

## Being Knowledgeable or Sociable? Different Patterns of Human Capital Development and Evaluation in Cognitive and Non-cognitive Skills\*

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*This paper develops a model of college admissions that emphasizes the role of college admissions as a human capital evaluation method. Given multiple dimensions of human capital, different patterns of human capital evaluation and development can emerge as multiple equilibria. These equilibria with a varying emphasis on different aspects of human capital can match an observed difference in college admission patterns between East Asian countries and the U.S. These different patterns are not Pareto ranked. Empirical implications of model are also discussed.*

JEL Classification: D02, J24

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### I. Introduction

University admissions provide an important evaluation method of human capital. College wage premium exists,<sup>1</sup> and part of it can be explained by a signalling theory - individuals with more developed human capital are more likely to attend higher education, or a higher education institution will admit only those individuals.<sup>2</sup>

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<sup>1</sup> For example, in the U.S., the hourly wages of college graduates are about 60% higher than those of high school graduates with 1 to 3 years of experience in the 1990s (Fang, 2006).

<sup>2</sup> The screening by higher education institutions, in an extreme case, is so perfect that the income

University admissions can also work as a major guideline for individuals concerning what kind of human capital they should equip themselves with in order to be productive in a society.

This paper introduces a model of university admissions that emphasizes their role as a human capital evaluation method. Though college admissions have been a subject of research from various perspectives,<sup>3</sup> this paper, to our knowledge, is the first theoretical attempt to emphasize this role.<sup>4</sup> By modeling an interaction of universities' admissions standards and students' decisions of human capital investment, we show that different evaluation and development patterns of human capital emerge as equilibria. Such different patterns can match empirical patterns we observe between East Asian countries and the U.S.

The empirical pattern we want to highlight is a stark difference in observed university admissions standards between East Asian countries and the U.S. While academic institutions in East Asia predominantly use academic measures when admitting students, those in the U.S. also use other measures such as leadership and community involvement in addition. Considering the university admissions' role as a preliminary evaluation of human capital, this means that human capital, especially its productive role, is evaluated differently in these two societies.<sup>5</sup>

This paper offers an explanation about persistent differences in human capital development patterns among countries even with the same economic fundamentals. We develop a model with multiple dimensions of human capital where a university tries to recognize and admit the most productive students and students develop human capital to be successful in university admissions. Kinds of human capital to be analyzed are cognitive skills usually meaning academic achievement and non-cognitive skills such as leadership and social skills.

A coordination problem arises, since a certain type of human capital, to be utilized, should both be developed and recognized as productive. Students would have an incentive to develop a type of human capital that is more likely to be recognized. Universities would have an incentive to more correctly recognize a type of human capital if there are more students equipped with it. Therefore, we can have multiple coordinations: one involves low investment and less recognition while the other involves high investment and more recognition. Moreover, since students have limited time to invest in human capital, there will be a trade-off between two

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prospect of individuals is not dependent on the specific institution they attended if admission results to various institutions are similar (Dale and Krueger, 2002).

<sup>3</sup> It has been a subject of a matching problem since Gale and Sharpley (1962). Specific aspects of college admissions such as an affirmative action (Bowen and Bok 1998 among others) or an early admission (Avery et al., 2003; Lee, 2009, and Avery and Levin, 2010) have also been hotly debated.

<sup>4</sup> Impacts of university admissions on high school education is well recognized by its practitioners. See Atkinson (2001).

<sup>5</sup> We later elaborate the differences in university admissions standards between the two societies and their implications in section 2.

dimensions (cognitive and non-cognitive) of human capital. If students invest more in one aspect of human capital, they have to reduce their investment in the other aspect.

With the coordination problem and trade-off combined, there can be multiple equilibria with different emphases on each type of human capital. If a university recognizes cognitive skills more, students will invest more in cognitive skills and have to reduce their time on non-cognitive skills. This will in turn induce the university to recognize less of non-cognitive skills and more of cognitive skills. If universities recognize non-cognitive skills more, the same logic will lead to an enhancement of non-cognitive skills. Especially, we can have coexisting equilibria with a complete emphasis on cognitive skills alone and with a similar emphasis on both skills.

Multiple aspects of human capital we assume in the model are recently getting growing attention in economic analysis. Traditionally, human capital has been equated with cognitive skills measured by IQ or other test scores in economic analysis. This is because the measures of cognitive skills are more readily available than those of non-cognitive skills, not because it is the only important aspect of human capital (Carneiro and Heckman, 2003). There have been new empirical analyses which also consider effects of non-cognitive skills on labor market and schooling outcomes (Borghans et al., 2008; Cunha and Heckman, 2008; Heckman et al., 2006 among others). These studies generally confirm non-negligible effects of non-cognitive skills. Non-academic measures used in the admission process of U.S. institutions such as leadership quality, community involvement, or personal ratings seem to accommodate the importance of non-cognitive skills.

It is also believed that non-cognitive skills can be obtained as a by-product of participation in social activities such as sports, drama club, student government, and so on (Postlewaite and Silverman, 2005). The wage premium generated by participating in sports activities may be due to the development of non-cognitive skills (Stevenson, 2010). Time used in these activities, therefore, can be thought of as an investment in non-cognitive skills.

Taking multiple dimensions of human capital into account, multiple equilibria of our model can match with the empirical patterns described above. In East Asian countries, we see more investment on cognitive skills (more time spent on academic activities) and more recognition of them in university admissions. On the contrary, in the U.S., we have relatively more investment in non-cognitive skills (more time spent on sports and socialization) and more recognition of them in university admissions.

Our results also shed light on the international comparison of test scores and its implications. It is reported that high scores in international tests are related to better economic performance (Hanushek and Woessmann, 2008). It will be beneficial to economy if we can improve cognitive skills by making education production more

efficient. However, it might be misleading if we draw the conclusion that we just have to invest more time and resources on the development of cognitive skills. This paper argues that there might be a cost of investing on cognitive skills, which is the underdevelopment of non-cognitive skills and that we should carefully weigh the cost and benefit.

This paper proceeds as follows. The remainder of this section explains primary motivation of this study and briefly discusses the related literature. Then we introduce the model in Section II and analyze it in Section III. Section IV contains a brief discussion on model settings and its empirical implications. Then the conclusion follows.

## 1. Motivation

There exists a considerable difference in observed university admissions standards between East Asian countries and the U.S. Table 1 shows the regular admissions standards of two well-known universities in Korea as an example: Seoul National University (SNU) and Korea University.<sup>6</sup> The important components in admission standards of the two universities are Korean SAT(KSAT), which is a nation-wide exam, and an essay test. These components are all academic. SNU places 30% weights in essay writing tests in the second round of selection, which measure mostly an academic ability. The only possible non-academic component is extra-curricular activities in high school records, which is given 5 to 10% weights.<sup>7</sup>

[Table 1] Admissions Standards of Korean Universities

		Components of Admissions Evaluation			
		KSAT	High School Record		Essay Test
			Curricular	Extracurricular	
SNU	Preliminary (200% of class)	100			
	Final	20	40	10	30
Korea Univ.	Priority (70% of Class)	100			
	General (30% of Class)	50	45	5	

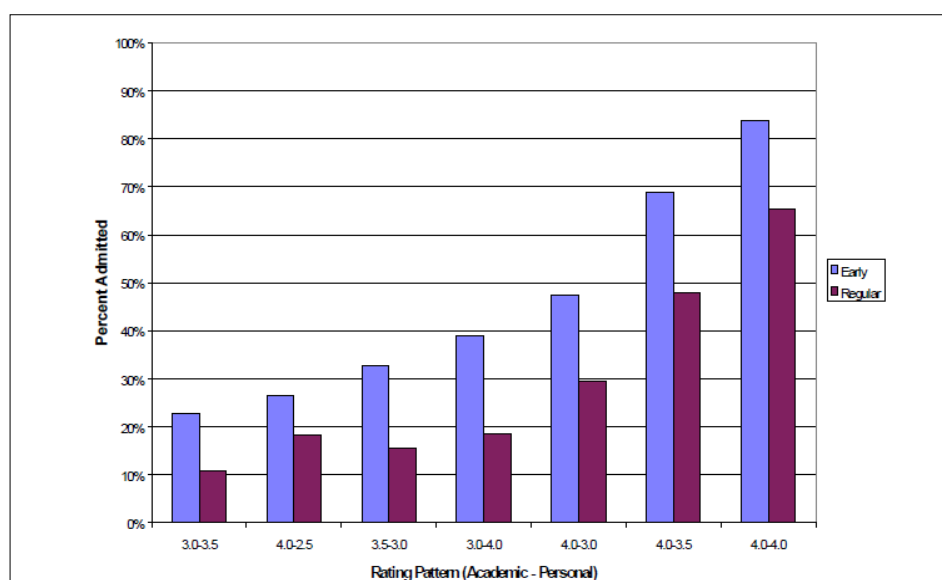
Institutions in the U.S. rarely announce their admissions standards publicly.

<sup>6</sup> They do not apply to the school of education and the school of arts, where an interview or a portfolio of the art works can play a role.

