

The Economics of MOOCs

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Massive open online courses, or MOOCs, have gained considerable attention in a short time. The first widely noted MOOC, a free online course on artificial intelligence offered by Stanford University in fall 2011, drew 160,000 students.¹ By November 2012, a *New York Times* article heralded “The Year of the MOOC.”²

MOOCs have been praised and condemned for their potential to transform higher education. An editorial in *Science* cited “the dazzling promise of affordable, high-quality, globally accessible online courses.”³ “Online education is not an enemy of residential education,” said MIT President Susan Hockfield, “but an inspiring and liberating ally.”⁴ Competition from MOOCs, predicted Sebastian Thrun, a Stanford computer science professor and founder of MOOC provider Udacity, would eliminate all but ten of the world’s universities within 50 years.⁵ Another computer scientist asked, “Will MOOCs destroy academia?”⁶ Still, some observers argue that the potential impact of MOOCs has been overstated. According

to one university president, “The response by many in academia and the media to...MOOCs... is reminiscent of the hysteria with which alien invaders were met in the pulp science-fiction films of the 1950s.”⁷

This chapter offers an economic analysis of MOOCs. After describing MOOCs and the major providers, it summarizes economic concepts useful for analyzing MOOCs, such as Clayton Christensen’s disruptive innovation, William Baumol and William Bowen’s performing arts “cost disease,” economies of scale, and marginal cost. The chapter then addresses the business model for MOOCs, the extent to which they are substitutes for face-to-face classes, and their potential impact on traditional higher education.

WHAT ARE MOOCs?

What kinds of courses are MOOCs? They are massive, sometimes involving more than 100,000 students at a time. They are open: no tuition is charged and no admissions officers screen potential students. And they are online:

students use the Internet to access lectures and assignments, to interact with other students, and to submit assignments for machine or peer grading. Some MOOCs are stand-alone courses for students in widely scattered locations, while “blended” or “hybrid” courses combine online and face-to-face components.

MOOCs are the latest incarnation of university-level distance learning. Technological changes have greatly reduced communication costs, reducing the barrier that geography poses to human interaction.⁸ Cheap and reliable postal systems enabled the development of correspondence courses. Many universities began radio broadcasts of classes in the 1920s and 1930s.⁹ Britain’s Open University, founded in 1969, worked with the BBC to broadcast classes on television.¹⁰

Fast Internet connections and falling computer prices have made online classes feasible. In these classes,

A participant may seek help on a problem set or clarification of an assignment from classmates who are distant but online. This capability of student-to-student and student-to-faculty interaction, coupled with instant access to information resources worldwide on the Internet, plus the efficient distribution of class materials (readings, homework assignments, and possibly stored video lectures) distinguishes modern online education from older “distance education” models built around correspondence or television.¹¹

The 1998 amendments to the 1965 Higher Education Act facilitated online higher education by distinguishing correspondence courses (for which students could receive minimal federal financial aid) from online courses (equivalent, for federal financial aid purposes, to face-to-face classes).¹² MIT’s Open Courseware initiative, begun in 2002, provided free online learning materials.¹³ By fall 2007, 3.9 million college students in the U.S. had enrolled in at least one online course.¹⁴

MOOCs are free, like MIT’s Open Courseware. They differ in this respect and in educational processes from earlier online classes:

MOOCs are more than good university lectures available online. The real innovation comes from integrating academics talking with interactive coursework, such as automated tests, quizzes and even games. Real-life lectures have no pause, rewind (or fast-forward) buttons; MOOCs let students learn at their own pace, typically with short, engaging videos, modelled on the hugely successful online lecturettes pioneered by TED, a non-profit organiser of upmarket mindfests.¹⁵

MOOC exercises often feature adaptive learning: using the student’s past performance to determine the appropriate level of difficulty for new questions. Some MOOCs substitute online simulations for science or engineering labs.¹⁶

Several firms provide software “platforms” that handle user registration, allow instructors to upload course content, permit students to access course content, and manage communication among instructors and students. For-profit MOOC firms include Coursera and Udacity. Founded and governed by MIT and Harvard, edX is a leading non-profit. Coursera attracted five million students and edX, 1.2 million by early fall 2013.¹⁷

