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Playing to your strength or overcoming your weakness: the role of effort substitutability in skill formation

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Abstract

This paper studies the allocation of a given time budget among a number of skill-building efforts to maximize an overall skill level. The main finding is that as an effort becomes relatively more effective, the time share of the effort should increase and the time shares of the other efforts should decrease (i.e., one should adopt the strategy of playing to your strength) if the elasticity of substitution is larger than one. However, the exact opposite is true (i.e., one should adopt the strategy of overcoming your weakness) if the elasticity of substitution is smaller than one.

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1. Introduction

Playing to your strength or overcoming your weakness? This question frequently arises in situations of skill-building when multiple efforts are needed for skill formation. For example, conducting economic research requires a combination of skills, including literature familiarity within a few fields of economics, technical capability in mathematics and statistics, and intuition about economic behavior and organizations in general.[1] Now suppose it has become much easier to acquaint oneself with the economics literature due to the explosive growth in online journals and ever-improving Internet search engines. How would this technological development alter a graduate economics student's allocation of skill-building time among literature familiarity, technical capability and economic intuition? In particular, should the graduate student spend more time boosting literature familiarity (playing to your strength) or spend more time building up technical capability or economic intuition (overcoming your weakness)?

In the above example about economic research skill building, the effort on literature familiarity becomes more effective because of technological progress. There are other changes in circumstances that may cause a shift in effectiveness of one skill-building effort relative to others, begetting the question of how the skill-building resource allocation should be adjusted. For example, a new immigrant to the U.S. from a non-English-speaking country must adjust his career-building strategy to take into account the sudden drop in language effectiveness in his new environment. He needs to reallocate time and financial resources between two career-building efforts: professional training and English learning. The specific question before him is whether to deepen the comparative advantage by expending more effort on non-language professional skills or to remedy the language deficiency by working harder to improve his English proficiency. Shifts in relative effort effectiveness may also take place simply because each individual has his or her own strengths and weaknesses and these strengths and weaknesses are revealed over time. For example, while some children are found to be more prone to success in academics, others may realize that they are more athletic. Should the parents of a child with a new-found sports aptitude steer the child further towards sports or rather encourage the child to put more effort into academics?

In this paper we study the allocation of a given time budget among a number of skill-building efforts to maximize an overall skill level. In particular, we are interested in how the time shares of these efforts are affected by various parameters of the model that represent technological and personal characteristics. The most interesting result is that as an effort becomes relatively more effective, the time share of the effort increases and the time shares of the other efforts decrease if the elasticity of substitution among the efforts is larger than one, but the time share of the effort decreases and the time shares of the other efforts increase if the elasticity of substitution among the efforts is smaller than one. In other words, substitutable efforts (elasticity of substitution larger than one) facilitate "playing to your strength" while complementary efforts (elasticity of substitution smaller than one) encourage "overcoming your weakness."

This critical role of effort substitutability in skill building is reinforced by another result in the paper which states that, as the substitutability among skill-building efforts becomes higher (lower), the time share of the most efficient effort should increase

[1] Of course, these three skills are not meant to be mutually exclusive or exhaustive.

(decrease) and that of the most inefficient effort should decrease (increase). Again, higher substitutability among skill-building efforts facilitates "playing to your strength," while lower substitutability encourages "overcoming your weakness."

2. The Model and the Results

Assume that an overall skill level is given by the following CES production function

$$S = \left[\sum_{i=1}^{n} \alpha_i \left(\delta_i T_i \right)^{\frac{\theta-1}{\theta}} \right]^{\frac{\theta}{\theta-1}}, \tag{1}$$

where S is the level of a relevant, comprehensive skill,[2] n is the number of skill-building efforts, α_i is the technological coefficient for effort i, δ_i is the effectiveness coefficient for effort i, T_i is the time on effort i, and θ $(1 \neq \theta > 0)$ is the elasticity of substitution among the efforts. Note that α_i and δ_i differ not only in the way they enter the production function but also in that the former is a technological parameter governing the relative importance of an input in the production process while the latter is a parameter representing personal characteristics. $\delta_i T_i$ can be interpreted as the effective time on effort i. Production function (1) is the general form of the CES family which also includes the following technologies as special limiting cases: $\theta = 0$ (Leontief technology), $\theta = 1$ (Cobb-Douglas technology) and $\theta = \infty$ (linear technology).[3]