<sup>7</sup> Even this component can be mostly academic, since award winning records in various academic competitions such as math olympiad count highly in this component. Recently, employing financial incentives, the Korean government tries to encourage universities to introduce new admissions practices that are based on the evaluation of admission officers. In early admissions, we may have seemingly quite different admissions standards. But it is still controversial whether the new practice really changes how universities admit students.

According to guides in web sites of Harvard and Yale University, non-academic qualities such as leadership, community involvement, curiosity, etc. are important in addition to academic accomplishments. Figure 1, which is a direct quote from Avery et al. (2001),<sup>8</sup> shows the admission rates of one institution according to the ratings of admission officers. This institution has a personal rating as well as an academic rating, and the admission rates vary according to the pair of these ratings. It is evident that the personal rating also affects the admissions rates.

[Figure 1] Admissions Rates according to Ratings; US Institution [Source: Avery et al. (2001)]



These clear differences in human capital evaluation lead to different patterns of human capital development in both societies. If we compare time use of high school students, East Asian students spend most of their time on academic activities, while U.S. students divide their time between academic activities and non-academic activities such as sports. Japanese high school students spend 60.4 hours per week on school work, and U.S. students spend less than half of that (30.0 hours). Instead U.S. students spend more time in 'playing games and sports' (7.0 hours per week) than Japanese students (0.7 hours per week).<sup>9</sup> Comparison results are similar between the U.S. and Korea. U.S. students spend 6.3 hours on educational activities on an average weekday, while Korean students spend 10.7 hours on them. Again

<sup>8</sup> The figure is originally produced to show different admissions rate in early and regular admissions, as it seems to be taken for granted that non-academic factors affect admissions rates.

<sup>9</sup> This comparison is based on years 1981-82 for U.S. and 1986 for Japan (Juster and Stafford, 1991).

U.S. students spend more time on socializing and sports (4.6 hours) than Korean students (2.0 hours).<sup>10</sup>

All these differences of human capital evaluation and development, however, cannot be wholly ascribed to discrepancies in desirable characters of human capital. Non-academic factors, though not much considered in university's admissions, also seem to be important in East Asian societies. According to a survey on employers in Korea,<sup>11</sup> important evaluation components in a job interview include non-academic factors such as responsibility (19.7%), a capability to cooperate (13.4%), and communication skills (12.7%) as well as academic factors - job related knowledge (20.8%).

Non-academic factors, which are often called non-cognitive skills, seem to contribute to the economic performance not just in the individual level but in the country level.<sup>12</sup> While there is a positive role of cognitive skills in countries' economic performances as shown by Hanusheck and Woessman (2008), Figure 2 suggests that non-cognitive skills also positively affect countries' economic performances. The figure shows that there exists a positive relationship (both conditional and unconditional) between a country's labor productivity (specifically, GDP per worker) and its proportion of students' time invested in non-cognitive skills.<sup>13</sup> Whether other variables, measures of cognitive skills in particular, are controlled for or not, labor productivity tends to be higher as more time is invested in non-cognitive skills.<sup>14</sup> If different patterns in human capital development emerge as each country needs different types of human capital according to their industrial structures or others, there cannot be a consistent correlation between each country's economic performance and its human capital development pattern. If each country optimally chooses its human capital development pattern and one does not invest in non-cognitive skills because they are not demanded, a country can still achieve a good economic performance without much investment in non-cognitive skills. The figure, however, shows otherwise. A theory is wanted that justifies an empirical relationship between a country's economic performance and investment in non-cognitive skills. This paper offers one such theory.

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<sup>10</sup> Such findings are from American Time Use Survey (<http://www.bls.gov/tus/charts/students.htm>) and Korean Time Use Survey (<http://kosis.kr>).

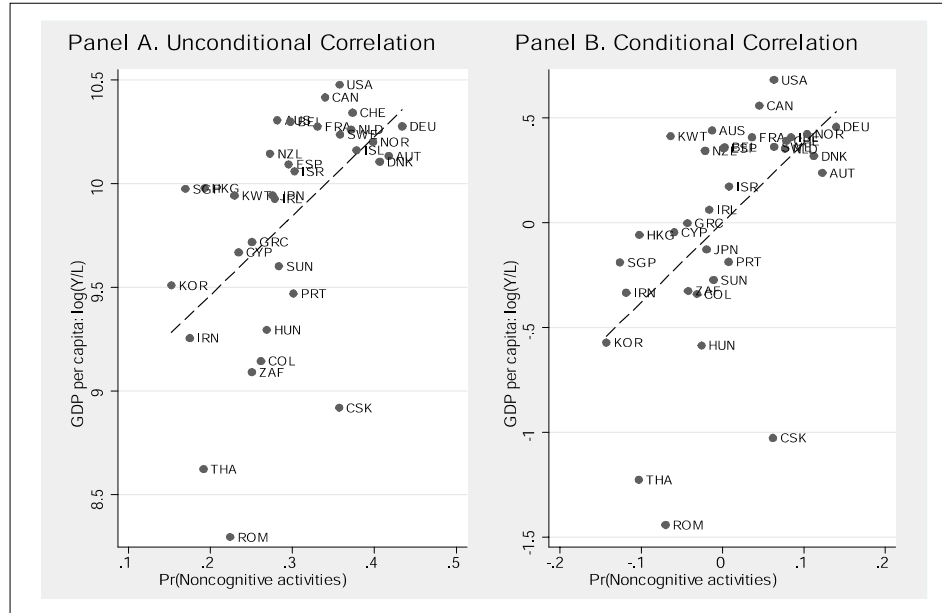
<sup>11</sup> A news release by the Korea Employers Federation, 2006.

<sup>12</sup> As will be discussed later, non-cognitive skills play a positive role in individual's schooling and labor market outcomes (Cunha and Heckman, 2008; Heckman et al., 2006).

<sup>13</sup> For more detailed description of the data and more formal presentation of this relationship, see the Appendix.

<sup>14</sup> There may be a reverse causality issue. Time investment on non-cognitive skills such as sports and socialization can also be treated as leisure which more developed economies can afford. According to this argument, more time is used for those activities as the economy develops. To address this issue, we need to track the past time use pattern of the developed economy and see whether the time share for these activities increased as the economy develops. Unfortunately, those data are not available.

[Figure 2] Unconditional and conditional correlations between labor productivity and a share of time use related to non-cognitive skills



Notes: The total number of observations is 33. Information on GDP per capita is drawn from Hall and Jones (1999). A share of daily time use related to non-cognitive skills and average math score for each country are constructed from The Third International Mathematics and Science Study, 1995 (Gonzalez and Smith, 1997).

## 2. Related Literature

Multiple aspects of human capital is recently gaining more attention in economics (Carneiro and Heckman, 2003; Heckman et al., 2006; Cunha and Heckman, 2007 and 2008; Borghans et al., 2008 among others). Studies empirically show a positive return of non-cognitive skills. This paper, to our knowledge, is the first theoretical undertaking that deals with different patterns of human capital evaluation with multiple dimensions of human capital.

This paper is directly related to Lee (2007) in that differences in studying time of high school students between the U.S. and East Asian countries are explicitly analyzed. Lee indicated that U.S. students study more in college than in high school while the opposite is true for East Asian students, explaining that signalling of students' abilities happens in high school for East Asian countries while it occurs in college in the U.S. Our study explains discrepancies of universities' admissions standards which were not addressed in Lee.

Though the purposes of modelling and specific settings are very different, the idea behind the modeling framework of this paper is very similar to that of Mailath

et al. (2000). Both Mailath et al. and this paper put together two coordination failure models whose idea is quite common (Diamond, 1982; Coate and Loury, 1993 among others). Mailath et al. assume two groups of workers and explain possible discrimination in the labor market by the interaction of search intensity of firms and skill investment decisions of workers. In this paper, we assume two kinds of skills and suggest a possibility of different treatments of the two skills. While they are more interested in one type of equilibrium (discriminating one), we are more interested in the coexistence of two types of equilibria (similar and unequal treatments of two skills).

## II. Model

**Human Capital** We assume there are two kinds of human capital,  $HK_i$  for  $i=1,2$ . We consider cognitive skills, which are usually measured by academic achievement, as  $HK_1$  and non-cognitive skills such as leadership, communication skills, and social skills as  $HK_2$ .<sup>15</sup>

**Student-Workers** There are a unit mass of identical student-workers. They can invest in  $HK_1$  and  $HK_2$ . Let  $t_i$  be the time invested in each type of human capital.<sup>16</sup>

They can be either equipped with human capital or not. The probability of being equipped with human capital depends on the time investment. For simplicity, we assume that the probability of being equipped with each type of human capital is equal with a same time investment. Specifically  $f(t)$  is the probability of being equipped with human capital if time  $t$  is invested. Then  $f(t_1)$  and  $f(t_2)$  are the probabilities of being equipped with each type of human capital. As a probability,  $f$  lies between 0 and 1 with  $f(0)=0$  and  $\lim_{t \rightarrow \infty} f(t)=1$ . We assume  $f$  is increasing and concave:  $0 < f' < \infty, f'' < 0$ .

The utility cost of the time investment is  $c(t_1 + t_2)$ . We assume that this cost function is increasing and convex:  $c' \geq 0$  with  $c'(0)=0$  and  $c'' > 0$ .

