PROMOTING STUDENT'S EFFORT: STANDARS *VERSUS* TOURNAMENTS (*)

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ABSTRACT

We analyze the incidence in student’s effort from implementing two different reward systems: a standard-based model and a tournament. In the former we work in detail the effects on effort due to changes in rewards, risk level, socieconomic background and passing standard, while in the later we focus on the Nash equilibrium solution for a symmetrical academic context between two students. We examine conditions under which standards perform better than tournaments in terms of induced effort, and viceversa. We show this depends crucially on the nature of the noise distorting academic achievement. Particularly relative advantage becomes a function of correlation between individual noises.

Keywords: Educational Standards, Tournaments, Student's effort, Incentives in Education.

JEL Numbers: I21, I28.

1. INTRODUCTION

Most of the reform proposals of the welfare state try to incorporate more discipline in the provision of public goods and services. In general, they intend to avoid wasting and promote efficiency, and education either as a public or private subsidized service does not escape from this revisionist dynamics. This challenge affects to a wide spectrum of institutions and also individuals, students included, which are supposed to contribute with their own effort. Educational policies should therefore be partly designed to induce students to push themselves closer to their potential.

As effort is not directly observable the problem is one of designing a subsidiary (second best) incentive mechanism conducting scholars to work adequately hard enough from a social viewpoint[1]. A feasible mechanism consists on setting rewards that are sensitive to some variable meaningfully correlated to effort. The simplest way is rewarding students according to their academic achievements. Needless to say that the influence of such scheme on scholars' motivation crucially depends on the accuracy of academic results as signal of diligence/negligence rates in learning.

The aim of the paper is to analyze the incidence in student's effort from implementing two known incentive systems that reward only the learning due to working hard rather that natural ability. The first one grants rewards depending whether or not the student passes a certain standard level of learning in an test, while the other awards rewards on the basis of relative performance[2].

"The rationale for standards is to alter incentives of students... to change behaviour in a way that induces learning" (Betts and Costrell, 2001. pp. 7) and for a long time this has influenced the way in which policy makers try to impro-

[1] Policy makers, and society overall, are interested in hard-working students, e.g.: assuming all have the same abilities and aptitudes, and owing to human capital effects, future productivity and hence GDP rises if students become more hard-working and less lazy.

[2] Most of the existing research on standards is theoretical. See for example Kang (1985), Becker and Rosen (1992), Betts (1998), Costrell (1993, 1994, 1997), Effinger and Polborn (1999) and Sobel (2000). Empirical studies that examine the effects of standards on student outcomes are scarce and more recent, e.g. Betts (1997), Figlio and Lucas (2000), Betts and Costrell (2000), Betts and Grogger (2000), Lillard and DeCicca (2001). The literature on incentives and contract design was originally concerned with the case where a principal employs only one agent and rewards him on the basis of absolute performance (see Rees (1987), Hart and Holmstrom (1987), Macho and Castrillo (1997), for a review of the literature). Several papers about tournaments (reward structures based on rank order) and more general compensation schemes for multi-agent settings appeared later (See Holmstrom (1979;1982), Lazear and Rosen (1981), Green and Stokey (1983), Nalebuff and Stiglitz (1983), Mookherjee (1984), Demski and Sappington (1984), Malcomsom (1986), Ma (1988), Yun (1997) among others).

ve the performance of the education system[3]. However policy makers may be interested not only in rewarding the student according to the grades attained, but also with respect to the other students on the same class if their grades could inform on each other's performance. This is particularly relevant when the academic achievement of each student is influenced primarily by common uncertainty factors that policy makers cannot control. In the educational context, especially at the higher education level, overcrowding and teaching quality deterioration seems to reinforce the importance of systematic failures. One example of relative performance is a tournament, in which the student is rewarded only in function of the place she achieves in an academic ranking. Although today the education community is, to some extent, reluctant to accept relative performance methods as a way of rewarding effort, actually many higher education institutions put into practice quasi-tournaments to this purpose.

We extend the analysis of Becker and Rosen (1992) incorporating risk aversion, formalizing some of its suggestions, illustrating most results with numerical examples and advancing in the comparison of these two incentive schemes. In the standard-based model, we work in detail the effects on the effort due to changes in rewards, risk level, socioeconomic background and passing standard, while in the other we focus on the Nash equilibrium solution for a symmetrical academic tournament between two students. Since rewards in both incentive systems are considered discrete and fixed, we have to assume, rather "ad hoc", that policy makers are basically interested in hard-working students because it is welfare improving. Then we compare both rewards structures in terms of the level of effort attained and look for the most efficient, that is the one stimulating effort the most. We show that the advantage of the one over the other depends crucially on the nature of the noise distorting academic achievement. Particularly, in our two players' game, relative predominance becomes a function of correlation between individual noises.

The paper is structured as follows. In Section 2 we set up a general framework for models of school reward systems. Section 3 analyses the case of a reward system based on learning standards. Section 4 does the same for the case of a reward system based on peer performance. In Section 5 we compare both schemes in terms of the effort level they are able to stimulate and analyze

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[3] Standards-based models have been widely used in the American education. The Federal Government's latest reform (January 2002) seeks to hold states, districts and schools accountable on the basis of results mesured by tests designed to determine whether students meet high standards in subjects as reading, math, history and science. In the UK radical changes were made to the education system in the early 1990s, following the Education Reform Act (1988) in order to improve educational standards and hence outcomes. More recently, the election of a Labour Government in 1997 has revitalized the debate about standards and the quality of secondary schooling in the UK. In Spain the centre-right government is also involved in an existing process of important education reforms aiming to increase educational standards.

the conditions under which one system performs better than the other. Finally, in Section 6 we set concluding remarks and extensions.

2. GENERAL FRAMEWORK FOR MODELS OF SCHOOL REWARD SYSTEMS

We think of a model comprising a representative university course, with a finite number of individuals attending this course. The analysis perfectly extends to other educational areas such as primary/secondary education. The main objective of university attendance is learning. Students control this by regulating the effort they devote to each course or subject. For example, students decide time engaged in learning and the intensity of their involvement in the process. Additionally, they also decide whether to cut class attendance, whether to pay attention or to use the library, tutorials, and so forth (Bishop, 1985).

Thus, let *e* denote the student's true attainment at university. We assume it is directly and only related with learning effort[4]. It could also be associated with innate abilities and aptitudes. However, hereafter *e* will exclusively represent an unidimensional measure of the effort level the student exerts in assimilating a particular learning. The set of possible efforts is denoted by $E \subseteq R$.[5]

One of the objectives of the academic authorities is recognition of learning. Since effort cannot be perfectly observed and so controlled, the university cannot reward effort directly. Thus, q denotes the student's educational achievement, which is captured by the score attained in an school test. The test in this case constitutes the basis for redistributing rewards. We assume that all individuals in the class have the same innate ability, so achievement depends exclusively on the effort the student dedicates to learning, e, and the value of a random variable, ε. The randomness of the outcome lies on the fact that the test is an imperfect tool trying to measure achievement of learning objectives, so students are unable to predict exactly how much they will be academically recognized or rewarded if they put a certain amount of effort into the task. Formally,

$$q(e, \varepsilon) = e + \varepsilon \qquad (1)$$

[4] Though student effort is considered by many economists to be the most important input in education production functions, empirical studies rarely include it as an independent variable: this is probably due mainly to the difficulty of obtaining an independent measure of effort. The one exception we are aware is Bonnesronning's (1998) study of Norwegian schools which provides positive and significant estimates of student effort on student achievement.

