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Equalizing Superstars: The Internet and the Democratization of Education

Equalizing Superstars: The Internet and the Democratization of Education[†]

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I. Introduction

Educational resources distributed via the Internet are proliferating rapidly. These new resources include lecture videos, online teaching notes, Internet chat groups, online interactive problem sets with instantaneous feedback/grading, educational games, and many other developing technologies. Numerous institutions have created fully autonomous software that grades student essays.[1] In the popular press, MOOCs (massive open online courses) have received the most fanfare, though the social value of these courses is as of yet unproven and the high dropout rates (in excess of 90 percent) have been fodder for much debate.[2]

One technology that promises to be particularly scalable is lecture videos and other online teaching tools. These make the skills of the most effective teachers widely available to students around the world, making lecturing almost "*nonrivalrous.*" One prominent concern, however, is that these sweeping technological changes will be disequalizing—as many of the leading technologies of the last several decades have been—creating winner-take-all "superstar" teachers and a wider gulf between different groups of students.[3] These important concerns notwithstanding, we contend that a major impact of web-based educational technologies will be the democratization of education: educational resources will be more equally distributed, and lower-skill teachers will benefit.

At the root of our results are two observations. First, in the status quo, there is considerable inequality in the distribution of educational resources both within countries and especially between countries. Second, for web-based technologies to exploit the comparative advantage of skilled lecturers, these technologies will need to be complemented with opportunities for face-to-face discussions with instructors.

In the model we use to formalize these ideas, new human capital is generated using the existing human capital of students (arising from prior education or as a family endowment) and various complementary teaching activities (e.g., lecturing, grading, class discussions, one-on-one conversations, etc.). Web-based technologies enable teachers to generate nonrival educational services that can be used as inputs in multiple countries/classrooms simultaneously (e.g., an Internet lecture that can be watched simultaneously in Beijing and Baltimore), but these still need to be complemented with one-on-one instruction provided by local teachers.

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[1] One leader is the edX consortium, which has produced EASE (Enhanced AI Scoring Engine), a "library that allows for machine learning based classification of textual content." See https://readthedocs.org/projects/ease/.

[2] See Perna et al. (2013) for some empirical facts on the first 17 UPenn MOOCs offered; Banerjee and Duflo (2014) provide empirical evidence of certain factors that influence the success of MOOCs.

[3] On superstar phenomena, see Rosen (1981); on the effect of technology on inequality over the last century, see Goldin and Katz (2008); on the effects of the recent wave of computerized and automated technologies on the wage and employment structure, see Acemoglu and Autor (2011); and on the rise of winner-take-all society more generally due to technological, sociological, and institutional reasons, see Frank and Cook (1996).

The ability to create nonrival educational services via the web generates four interrelated consequences.

The first is a two-part "technological windfall" for students: (i) students now have access to lectures of the best ("superstar") global teachers, rather than relying entirely on lectures from local teachers; and (ii) the teacher resources freed from lecturing are reallocated to other, complementary teaching activities. Both of these effects raise the educational attainment of all students in all countries (except the leader country).

The second consequence is a "democratizing effect," which reduces inequality of human capital between students, since gains in educational attainment are disproportionately concentrated at the bottom of the educational attainment gradient.

The third consequence is an expected negative "crowd-out" effect on nonsuperstar teachers, who are dislocated from their lecturing tasks. They instead focus on teaching activities that are not web-based, and due to diminishing returns in these tasks, their marginal product and thus wages are depressed.

The fourth consequence, however, is a "complementarity effect." This offsets the third effect, and may lead to a net positive effect on the salaries of nonsuperstar teachers. Web-based technologies raise the quantity and quality of web-based educational inputs that are complementary for local teachers, thereby raising these local teachers' marginal product and earnings.

A priori either the third or fourth effect could dominate. We show that the positive complementarity effect dominates for teachers with sufficiently low levels of human capital, while the crowd-out effect dominates for teachers with sufficiently high (but nonsuperstar) levels of human capital. In particular, teachers with skill levels below a critical threshold see their earnings increase.

To aid exposition, we refer to two human capital production regimes: the pre- and post-Internet regimes.