Provider web sites state their pedagogical aims. “A key factor in the design of the Coursera system,” stated the firm’s web site:

is the extensive use of interactive exercises, which we believe are critical for student engagement and learning. Even within our videos, there are multiple opportunities for interactions: the video frequently stops, and students are asked to answer a simple question to test whether they are tracking the material.... Many of our courses’ homework

are designed to give students multiple opportunities to learn the content and demonstrate their knowledge.... [W]e typically give immediate feedback on...[a] concept the student did not understand....[W]e have invested substantial effort in developing the technology of peer assessments, where students can evaluate and provide feedback on each other's work.¹⁸

The edX web site described the firm's research on learning analytics:

By carefully assessing course data, from mouse clicks to time spent on tasks, to evaluating how students respond to various assessments, researchers hope to shed light on how learners access information and master materials, with the ultimate aim of improving course outcomes. We are not only expanding access to knowledge, but developing best practices to enhance the student experience and improve teaching and learning both on campus and online.¹⁹

Many leading universities partnered with Coursera, edX, or Udacity to provide the content for MOOCs.²⁰ EdX partners with Berkeley, CalTech, Cornell, the University of Texas, and the University of Washington.²¹ "For decades," notes one observer, "elite educators were preoccupied with 'faculty-to-student ratio:' the best classroom was the one where everybody knew your name. Now top schools are broadcast networks."²²

DISRUPTIVE INNOVATION

Much hype stems from the belief that MOOCs will transform higher education. Capitalism, wrote economist Joseph Schumpeter in 1942, involves creative destruction, in which innovations introduced by entrepreneurs destroy the old economic structure as they create a new one.²³ Harvard Business School professor Clayton Christensen extended Schumpeter's work. Established suppliers, he claimed, usually

overlook opportunities to adopt "disruptive innovations" allowing them to serve new markets. Such innovations often involve "moving downmarket" by cutting quality to reduce price. These suppliers shun disruptive innovations because they would undermine profit margins on sales to existing customers, who prefer previous technologies. But new entrants to the industry, not limited by such constraints, can offer low-price packages to *potential* customers who were unwilling to buy at the prevailing price. Eventually,

the performance attributes that existing customers do value improve at such a rapid rate that the new technology can later invade those established markets. Only at this point will mainstream customers want the technology. Unfortunately for the established suppliers, by then it is often too late: the pioneers of the new technology dominate the market.²⁴

Higher education, Christensen argued, is an industry ripe for disruptive innovation. "Most universities," he noted, "continue to deliver education face-to-face, in inconvenient, centralized settings."²⁵ Many potential customers must pay for more services than they want or are priced out of the market. Low-cost providers, he claimed, can sell to these "overshot" customers or to nonconsumers.

The higher education market, Christensen noted, has different segments:

Elite private universities comprise the innermost circle, accessible primarily by those with the best academic credentials and the ability to afford very high tuition. The next circle is comprised of state universities, whose admissions standards and tuition typically make them more accessible to a larger population of students. The third circle represents junior and community colleges, whose costs are lower still, and which typically have open admission

policies. The outermost circle represents online education, which is accessible to an even larger population of students such as those from rural areas and working adults who cannot attend classes at traditional times. For-profit universities stand astride the three outer circles.²⁶

“Community colleges that have become four-year institutions and then research universities offering graduate degrees have not been able to carry their low-cost business models up-market,” Christensen argued. “They have had to transform from their original form and replicate the cost structure of the institutions they are striving to emulate.”²⁷ But online learning, he contended, is a disruptive technology that will allow low-cost universities to move up-market. Improvements in “bandwidth, video quality, online sharing tools, etc.” have raised the quality of MOOCs enough, Christensen argued, to appeal to established customers for higher education.²⁸

MOOCs also allow prestigious universities to appeal to potential customers who had not previously bought their educational services. “It’s unusual and remarkably difficult,” Christensen noted:

for established market leaders to pioneer—or even catch up—with disruptions. Yet interestingly, the big, reputable universities are the ones leading the MOOC wave. This includes MIT and Harvard (through edX) as well as Stanford, whose groundbreaking AI course morphed into Udacity (and whose professors independently founded Coursera).²⁹

The endorsement by prestigious schools signals MOOC quality, and MOOCs allow prestigious schools to leverage their brands to gain new markets.

Low-cost universities that adopt MOOCs, Christensen acknowledged, focus narrowly on helping students “get better employment.” In

contrast, the “job that many 18-year-old high school graduates hire a university to do is in some ways to provide an out-of-home transition to independent adulthood.”³⁰ But low-cost universities, he predicted, will improve at the latter job.