An individual chooses T_i $(i = 1, \cdots, n)$ to maximize the skill level given by (1), subject to a time constraint $\sum T_i = \bar{T}$, where $\bar{T}$ is an exogenously given total time spent on skill formation. The first order conditions are

$$\frac{\partial S}{\partial T_1} = \cdots = \frac{\partial S}{\partial T_i} = \cdots = \frac{\partial S}{\partial T_n}, \tag{2}$$

which state that when the allocation of time is optimal, a small amount of additional time would produce the same amount of skill regardless of on which effort it is spent. It can be derived from the first order conditions and the time constraint that

$$\frac{T_i}{\bar{T}} = \frac{1}{\sum_{j=1}^{n} \left(\frac{\alpha_i}{\alpha_j} \right)^{-\theta} \left(\frac{\delta_i}{\delta_j} \right)^{1-\theta}}, \qquad i, j = 1, \cdots, n. \tag{3}$$

[2] The analysis in this paper does not require a specification of the appropriate cardinal measurement of the skill. In other words, all the results obtained in this paper still hold as long as the skill level is measured by a monotonic transformation of S. In particular, the production function of (1), which exhibits constant returns to scale, can be easily modified to accommodate decreasing returns to scale, increasing returns to scale or mixed returns to scale without changing the results obtained in the paper. This flexibility is important. For example, Trostel (2004) finds that human capital production displays increasing returns to scale at lower education levels and decreasing returns to scale at higher education levels.

[3] According to Blackorby and Russell (1989), (1) is the general form of production functions with a constant elasticity of substitution when the concept of elasticity of substitution is of the Morishima type.

From (3), the following propositions are readily obtained, each corresponding to a different set of parameters in (3) – α_i / α_j, δ_i / δ_j, or θ.

Proposition 1. *The optimal time share of a skill-building effort ($T_i / \bar{T}$) increases as its technological coefficient relative to those of other efforts (α_i / α_j, $j \neq i$) increases.*

Proposition 2. *When $\theta > 1$, the optimal time share of a skill-building effort ($T_i / \bar{T}$) increases as its effectiveness coefficient relative to those of other efforts (δ_i / δ_j, $j \neq i$) increases; when $\theta < 1$, the optimal time share of a skill-building effort ($T_i / \bar{T}$) decreases as its effectiveness coefficient relative to those of other efforts (δ_i / δ_j, $j \neq i$) increases.*

Proposition 3. *If effort i has the highest combined efficiency in the sense that $\alpha_i \delta_i \geq \alpha_j \delta_j$ for all $j \neq i$ and the strict inequality holds for at least one j, then the optimal time share of effort i ($T_i / \bar{T}$) increases as the elasticity of substitution (θ) increases; if effort i has the lowest combined efficiency in the sense that $\alpha_i \delta_i \leq \alpha_j \delta_j$ for all $j \neq i$ and the strict inequality holds for at least one j, then the optimal time share of effort i ($T_i / \bar{T}$) decreases as the elasticity of substitution (θ) increases.*

Of the three propositions, Proposition 1 is straightforward, while Propositions 2 and 3 are more interesting. Proposition 2 says that the effect of relative effort effectiveness (δ_i / δ_j, $j \neq i$) on an effort's time share ($T_i / \bar{T}$) depends on whether $\theta > 1$ or $\theta < 1$. Specifically, as an effort becomes relatively more effective, the time share of the effort increases and the time shares of the other efforts decrease (playing to your strength) if $\theta > 1$, but the time share of the effort decreases and the time shares of the other efforts increase (overcoming your weakness) if $\theta < 1$. This result can be given the following intuition. When the efforts are more substitutable ($\theta > 1$), focusing on one of the efforts can more or less get the skill level increased, and the effort that becomes more effective should be given more time. On the other hand, when the efforts are less substitutable ($\theta < 1$), all kinds of efforts are pretty much needed to get the skill level increased, and the effort that becomes more effective should be given less time so that all other efforts can catch up.