**University-Firm** A university-firm has two kinds of positions,  $j=1,2$  and can admit or hire student-workers for each position. Let  $v$  be the value a student-worker produces when (s)he is hired. If a student-worker, who is equipped with

<sup>15</sup> Even though there can be many subdivisions in these skills (Borghans et al., 2006), we just follow this widely used classification for analytical convenience.

<sup>16</sup> In this paper, the differences of two types of human capital are abstracted as we focus on the tradeoff of investments between them. These differences are more important in the study on how these are formed and maintained along an individual's life cycle. See Cunha and Heckman (2007) and the following empirical studies.



$HK_1$ , is admitted or hired for position 1, then  $v = \phi_1$ . If a student-worker, who is equipped with  $HK_2$ , is admitted for position 2, then  $v = \phi_2$ . Let us call  $\phi_i$  the productivity of  $HK_i$ . If a non-qualified student-worker is admitted for each position, then  $v = -D$ , i.e., a net loss incurs. If a student-worker is not admitted, (s)he will produce nothing. A student-worker equipped with both  $HK_1$  and  $HK_2$  can be admitted for both positions at the same time. Then her or his production is  $\phi_1 + \phi_2$ .

A university-firm cannot directly observe whether a student-worker is equipped with the human capital, but it can invest in a technology to recognize the human capital. Let  $p_i$  be the probability of recognizing  $HK_i$  if one has it. The cost of acquiring the technology  $p_i$  is  $\psi(p_i)$  with

$$\psi(0) = 0, \quad \lim_{p \rightarrow 1} \psi(p) = \infty, \quad \psi' \geq 0 \quad \text{with} \quad \psi'(0) = 0,^{17} \quad \psi'' > 0.$$

The cost of investment in two recognition technologies is separable, so that the cost of acquiring technologies  $p_1$  and  $p_2$  is  $\psi(p_1) + \psi(p_2)$ . We also assume that there is no more additional cost once the recognition technology is obtained. That is, the recognition technology can be applied to student-workers without any cost.

**Utility or Profit** The wage of a student-worker is determined through a bargaining process. We will assume that the bargaining process results in an equal sharing of a produced value given that it is positive. That is, the student-worker's wage  $w$  is  $\frac{1}{2}\phi_i$  if (s)he is hired in position  $j = i$  and the university-firm's revenue  $R$  is  $v - w$ . For example, if a student-worker with  $HK_1$  is hired for position 1, then  $w = R = \frac{1}{2}\phi_1$ . If a non-qualified student-worker is hired, then  $w = \frac{1}{2}\phi_i$  and  $R = -D - \frac{1}{2}\phi_i$ . Of course, if a student-worker is not hired,  $w = R = 0$ .

A student-worker's utility  $u$  is the wage (s)he will get minus the cost of human capital investment:

$$u = w - c(t_1 + t_2).$$

The university-firm's profit  $\pi$  is the revenue it generates from admission or hiring minus the cost of investment on the recognition of each human capital. We abuse the notation, and denote  $R$  also as an integrated sum of revenue from all hired student-workers;

$$\pi = R - \psi(p_1) - \psi(p_2).$$

<sup>17</sup> The condition  $\psi'(0) = \psi''(0) = 0$  is not essential. It is just for expositional convenience.

**Time Line** The model follows the time line below:

1. The university-firm and the student-workers simultaneously make investment decisions. While the university-firm decides how much to invest in recognition technologies of each human capital  $p_i$ , the student-workers decide how much time to spend on the acquisition of each human capital  $t_i$ .
2. The student-workers' stochastic acquisition of human capital is realized.
3. The university-firm applies its recognition technologies to all the student-workers.
4. The university-firm makes an admission or hiring decision on each student-worker.

### III. Analysis

We will analyze the model from the back. That is, we first analyze the university-firm's admission-hiring decision. Then we examine the investment decisions of the university-firm and the student-workers.

#### 1. University-Firm's Decision

##### 1.1. Admission-Hiring Decision

In the first stage, the student-workers made investment decisions on  $t_i$  and the university firm on  $p_i$ . Since they are all identical, we restrict our attention to a symmetric equilibrium so that all student-workers made a same decision on  $t_i$ . Let us define  $\gamma_i = f(t_i)$ .

Note that a decision of admitting or hiring a student-worker in one position is totally independent of a decision in the other position. We take the university-firm's decision on each position separately.

Once the recognition technology is applied, a student-worker is either recognized as being equipped with human capital  $HK_i$  or not. If a student-worker is recognized as equipped with the human capital, the university-firm will admit or hire her (or him) in the relevant position since  $R = \frac{1}{2}\phi_i > 0$ .

If a student-worker is not recognized as equipped with the human capital, it is either because (s)he is not equipped with it or because it is not recognized although (s)he is equipped with it. The expected revenue of admitting or hiring one who is not recognized as being equipped with the human capital is

$$-\frac{(1-\gamma_i)}{(1-\gamma_i)+\gamma_i(1-p_i)}\left(D+\frac{1}{2}\phi_i\right)+\frac{\gamma_i(1-p_i)}{(1-\gamma_i)+\gamma_i(1-p_i)}\frac{1}{2}\phi_i. \quad (1)$$

We assume that  $D$  is large enough so that (1) is negative.<sup>18</sup> Then the university-firm will only admit or hire student-workers who are recognized as being equipped with the human capital.

### 1.2. Investment Decisions on Recognition Technology

In the first stage, the university-firm should make investment decisions on recognition technologies for both kinds of human capital. Since the cost of investment is separable, the investment decisions related to each human capital are separately made.

Consider the investment decision on recognition technology for  $HK_i$ . Given student-workers' decisions  $\gamma_i$ , which is a portion of student-workers being equipped with  $HK_i$ , the university-firm's profit from  $HK_i$ ,  $\pi_i$ , is

$$\pi_i = \frac{1}{2}\phi_i\gamma_i p_i - \psi(p_i).$$

A portion of student-workers who are equipped with the human capital and recognized as such by the university-firm is  $\gamma_i p_i$ . They generate the revenue  $\frac{1}{2}\phi_i$ . The optimal  $p_i^*$  that maximizes  $\pi_i$  satisfies the following FOC:

$$\frac{1}{2}\phi_i\gamma_i = \frac{1}{2}\phi_i f(t_i) = \psi'(p_i^*) \quad \text{for } i=1,2. \quad (2)$$

Note that  $p_i^*$  is increasing in  $\gamma_i$ , henceforth in  $t_i$ . That is, as there are more student-workers equipped with  $HK_i$  to be recognized, it is more profitable to increase the possibility of recognizing them.

## 2. Student-Workers' Investment Decision on Human Capital

We turn to the student-workers' investment decision on  $HK_i$ . Given the university-firm's investment decision  $p_i$ , a student-worker's utility is

$$u = \frac{1}{2}\phi_1 p_1 f(t_1) + \frac{1}{2}\phi_2 p_2 f(t_2) - c(t_1 + t_2).$$

The following FOC will characterize the optimal  $t_i^*$ :

$$\frac{1}{2}\phi_i p_i f'(t_i^*) \leq c'(t_1^* + t_2^*) \quad \text{and equality holds if } t_i^* > 0 \quad \text{for } i=1,2. \quad (3)$$

<sup>18</sup> For the specific condition, see footnote 19.

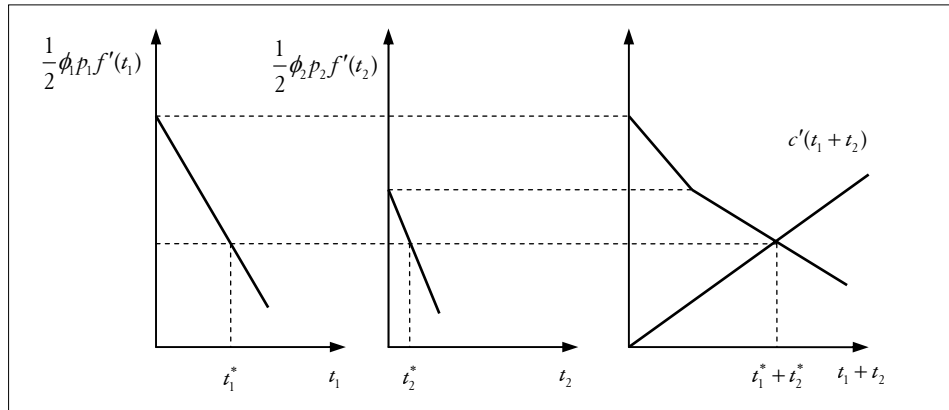
Student-workers will invest until the marginal benefit of investment is equal to the marginal cost. If the marginal cost is larger than the marginal benefit, no investment will incur. If the optimal investment is interior, the student-workers will allocate their time investment so that the marginal benefit from each human capital investment is the same with each other and the same as the marginal cost:

$$\frac{1}{2}\phi_1 p_1 f'(t_1^*) = \frac{1}{2}\phi_2 p_2 f'(t_2^*) = c'(t_1^* + t_2^*).$$

Figure 3 graphically shows a student-worker's optimal time allocation. Given the university-firm's recognition technology  $p_i$ 's, a student-worker will first invest in human capital with a greater marginal benefit, in this case  $HK_1$ . Once the marginal benefit of the investment for each human capital is the same, the additional time investment would be divided for both kinds of human capital until those marginal benefits are equal to the marginal cost of investment. At the optimum, therefore, the marginal benefits of the investment for both kinds of human capital are the same and they are equal to the marginal cost of investment.<sup>19</sup>

Suppose that  $p_1$ , the university-firm's investment in recognition technology for  $HK_1$ , increases. This will increase the marginal benefit for the student-workers' investment in  $HK_1$ , and hence  $t_1$  will increase. Also, this increase in  $t_1$  will increase the marginal cost and crowd out the investment for  $HK_2$ .