COSTS OF HIGHER EDUCATION

Concerns about affordability of higher education motivated interest in MOOCs. Tuition at American colleges and universities increased much faster than the overall price level or than average family incomes between 1980 and 2011.³¹ Cutbacks in state funding for public higher education account for part of the tuition increase. But one scholar noted another cause: a winner-take-all society providing large rewards to students in the best colleges and universities leads selective schools to compete on quality, not price.³²

Higher education shares some characteristics of the live performing arts. Both show lower productivity growth than most other industries. “Whereas the amount of labor necessary to produce a typical manufactured product has constantly declined since the beginning of the industrial era, it requires about as many minutes for Richard II to tell his ‘sad stories of the death of kings’ as it did on the stage of the Globe Theatre.”³³ Similarly, a two-hour seminar requires the same amount of faculty time as it did a century ago.

The problem is that industries having little or no productivity growth must compete for labor with industries showing high productivity growth, which can raise wages without raising product prices. But “for an activity such as the live performing arts where productivity is stationary, every increase in money wages will be translated automatically into an equivalent increase in unit labor costs—there is no offsetting increase in output per man-hour as there is in a rising productivity industry.”³⁴ Live performing arts thus suffer from “Baumol’s cost disease:” their costs continually increase because labor market competition from other

industries forces them to raise wages by more than their own productivity growth.

Yet productivity growth is possible in the performing arts:

The development of motion pictures and phonograph records, radio and television has made possible a revolutionary change in the mechanics of presentation.... This in turn has meant that the cost of providing a given hour of entertainment to each member of the audience has dropped precipitously.... For example, an orchestral performance on television, which...takes less than twice the man-hours of a live performance, can reach an audience of 20 million instead of the 2,500 persons who occupy a concert hall, thus yielding an increase in productivity of four hundred thousand percent! But these developments have not helped the live performing arts directly. In fact, the competition of the mass media for both the audience and personnel of the living arts has sometimes had serious adverse consequences for the performing organizations.³⁵

In Christensen's terminology, movies, records, radio, and television were disruptive innovations. They created new markets—persons interested in theatre or music who had limited ability to pay—and displaced existing technologies (live performances). MOOCs are the higher education counterpart to an orchestral performance on television, sacrificing face-to-face interaction between the performer and the audience but cutting unit costs.

COSTS OF MOOCs

Economies of scale, which occur when long-run average total cost falls as the number of units of production increases, produce the lower unit costs associated with MOOCs. Like movies or prescription drugs, MOOCs have substantial initial development costs. Faculty, videographers, educational consultants, and computer specialists must prepare lecture

videos, interactive online assignments, and online quizzes. They may also need to provide norms for machine or peer grading of essays. A Berkeley professor who co-taught three MOOCs said, "It takes an immense amount of work to produce an adequate MOOC and a staggering amount of work to produce a really good one."³⁶ Faculty at MIT reported spending much of a semester developing a MOOC.³⁷ Speakers at a recent MOOC research conference "repeatedly pointed out that the cost of MOOC production...can reach hundreds of thousands of dollars."³⁸ But producers can spread these development costs over tens or hundreds of thousands of students; at most, universities can accommodate mere hundreds in a large lecture hall in a conventional introductory class. A \$300,000 fixed cost for course development is only \$3 per student if 100,000 students take the course.

MOOCs not only allow colleges and universities to realize economies of scale by serving a larger market, they also let institutions avoid the costs of duplicating effort. Using a MOOC, rather than local faculty, to give lectures and design assignments is a form of subcontracting. Subcontractors can develop specialized expertise, which they bring to many customers who use a small amount of the same service. But using MOOCs may differ in two important ways from, for example, contracting with Sodexo to operate a college's food services. First, lectures, unlike cafeterias, are central to a college or university's core mission. Second, MOOCs are alleged to have extremely low marginal cost: the incremental cost of providing instruction to one additional student, which does not include the fixed cost of initial course development.

A MOOC with 100,000 students, says a co-founder of Coursera, could achieve a marginal cost of under \$1 per student. There would be no need to hire instructors to answer students' questions or grade assignments. Instead, peers could answer questions, and either computers or peers could grade assignments.³⁹ Very

low marginal cost has implications for product pricing. “Free products and services appear over the Internet,” noted an MIT management professor, “because the marginal cost of reproducing and delivering a digital good is essentially zero.”⁴⁰

A near-zero estimate of marginal cost seems overly optimistic. First, many students maintain their motivation to complete a course through interaction with a live instructor. Student attrition is a severe problem for MOOCs; a study of a million users of Coursera courses offered by the University of Pennsylvania found that only four percent completed their courses.⁴¹ Concern about attrition led many to suggest hybrids that combine MOOC lectures and exercises with a local instructor who works with small groups of students. But hiring the local instructor raises marginal cost.