[5] As pointed out, more generally student effort can have many dimensions, so *e* could be a vector with each of its elements measuring school effort in a distinct activity. In this case, $E \subseteq R^M$ for some M.

We assume that (1) can take values in $\left[\underline{q},\overline{q}\right]$ and is stochastically related to *e* in a manner described by the distribution function $F(q;e)$ with $F'(q;e)=f(q;e)>0$ for all $e\in E$ and all $q\in\left[\underline{q},\overline{q}\right]$, symmetrical and unimodal with zero mean and standard deviation of σ. That is, given a distribution of ε, $F(q;e)$ is simply the distribution induced on *q* via the relationship $q=q(e,\varepsilon)$. Changes in *e* thus alter the distribution of academic outcomes.

Prior to the test the student must decide how much effort to invest keeping in mind this is the only way she can affect the score. Potentially, there are a variety of factors conditioning the choice of learning efforts[6]. With regard to rewards, which are the essence of any incentive-based mechanism, these may comprise: *i*) the honor and esteem that parents, peers and teachers give to achievement, *ii*) recognition by academic authorities in terms of grants, scholarships, awards, student loans in more favourable conditions, tuition discounts, etc. and *iii*) recognition by employers and society in general, e.g.: higher earnings, better quality jobs, influence, fame, social status, success, and so on[7]. Hereafter in the paper we will refer to rewards in this broad sense.

In order to simplify the analysis, we consider the student as an utility maximizer with a function $U(w,e)$, the arguments of which they are the rewards the student receives, *w*, in response to academic achievement, with $w > 0$, and effort *e*. Let us also assume it to be additively separable in both components, therefore we have a von Neumann-Morgenstern utility function for *w*, and a cost function capturing the disutility of *e*. Formally,

$$U(w,e)=u(w)-\psi(e) \qquad (2)$$

Although separability imposes a restriction on the model (we discuss it on subsection 3.2) it simplifies considerably the analysis since it implies that risk aversion does not vary with effort. Furthermore $u(w)$ is defined for $w > 0$, and it is assumed to satisfy $u'(w)>0$, $\$\ u''(w)\le 0$. Finally, we assume the cost of effort is increasing and convex $\psi'(e)>0$, $\psi''(e)>0$.

There are various types of reward structures, but for simplicity reasons we will confine to the following binary case. Formally,

$$w(q)=\begin{cases} w_1=\overline{w}+x & \text{if} \quad q \text{ is high enough} \\ w_2=\overline{w}-x & \text{if} \quad \text{otherwise} \end{cases} \qquad (3)$$

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6 For example, the honor accorded to particular subjects of study, the teacher's devotion to instruction, peer effects, the degree of uncertainty (risk) in the school environment, risk preferences, the reward structure and the rewards themselves.

7 Some of these rewards types are cited in Bishop (1985).

This reward structure resembles a principal-agent incentive scheme which sets up payments contingent on observed results in an uncertain environment[8]. However it is worth noting that this incentive scheme is neither unique nor necessarily the best in terms of optimal induced effort. In fact, there are other potential schemes likely to induce more effort which we do not study here[9].

We interpret $\overline{w}$ as the financial support the individual receives from her parents, and $x > 0$, as the benefits she will receive/lose in response to academic achievement. Obviously, this reward structure essentially depends on the criterion determining the scope of the "high enough" expression. Here we will restrict the set of possible criteria to two solely: i) *a reward system based on absolute standards*, and ii) *a reward system based on relative peer performance*.

3. REWARD SYSTEM BASED ON ABSOLUTE STANDARDS

Let us assume that $\hat{q}$ denotes a critical or threshold value determined by policy makers as frontier between learning considered "high enough" and those supposed to be insufficient ones. This critical value is what we call an absolute or passing standard and it is fixed and announced to the students in advance. In this case, the reward system adopts the following structure:

$$w(q) = \begin{cases} w_1 = \overline{w} + x & \text{if} \quad q \geq \hat{q} \\ w_2 = \overline{w} - x & \text{if} \quad q < \hat{q} \end{cases} \tag{4}$$

Thus, if q greater or equal than $\hat{q}$ the individual gets w_1, whereas if $\hat{q}$ falls below the passing standard she earns w_2. However, the student cannot be certain of which grade will be awarded for any given amount of effort incorporated, due to the fact that random errors are also inherent in testing. Then, when he faces a fixed and known threshold, the probability of passing it, given $F(q;e)$ symmetrical, can be defined in the following way:

$$\mathrm{Prob}(q \geq \hat{q}) = \mathrm{Prob}(e + \varepsilon \geq \hat{q}) = \mathrm{Prob}(-\varepsilon \leq e - \hat{q}) = F(e - \hat{q}) = 1 - F(\hat{q} - e) \tag{5}$$

Students adjust learning strategies to maximize

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[8] We suggest this approach as a promising extension on Section 6.

[9] It has been long argued (for example see Bishop 1988, 1990) that credentials conveying only a binary signal to employers provide inferior incentives to more continues cases. Consequently, a continuous and increasing function *w(q)* could be considered. Furthermore, conditions under which this continuous function is reduced to (3) could also be explored. However, this is not pursued here, since our main interest focuses on the comparison of standards and tournaments rather than on whether richer and more finely graded information provide superior incentives.

$$\begin{aligned} EU &= [1-F(\hat{q}-e)]u(\overline{w}+x)+F(\hat{q}-e)u(\overline{w}-x)-\psi(e) \\ &= u(\overline{w}+x)+F(\hat{q}-e)[u(\overline{w}+x)-u(\overline{w}-x)]-\psi(e) \end{aligned} \quad (6)$$

This expression represents the expected utility to be maximized, and it is similar to that of Kang (1985), and Becker and Rosen (1992), except that here we introduce risk aversion while they assume risk neutral students. First and second order conditions are given by:

$$EU' = f(\hat{q}-e)[u(\overline{w}+x)-u(\overline{w}-x)]-\psi'(e)=0 \quad (7)$$

and

$$EU'' = -f'(\hat{q}-e)[u(\overline{w}+x)-u(\overline{w}-x)]-\psi''(e)<0 \quad (8)$$

In order for an effort level satisfying (7) to be a maximum, a sufficient condition is $f'(\hat{q}-e)\geq 0$. In any case, hereafter we will assume (8) is globally satisfied and therefore a unique optimum effort level exists. (7) implicitly defines the student's expected effort reaction function to changes in some environmental factors such as the magnitude of the rewards, the student's initial financial support, the level of the passing standard and risk. Denoting $A=[u(\overline{w}+x)-u(\overline{w}-x)]$, $A'_w=[u'(\overline{w}+x)-u'(\overline{w}-x)]$ and $A'_x=[u'(\overline{w}+x)+u'(\overline{w}-x)]$ totally differentiation of (7) yields:

$$f'(\hat{q}-e)A\, d\hat{q}-[f'(\hat{q}-e)A+\psi''(e)]de+f(\hat{q}-e)A'_x\, dx+f(\hat{q}-e)A'_w\, d\overline{w}=0 \quad (9)$$

3.1. Effort and Reward

Let's begin by showing the effect on student's effort of an increase in the magnitude of the rewards or benefits the student will receive in response to academic achievement. "Ceteris paribus", from equation (9) we get

$$\left.\frac{de}{dx}\right|_{d\overline{w},d\hat{q}=0}=\frac{f(\hat{q}-e)A'_x}{-EU''(.)} \quad (10)$$

Clearly, if (8) is satisfied, $-EU''(.)>0$, the sign on this ratio is definitely positive and hence as the reward for passing the test is large, the student will put forth more effort. Thus the message is straight: if we want to increase student effort to overcome a learning standard then an unambiguous way consists on increasing the reward for its attainment.