A. *Pre-Internet Allocation*

The world consists of N islands (e.g., countries), each inhabited by a continuum $s > 0$ of students and a continuum 1 of teachers. Without loss of generality, we normalize $s = 1$.

We study the impact of technology in enabling cross-island application of teachers' knowledge and skills. We assume that the human capital of all students before they enter formal schooling is the same within an island, and in each country j we denote this endowment by e_j. We also assume that the human capital of all teachers within an island is the same, given by h_j on island j. All teachers in the world have one unit of time.

The post-schooling human capital of students on island j, which we refer to as educational attainment, is also equal to their labor earnings, and is given by

$$(1) \qquad y_j = e_j^{1-\alpha} X_j^{\alpha},$$

where $\alpha \in (0, 1)$ and X_j is an aggregator of the teaching services supplied on island j. Specifically, we assume a Cobb-Douglas (unit elasticity) aggregator of the form

$$\ln X_j = \int_0^1 \ln x_j(i) \, di,$$

where $x_j(i)$ is the amount of teaching task i available to students on island j.

The resource constraint for the skills and time of teachers on island j implies

$$\int_0^1 x_j(i) \, di = h_j.$$

The total supply of skills on island j is h_j (the skill level of teachers multiplied by their unit time endowment) and this can be allocated in any way across the different teaching tasks.

We assume that all services and teaching tasks are competitively priced, and teachers choose the allocation of their time and skills to these tasks given market prices. Since there are no externalities, this allocation can be alternatively computed as the solution to the maximization problem of an island-level social planner maximizing average (or total) post-schooling human capital on the island.

In view of the concavity of the production function (1) in $x_j(i)$, this allocation will involve

$$x_j(i) = h_j,$$

giving a post-schooling human capital of

$$y_j = e_j^{1-\alpha} h_j^{\alpha},$$

or, in logs,

$$(2) \qquad \ln y_j = (1 - \alpha) \ln e_j + \alpha \ln h_j.$$

In what follows, we assume that there is perfect rank correlation between e_j and h_j, meaning that $e_j > e_k$ implies $h_j > h_k$ for all j, k. Intuitively, islands that have higher human capital students also have higher human capital teachers.[4] Then, from (2), the cross-island distribution of post-schooling human capital is more unequal than in the hypothetical case, in which all islands have access to the same quality teachers.

We can also determine the incomes of teachers on different islands. These are given by the marginal contribution of teachers to student labor earnings (in a competitive equilibrium) times the supply of teaching skills. This can be written

$$(3) \qquad w_j \; = \; \frac{\partial y_j}{\partial h_j} \, h_j \; = \; \alpha e_j^{1-\alpha} \, h_j^{\alpha-1} \, h_j$$

$$= \; \alpha \, e_j^{1-\alpha} \, h_j^{\alpha}.$$

From now on, we rank the islands in descending order of teacher skills, so that island 1 has the teachers with the highest value of h_j.

B. *Post-Internet: Student Attainment*

To operationalize the introduction of web-based technologies, we imagine a technological change that enables a teaching task to be performed by a single teacher and then broadcast to the rest of the world. Only some teaching tasks have this special nonrivalrous property, specifically those indexed from $[0, \beta]$ for some $\beta < 1$. We use the term "lecturing" for those tasks that can be scaled to an arbitrary number of students at essentially zero marginal cost (e.g., creating video lectures or writing problem sets). We refer to the remaining tasks in the set, with mass $(\beta, 1]$, as "hands-on instruction" (e.g., small group interactions), which need to be performed by teachers on the same island as their students. For simplicity, we assume that each lecturing task uses exactly one unit of teacher time.

Given this new technology, lecturing tasks are performed by teachers on island 1, and thus students in each island $j = 1, \dots, N$ have access to

$$x_j'(i) = h_1 \text{ for all } i \in [0, \beta] \text{ and } j = 1, \dots, N,$$

where throughout we use variables with a prime (e.g., x') to denote post-Internet values. In view of this, and the resource constraint on island 1, the post-schooling human capital of students on island 1 does not change. In particular, the fraction β of teachers will now be working in lecturing tasks that are being broadcast to the rest of the world while the remaining $1 - \beta$ fraction of teachers work in hands-on instruction.