Second, students buy a bundle of services when they go to college. Besides courses, many students also expect athletic programs and other extracurricular activities, student affairs services, career guidance and placement, academic advising, and, often, a residential campus experience. Third, cheating may occur on tests unless proctors verify test-taker identities and monitor testing.⁴² Fourth, fair-use provisions probably do not permit use of copyrighted material in a MOOC without paying a licensing fee.⁴³ Fifth, some costs such as those of classroom facilities may be shifted to students (who may do their course work from a computer in their home), not eliminated.

Finally, computer grading may not suffice. Computers can provide immediate feedback on some quantitative assignments or on multiple-choice tests, directing students to advance to the next section or to additional review. But many doubt that machine grading works well for essays. In any case, it is not always cheaper than essay grading by human instructors.

Grading essays by computer begins with “machine learning.” Humans need not write a computer program explicitly stating the characteristics of an excellent essay. Instead, the

computer is provided with training data: hundreds or thousands of sample essays evaluated by skilled graders. The computer analyzes the training data to determine the parameters of the implicit algorithm used by these graders to classify essays as worthy of an A, B, C, D, or F. Once this artificial intelligence system is calibrated, the computer can use the classification algorithm to grade thousands or millions of additional essays, at near-zero marginal cost. Machine scoring, in turn, allows providers of college entrance exams such as the SAT or ACT to benefit from economies of scale. The economics of machine scoring are less attractive for a small seminar: why provide hundreds of carefully graded essays as training data if the machine has only 15 essays to score?

Can computers grade essays adequately? One doubter wrote a series of essays and submitted them to e-Rater, the automated essay rating system developed by the Educational Testing Service (ETS).⁴⁴ E-Rater rewards long essays, long sentences, and use of fancy words, this study concluded, allowing students who understand e-Rater’s biases to game the system. Most important, e-Rater couldn’t determine the accuracy of factual claims. It assigned the highest possible score to an essay that included this nonsensical claim: “The average teaching assistant makes six times as much money as college presidents. In addition, they often receive a plethora of extra benefits such as private jets, vacations in the south seas, starring roles in motion pictures.”⁴⁵

An ETS researcher acknowledged this objection: “If AES [automated essay scoring] is supposed to replace a human reader, then it should be rejected out of hand since a machine cannot truly understand the essay, cannot read it as a human reader would, and cannot interpret its meaning. Most validation efforts of AES have implicitly or explicitly tried to answer this objection by showing that machine *scores* are indistinguishable from human scores.”⁴⁶ But the researcher argued that, “machine processing of text cannot achieve an understanding of

the essay, and is therefore limited to measuring a subset of the writing construct.”⁴⁷ Machine scoring of essays, he suggested, should be used in addition to, rather than instead of, human scoring.

At best, machines can replace only part of the human labor needed to grade essays. That reality and the need for local instructors (in a blended MOOC) to keep students engaged make MOOCs fundamentally different from other online services with near-zero marginal cost.

BUSINESS MODELS FOR MOOCs

MOOCs need money to cover their start-up expenses. Coursera had raised \$85 million in venture capital by November 2013, including funds from university partners, the World Bank, and venture capital firms.⁴⁸ MIT and Harvard provided \$30 million each in start-up funds for edX.⁴⁹ The Gates Foundation gives millions of dollars in grants to support MOOC research, including course development.⁵⁰

But MOOCs also need money to cover ongoing operating expenses. Where do they get this money if students can access MOOCs for free? Two professors of management information systems, Chrysanthos Dellarocas and Marshall Van Alstyne, noted the challenges that the Internet poses to many service businesses:

Education is only the latest industry to face digital disruption. Music, movies, news, travel and real estate already traveled this path. Media companies painfully discovered that free alternatives such as YouTube videos, news blogs, independent fiction, Wikipedia pages, and the ease of piracy place limits on charging for content.⁵¹

Dellarocas and Van Alstyne proposed several business models for MOOCs. “Education is better positioned than media to generate direct revenue from content,” they asserted, because grades can be withheld from those who do not pay tuition.⁵² Besides charging students for content, they added, MOOCs could

charge students for complements or charge groups other than students who benefit from the MOOC. Complements are goods or services used together, like turkey and cranberries. MOOC complements include certification, diagnostics, tutoring, and collaborative group learning. MOOCs can attract paying customers for these complements by offering the basic course content free.

