EQUALIZING SUPERSTARS: THE INTERNET AND THE DEMOCRATIZATION OF EDUCATION

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Abstract. Educational resources distributed via the Internet are rapidly proliferating. One prominent concern associated with these potentially transformative developments is that, as many of the leading technologies of the last several decades have been, these new sweeping technological changes will be highly disequalizing, creating superstar teachers, a wider gulf between different groups of students and potentially a winner-take-all educational system. In this paper, we argue that, these important concerns notwithstanding, a major impact of the superstars created by web-based educational technologies will be the democratization of education: not only will educational resources be more equally distributed, but also lower-skilled teachers will be winners from this technology. At the root of our results is the observation that for web-based technologies to exploit the comparative advantage of skilled lecturers, they will need to be complemented with opportunities for face-to-face discussions with instructors, and web-based lectures will increase the quantity and quality of teaching services complementary to such instruction, potentially increasing the marginal product and wages of lower-skill teachers.

Still Preliminary and Incomplete.

1. Introduction

Educational resources distributed via the Internet are rapidly proliferating. These new resources include lecture videos, on-line teaching notes, Internet chat groups, on-line 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, MOOC's (massive open on-line courses) have received the most fanfare, though the social value of these courses is as yet unproven and the high drop-out rates (in excess of 90%) have been fodder for much debate (see Ahmad et

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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/.

al., 2013, for some empirical facts on the first seventeen UPenn MOOCs offered; Bannerjee and Duflo, 2014, provide empirical evidence of certain factors that influence the success of MOOCs).

Two technologies that promise to be scalable and transformative are lecture videos and interactive problem sets (including interactive educational games), though there is much uncertainty about how they will change the landscape of education and who the winners and losers will be. One prominent concern is that, as many of the leading technologies of the last several decades have been, these new sweeping technological changes will be highly disequalizing, creating superstar teachers, a wider gulf between different groups of students and potentially a winner-take-all educational system.[2]

In this paper, we argue that, these important concerns notwithstanding, a major impact of the superstars created by web-based educational technologies will be the democratization of education: not only will educational resources be more equally distributed, but also lower-skilled teachers will be winners from this technology.

At the root of our results is the observation that for web-based technologies to exploit the comparative advantage of skilled lecturers, they 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 (coming from prior education or as family endowment) and various complementary teaching activities (e.g., lecturing, grading, class discussions, one-on-one conversations and so on). Web-based technologies enable teachers to generate non-rival educational services that can be used as inputs in multiple countries/classrooms

[2]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 (2010); and on the rise of winner-take-all society more generally due to technological, sociological and institutional reasons, see Frank and Cook (1996).

simultaneously (e.g., an Internet lecture that can be watched in Beijing and Baltimore simultaneously), but these still need to be complemented with one-on-one instruction provided by local teachers.

The ability to create non-rival educational services via the web creates four interrelated consequences.

The first is a "technological windfall" for all students who now have access to lectures of the best ("superstar") global teachers rather than having to rely entirely on lectures from local teachers. In addition, the teacher resources freed from lecturing can be 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 is a "democratizing effect" reducing inequality of human capital among students. This is because the gains in educational attainment are disproportionately concentrated at the bottom end of the educational attainment gradient.

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

Interestingly, however, the fourth consequence is a "complementarity effect," offsetting the third effect and creating a potentially net positive effect on the salaries of non-superstar teachers. Web-based technologies simultaneously 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, but we show that the positive complementarity effect dominates for teachers with low levels of human capital, while the crowd-out effect may dominate for teachers with high (but non-superstar) levels of human capital. In particular, initially, either all teachers or those below a critical threshold see their earnings increase.

We conclude by discussing extensions of the model and the particular implications of the model for economic education.

2. Model

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

2.1. **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 country j we denote it by e_j (for endowment). 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

$$y_j = e_j^{1-\alpha} X_j^{\alpha} \tag{1}$$

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 services 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

$$\ln y_j = (1-\alpha)\ln e_j + \alpha \ln h_j. \tag{2}$$

In what follows, we assume that there is perfect rank correlation between e_j and h_j, meaning that, for any j, k, if $e_j > e_k$, then $h_j > h_k$, i.e., islands that have higher human capital students also have higher human capital teachers. In fact, all we require is that $\ln e_j$ and $\ln h_j$ are positively correlated across islands (e.g., normally distributed across islands with positive covariance). Either assumption implies, from (2), the cross-island distribution of post-schooling human capital is more unequal than 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), and thus by

$$w_j = \alpha e_j^{1-\alpha} h_j^{\alpha-1} h_j = \alpha e_j^{1-\alpha} h_j^{\alpha}. \tag{3}$$

Also for future reference, we rank the islands in descending order of teacher skills, so that island 1 has the teachers with the highest value of h_j.