3.2. Effort and Socieconomic Background

The separability of the utility function allows us to simplify considerably the analysis, but at a certain cost. In particular, this property constraints the role of risk aversion in the model as it basically works through the parameter $\overline{w}$, which captures the socieconomic background the scholar comes from. Due to decreasing marginal utility, well-off individuals are supposed to display less absolute risk aversion than the less well-off ones. In our uncertain academic context it implies that as students become better-off they bear more risk of failing and so working is less intense. To see this, note that $\overline{w}$ levels affect the way *x* encourages effort: the higher the reward offered to the student the higher the effort she is willing to exert as we have just shown in subsection 3.1, but as she becomes better-off the incentive to harder work is less worth and the student makes less effort. We call this the *indirect risk aversion effect*, and it can be easily check by solving for the respective derivative in equation (9). Formally,

$$\left.\frac{de}{d\overline{w}}\right|_{dx,d\hat{q}=0} = \frac{f(\hat{q}-e)A'_w}{-EU''(.)} < 0 \qquad (11)$$

Marginal utility of money is decreasing, $A'_w < 0$, so the expression above is negative. Note that if the individual is risk neutral, then $\overline{w}$ has no effect on the level of effort, and consequently $\overline{w}$ is irrelevant from the perspective of the educational policy.

Since differences across individuals are obviated, (11) should be accepted in a general way. Nevertheless, it seems to be directly applied to a framework where students come from distinct social positions. In this case the message of this subsection is also that those ones from better backgrounds “ceteris paribus” exert relatively less effort in the process of learning and therefore in attempting to pass the standard. In other words, more well-off households by giving relatively higher coverage to their teenagers, discourage them from doing well in terms of effort. Moreover, another way background negatively influences on learning can be invoked. If we recognized that student's ability also depends on her family social position, then a less cost of effort could reflect a higher ability and “ceteris paribus” the same results might be achieved with less effort. Therefore the *indirect risk aversion effect* through the utility function $u(.)$ can be reinforced by an additional *ability effect* operating through the cost function $\psi(.)$. Here we remark only the first effect because, as far as we know, it has not been considered yet. We invite to pursue this line on research on Section 6.

3.3. Effort and Risk

Uncertainty does not always discourages effort[10]. A higher risk, represented here by an increase in σ, generates ambiguous effects on the resulted effort le-

[10] Bishop (1985, pp.11) affirms that “... learning theory indicates that uncertainty discourages effort”. However, as we prove this is not always the case when implementing a reward system based on absolute standards.

vels. The reason rests on that the value of $f(\hat{q}-e)$ may either increase or decrease depending on which point of the function $f(\varepsilon)$ we locate. If the distribution function is both symmetrical and unimodal then an increase in the standard deviation generates a “flattening” effect of the density function, that is, the mode value falls and density at extreme values increase. For instance, if we assume ε follows a normal distribution with zero mean and standard deviation of σ, then

$$f_\sigma(\varepsilon,\sigma)=\frac{1}{\sqrt{2\pi}}e^{\frac{-\varepsilon^2}{2\sigma^2}}\left(\frac{\varepsilon^2-\sigma^2}{\sigma^4}\right)$$

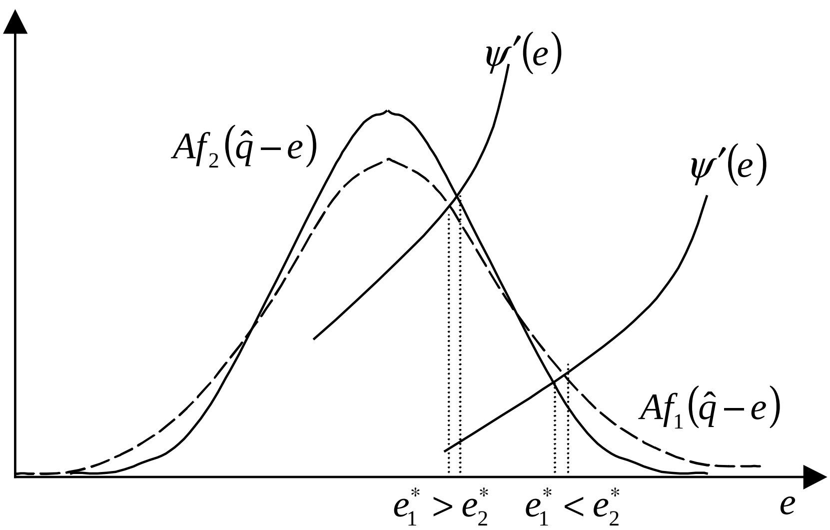
and therefore

$$f_\sigma(\varepsilon,\sigma)=\begin{cases}>0 & \text{if } |\varepsilon|>\sigma\\ =0 & \text{if } |\varepsilon|=\sigma\\ <0 & \text{if } |\varepsilon|<\sigma\end{cases}$$

Consequently, for a given passing standard level if marginal benefit and marginal cost of effort intersect near the “mode” then effort falls as stochastic noise rises. See Figure 1 at this respect. Just the opposite turns up if we are far from the modal point. This result holds regardless of the nature of the stochastic error conditioning school performance.

Figure 1

EFFORT AND RISK IN THE REWARD SYSTEM WITH ABSOLUTE STANDARDS



3.4. Effort and Passing Standard

The main purpose of recognizing rewarding learning achievements is to incentive students to achieve all they are capable. In this sense, the setting of the standards becomes a key issue in the analysis. What happens to learning when standards are raised? From (9) it is possible to solve for the desired derivative

$$\left.\frac{de}{d\hat{q}}\right|_{dx,d\overline{w}=0} = \frac{f'(\hat{q}-e)A}{-EU''(.)} \tag{12}$$

Since the value of the denominator above is positive then the sign of this derivative depends crucially on the sign of $f'(\hat{q}-e)$. Thus, if $f'(\hat{q}-e)>0$, which associates with levels of standards less than optimal efforts, $\hat{q}<e$, the probability of passing the standard is relatively high and always greater than 1/2. In this case, rising the standard unambiguously generates more effort. However, if $f'(\hat{q}-e)<0$, because the level of standard is so high, $\hat{q}>e$, so that the probability of failure exceeds of 1/2, then an increase in $\hat{q}$ reduces the optimal effort level. In other words, raising the criterion for a passing grade raises the effort that student puts into learning but up to a point. When the critical value is low, students tend to work harder as policy makers raise the passing standard. However, when the standard becomes too high students tend to lose motivation because they feel that the effort required to pass the test is too high compared with the return they receive for passing the test. Some of them would decide to cut class attendance or even drop out the education system temporarily. Therefore, when rewards are based on a pass-fail criterion the student will give up trying to learn when $\hat{q}$ is too high. Likewise, the probability of passing the exam decreases as the standard raises.