On other islands, however, the post-schooling levels of human capital will change for two reasons. First, the students have access to the higher quality lectures from "superstar" teachers on island 1. Second, the teachers on islands $j = 2, \dots, N$ can now focus on instruction, so instruction tasks are more abundantly supplied.

It follows that the post-schooling human capital of students on island $j = 2, \dots, N$ is given by

$$y_j' \; = \; e_j^{1-\alpha} \, h_1^{\alpha\beta} \left(\frac{h_j}{1 - \beta} \right)^{\alpha(1-\beta)},$$

or, in logs,

$$(4) \quad \ln y_j' \; = \; (1 - \alpha) \ln e_j + \alpha\beta \ln h_1$$

$$+ \; \alpha(1 - \beta) \ln h_j$$

$$- \; \alpha(1 - \beta)\ln(1 - \beta).$$

From this equation, we can compute the percentage increase in human capital of students on island $j = 2, \dots, N$ as

$$\ln \frac{y_j'}{y_j} \; = \; \alpha\beta \ln \frac{h_1}{h_j}$$

$$+ \; \alpha(\beta - 1)\ln(1 - \beta) > 0.$$

Note that *both* terms on the right-hand side of the equality are positive, and that they jointly comprise the "technology windfall" mentioned in the introduction. The first term captures the benefits of substitution of h_1 for h_j in (web-based) lecturing activities. The second term captures the effect of greater hands-on instruction: because local teachers no longer need to lecture, they reallocate their time to hands-on instruction. Hands-on instruction thus rises by a factor of $1/(1 - \beta)$. Together, these two effects establish our first claim from the introduction, that

all students on nonleader islands benefit from web-based education.

Our second claim, concerning the "democratizing effect" of web-based education, also follows from equation (4). Consider two islands, j and k ($\neq 1$) with $h_j < h_k$ (and thus by assumption $y_j < y_k$). We then have

$$\ln \frac{y_k'}{y_j'} - \ln \frac{y_k}{y_j} = -\alpha\beta \ln \frac{h_k}{h_j} < 0,$$

implying that the human capital gap between the two islands will narrow after web-based education proliferates. Moreover, this expression also implies that the larger the initial percentage difference between h_j and h_k, $\ln(h_k/h_j)$, the larger the percentage point fall in the human capital gap. This is true regardless of the values of e_j and e_k. Consequently, web-based education compresses human capital inequality across islands.

In fact, the result is even more stark: the post-Internet regime has no effect on the educational attainment of students on the lead island and pulls up the post-schooling human capital of students on all other islands.[5] Moreover, the model implies the possibility of local overtaking: students on islands with endowments, e_j and h_j, that are close to the lead island will overtake students on the lead island, because the students on such close trailing islands receive the combined benefits of lead-island lectures and greater hands-on instruction from local teachers (i.e., hands-on instruction is scaled up by factor $1/(1 - \beta)$). After web-based education, the educational outcome of a trailing island exceeds the educational outcome of the lead island ($\ln y_j' > \ln y_1'$) if and only if:

$$\frac{(1 - \alpha)}{\alpha(1 - \beta)} \ln \frac{e_j}{e_1} + \ln \frac{h_j}{h_1} > \ln(1 - \beta).$$

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[5] One can imagine that if the time and effort of teachers on island 1 are diverted to Internet-related activities, students on this island might be made worse off. Countering this, if teachers could increase the time they devote to lecturing, this would increase their remuneration and may attract more talented, or simply more, agents into teaching. This would tend to benefit students on this island.

C. *Post-Internet: Teacher Wages*

In the post-Internet allocation, a teacher's marginal product and thus wages on islands $j = 2, \dots, N$ is given by:

$$(5) \quad w_j' = \alpha(1 - \beta)e_j^{1-\alpha} \, h_1^{\alpha\beta}\left(\frac{h_j}{1 - \beta}\right)^{\alpha(1-\beta)}.$$

This expression encapsulates both the third and fourth effects of web-based education on teacher earnings discussed in the introduction: "crowd-out" and "complementarity".

