso-cost line shows the various combinations of in-class effort and out-of-class effort that the student can use for the given maximum affordable learning opportunity cost.
7. Surveys from King and Bannon (2002) and Lin (2014) demonstrated that the majority of college students would not be able to afford college if they did not work.