[Figure 3] Optimal Time Allocation for  $HK_1$  and  $HK_2$



<sup>19</sup> The maximum incentive to invest in  $HK_i$  is obtained when  $p_i = 1$  and  $t_j = 0$ . In that case, the maximum investment  $\bar{t}_i$  is obtained by

$$\frac{1}{2}\phi_i f'(\bar{t}_i) = c'(\bar{t}_i).$$

If we let  $\bar{\gamma}_i = f'(\bar{t}_i)$ , in any equilibrium  $\gamma_i < \bar{\gamma}_i$ . The expression (1) is largest when  $\gamma_i$  is large and  $p_i$  is small. Therefore, if  $D \geq \frac{\bar{\gamma}_i - 1}{1 - \bar{\gamma}_i} \phi_i - \frac{1}{2} \phi_i = \frac{2\bar{\gamma}_i - 1}{1 - \bar{\gamma}_i} \frac{1}{2} \phi_i$ , (1) is negative for any possible  $\gamma_i$  and  $p_i$ .

We should note that there exists a complementarity between student-worker's investment and the university-firm's. The more university-firm invests in  $p_i$ , the more incentive student-workers will have to invest in  $HK_i$ , and vice versa. This raises a possibility that there can be multiple equilibria including both low investment coordination and high investment coordination. Moreover, it is also possible that they coordinate in equilibria emphasizing either  $HK_1$  or  $HK_2$  even with the same environment, which we will investigate in the next section.

### 3. Equilibrium

The equilibrium of the model is a combination of the university-firm's decision and student-workers' decisions which are consistent with each other. Therefore, the following equilibrium characterization results.

**Proposition 1** *An equilibrium is a pair  $((p_i^*)_{i=1}^2, (t_i^*)_{i=1}^2)$  which satisfies (2) and (3).*

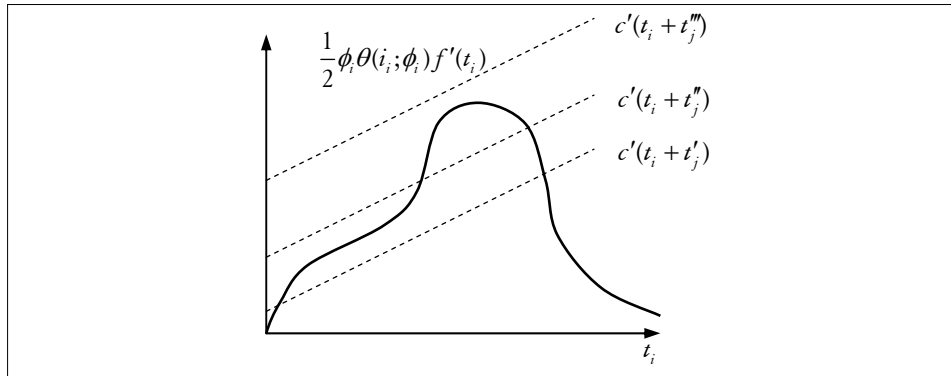
To get a better grasp of the equilibrium characterization, we will focus on an equilibrium description involving  $t_1$  and  $t_2$  only. From (2), we define a function  $\theta$  which gives the optimal  $p_i^*$  given  $t_i$ .

$$p_i^* = (\psi')^{-1} \left( \frac{1}{2} \phi_i f(t_i) \right) \equiv \theta(t_i; \phi_i) \quad (4)$$

Function  $\theta$  is an increasing function of  $t_i$  and  $\phi_i$  since  $\psi'$  is increasing, and it is 0 when  $t_i = 0$ . If we plug (4) in (3), we get

$$\frac{1}{2} \phi_i \theta(t_i^*; \phi_i) f'(t_i^*) \leq c'(t_1^* + t_2^*) \text{ and equality holds if } t_i^* > 0 \text{ for } i=1,2. \quad (5)$$

[Figure 4] Equilibrium  $t_i$  when  $t_j$  is given



Then, an equilibrium is  $(t_i^*)_{i=1}^2$  satisfying (5).

**Corollary 1** *The equilibrium is  $(t_i^*)_{i=1}^2$  satisfying (5).*

Figure 4 shows the determination of  $t_i$  with given  $t_j$  according to (5). Expression  $\frac{1}{2}\phi_i\theta(t_i;\phi_i)f'(t_i)$  is 0 when  $t_i=0$  since  $\theta(0)=0$  and  $f'(0)$  is finite, and approaches 0 as  $t_i \rightarrow \infty$  since  $\lim_{t_i \rightarrow \infty} f'(t_i)=0$  and  $\theta(t_i)$  is finite. It can have any shape in the middle; it will increase when the effect of increasing  $\theta$  is dominant and decreases when the effect of decreasing  $f'$  is dominant. Expression  $c'(t_i+t_j)$  is increasing in  $t_i$  given  $t_j$ . An intersection of the two graphs will give  $t_i$  satisfying (5) when  $t_j$  is fixed.

We can point out the following four things about the determination of  $t_i$ .<sup>20</sup> First,  $t_i=0$  always satisfies the condition whatever  $t_j$  is. The graph of  $c'$  is always (weakly) above the graph of  $\frac{1}{2}\phi_i\theta(t_i;\phi_i)f'(t_i)$  when  $t_i=0$  (they are the same when  $t_j=0$  as  $c'(0)=0$ ). This will satisfy the inequality of (5). If student-workers do not invest in  $HK_i$ , the university-firm has no incentive to invest in the recognition technology for that human capital. If the university-firm does not recognize the human capital, student-workers would not invest in that human capital. Therefore, zero investment in  $HK_i$  always satisfies (5).

Second, we can have multiple intersections. As explained before, there exists a complementarity between the university-firm's investment and student-workers' investment. It is possible that they can coordinate in a lower investment level as they expect a low investment from each other. It is also possible that they expect a higher investment from each other and coordinate in a higher investment level.

Third, when there are multiple intersections, they are Pareto ranked. If student-workers invest more in  $HK_i$ , the university-firm will be better off even with the same investment in the recognition technology. Since the university-firm optimizes its investment level at these intersections, the university-firm would be better off with a higher coordination. Likewise, student-workers would be better off in a higher investment coordination.

Fourth, there exists at least one stable intersection in the following sense.

**Definition 2** *An intersection  $t_i$  is (locally) stable if there exists  $\delta > 0$  such that for all positive  $t^0$  satisfying  $|t^0 - t_i| < \delta$*

$$(t^0 - t_i) \left[ \frac{1}{2}\phi_i\theta(t^0;\phi_i)f'(t^0) - c'(t^0 + t_j) \right] < 0.$$

We can say  $t_i$  is (locally) stable if an investment level tends to increase

<sup>20</sup> Intersections in Fig 4 are not equilibrium yet, since it only satisfies one equation in (5).

(decrease) when it is slightly lower (higher) than  $t_i$ . Student-workers will increase an investment at  $t^0$  if the marginal benefit is greater than the marginal cost, and decrease an investment otherwise. The above definition states that  $t_i$  is stable if the marginal benefit is greater (smaller) than the marginal cost when the investment level is lower (higher) than  $t_i$ . According to it, the intersections are stable if the graph of  $\frac{1}{2}\phi_i\theta(t_i;\phi_i)f'(t_i)$  cuts that of  $c'(t_i+t_j)$  from the above as  $t_i$  increases. When student-workers invest slightly more on  $HK_i$ , this will increase an investment in the university-firm's side. This in turn will provide more investment incentive for student-workers. On the other hand,  $f'$  decreases and  $c'$  increases, which will reduce an incentive of investment. If the former dominates the latter, then student-workers will increase an investment more and the intersection is not stable. Note that  $t_i=0$  is stable once  $t_j>0$  and may or may not be stable when  $t_j=0$  depending on whether the graph of  $\frac{1}{2}\phi_i\theta(t_i;\phi_i)f'(t_i)$  is above that of  $c'(t_i+t_j)$  near  $t_i=0$ . If  $t_i=0$  is not stable when  $t_j=0$  (i.e., the graph of  $\frac{1}{2}\phi_i\theta(t_i;\phi_i)f'(t_i)$  is above that of  $c'(t_i+t_j)$  near  $t_i=0$ ), then the graph of  $\frac{1}{2}\phi_i\theta(t_i;\phi_i)f'(t_i)$  should cut through that of  $c'(t_i+t_j)$  from the above at some point since the former eventually goes to 0. Therefore, a stable intersection exists. Henceforth, we restrict our attention to the stable intersections.