Condition $f'(\hat{q}-e)=0$, which requires $\hat{q}=e$, determines the value of $\hat{q}^*$ that makes $e^*(\hat{q})$ maximum. In other words, it is the $\hat{q}$ value that implies that the optimal effort e^* is the highest possible given student's utility and cost of effort functions[11]. Therefore, condition $f'(\hat{q}-e)=0$ allows us to reformulate (7) as

$$f(0)A = \psi'(\hat{q}^*)$$

which implicitly determines the critical learning standard $\hat{q}^*$ that promotes in the student the highest optimal effort. This value induces such an effort that the probability of passing the standard is similar to that of failure, 1/2. In particular we have

$$\hat{q}^* = (\psi')^{-1}[f(0)A] = e^* \tag{13}$$

Remember that the two parameters the education policy makers control are *x* (partially) and $\hat{q}$. By increasing *x*, effort is encouraged, but this might be severely

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11 Second order differential of effort with respect to the passing standard is: $\frac{d^2e}{d\hat{q}^2} = \frac{f''(\hat{q}-e)A\psi''(e)}{[-EU''(.)]^2}$.

This ratio is negative if and only if $f''(\hat{q}-e)<0$. Note that this condition is satisfied only if $f(.)$ is concave near the mode.

onerous for the public budget (e.g. if *x* represents scholarships, grants, tuition discounts, awards, more favourable student loans), or have natural limits. If given a value of *x*, we wonder for the highest effort that we are able to promote by handling $\hat{q}$, then $\hat{q}^*$ represents the reference value that makes e^* maximum. This implies establishing a standard learning level that efficient students (maximizers) have to play against the system (nature or noise) a symmetrical game such that the probability of earning w_1 is the same as the probability of getting simply w_2.

We end this section with the consideration of an example which illustrates the results above obtained with general functional forms and give a more detailed explanation of the magnitude of the effects of the factors conditioning learning motivation. For this purpose, let:

$$f(\varepsilon)=\frac{1}{2\pi\sigma}\exp^{-\frac{1}{2\sigma^2}\varepsilon^2} \qquad (14)$$

$$u(w)=\ln(w) \qquad (15)$$

$$\psi(e)=\frac{1}{2}e^2 \qquad (16)$$

The benchmark case is work out for a risk averse student with parameters, $\overline{w}=3$, $x=1$, and $\sigma=0.5$. The rest of the examples are simply variations of the benchmark case due to changes in the parameters representing the initial socioeconomic condition $\overline{w}$, the standard deviation in test score σ, the reward from passing the standard *x*, and the risk preferences. These numerical examples nicely illustrate the results derived above. These are captured in Figure 2 which illustrates the relationship between the passing standard and the effort level in the benchmark case and the shift patterns of this relationship when some of the initial parameters are modified.

— In the benchmark case, as the passing standard is raised the student's effort increases. Therefore, initially, implementing educational standards constitutes a valid technique of providing the student the incentives to exert high effort. Furthermore, although not illustrated in the figure, the probability of passing the standard when this is low is extremely high. In addition, the student's effort is maximized when the passing standard is 0.55. Note that this effort level is exactly $e^*=0.55$. Thus, if policy makers' objective consists on inducing students the highest effort, then $\hat{q}^*=0.55=e^*$ is the strategy which sets up the critical value of the learning standard at the optimal level. At this point the probability of passing $\hat{q}$ is exactly 50%. However, beyond that point raising the standard discourages effort and the probability of passing decreases steadily.
— When the magnitude of the reward in response to academic achievement is large, *x* = 1.5, the student will exert more effort for any given

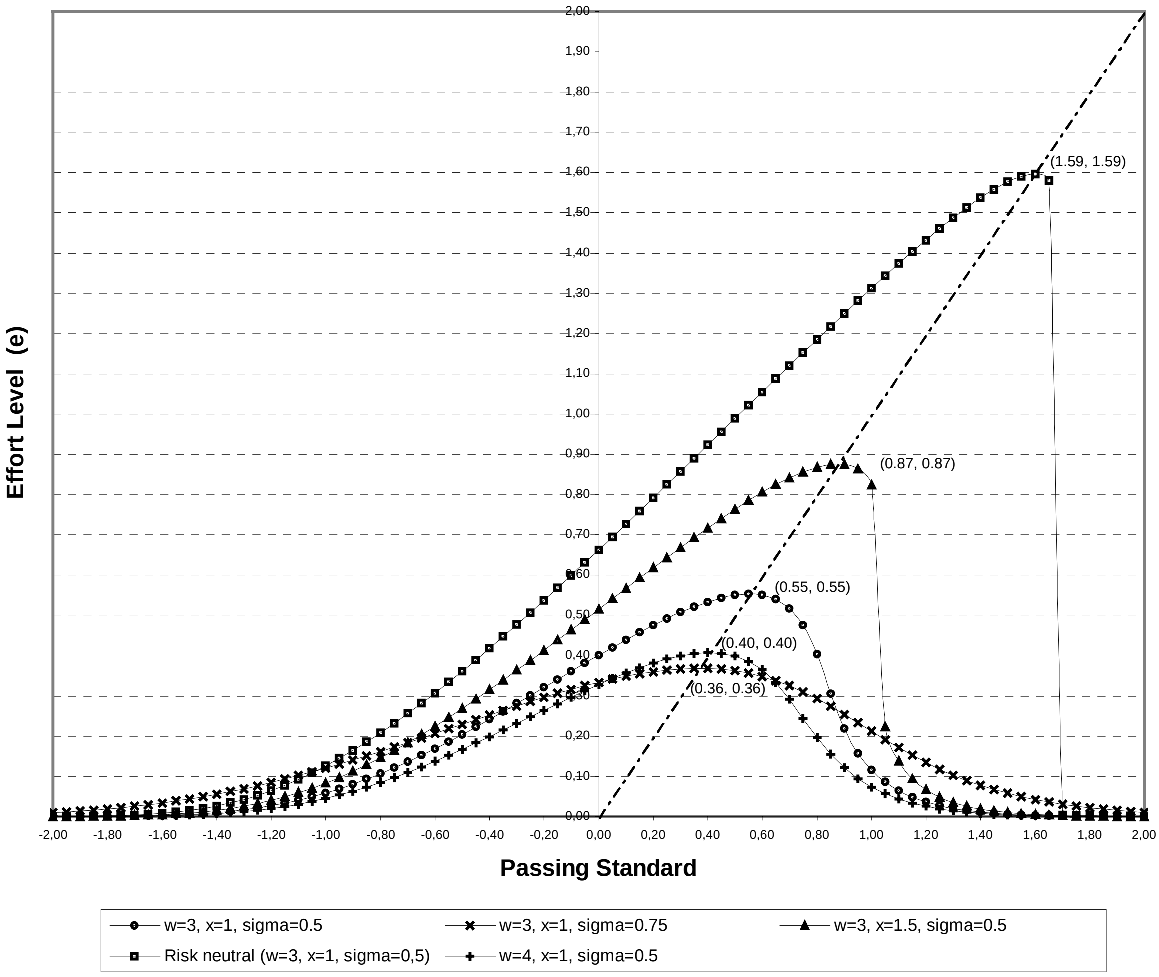
level of passing standard. In this case the optimal value of $\hat{q}$ is now greater, $\hat{q}^* = 0.87 = e^*$. Similarly, the increased reward raises the probability of passing at all levels of the passing standard.