To see the "crowd-out" effect, note that post-Internet teachers on islands $j = 2, \dots, N$ will reallocate their time from instructional tasks in the complete task interval, $[0, 1]$, to hands-on instruction tasks in the subinterval $(\beta, 1]$. Since there are diminishing returns to each teaching task i, this "crowd-out" will tend to depress teachers' marginal products and earnings. If we compare (5), with the counterfactual assumption that $h_1 = h_j$, to (3), we quantify this "crowd-out" effect and find that $w_j' < w_j$.

The "complementarity" effect, on the other hand, is captured by the fact that $h_1 > h_j$— inputs complementary to the services of local teachers have now increased, pushing up the marginal product and earnings of local teachers.

Combining these two effects and directly comparing (5) to (3), we see that the wages of domestic teachers on island j will increase if and only if

$$(6) \qquad \left(\frac{h_1}{h_j}\right)^{\alpha\beta}(1 - \beta)^{1-\alpha(1-\beta)} > 1.$$

This expression will be satisfied if island j's teachers are not too close, in terms of their skills, to the teachers on island 1. However, the wages of teachers on islands with h_j sufficiently close to h_1 (whom we call "middle skill" teachers) will fall.

In fact, we can use equation (6) to provide an explicit threshold at which a marginal introduction of web-based education (i.e., β close to zero) will increase local teachers' wages. Taking logs on both sides of equation (6), we see that teachers' wages on island j will increase if and only if

$$\frac{\alpha\beta \ln \frac{h_1}{h_j}}{(\alpha(1 - \beta) - 1) \ln(1 - \beta)} > 1.$$

To evaluate this ratio for small β, we take the limit as $\beta \to 0$ and use L'Hôpital's rule. We see

that teachers' wages on island j will increase with the introduction of a small amount of web-based education if and only if

$$\ln \frac{h_1}{h_j} > \frac{1}{\alpha} - 1.$$

For any value of α, then, there exists a threshold $\bar{h}_\alpha$ such that in all islands with $h_j < \bar{h}_\alpha$, the wages of teachers will increase following the introduction of web-based education. Moreover, as α approaches 1, $\bar{h}_\alpha$ approaches h_1, making it more likely that teacher wages will increase on all islands.[6]

II. Conclusion

There is substantial uncertainty about the ultimate impact of web-based educational innovations. Our stylized model suggests that, in contrast to the disequalizing effects of many other disruptive technologies, web-based education will have broadly equalizing effects. Not only will human capital around the globe be enhanced, but human capital inequality may also decrease. At the same time, many (though not all) teachers will prosper.

Our model was purposefully chosen to be highly simplified, and thus leaves out many relevant and interesting issues. First, we have abstracted from occupational choice. Changes in teachers' wages will induce entry and exit from this occupation. This is potentially complicated by the fact that web-based technologies will also change wages in nonteaching occupations.

Second, a major issue in the economics of education is changing costs. On the one hand, these new web-based technologies require computers and broadband access, which are costly for stu-

dents in many regions. On the other hand, these new technologies will economize on textbooks and other nonweb resources. Our analysis also suggests that the teacher wage bill may increase or decrease.

Third, we have abstracted from within-country inequality of student endowments. For example, web-based education may be less equalizing if the already-advantaged students have disproportionate access to the web. The extent of this effect, especially its magnitude relative to the equalizing effects we have identified, is an interesting area for empirical study.

Finally, web-based delivery of educational resources may lower the cost of experimenting with new teaching techniques and acquiring feedback on what works and why. These experiments may lead us to deeper insights about the education production function. In this way, recent educational innovations may not only help us teach our students; they may also help us teach ourselves.

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[6] Our model also implies that there will be no change in the wages of teachers on island 1. This is a consequence of the fact that the pre- and post-Internet allocations on this island are identical: a fraction β of teachers are still working on lecturing tasks and the remaining $1 - \beta$ are working on hands-on instruction. The latter have the same marginal product as before, in terms of their contribution to student human capital. Several assumptions we have made for simplicity are important for this result. For example, if the amount of time teachers on island 1 devote to lecturing could increase, if there were human capital differences among these teachers, or if agents with higher human capital could enter teaching, then the earnings of island 1 teachers would also increase in the post-Internet allocation. Nevertheless, this result highlights that any increase in inequality between the very top teachers and the rest in the post-Internet era may be limited.