Now we can define a relationship between investment levels in two kinds of human capital from Figure 4. That is, when  $t_j$  is given, we can find a stable intersection defining  $t_i$ . Let  $\varphi_i$  define the relationship. By abusing the notation, we write

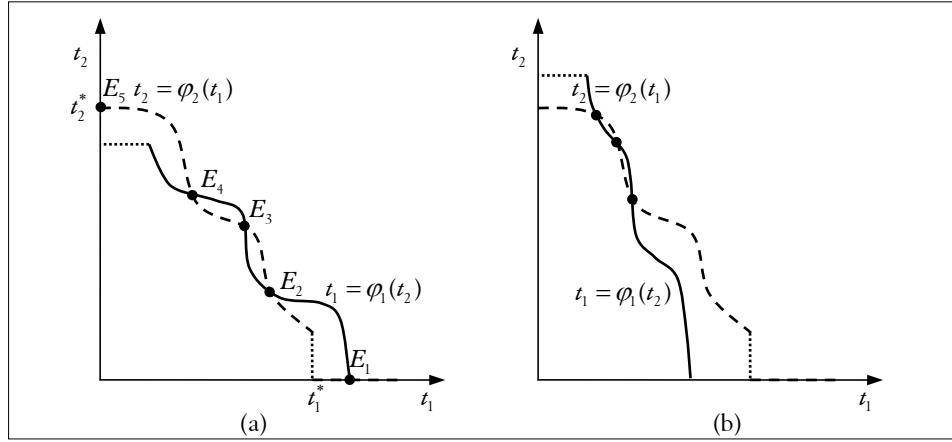
$$t_i \in \varphi_i(t_j) \text{ for } i=1,2 \quad (6)$$

where  $t_i$  is a stable intersection in Figure 4 given  $t_j$ . The pairs  $(t_1, t_2)$  satisfying (6) will comprise a stable subset of equilibria. Note that  $\varphi_i$  is a correspondence as there can be many stable intersections for a given  $t_j$ .

In the figure, we can see that for any stable intersections, the investment in  $HK_i$  decreases as the investment in  $HK_j$  increases. If  $t_j$  increases from  $t'_j$  to  $t''_j$ , the graph of  $c'$  moves up and the intersection  $t_i$  would decrease in any stable intersections. If the investment in the other kind of human capital increases, this will increase the marginal cost of time investment. Therefore, the investment for  $HK_i$  will decrease. Since this will trigger a decrease in the university-firm's investment,  $t_i$  will decrease further. If  $t_j$  increases further to  $t'''_j$ , then no investment will be made in  $HK_i$ .

Figure 5 shows  $\varphi_1$ ,  $\varphi_2$ , and their intersections, which are stable equilibria in the sense of Definition 2. For expositional convenience, we ignore  $t_i=0$  when there are other stable intersections. We consider a case in which there is at most one stable intersection other than 0 as is the case in Figure 4. Then  $\varphi_i$  can be treated as a function. The intuition we get from the figure can be extended to a general case.

[Figure 5] Student-workers' equilibrium time allocation



The graph  $\varphi_i$  is decreasing as explained and it is not continuous. Consider  $\varphi_1$  for example (solid graph in the figure). It starts from a positive level at  $t_2 = 0$  and decreases as  $t_2$  increases. Once  $t_2$  goes over a certain level, then  $\varphi_1$  jumps to 0.

An equilibrium exists as there exists an intersection of two curves even though two curves are not continuous. As in panel (a), if  $\varphi_1$  starts from over  $t_1^*$  when  $t_2 = 0$ , there exists an intersection with  $t_2 = 0$ . If  $\varphi_1$  starts from under  $t_1^*$  and lies below  $\varphi_2$ , then  $\varphi_1$  would end up below  $t_2^*$  and there should be an intersection with  $t_1 = 0$ . If  $\varphi_1$  starts from under  $t_1^*$  and end up over  $t_2^*$ , then  $\varphi_1$  should cross  $\varphi_2$  as in panel (b). Therefore, an equilibrium exists. For later use, note also that  $\varphi_1$  cuts  $\varphi_2$  from below at least once as  $t_2$  increases in all cases.

We can discuss another aspect of stability of an equilibrium. Even though an equilibrium is already stable one by the standard of Definition 2, we can add another definition of stability to an equilibrium in Figure 5.

**Definition 3** Suppose there exists an equilibrium  $E$ . We denote  $t_1^{n+1} \equiv \varphi_1(t_2^n)$  and  $t_2^{n+1} \equiv \varphi_2(t_1^n)$  in the neighborhood of  $E$ . An equilibrium  $E$  is (locally) stable if there exists  $\delta > 0$  such that  $\lim_{n \rightarrow \infty} (t_1^n, t_2^n) = E$  for all  $(t_1^0, t_2^0) \in \mathbb{R}_+^2$  such that  $\|(t_1^0, t_2^0) - E\| < \delta$ .

Definition 3 is a usual definition of stability that a system returns to the original equilibrium after small disturbances. According to this, an equilibrium is stable if  $\varphi_1$  cuts  $\varphi_2$  from below as  $t_2$  increases. Suppose the university-firm increases the recognition of  $HK_1$ . Then student-workers increase an investment in  $HK_1$  and reduce their time for  $HK_2$ . This will lead to a lower recognition of  $HK_2$  and student-workers further reduce an investment in  $HK_2$  and increase that in  $HK_1$ . The increase in the investment for  $HK_1$  may or may not be large enough to justify the supposed increase in recognition of  $HK_1$ . If it is large enough, then this will



further increase the recognition of  $HK_1$  and the equilibrium is not stable. If it is not, then the increased recognition of  $HK_1$  will roll back to the original level and the equilibrium is stable.

A stable equilibrium by Definition 3 exists as we already argued above that  $\varphi_1$  cuts  $\varphi_2$  from below at least once as  $t_2$  increases. We will restrict our attention to stable equilibria in the following discussion and comparative statics.

**Proposition 2** *A stable equilibrium satisfying (6) and Definition 3 exists.*

As illustrated in panel (a) of Figure 5, there can be many equilibria. According to Definition 3,  $E_1$ ,  $E_3$ , and  $E_5$  are stable while  $E_2$  and  $E_4$  are not. Even if we restrict our attention to stable equilibria only, we still have multiple equilibria in the figure. In these equilibria, we can say there exists a trade-off between two kinds of human capital. The marginal cost of time investment is dependent on the time spent on the other type of human capital. Moreover, there exists a complementarity between student-workers' investment and the university-firm's investment. Therefore, a higher investment and recognition coordination in  $HK_1$  will lead to a lower investment and recognition coordination in  $HK_2$ . That is, if there is more emphasis on evaluation and development of one kind of human capital, the other kind of human capital is relatively ignored. In extreme equilibria like  $E_1$  and  $E_5$ , we may have no investment at all in one kind of human capital.

**Proposition 3** *Given economic environment  $(\phi_1, \phi_2, \psi, f, c)$ , we can have multiple stable equilibria. In these equilibria, we have a trade-off in evaluation and development between  $HK_1$  and  $HK_2$ . If one equilibrium has more recognition and development of  $HK_1$  than the other, it will have less recognition and development of  $HK_2$ .*

In particular, equilibria like  $E_1$  and  $E_3$  can coexist under the same economic environment. In  $E_1$ , all the emphasis goes to cognitive skills as in East Asian countries. In  $E_3$ , cognitive and non-cognitive skills receive a similar emphasis as in the U.S. In East Asian countries, universities do not pay much attention to the recognition of non-cognitive skills ( $p_2 = 0$ ) as students do not invest much in the development of these skills ( $t_2 = 0$ ). Since universities do not recognize these skills, students do not have an incentive to invest in these skills. As a result, we observe admission standards centered on cognitive skills and students spending more time on academic activities. On the contrary, in the U.S., universities pay attention to non-cognitive skills as well as cognitive skills (positive  $p_1$  and  $p_2$ ). Students spend some of their time developing non-cognitive skills (positive  $t_1$  and  $t_2$ ). As students invest some time in non-cognitive skills, universities also pay attention to recognizing them.

#### 4. Comparative Statics

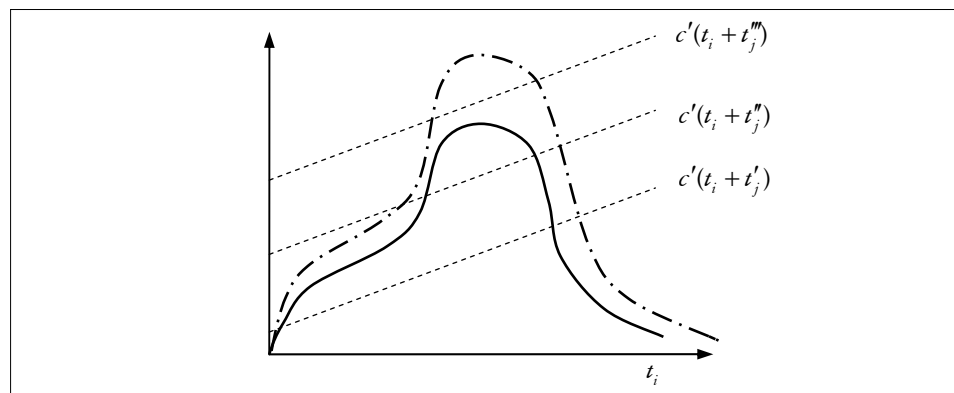
In this section, we discuss an effect of a change in the economic environment on equilibria. We especially focus on two parameters. We first discuss an effect of a change in the productivity of human capital  $\phi_i$ . In the main analysis, we assumed that the costs of the recognition technologies are the same. We relax this assumption and discuss an effect of cost differences.