— Students may differ in the socioeconomic conditions under which they affront the learning process at university. As the figure shows, those students with higher socioeconomic status, $\overline{w} = 4$, put forth less effort for any given level of passing standard. Therefore students as they become better-off, take more risk and as a result effort is less intense (indirect risk aversion effect). The optimal standard which makes e^* maximum is now $\hat{q}^* = 0.40$.

— If the student is risk neutral rather than exhibits some degree of risk aversion, so $u(w) = w$, then for any given passing standard the student tends now to work harder. Actually, the levels of effort attained in this case are the highest of all the experiments we have carried out. In particular, optimal effort becomes $\hat{q}^* = 1.59 = e^*$. However, note how just after this critical level is passed, student's effort drop to zero. In other words, the student behaves as if he drops out from the competition.

Figure 2

CHANGE IN EFFORT LEVEL IN RESPONSE TO CHANGE IN PASSING STANDARD



— Finally, the link between effort and risk conditioning academic qualifications is ambiguous. We observe that for low learning standards an increase in the randomness of the exam stimulates effort. Just the opposite occurs when the standards are set at high levels. However, when the strategy adopted is the one getting from the student the best response effort, then $\hat{q}^* = 0.36 = e^*$, so uncertainty discourages effort certainly.

4. REWARD SYSTEM BASED OF RELATIVE PERFORMANCE

The previous approach confronts a student against himself in the sense that she needs to pass a previous announced threshold value or absolute learning standard in an uncertain context. Now, let us assume that even though policy makers cannot directly observe *e* or control ε they may be able to observe some variable, α, in addition to the realization of academic achievement, which can be used in defining the reward function for a particular student in response to effort[12]. In our case a good candidate for α is the performance of peers. Therefore, the approach we shall now consider puts a student in front of other(s) encouraging him to overcome his opponent in an environment also uncertain. It is the case of a reward system based on relative performance, from which a rank-order tournament is the simplest scheme. In a rank order tournament rewards depend solely on ordinal comparisons of academic scores across students. That is, the contest is rank order because the margin of winning does not affect rewards. Therefore, in the case of a two-player tournament the student getting the highest score wins regardless of whether his grade exceeds or not a standard learning level[13].

For simplicity, we will consider this case of two only students, "a" and "b", that compete each other to reach a given reward. Formally, the incentive mechanism for student "a" can be expressed in the following terms:

$$w_a(q_a, q_b) = \begin{cases} w_1 = \overline{w} + x & \text{if} \quad q_a \geq q_b \\ w_2 = \overline{w} - x & \text{if} \quad q_a < q_b \end{cases} \qquad (17)$$

12 In the principal-agent framework, this has sense when *q* is not a sufficient statistic in the sense of Holmstrom (1979;1982) and Mookherjee (1984), so rewards should be made depend at least to some degree on α, as it contains information about *e* beyond that conveyed by *q*.

13 Sobel (2000) for the case of promotion processes in research universities uses a different approach combining standards and relative performance. In contrast to tournaments models, relative performance is not used to determine which of several possible workers will receive a prize. Instead, candidates must compare well against a standard created by the performance of past candidates.

and similarly, for the student "b". We still assume that both students are identical in terms of preferences and learning costs, with the same characteristics assumed in Section 3. Likewise, academic scores also have the same stochastic structure than before:

$$q_i = e_i + \varepsilon_i \quad \text{for} \quad i = a, b.$$

where now ε_i are random variables normally distributed with $E(\varepsilon_i) = 0$, and $E(\varepsilon_i)^2 = \sigma_i^2 = \sigma^2$, for *i = a, b*. Denoting $\delta = \varepsilon_b - \varepsilon_a$, student a's probability of success is now defined as follows:

$$\begin{gathered} \text{Prob}(q_a \geq q_b) = \text{Prob}(e_a + \varepsilon_a \geq e_b + \varepsilon_b) = \text{Prob}(\varepsilon_b - \varepsilon_a \leq e_a - e_b) \\ \text{Prob}(\delta \leq e_a - e_b) = G(e_a - e_b) \end{gathered} \tag{18}$$

The objective function for student "a" is expressed as:

$$\begin{aligned} EU_a &= G(e_a - e_b)u(\overline{w} + x) + [1 - G(e_a - e_b)]u(\overline{w} - x) - \psi(e_a) \\ &= u(\overline{w} - x) + G(e_a - e_b)A - \psi(e_a) \end{aligned} \tag{19}$$

It is clear that student a's utility not only depends on his particular effort but also on effort exerted by student "b", and reciprocally, so this is a competitive contest in which both students must choose their respective efforts keeping in mind what the other can do. Unlike the incentives to pass the absolute standard, now peer competition requires student "a" to consider student b's effort level when choosing the strategy to maximize his own expected utility. Thus, we assume that the players (students) choose their efforts levels simultaneously and we employ a Nash equilibrium as the solution concept[14]. Formally, first order condition in this case is given by

$$EU'_a = g(e_a - e_b)A - \psi'(e_a) = 0 \tag{20}$$

where $g(e_a - e_b) = G'(e_a - e_b)$. The second order condition for a maximum is

$$EU''_a = g'(e_a - e_b)A - \psi''(e_a) < 0 \tag{21}$$

Now, in order for an effort level satisfying (20) to be a local maximum, a sufficient condition is $g'(e_a - e_b) \leq 0$. In any case, hereafter we will assume the second order condition (21) is satisfied and therefore an optimum effort level exists.

Note that (20) has the same structure that equation (7). The only difference between both expressions rests on that now the other student's effort, e_b, instead of $\hat{q}$, appears in the probability statement, so we have $g(e_a - e_b)$ instead of $f(\hat{q} - e)$. Hence that effects on the resulted effort due to a change in either the reward, *x*, or the variability of testing, σ_a, or even in the effect of risk aversion

[14] We accept the non cooperative equilibrium as the solution concept. Though ex ante there might be incentives for students to collude in choosing their efforts, these agreements are not likely to overcome the prisoner's dilemma.

caused by a change of $\overline{w}$, are the same as before, therefore we will not insist here on it.

Let $\xi_a(e_b)$ denote student a's set of optimal effort level choices for each e_b. That is, equation (20) implicitly defines student's expected Nash best response function $\xi_a(.)$. Differentiating (20) with respect to e_a and e_b, and solving for the desired derivative yields

$$\frac{de_a}{de_b} = \frac{g'(e_a - e_b)A}{EU''_a} \qquad (22)$$

We have assumed $EU''_a < 0$ so the sign of (22) depends essentially on the sign of $g'(e_a - e_b)$. If $g'(e_a - e_b) < 0$, which is satisfied when $e_a > e_b$, then $\frac{de_a}{de_b} > 0$, and the probability of winning the contest exceeds of 1/2. On the contrary, if $g'(e_a - e_b) > 0$, which associates with a situation characterized by $e_a < e_b$, it follows that $\frac{de_a}{de_b} < 0$. In this case the probability of beating the performance of student "b" is less than 1/2.