Other groups who potentially benefit from MOOCs include governments, employers, sponsors, and colleges or universities. Governments already subsidize education. Dellarocas and Van Alstyne cite external benefits that spill over to the broader society, including higher income tax payments and lower crime rates, as justification for these public subsidies; others cite equal opportunity. “MOOCs,” Dellarocas and Van Alstyne wrote, “could be as defensible as Pell grants.”⁵³ Employers could use MOOC student performance data for employee selection or use MOOCs to train employees in specific job-related skills. Potential sponsors include advertisers and organizations that might benefit from an experiential learning component, in which student teams solve organizational problems. Colleges and universities could benefit from a syndication system similar to the Associated Press:

Today’s traditional universities operate like newspapers that insist on producing original articles of variable quality for all stories. In a world of rising costs and global information transparency this is unsustainable. From an economic standpoint, universities will find it too costly to hire professors for every subject students request. From a quality perspective, students will steer clear of substandard local teaching when they know a blockbuster digital course is available.⁵⁴

Dellarocas and Van Alstyne proposed consortia in which colleges and universities make their MOOCs available to each other for a fee,

with each institution providing local study groups for their students. Colleges and universities could also use MOOC data on individual performance for student recruiting.

Whatever the revenue source, the key to the financial success of MOOCs remains the extent to which they cut costs. “If MOOCs reduce the cost of higher education by one-third,...yet only earn for themselves 1% of that benefit,” declared one commentary, “that would ‘still be a very nice business.’”⁵⁵

MOOCs VS. FACE-TO-FACE CLASSES

How important is price when a buyer of educational services is choosing between MOOCs and traditional face-to-face classes? It depends on the degree of perceived similarity between them. If a buyer sees MOOCs as a close substitute for traditional higher education, they will gain market share even if their prices are only slightly lower. If a buyer sees MOOCs as inferior, they must offer substantially lower prices than face-to-face classes. When evaluating educational quality, MOOCs provide instant feedback through machine grading, but offer fewer of the social connections that motivate students.

An experiment about the relative efficacy of live and online lectures randomly assigned students in an introductory microeconomics course to watch the lectures live in a room with 190 students or on a video recording available on the Internet. The treatment and control groups had the same homework assignments, TA support, and exams. The researchers found that Hispanic students, students with a prior GPA below the median, and male students had higher average scores on the microeconomics exams if they attended the live lectures. The difference on a 100-point exam was 11.3 points (a full letter grade) for Hispanics and 4.1 points for low achievers—both significant at the one percent level—and 3.5 points for males (significant at the five percent level). Live lectures had a positive, but statistically insignificant, effect on the exam scores for whites, blacks, Asians,

females, and students with a prior GPA above the median.⁵⁶

Do the cost savings associated with economies of scale justify worse educational outcomes of MOOCs? These cost savings are greatest “at universities with low faculty teaching loads, or for fields with relatively high faculty salaries, or at other institutions/fields if a course is developed once and replayed with much lower levels of faculty involvement.”⁵⁷ The study compared online and live lectures in a *large* class. The per-student cost savings and the educational disadvantages of MOOCs would plausibly be bigger when comparing MOOCs and live instruction in a *small* class where students received personal attention.

CONCLUSION

A recent Gallup survey found that 47 percent of 1,081 responding college and university chief academic officers agreed or strongly agreed that MOOCs “could threaten the business model of my institution.”⁵⁸ An MIT scholar warned of the danger “if increasing numbers of universities and colleges joined the free online education movement and set a new threshold price for the industry—zero—which becomes commonly accepted and difficult to undo...‘free’ sends a signal to the world that what you are offering costs little and may not be worth paying for.”⁵⁹ Elite institutions, he predicted, will survive, partly because they offer something that online classes cannot: “We often say at MIT that the personal networks and bonds our students form while at the university are probably the most valuable part of their education.”⁶⁰ But MOOCs, he believed, threatened “second- and third-tier universities and colleges, and community colleges.”⁶¹

Universities traditionally profited from large lecture classes. A class of 250 students generated ten times the tuition revenue as a class of 25, but at much less than ten times the cost, especially if low-paid graduate teaching assistants handled discussion sections for large classes. Universities could use the profits to

subsidize small seminars and support faculty research. Competition from MOOCs may reduce the price that universities can charge for large lecture classes, eliminating the funding stream for cross-subsidies. Colleges and universities will compete with MOOCs on price in a commodity business unless they differentiate their product by offering appealing extracurricular activities, residential life, mentoring by devoted faculty, and alumni networks. But leading universities that become content providers for MOOCs can extend their brands.