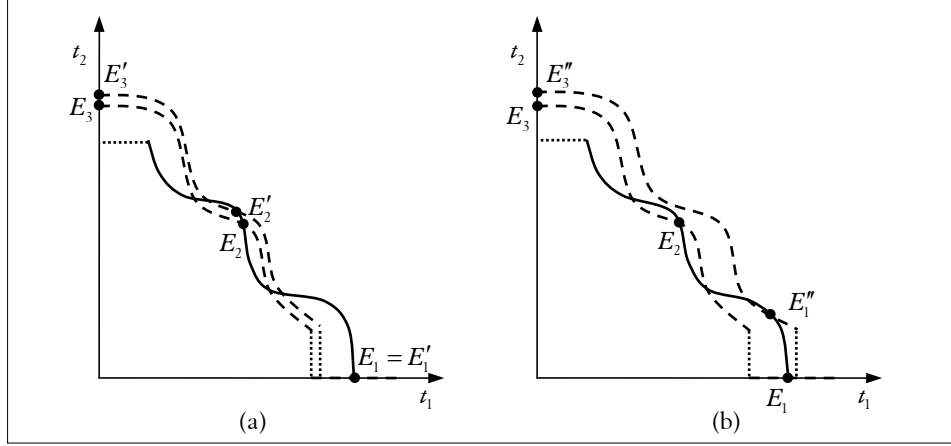
##### 4.1. Change in $\phi_i$

Suppose that there is an increase in  $\phi_2$ , i.e., non-cognitive skills become more important in the economy. In equation (5), this will directly increase the LHS since it will increase the payoff when admitted (or employed). Also it will indirectly increase the LHS since the university-firm will have more incentive to invest in the recognition technology, or  $\theta(t_2; \phi_2)$  increases. The resulting change in  $\phi_2$  can be recognized in Figure 6.

As is clear in the figure, when the term  $\frac{1}{2}\phi_2\theta(t_2; \phi_2)f'(t_2)$  increases,  $t_2$  of any stable intersection will increase. Therefore,  $\phi_2$  will increase given  $t_1$  as in Figure 7. As the graph of  $\phi_2$  moves upward, all the stable equilibria show an (weak) increase in  $t_2$  and a (weak) decrease in  $t_1$ . Note that we can still have an extreme equilibrium  $E_1$  as panel (a) shows. That is, even if the productivity of  $HK_2$  is larger than that of  $HK_1$  and the difference increases, it is possible that an economy remains in the equilibrium in which only  $HK_1$  matters. If the productivity of  $HK_2$  increases further enough, then the extreme equilibrium  $E_1$  will disappear and we may observe some emphasis on  $HK_2$  as  $E_1''$  in panel (b). Of course, if we increase  $\phi_2$  further enough, then the unique equilibrium will be like  $E_3$ , that is, only  $HK_2$  matters in the economy.

[Figure 6] The effect of increase in  $\phi_i$  on the shape of  $\phi_i$



[Figure 7] The effect of increase in  $\phi_2$  on equilibria

This analysis sheds some light on a change in East Asian countries in the future. Even if non-cognitive skills become more important, it may not be easy to move away from the present arrangement. Suppose some of universities start changing their admission practices. This may not affect students' behavior since a portion of changed universities might be small. Even if it does change students' behavior, it will take time and these universities should endure disadvantages in the meantime.

#### 4.2. Change in an Investment Cost in Recognition Technology

We turn to an effect of a change in the recognition cost. In the main analysis, we assumed that the costs of investment in the recognition technologies are the same. However, one type of human capital may be harder to recognize than the other. For example, while  $HK_1$  is relatively easier to recognize through various kinds of tests,  $HK_2$  is hardly measured directly and is usually evaluated through circumstantial evidence such as a participation in activities which are deemed to increase  $HK_2$ . Here we assume that recognition technologies require different costs of investment,  $\psi_1$  and  $\psi_2$ .

Suppose that  $HK_2$  becomes easier to recognize. That is,  $\psi_2$  decreases for any  $p_2$ . This will increase the LHS of equation (5). Therefore it will have qualitatively the same effect as an increase in  $\phi_2$  analyzed before. For any stable equilibria,  $t_2$  (weakly) increases and  $t_1$  (weakly) decreases.

Differences in the recognition technology in two kinds of human capital might be the main reason why we have the present arrangement in East Asian countries. It might have been much easier to observe and verify the accumulation of cognitive skills. Then paying attention to cognitive skills only might have been a unique equilibrium. It is possible, however, that they remain in that equilibrium even though recognition of non-cognitive skills becomes cheaper.

## 5. Welfare Analysis - An Illustration

When we have multiple equilibria which possibly represent different social arrangements in East Asia and the U.S., we are naturally interested in the Pareto ranking of these equilibria. The question is which arrangement will utilize human resources better with a given productivity of each skill.

If we jump to the answer, there is no generally-held Pareto ranking among equilibria. This will be illustrated in this section. We will compare the equilibrium with exclusive emphasis on  $HK_1$  with the one with similar emphasis on both skills. If emphasis is exclusively put on one skill, the complementarity between the student-workers' investment and the university-firm's recognition will be fully exploited. However, this exploitation of complementarity comes with decreasing returns to investment. If the benefit of exploiting complementarity is larger than the cost of decreasing returns, the equilibrium with exclusive emphasis on one skill will yield a better outcome. Otherwise, the equilibrium with similar emphasis on both skills will be better.

Let us consider the social planner's problem. We maintain the constraint that both student-workers investment and the university-firm's recognition are necessary for  $HK_i$  to contribute to the outcome of the economy. Then the economy's welfare  $W$  can be written as

$$W = \sum_{i=1}^2 [\phi_i f(t_i) p_i - \psi(p_i)] - c(t_1 + t_2). \quad (7)$$

The social planner will choose  $(t_i, p_i)_{i=1}^2$  to maximize  $W$ .

This is not a well-defined concave programming problem, and the first order condition does not characterize the optimum. If we fix  $t_i$ 's, however, an optimal  $p_i^o$  is determined by the first order condition.

$$\phi_i f(t_i) = \psi'(p_i^o) \quad \text{for } i=1,2$$

This is similar to the university-firm's optimal decision (2) except that we have the entire value of  $\phi_i$  as benefit rather than  $\frac{1}{2}\phi_i$ . We can use the  $\theta$  function defined in (4) to express  $p_i^o$  in terms of  $t_i$ ;  $p_i^o = \theta(t_i; 2\phi_i)$ . If we plug this back into (7), the social planner's problem is to choose  $(t_i)_{i=1}^2$  to maximize

$$W = \sum_{i=1}^2 [\phi_i f(t_i) \theta(t_i; 2\phi_i) - \psi(\theta(t_i; 2\phi_i))] - c(t_1 + t_2).$$

The marginal benefit of increasing  $t_i$  can be defined as

$$\begin{aligned}
 MB_{t_i} &\equiv \frac{d}{dt_i} \{ \phi_i f(t_i) \theta(t_i; 2\phi_i) - \psi(\theta(t_i; 2\phi_i)) \} \\
 &= \phi_i f'(t_i) \theta(t_i; 2\phi_i).
 \end{aligned}$$

Note that an indirect effect through the change of  $\theta(t_i; 2\phi_i)$  will be 0 as  $p_i^o$  is optimally chosen given  $t_i$ .

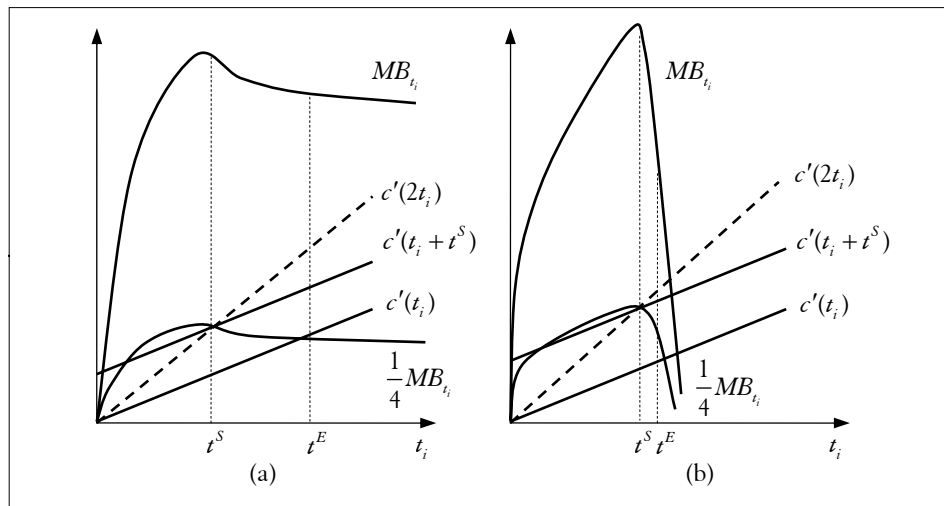
Since our purpose is to illustrate that the equilibria are not generally Pareto ranked, we consider a symmetric case for simplicity,  $\phi_1 = \phi_2$ . We will compare the welfare between the extreme equilibrium with  $t_2 = 0$  and the symmetric one with  $t_1 = t_2$ . We further assume, for expositional convenience, that  $c'$  and  $\psi'$  are linear. Then

$$MB_{t_i} = 4 \left\{ \frac{1}{2} \phi_i f'(t_i) \theta(t_i; \phi_i) \right\}$$

as  $\theta(t_i; 2\phi_i) = 2\theta(t_i; \phi_i)$ . Note that  $\frac{1}{4}MB_{t_i}$  is the same as the LHS of equilibrium condition (5). In a symmetric equilibrium, as  $t_i = t_2 = t^S$ , an equilibrium is achieved when  $\frac{1}{4}MB_t = c'(2t^S)$ . In an extreme equilibrium where  $t_1 = t^E$ , an equilibrium is achieved when  $\frac{1}{4}MB_t = c'(t^E)$ .