Given the assumption of students' homogeneity then their strategies are symmetrical. This implies that the non-cooperative equilibrium solution of this game is a Nash equilibrium characterized by both students choosing exactly the same effort level $(e_a^*, e_b^*) = (e^*, e^*)$. This occurs at the intersection of the reaction functions we depict in Figure (3)[15], where $\frac{de_a}{de_b} = 0$, with corresponds to $g'(0) = 0$. It follows that if $(e_a^*, e_b^*) = (e^*, e^*)$, then $G(e_a^* - e_b^*) = G(0) = 1/2$, that is in equilibrium both students have the same probability of winning the contest, and $g(e_a^* - e_b^*) = g(0)$, so the common optimal effort is implicitly determined by the following equation:

$$g(0)A = \psi'(e^*)$$

Solving for e^* we get

$$e^* = (\psi')^{-1}[g(0)A] \qquad (23)$$

As in the case of a reward system based on absolute standards, in this section we carry out a numerical example, which allow us to give a more precise description of the magnitude of the effects that take part in a tournament when factors conditioning learning motivation are allowed to vary. To cope with this task we maintain the assumptions set up on Section 3 and add one more. In particular, we assume the correlation coefficient of ε_a and ε_b is $\rho = 0.5$ so $G(\delta) = G(e_a - e_b)$ is also normal with zero mean and standard deviation of $\sigma_\delta = 0.5$.

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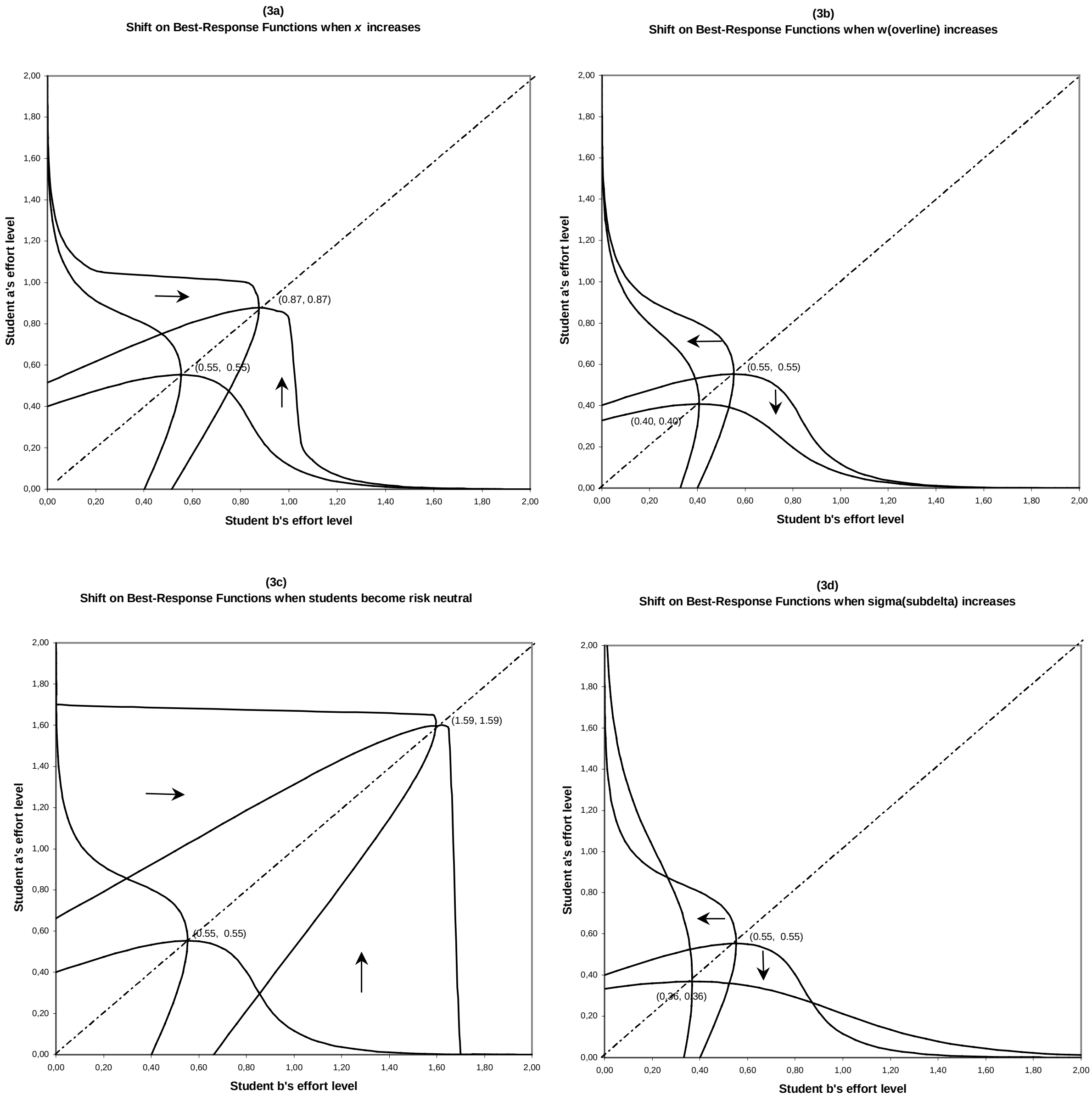
[15] Formal derivation of the shape of the students' reaction functions is shown in the appendix.

Figure 3
BEST-RESPONSE FUNCTIONS AND NASH EQUILIBRIA



All the simulations carried out are the same as in the previous case. The benchmark case is illustrative of two risk averse students with parameters $\overline{w} = 3$, $x = 1$, $\sigma_\delta = 0.5$. Figures 3a, 3b, 3c, and 3d illustrate the students' best-response functions and the Nash equilibrium in the benchmark case and the shift patterns of this functions and the resulted Nash equilibrium when some of the initial parameters are modified.

— In the benchmark case we observe that as e_b increases from zero, student a's reaction function lies above the 45º line and increases in e_b, lies on the curve and reaches the maximum, and then lies below the 45º line and decreases in e_b. Student b's reaction function is symmetrical. Therefore, the Nash equilibrium (e_a^*, e_b^*) is located on the 45º line, which in turn means that both students choose exactly the same effort level, in particular $e^* = 0.55$. When the parameter *x* increases from 1 to 1.5, student a's reaction function shifts upwards and student b's reaction function shifts to the right so both students simultaneously expend more effort trying to beat the contest. Thus if we want to increase students' efforts conditional on the rewards and the errors in measurement, we need to increase the returns for their attainment. The optimal effort value in this case is $e^* = 0.87$.

— By contrast, the opposite effect takes place when the socioeconomic parameter $\overline{w}$ increases from 3 to 4. In particular, student a's reaction function shifts downwards and student b's reaction function shifts to the left. This sets the new Nash equilibrium at $e^* = 0.40$.