2.2. **Post-Internet: Student Attainment.** To operationalize the introduction of web-based technologies, we imagine a technological change that enables a subset of teaching tasks, say those in $[0, \beta]$, to be performed by only one teacher and then broadcast to the rest of the world. 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 $j = 1, ..., N$ have access to

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

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. (Fraction β of teachers are working in lecturing tasks that are being broadcast to the rest of the world and the remaining $1 - \beta$ of teachers are working 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 higher quality lectures (from "superstar" teachers on island 1). Second, because the teachers in these islands can now focus on instruction, the services of these tasks are more abundantly supplied.

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

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

or

$$\ln y'_j = (1-\alpha) \ln e_j + \alpha\beta \ln h_1 + \alpha(1-\beta) \ln h_j - \alpha(1-\beta) \ln(1-\beta) \tag{4}$$

From this equation, we can compute the percentage increase in human capital of students on island $j = 2, ..., N$ 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 this expression are positive. The first term captures the benefits of substitution of h_1 for h_j in (web-based) lecturing activities and is the "technology windfall" mentioned in the Introduction. The second term is the "reallocation effect" also mentioned in the Introduction and captures the effect of greater hands-on instruction, which is increased because local teachers no longer need to lecture, enabling them to reallocate their time to hands-on instruction (which rises by factor $1/(1-\beta)$). These two effects together establish our first claim from the Introduction, that all students in non-leader 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

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

implying that the human capital gap between the two islands will narrow after web-based education spreads. 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 in the human capital gap (and 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 a little more stark: the post-Internet regime has no effect on the educational attainment of students in the lead island and pulls up the post-schooling human capital of students in all other islands.[3] 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

[3]One can imagine that because the time and effort of teachers in country 1 are diverted to Internet-related activities, students in country 1 might even be made worse off.

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:

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

2.3. **Post-Internet: Teacher Wages.** It is straightforward to compute a teacher's marginal product and thus wages in the post-Internet allocation:

$$w'_j = \alpha(1-\beta) e_j^{1-\alpha} h_1^{\alpha\beta} \left(\frac{h_j}{1-\beta}\right)^{\alpha(1-\beta)}. \tag{5}$$

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 in the post-Internet allocation, teachers on islands $j = 2, ..., N$ will focus on the hands-on instruction tasks in $(\beta, 1]$. Since there are diminishing returns, this will tend to depress their marginal products and earnings. If we were to compare (5), with $h_1 = h_j$, to (3), we would capture only this effect, and we would have that $w'_j < w_j$ because of this crowd out.

The complementarities effect, on the other hand, is captured by the fact that $h_1 > h_j$ — the complementary inputs to the services of local teachers have now increased, pushing 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

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

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

Specifically, we can use equation (6) to provide an explicit threshold for a marginal introduction of web-based education (i.e., β close to zero) to increase local teacher wages. Let us take logs on both sides of equation (6), which implies that teacher 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'Hôpitals rule, which implies that teacher wages on island j will increase with the introduction of a small amount the web-based education if and only if

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

For any value of α, this provides 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 in all islands.

3. Conclusion

There is much uncertainty about both the ultimate human capital impacts of web-based educational innovations and their broader economic implications. Our stylized model suggests that, in contrast to the disequalizing effects of many other disruptive technologies discussed in the economics literature, web-based education will have broadly equalizing effects. Not only will human capital around the globe be enhanced, but human capital inequalities will also decrease with the introduction of web technologies. We predict a win-win for the democratization of teaching. This all takes place in a world where many, but not all, teachers prosper. In this way, our model provides several testable implications that future research can address.

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 teacher wages will induce new teachers to enter or existing teachers to exit this occupation. This is potentially complicated by the fact that web-based technologies will also change wages in non-teaching occupations.

Second, a major issue in the economics of education is rising costs. Web-based education can also impact costs. On the one hand, these new technologies require computers and broadband access, which are costly for students in many developing countries and regions. On the other hand, they may economize on textbooks and other non-web resources. Our analysis also suggests that the teacher wage bill component of education costs may increase or decrease.

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

Finally, web-based delivery of educational resources potentially lowers the cost of trying new ideas and acquiring feedback on what works and why, serving to enhance the potential for experimentation that can teach us deeper insights about the education production function. In this way, recent educational innovations may have moved us one step closer to using schools to not only teach students, but to also importantly teach ourselves.

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