Fig 8 shows the determination of two types of equilibria and their welfare comparison. Two types of equilibria are the same in that  $t^S$  amount of time is initially invested on  $HK_1$ . A difference is made in the type of human capital the additional time is invested on. In an extreme equilibrium, additional time  $t^E - t^S$  will be invested further on  $HK_1$ . In a symmetric equilibrium, additional time  $t^S$

[Figure 8] Welfare Comparison - Extreme Equilibrium and Symmetric Equilibrium



will be invested on  $HK_2$ .

Welfare differences of two types of equilibrium come from differences in benefit and cost brought by this additional time investment. If it takes a high initial investment to build up the benefit of complementarity and the benefit does not diminish quickly as in panel (a), welfare gains of this additional time investment is larger in an extreme equilibrium. In the figure, the area under  $MB_t$  and above  $c'(t)$  over  $[t^S, t^E]$  is larger than that under  $MB_t$  and above  $c'(t+t^S)$  over  $[0, t^S]$ . If the benefit of complementarity is quickly built up but diminishes quickly as in panel (b), a symmetric equilibrium will bring a larger welfare gain.

It is illustrated that there will be no generally-held Pareto ranking among equilibria. While the extreme equilibrium exploits the complementarity between the students' and the university-firm's investments, the symmetric equilibrium can enjoy higher returns to investment. Which is Pareto better depends on the relative size of two benefits. Therefore, we cannot a priori tell whether U.S. or East Asian societies have a better arrangement for the utilization of human resources.

## IV. Discussion

### 1. Why Does Each Society End Up in the Present Equilibrium?

Models of multiple equilibria can explain how different arrangements can be maintained as economic fundamentals become similar, but do not offer an explanation why a certain equilibrium is chosen for each society. This paper is no exception. In this section, we will propose some possible historic origins which may help to explain how the current arrangement is reached.

In East Asian societies, it is a very long tradition to select an elite group through an examination testing cognitive skills only. Appointment as a public official is an important route to joining the ruling elite, and these public officials are selected through such an exam. In China, the "imperial examination" started in Sui dynasty (589-618) and lasted for 1,300 years until 1905 (Miyazaki, 1976). The modern examination system for hiring civil servants is believed to indirectly evolve from the imperial exam. This also affected surrounding countries. For example, in Korea, the *gwageo*, a similar national civil service exam, first started in 788 and continued until 1894 (Lee, 1981). It is also believed that a modern day civil service exam originated from this. Such a long tradition of selection based on an exam could have affected the modern way of human capital evaluation.

In the U.S., it seems that a cultural and educational ideal of elite Protestants played an important role in the current shape of admissions process.<sup>21</sup> The WASP

<sup>21</sup> Current discussions on the U.S. are heavily indebted to Karabel (2005).

(White Anglo-Saxon Protestant) upper class, which was a leading group in the late 19th century, emphasized other conditions as well as an intellectual development for a desirable human. Aims of elite boarding schools, which were major suppliers of students to leading private universities, were to “cultivate manly Christian character, having regard to moral and physical as well as intellectual development...” Though the passing of an entrance exam was the only requirement for an admission to elite universities at that time, it seems that other characters were taken for granted through the secondary education. The Rhodes scholarships, the oldest international educational fellowships which started in 1902 and are still in action, explicitly show this ideal in its four selection criteria: scholastic attainments, energy shown in sports activity, character, and morality.<sup>22</sup>

As secondary education expanded in 1920s, elite universities started to restrict the size of freshmen class - birth of selective admissions. Rather than increasing academic standards of entrance exams, they chose to turn to the cultural and educational ideal of elite Protestants, which was embodied in the Rhodes criteria.<sup>23</sup> Subjective criteria such as character came to play an important role in admissions. While the relative importance of objective academic criterion and subjective personal one may have been changing since, the basic structure of admissions standards has been maintained.

## 2. Empirical Implications

### 2.1. Effects of Cognitive and Non-cognitive Skills on Labor Market Outcome

Our model suggests that effects of cognitive and non-cognitive skills on labor market outcomes may vary among countries. Some countries emphasize cognitive skills more than others. If cognitive skill is more emphasized, the effect of cognitive skill (non-cognitive skill) on labor market outcomes will be bigger (smaller) as it is more (less) often recognized. According to the model, different emphasis can be captured by the allocated time for each skill. Therefore, a country with more time spent on cognitive development would have a larger effect of cognitive skills on labor market outcomes.

There have been some studies showing a positive impact of non-cognitive skills on labor market outcomes. These studies mostly used U.S. data. In East Asian countries, however, as non-cognitive skills are not recognized as well as in the U.S., this effect would be smaller. On the other hand, the effect of cognitive measures on labor market outcomes would be greater in East Asian countries.

<sup>22</sup> Rhodes Brochure at <http://www.rhodesscholar.org/info>.

<sup>23</sup> Karabel (2005) also argues that this change was to restrict the growing Jewish population among freshmen.

## 2.2. Productivity Comparison between the Students with the Same Cognitive Skills

Our model argues that if we compare the students with the same measured cognitive skill, one from the country with more emphasis on non-cognitive skills will be more productive. That is, if we have two students from US and East Asia with the same test score, one from the US tends to be more productive as they are likely to invest more on non-cognitive skill. Also if we can find systematic difference of students' time use among different ethnic groups in one society,<sup>24</sup> one's economic performance would be better with the same academic achievement if he is from the ethnic group with less time spent on studying.

Though this empirical implication can conceptually be tested by comparing the wage levels of workers in the same labor market but educated in different societies or in different ethnic groups, the wage difference may contain the component of discrimination. It remains critical whether we can tease out the component of discrimination.

## V. Conclusion

This paper introduces a model of human capital investment and evaluation with multiple aspects of human capital. When there is an interaction between investment and evaluation, there can be multiple equilibria. Therefore, with the same economic environment, one society emphasizes only one aspect of human capital while other society emphasizes both aspects.

The model can accommodate the discrepancies in university admissions standards between the U.S. and East Asian countries. The model predicts that more time investment in academic activities will go together with more emphasis on academic evaluation, and that even time investment on academic and non-cognitive skill activities with even emphasis on both aspects. This is consistent with what we observe in East Asian countries and the U.S. We cannot a priori tell which arrangement is more efficient to utilize human capital.

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<sup>24</sup> According to a research in Sydney for year 3 pupils, students of Chienese ethnicity spend 1 hour a day on homework while those of Anglo-Australian ethnicity spend 20 minutes ("Chinese student top the tests out of habit, not ethnicity, study shows", The Sydney Morning Herald Dec. 29, 2010).



## Appendix

### Empirical Relationship between a Country's Economic Performance and the Investments in Non-cognitive Skills

In this appendix, we aim to provide empirical relevance of a country's investment in non-cognitive skills for its economic performances. For this purpose, we estimate the following model of economic performance or growth regressions that considers the quality of both cognitive and non-cognitive human capital:

$$y_i = \beta_0 + \beta_1 C_i + \beta_2 NC_i + \beta_3 X_i + u_i$$

where  $y_i$  is a measure of country  $i$ 's economic performance;  $C_i$  is  $i$ 's level of cognitive skills proxied by the average score of an international standardized test;  $NC_i$  is  $i$ 's level of an investment in non-cognitive skills;  $X_i$  is a vector of  $i$ 's observable characteristics; and  $u_i$  is the error term.

In the analysis that follows,  $y_i$  is measured by either a country's contemporary level of output per worker, total factor productivity, or average growth rate of GDP per capita from 1960 to 2000, following conventional models.  $C_i$  is proxied by a country's average math score of an international test and  $NC_i$  by a country's average share of students' daily time devoted to activities related to non-cognitive skills. Depending on the specification,  $X_i$  includes GDP per capita in 1960, years of schooling in 1960 and 1988 and a measure of physical capital stocks in 1988.