— However, for risk-neutral expected utility maximizer students, a tournament system induce both students to put forth more effort. Particularly, as in the case of increased rewards, the reaction functions shifts upwards and to the right, so optimal effort becomes $e^* = 1.59$.

— Finally, when the variability of testing σ_δ grows from 0.5 to 0.75, effort in beating a competitor unambiguously falls from $e^* = 0.55$ to $e^* = 0.36$ because hard work does not serve as well to accurately differentiate the student. This confirms Bishop's view of learning theory characterized by uncertainty discouraging motivation and effort to learn.

5. COMPARISONS

Thus far both reward systems lead to similar results. Consequently, it seems as if policy makers were indifferent between using one system or another. However, the view of education as principal-agent problem lead us to formulate the question of which system is more efficient. That is, if motivating students to achieve all they are capable is the main objective of recognizing and rewarding academic achievement then it is essential to compare both systems in adaptation to this objective. Which system stimulates effort the most? To cope with this task we will restrict to the action promoting the highest effort when using absolute standards.

In this respect, differences between both systems confine ourselves to compare equations (13) and (23), which takes us in turn to compare $f(0)$ with $g(0)$, and in particular the standard deviations of ε and δ. Formally,

$$\sigma_\delta^2 = Var(\delta) = Var(\varepsilon_b - \varepsilon_a) = \sigma_a^2 + \sigma_b^2 - 2Cov(\varepsilon_a \varepsilon_b)$$

which becomes

$$\sigma_\delta = \left(\sigma_a^2 + \sigma_b^2 - 2\rho\sigma_a\sigma_b\right)^{1/2} = \left(2\sigma^2(1-\rho)\right)^{1/2} \tag{24}$$

This expression allows us to get the following result:

$$\begin{aligned} \sigma_\delta > \sigma \quad & \text{if} \quad -1 \leq \rho < 0.5 \\ \sigma_\delta = \sigma \quad & \text{if} \quad \rho = 0.5 \\ \sigma_\delta < \sigma \quad & \text{if} \quad 0.5 < \rho \leq 1 \end{aligned} \tag{25}$$

Thus, only if ε_a and ε_b, which randomly affect student test's scores, are sufficiently correlated, $\rho > 0.5$, then uncertain elements surrounding a tournament are relatively smaller and effort will be higher. Just the opposite occurs if $\rho < 0.5$. In this context, a high correlation means that risks conditioning academic achievement are mainly systematic (common to all students), while when correlation is low, idiosyncratic elements (specific to each student) prevail.

A numerical example can be also useful in order to get deeper insights into the comparison of both regimes. With the assumptions set up in previous sections we show in Figure 4 the optimal effort levels attained by a student involved in both regimes. The main results of the example are the following:

— A tournament eliminates the incidence of systematic factors (e.g. variation in test quality, deficiencies in exam's design, realization and correction, etc.) but it introduces the occurrence of idiosyncratic elements (e.g. illness, anxiety on the day of the test, and other personal factors). In the limit case of $\rho = 1$, a tournament eliminates all the randomness in the output from effort and improves competition between both students, who make an effort in the extreme. In this case, the optimal effort is the highest feasible, $e^* = 3.9$ (for $\rho = 0.99$), compared with the level attained by implementing standards which is $e^* = 0.55$. Hence in the perfect correlation case policy makers can extract maximum advantage from using the performance of other peers as a benchmark to evaluate and reward the performance of any student[16]. Thus when the uncertainty is only common to all the students in the same class then peer's performance can provide information about another student's state of uncertainty. It is worth mentioning the fact that competition among students due to relative evaluations has merit only as a device to extract information optimally. Competition is "per se" worthless.

— However, when $\rho = 0$, a tournament introduces distorting elements since it allows personal factors to play in. This propitiates that a student's expected reward does not only depend on his particular actions but also

[16] The perfect correlation case might however seem rather extreme and unlikely to be satisfied exactly in most situations of interest.

on the others'. Under these conditions the relationship among scores, rewards and effort becomes less distinct, and therefore students put less effort into their study. Optimal effort in this case is equal to $e^* = 0.39$, a level much less intense than the $e^* = 0.55$ which policy makers are in conditions to achieve when the student is forced to pass a learning standard.

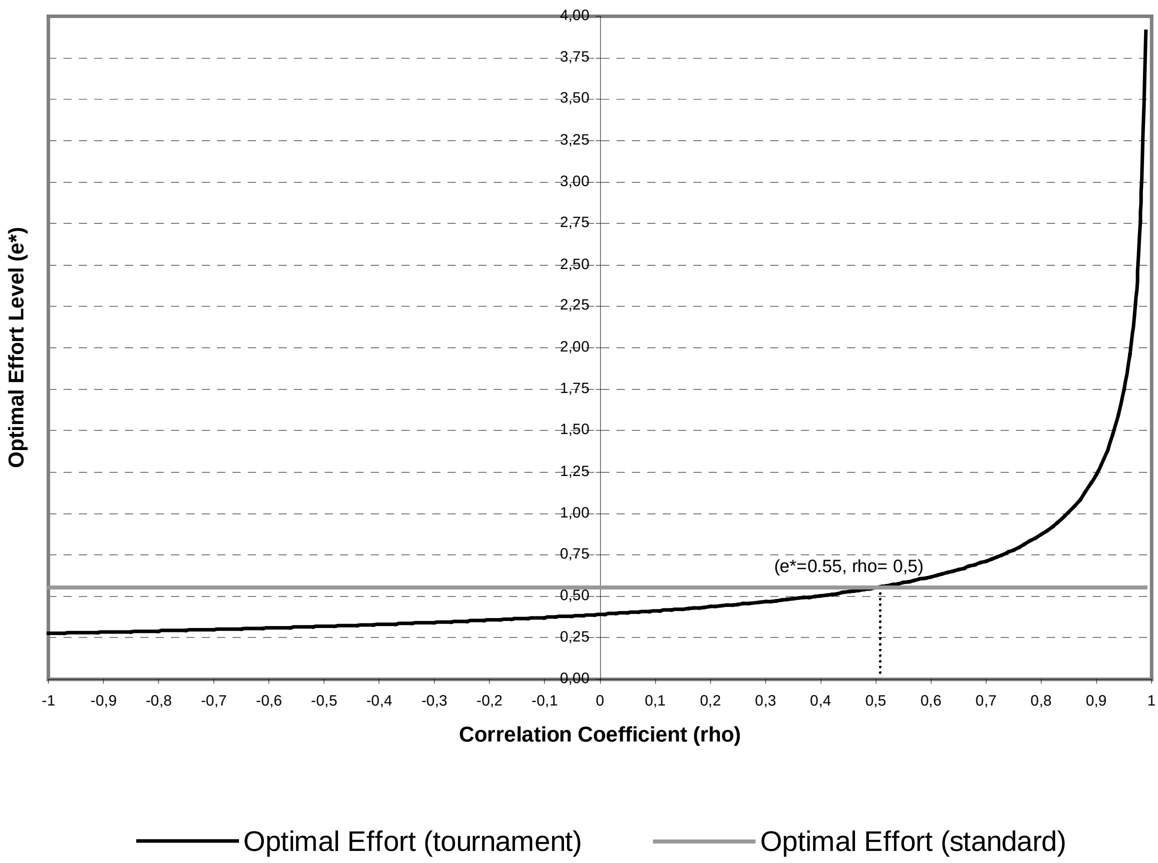
— The most adverse situation takes place when $\rho = -1$, that is, when personal circumstances conditioning test results are perfect but negatively correlated, then risk factors double the sum. Finally, when $\rho = 0.5$, both systems are equally efficient as they get from the students the same maximum effort level, $e^* = 0.55$.