MOOCs will provide access to education to students in remote domestic locations, those unable to take classes during normal hours, and students in developing countries who cannot afford a traditional university education. Some students may prefer MOOCs because of price or convenience even if small face-to-face classes continue to offer higher educational quality. MOOCs may reduce the number of faculty positions with video lectures, machine or peer grading, and online lab simulations. A few star lecturers will gain influence and perhaps substantial increases in earnings.

Predictions of near-zero marginal cost for MOOCs are exaggerated. Consequently, MOOCs may not devastate traditional suppliers of higher education as the Internet has devastated newspapers and travel agents. But blended MOOCs, where local instructors engage students, are likely to have a growing role in higher education.

NOTES

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¹ Pérez-Peña, 2012.

² Pappano, 2012. *Inside Higher Ed* published a collection of articles called “The MOOC Moment” in May 2013, *Inside Higher Ed*, 2013.

³ Singer and Bonvillian, 2013.

⁴ Kolowich, 2013.

⁵ *The Economist*, 2012.

⁶ Vardi, 2012.

⁷ Crow, 2013.

⁸ Cairncross, 2001.

⁹ Matt and Fernandez, 2013. These universities included Columbia, Harvard, NYU, Ohio State, the University of California, the University of Minnesota, and the University of Wisconsin.

¹⁰ Pickrell, 2001.

¹¹ Mayadas et al., 2009, 86.

¹² *Ibid.*, 87.

¹³ Cusumano, 2013, 1. The university and the Hewlett and Mellon Foundations funded the initiative.

¹⁴ Mayadas et al., 2009, 86.

¹⁵ *The Economist*, 2012.

¹⁶ Waldrop, 2013.

¹⁷ Fowler, 2013.

¹⁸ <https://www.coursera.org/about/pedagogy>.

¹⁹ <https://www.edx.org/research-pedagogy>.

²⁰ <https://www.coursera.org/partners>. Coursera’s partner universities include Brown, CalTech, Columbia, Duke, Johns Hopkins, Princeton, Stanford, the University of Illinois, the University of Michigan, the University of Minnesota, the University of Pennsylvania, the University of Virginia, the University of Washington, the University of Wisconsin-Madison, and Yale.

²¹ <https://www.edx.org/schools>.

²² Heller, 2013, 83.

²³ Schumpeter, 1942.

²⁴ Bower and Christensen, 1995, 44.

²⁵ Christensen et al., 2004, 102.

²⁶ Christensen et al., 2011, 25.

²⁷ *Ibid.*, 28.

²⁸ Horn and Christensen, 2013.

²⁹ *Ibid.*

³⁰ Christensen et al., 2011, 40.

³¹ Zumeta, 2012.

³² Ehrenberg, 2000.

³³ Baumol and Bowen, 1966, 164.

³⁴ *Ibid.*, 171.

³⁵ *Ibid.*, 163.

³⁶ Kolowich, 2013.

- ³⁷ Sive and Sarma, 2013.
- ³⁸ Straumsheim, 2013.
- ³⁹ Remarks by Daphne Koller, reported in Newfield, 2013.
- ⁴⁰ Cusumano, 2013, 3.
- ⁴¹ Stein, 2013.
- ⁴² Harmon and Lambrinos, 2008.
- ⁴³ Educause, 2012.
- ⁴⁴ Les Perelman, director of writing at MIT.
- ⁴⁵ Quoted in Winerip, 2012.
- ⁴⁶ Attali, 2013, 182, emphasis in the original.
- ⁴⁷ *Ibid.*, 194.
- ⁴⁸ Shu, 2013; Lewin, 2013.
- ⁴⁹ Lewin, 2012a.
- ⁵⁰ Lewin, 2012b.
- ⁵¹ Dellarocas and Van Alstyne, 2013, 25.
- ⁵² *Ibid.*, 26.
- ⁵³ *Ibid.*
- ⁵⁴ *Ibid.*, 28.
- ⁵⁵ *The Economist*, 2013.
- ⁵⁶ Figlio et al., 2013.
- ⁵⁷ *Ibid.*, 782.
- ⁵⁸ Jaschik and Lederman, 2013, 21.
- ⁵⁹ Cusumano, 2013, 2.
- ⁶⁰ *Ibid.*, 2013, 4.
- ⁶¹ *Ibid.*, 3.
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