Variables used in the regressions are drawn from three separate sources. Information on the average growth rate of GDP per capita from 1960 to 2000, GDP per capita in 1960, and years of schooling in 1960 is extracted from Jamison et al. (2006). The contemporary level of output per worker ( $\log(Y/L)$ ), the total factor productivity ( $\log(TFP)$ ), the capital-output ratio ( $(\alpha/(1-\alpha)) \cdot \log(K/Y)$ ) and years of schooling in 1988 are drawn from Hall and Jones (1999). A country's average math score and average share of daily time on activities related to non-cognitive skills are extracted from the Third International Mathematics and Science Study (TIMSS), 1995, for the 13-year-old students (Population 2) (Gonzalez and Smith, 1997).

To the best of our knowledge, TIMSS 1995 is the only international data source that contains information on both a country's average score of cognitive tests and a share of activities related to non-cognitive skills. Other international data sets such as the Programme for International Student Assessment (PISA) of the OECD and the Progress in International Reading Literacy Study (PIRLS) provide information on a country's average scores of cognitive tests but not a measure of an investment in non-cognitive skills. Based on the answers to a student's daily time use in TIMSS

1995, we classify ‘playing sports’ and ‘playing or talking with friends outside of school’ as activities related to non-cognitive skills. These non-cognitive skill activities exclude miscellaneous activities such as ‘watching TVs and videos’, ‘playing computer games’, and ‘working at a paid job’ as well as academic activities such as ‘studying mathematics or science after school’, ‘taking extra lesson/cramming school in mathematics or science’, etc. In the analysis a share of daily hours spent on the non-cognitive skill activities out of daily total used time is used as a measure of an investment in non-cognitive skills.

[Appendix Table 1] Correlation Coefficients between Variables (N=30)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
(1) Avg growth rate (1960-2000)	1.000						
(2) $\log(Y/L)$	-0.171	1.000					
(3) $\log(\text{Total Factor Productivity})$	0.017	0.861	1.000				
(4) Avg math score/100 in 1995	0.548	0.399	0.302	1.000			
(5) Share of activities related to non-cognitive skills	-0.502	0.620	0.396	-0.063	1.000		
(6) Years of schooling in 1988	-0.276	0.607	0.166	0.341	0.483	1.000	
(7) Capital-output ratio in 1988	-0.445	0.471	0.113	0.095	0.585	0.446	1.000

Appendix Table 1 shows unconditional correlation coefficients between variables for 30 countries that have valid information for subsequent analysis.<sup>25</sup> Two observations are noteworthy. First, the average math score of a country—a measure of the quality of cognitive human capital—has a positive correlation with the average growth rate (0.548),  $\log(Y/L)$  (0.399) and  $\log(TFP)$  (0.302) but it has a negative correlation with the share of activities related to non-cognitive skills (-0.063). Second, the share of activities related to non-cognitive skills has a positive correlation with  $\log(Y/L)$  (0.620) and  $\log(TFP)$  (0.396), while having a negative correlation with the average growth rate (-0.502). As suggested in the paper, a negative correlation between the average math score and the share of non-cognitive skill activities implies that conventional cross-country regressions that control for the quality of cognitive human capital alone are likely to be subject to a negative bias. To avoid such a bias, the regressions need to control also for an investment in non-cognitive skills that increases a country’s economic performance.

Appendix Table 2 presents empirical evidence supporting such possibilities. In column (1), following conventional cross-country regressions,  $\log(Y/L)$  is regressed against measures of the quality of cognitive human capital, the quantity of

<sup>25</sup> These 30 countries are as follows: Australia, Austria, Belgium, Canada, Colombia, Cyprus, Denmark, France, West Germany, Greece, Hong Kong, Hungary, Iceland, Iran, Ireland, Israel, Japan, South Korea, Netherlands, New Zealand, Norway, Portugal, Romania, Singapore, South Africa, Spain, Sweden, Switzerland, Thailand, U.S.A.

general human capital (years of schooling) and the capital-output ratio as defined in Hall and Jones (1999). Such a specification is based on a decomposition of output per worker into educational attainment, the capital-output ratio and total factor productivity suggested in Hall and Jones (1999). The average math score (0.151) is positively associated with  $\log(Y/L)$ , although the estimate is not statistically significant; the years of schooling (0.113) is also positively and statistically significantly associated with  $\log(Y/L)$ ; the capital-output ratio (0.609) is positively associated with  $\log(Y/L)$ , although insignificant. If the share of non-cognitive skill activities is added as in column (2), the degree of association between the average math score and  $\log(Y/L)$  (0.246) becomes about 1.6 times as large. Although the coefficient of the average math score is significant only at the 0.08 level (partly due to a small sample), an increase in the size of the coefficient suggests that there is an omitted variable in the conventional cross-country regression as in column (1). As expected, the estimate for the share of non-cognitive skill activities is significantly positive. A 10 percent increase in the share of non-cognitive activities from the sample mean (i.e., from 0.296 to 0.326) increases a country's output per worker by approximately 9.6 percent.

[Appendix Table 2] Cross-country Regression Results by OLS

Dependent variables:	Mean (S.D.)	log (Y/L)		log (TFP)		Avg growth rate (1960-2000)	
		(1)	(2)	(3)	(4)	(5)	(6)
Avg math score/100 in 1995	5.014 (0.572)	0.151 (0.106)	0.246* (0.135)	0.157* (0.096)	0.168 (0.111)	1.328* (0.169)	1.445* (0.189)
Share of activities related to non-cognitive skills	0.296 (0.076)		3.206* (1.223)		1.791* (0.941)		3.642 (2.415)
Years of schooling in 1988	7.797 (2.315)	0.113* (0.038)	0.073* (0.040)				
Capital-output ratio in 1988	0.471 (0.121)	0.609 (0.796)	-0.272 (0.900)				
GDP per capita in 1960	7891.0 (4358.2)					0.000* (0.000)	0.000* (0.000)
Years of schooling in 1960	6.984 (2.621)					0.013 (0.104)	-0.031 (0.100)
Constant	-	7.897* (0.546)	7.189* (0.717)	7.667* (0.473)	7.085* (0.665)	-2.093* (0.934)	-3.191* (1.139)
R-squared		0.370	0.480	0.040	0.130	0.728	0.744
Sample size		32	32	32	32	28	28

Notes: Standard errors are in parentheses. \* indicates that the estimate is significant at the 0.1 level.

A similar but less dramatic pattern arises if total factor productivity of a country, which is a measure of productivity that is more closely related with a country's

quality of human capital according Hall and Jones (1999), is considered as a dependent variable in columns (3) and (4). When  $\log(TFP)$  is regressed against the average math score alone in column (3), the average math score (0.157) is positively associated with  $\log(TFP)$ , the coefficient being significantly different from zero at the 0.1 level. In column (3), the years of schooling and the capital-output ratio, which are included in columns (1) and (2), are not controlled for because both of them have been already considered in generating  $\log(TFP)$  by Hall and Jones (1999).<sup>26</sup> If the share of non-cognitive skill activities is added as in column (4), the degree of association between the average math score and  $\log(TFP)$  increases to 0.168, which is significantly different from zero at the 0.14 level. Moreover, the estimate for the share of non-cognitive skill activities is significantly positive. Therefore cross-country regressions that control for the quality of cognitive human capital alone but omit an investment in non-cognitive human capital understate the true impact of cognitive human capital on a country's productivity. Activities related to non-cognitive skills positively affect a country's productivity. A 10 percent increase in the share of non-cognitive activities from the sample mean (i.e., from 0.296 to 0.326) increases a country's total factor productivity by approximately 5.4 percent.

Discussing why the U.S. has been showing robust economic performances while it has never done well in international cognitive assessments, Hanushek and Woessmann (2008) propose the following three factors as potential explanations: openness and fluidity of its markets, rapid quantitative expansion of education, and efficient higher education. The finding of the current paper that non-cognitive skills matter a country's productivity adds one more reason why the U.S. is exceptional to their explanations, shedding light on potential determinants of a country's economic performance. Among 32 countries considered in our empirical analysis, the U.S. ranks relatively high at the 12nd place in the share of non-cognitive skill activities while ranking at the 24th in the average math score.

When the average growth rate of per capita GDP between 1960 and 2000 is employed as a dependent variable as in columns (5) and (6), the share of non-cognitive skill activities is also found to have a positive effect, while the estimate is significant at the 0.145 level. As expected, the estimate for the average math score increases as the share of non-cognitive skill activities is added as an explanatory variable, suggesting that the true impact of cognitive skill on growth is likely to be understated if an investment in non-cognitive human capital is omitted. While specifications based on the growth rate of output per capita as in columns (5) and (6) are more popular in the growth literature (Mankiw et al., 1992; Barro and Sala-i-

<sup>26</sup> Including the years of schooling and the capital-output ratio in columns (3) and (4) fails to yield qualitatively different results than those presented in Appendix Table 2. If they are controlled for as explanatory variables, the coefficient of the average math score is 0.131 (s.e. 0.112) for column (3), and 0.223 (s.e. 0.140) for column (4), while insignificant in both specifications.

Martin, 1992), we put more weight on the estimates of columns (2) and (4). The empirical evidence for this paper is likely to be better illustrated by specifications based on the level of the output per worker or the total factor productivity. If the growth rate of the output per worker is used as an outcome variable, it is in general difficult to distinguish the role of capital accumulation from that of productivity enhancement in economic performance. Both cognitive and non-cognitive human capitals, however, are likely to be more closely related with productivity enhancement than with capital accumulation.

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