To summarize, the advantage of a reward system over the other depends crucially on the nature of the noise distorting academic achievement. If systematic factors prevail then a reward system based on peer performance is preferred to a reward system based on absolute standards. The opposite takes place if specific or personal errors predominate.

Figure 4

OPTIMAL EFFORT: STANDARDS *VERSUS* TOURNAMENTS

$$\overline{w} = 3, x = 1, \sigma = 0.5, \sigma_\delta = \sqrt{2\sigma^2[1-\rho]}$$



6. CONCLUDING REMARKS AND EXTENSIONS

We have considered risk averse students who control their learning by regulating the effort they devote to each course, and where rewards in response to effort are assumed to be discrete and fixed in advance. Then, we have analyzed the incidence in student's effort from implementing two possible reward systems. The first one grants rewards depending whether or not the student pass/fails a certain standard level of learning in a test, while the other awards rewards on the basis of relative performance. Next we have compared both rewards structures in terms of the level of effort attained.

We show that each of these reward systems lead to similar results. Both systems predict that an increase in the reward for learning will induce an increase in effort. Both schemes also predict that more well-off students exert relatively less effort in the process of learning and therefore in attempting to pass the standard and/or beating her contest. A somewhat less obvious prediction is that uncertainty conditioning academic achievement reduces learning. In the case of a reward system based on peer performance a higher uncertainty discourages effort certainly, but in a reward system based on absolute standards this effect only takes place under certain conditions. More significantly, we also show that up to a point, raising the criterion for a passing grade raises the effort that student puts into learning. This critical value induces such an effort that the probability of passing the standard (under symmetric distributions) is the same as the probability of failure. Passing this point, raising the standard discourages effort, forcing students to drop out the course when the standard is very high. Setting the 50 % rule is therefore the optimal education policy as it implies establishing a standard learning level that makes student's effort maximum. Policy makers should take account of this rule if by using standards to induce students to achieve all that they are capable they aim to promote efficiency and hence improve welfare.

In addition, the non-cooperative equilibrium solution of the tournament played by the students is a Nash equilibrium characterized by both students choosing exactly the same effort level and having each student the same probability of winning (losing) the contest. We show that the advantage of a reward system over the other depends crucially on the nature of the noise distorting academic achievement. If systematic factors prevail then a reward system based on peer performance is preferred to a reward system based on absolute standards, while if idiosyncratic factors predominate the last is more efficient.

Our paper may contribute for a better understanding of how students' effort will be affected by different reward systems. This kind of analysis is potentially very valuable because it provides information to policy makers who seek to improve the performance of the educational sector. In particular, it emphasizes the importance of manipulating student effort, which presumably is the most important input to education production.

Finally, we suggest three ways to extend this work. First, heterogeneity can be introduced into the model. The preceding analysis assumes that if a unique symmetric Nash Equilibrium exists under a rank-order contract for a contest consisting of homogeneous students, then each student in the contest chooses the same equilibrium effort level. But if students differ in ability the more skilled obtain better results with less effort. Thus mixing heterogeneous students in the same class may result in a reduced effort level of many students as the reward systems we have so far analyzed do not manage to adapt the current diversity in the classroom. A possible solution would be "streaming", that is stratifying students according to ability levels as relative rewards can be maintained within groups. However an adverse selection problem appears if abilities cannot be accurately differentiated before grouping.

Second, peer effects can be introduced. One of the main claimed results of the pioneering Coleman Report (1966) was that the most significant determinant of a student's academic achievement, apart from his own ability, was the ability of his classmates, that is the so called peer group effect[17]. The presence of more able students in the classroom that have a favourable effect on educational achievements, perhaps by imparting higher motivation or better learning discipline, would add powerful insights into the paper, especially when looking at the effort resulted from implementing incentive schemes of the type above described.

Last, but not the least, a principal-agent framework can be developed. As Betts (1997, pp. 2) remarks: "...such models (principal-agent) could be applied to education, where schools can be though of as the principal (in the economic sense) attempting to maximize the rate of student learning, and students can be thought of as agents whose utility functions might not match that of the school administrator". However, so far, only a few papers have viewed education as a principal-agent problem. Recent examples are Betts and Costrell (2001), Costrell (1993, 1994, 1997), Betts (1997, 1998) and Effinger and Polborn (1999). But all of them just focus on analyzing the role of educational standards in improving the quality of public education assuming that learning and academic achievement response positively to incentives[18]. It will be interesting to explore the implications on academic effort resulted from the implementation of standards and tournaments under a complete moral hazard approach.

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[17] This is a reasonably well documented phenomenon: for example, see Summers and Wolfe (1977), Henderson et al. (1978) for early economic empirical studies. More recent empirical papers are Epple et al. (2001) and Zimmer and Toma (2000). From a theoretical viewpoint, the analysis of Arnott and Rowse (1987) and de Bartolome (1990) were among the first to take the peer group effect explicitly into account.

[18] As far as we know Becker and Rosen (1992) is the only paper analyzing the effects of implementing tournaments as a way of inducing students to work harder. But they do not strictly follow a principal-agent approach.

APPENDIX

REACTION FUNCTIONS IN THE REWARD SYSTEM BASED ON PEER PERFORMANCE

Let us derive the shape of student a's reaction function. We already know that $\frac{de_a}{de_b} \gtreqless 0$ if and only if $g'(e_a - e_b) \lesseqgtr 0$, which in turn occurs when $(e_a - e_b) \gtreqless 0$. Let us now suppose that $\frac{de_a}{de_b} > 1$. Then, as $EU''_a < 0$, we have

$$g'(e_a - e_b)A < g'(e_a - e_b)A - \psi''(e_a)$$

This condition simplifies straightforwardly to $\psi''(e_a) < 0$, which by assumption is not possible, and as a result $\frac{de_a}{de_b} < 1$. In addition let us check for the concavity of the reaction function. Formally,

$$\frac{d^2 e_a}{de_b^2} = -\frac{g''(e_a - e_b)A}{g'(e_a - e_b)A - \psi''(e_a)} + \frac{g'(e_a - e_b)A^2 g''(e_a - e_b)}{[g'(e_a - e_b)A - \psi''(e_a)]^2}$$

which simplifies to

$$\frac{d^2 e_a}{de_b^2} = \frac{g''(e_a - e_b)A\psi''(e_a)}{[-g'(e_a - e_b)A + \psi''(e_a)]^2}$$

Once again the denominator is positive, then $\frac{d^2 e_a}{de_b^2} \gtreqless 0$ if $g''(e_a - e_b) \gtreqless 0$. Finally, as students "a" and "b" are homogeneous, their strategies are symmetrical and so their reaction functions.

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