Proposition 3 says that, as the substitutability among skill-building efforts becomes higher, the time share of the most efficient effort will increase and that of the most inefficient effort will decrease (playing to your strength). Conversely, as the substitutability among skill-building efforts becomes lower, the time share of the most efficient effort will decrease and that of the most inefficient effort will increase (overcoming your weakness). The intuition for Proposition 3 is similar to that for Proposition 2. Note that as long as all efforts are not equally efficient, there must be one or more efforts that can be labeled "most efficient" and one or more efforts that can be labeled "most inefficient." In the case that all efforts are equally efficient in the sense that

$\alpha_1\delta_1 = \cdots = \alpha_n\delta_n$, then θ has no effects on optimal time allocation among efforts. In this case, there is no stand-out strength or weakness and "playing to your strength or overcoming your weakness" becomes irrelevant.

Propositions 2 and 3 reinforce each other in that both imply that higher substitutability among skill-building efforts facilitates "playing to your strength," while lower substitutability encourages "overcoming your weakness."

There have been some empirical investigations into the substitutability/ complementarity among various skills (or skill-building efforts) that contribute to human capital (the overall skill level). For example, Cunha et al. (2010) find strong complementarity, corresponding to $\theta < 1$, between broadly defined cognitive and non-cognitive skills. There is also evidence that refining the classification of contributing skills may turn complementarity into substitutability. For example, Berman et al. (2003) find language proficiency and non-language professional training to be complementary for immigrant workers. On the other hand, after decomposing non-language training into schooling, pre-immigration experience and post-immigration experience, Chiswick and Miller (2003) find that while there is complementarity between language proficiency and both schooling and pre-immigration experience, language proficiency and post-immigration experience are substitutes.

We would like to end this section with a discussion of various factors that may cause changes in the exogenous parameters in the model: relative technological coefficients ($\alpha_i / \alpha_j, \ j \neq i$), relative effectiveness coefficients ($\delta_i / \delta_j, \ j \neq i$) and the elasticity of substitution (θ). Of course, changes in α_i / α_j and θ would be exclusively caused by technological progress. On the other hand, changes in δ_i / δ_j can be both technological and non-technological/personal. For example, the Internet has made it much easier to find information, increasing the relative effectiveness of the effort to acquire information. This is a technology-driven change that is encountered by all individuals. In addition, individual-specific shocks such as a change in one's language environment or a revelation of a previously unknown talent would also cause changes in the effectiveness of one effort relative to others.

3. Conclusion

In many skill-building situations involving multiple efforts, one may be faced with a shift in the relative effectiveness of one of the skill-building efforts. Should the gain in effectiveness of one effort lead to more time allocated to that effort (playing to your strength) or more time allocated to the other, relatively less effective efforts (overcoming your weakness)? The answer to this question, according to the main result obtained in this paper, depends on the substitutability among the efforts. If the elasticity of substitution is larger than one, "playing to your strength" is the optimal response. Otherwise, "overcoming your weakness" is the best strategy.

We conclude by applying this finding to the example of economic research skill building at the beginning of the paper. Economic research requires both ideas and technical skills that implement the ideas. Among the three essential efforts for economic research (i.e., literature familiarity, technical capability and economic intuition), literature familiarity and economic intuition can be regarded as substitutes because both

of them mainly contribute to the creation of ideas, while literature familiarity and technical capability can be regarded as complements because the former mainly contributes to the creation of ideas and the latter mainly contributes to the implementation of ideas. Therefore, "playing to your strength" applies when considering the effect of the increased effectiveness of the literature-familiarizing effort on the time allocated to literature familiarity and economic intuition. In other words, more time on the former and less time on the latter. On the other hand, "overcoming your weakness" applies when considering the effect of the increased effectiveness of the literature-familiarizing effort on the time allocated to literature familiarity and technical capability, leading to less time on literature familiarity and more time on technical capability. Overall, the increased effectiveness of the effort on literature familiarity due to the Internet revolution is likely to induce an optimizing graduate student to spend more time on enhancing technical capability and less time on accumulating economic intuition, with the effect on time spent on literature familiarity determined by the relative magnitudes in the other two adjustments.

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