Higher Education's Information Challenge

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Introduction

Universities process information. They create, teach, cache, and accredit it. In an information economy, their roles in refining information might move us to value them as essential resources. Ironically, however, the level of public funding would not necessarily mark higher education as an investment priority even though the information economy continues to expand. The Internet experiences triple digit growth annually, virtual communities form around "collaboratories," web browsers now deliver customized news from the New York Times, and software companies enjoy price to earnings ratios that are four times those of auto manufacturers. Yet, between 1980-1995, federal funds to post-secondary schools declined by 14% [11]. Why should universities, as processors of information, not share in the associated profits and prestige of the information age?

"Creative destruction" might account for some of this inconsistency. The price of information technology (IT) has declined by an order of magnitude relative to its price per cycle fifteen years ago.[1] IT enables long distance learning, non-judgmental and infinitely patient mentoring, and public access to vast information resources. In the argot of the economists, perhaps technology is a substitute for the university good. Between substitutes, declining prices for one then force proportional cuts in the other. This might even explain growing consumption of educational goods and services as prices of substitutes become increasingly affordable. Or perhaps, based on laws of supply and demand, "a world awash in information is one in which information has very little market value" [14, p. 106]. Universities, as information delivery systems, face a growing challenge in charging to convey information products that can be obtained elsewhere at negligible cost to the source. Information is unique in that its giver still keeps the gift.

These dour observations, however, only partially describe the forces acting on universities and they often underestimate university contributions to social welfare. Access to information, for example, only weakly substitutes for access to education and expertise. When faced with a complex and time sensitive legal problem, technological access to a good law library is no substitute for a well educated lawyer. Complex environments typically increase the demand for skilled labor. On the welfare side, various studies of the economics of science have found that knowledge stocks – as measured by publication counts and scientific employment – contributed substantially to productivity in eighteen industries and that each of several major innovations – magnetic ferrites, video tape recorders, oral contraceptives, electron microscopes, and matrix isolation – depended on research that emphasized basic understanding over applications [35]. What remains under-appreciated is that these studies found that lags of

[1] If progress in the economy had matched that of the computer sector, a Cadillac would cost $4.98 and a year's worth of groceries would cost 10 minutes of labor [6].

20-30 years obscured the connection between knowledge and productivity.

One notable scholar has written of the "dim future of the university" [22] while Drucker has argued that traditional colleges will become relics in the 21st century [16]. Changing technology and environments imply that universities need to adapt since traditional structures face too many non-traditional needs. There is reason for optimism, however. Few scholars, if any, have argued that universities provide no value or that collectively we have no influence. If anything, the moral of new technology is that it gives us new options and we must choose how to use it.

This essay seeks to identify technology and information forces acting on universities, to offer an economic justification for continued public support, and to suggest an organizational modification that might enhance their success. Doing this involves sketching the university as an information processor in order to guide questions, highlight options, and formulate possible answers. If our primary goal is to build a better university and universities process information, then it helps to know which factors improve information processing.

Assumptions

My working assumptions about universities focus on the information per se in order to model a particular view of their operations. There are other models of how universities operate but I want to abstract away from the particulars of individual institutions and examine the economy of ideas and their delivery in the context of teaching and research.

First, *information processes are integral to university functions*. Universities create, warehouse, distribute, and evaluate information. As houses of research, they generate new information. Their libraries store not only the results of their working papers and interim reports but also the publications essential for teaching and learning. In the process of teaching, they disseminate new and existing information. Through education, they inculcate students with methods, tests, facts, and representations. Then, as arbiters of information quality, university faculty referee new publications. By conferring degrees, universities attest to the quality of the information that new graduates seek to apply professionally. Broadly speaking, this is an assumption that viewing universities as information processors helps understand what universities do.

The second assumption is that *technology improvements simplify information processing*. Information technology (IT) facilitates searching, screening, storing, and connecting. IT aids computation. Whether this is good or bad for universities depends, in part, on whether IT substitutes for university functions or complements them. Declining costs of a substitute can reduce demand for the university good while declining costs of a complement can increase it. To the extent that both phenomena are present, one success strategy might be to emphasize university functions that are complements of IT and to avoid functions that are substitutes.

The third, and most crucial, assumption is that *information is "nonrival*." When two or more consumers simultaneously attempt to use rival assets they can physically displace one another. Unlike tangible goods, nonrival assets are neither depleted nor divided when shared and they can be reproduced almost limitlessly. Because of its nonrival quality, people can give information away without actually losing it themselves. A professor, for example, does not lose her knowledge by telling students what she knows – her understanding may even improve. And, by inference, information once given can never be withdrawn.

Of course the nonrival question of depleting information differs from the economic question of valuing information. Value may still depend on scarcity or even ubiquity. Stock price leads, for example, decrease in value as they are distributed but computer operating systems increase. Nonrivalry only refers to the property of negligible cost copying. This assumption is also distinct from "excludability," which represents a *de jure* proscription rather than a *de facto* ability to prevent others from using an asset, e.g. trade laws protect accessible but patented information.

A fourth assumption is that *people are boundedly rational.* As finite creatures, we have a limited capacity for mental calculation [33]. We can optimize only a few polynomial equations in our heads; can listen to no more than a few people at one time; and we can read only a finite number of books in a lifetime. Information technology can loosen the bounds on rationality but will not lift them entirely. The Internet can provide access to millions of other users and a wide range of knowledge sources, but no one person can interact with them all.

Consider that as of May 1996, the AltaVista search engine had indexed more that 33 million articles and web pages. It would take over five years to read just the new listings added each month.[2] Even if information technology were to double our individual capacities, we would need to draw the line on our threshold of interest somewhere. The information we seek, read, review, and comprehend is finite. Computationally, the number of our simultaneous conversations is also finite. Information technology is unlikely to permit individuals to widen their focus to the entire population. "You can [have access] to hundreds of millions, but you can't know them all because all you can remember is 3000. All you can do is replace the label 'physical acquaintance' with 'virtual acquaintance'" [30, from an interview with M. Dertouzos]. Bounded rationality simply means that we will need to make choices about which information to process, and live with the long term results of these choices. For purposes of this essay, I will take bounded rationality to mean that there are limits on computation and that there are a finite number of partners that anyone can speak with at any given time.

Convex Growth & the Information Explosion

These assumptions are all that is necessary – or very nearly so – to account for an information explosion. The point is to understand why this is happening and then to anticipate and manage the consequences. Vastly increasing the amount of new information has significant implications for a university's structure, specialization, reward systems, and reputation. Nonrivalry can help to explain an information explosion.[3]

The basic argument is analogous to that for compound interest and relies on recovering the inputs to production after production is finished. If more input can be used to produce more output but the input is never actually consumed, then each new period faces an increased level of resources with which to produce. The new growth literature in economics depends on this mechanism. Knowledge generated through research at one firm spills over to increase productivity at other firms and all firms benefit from a rise in the total knowledge stock. Under certain reasonable economic assumptions, the knowledge stock then grows at an increasing rate.

The truth is much more complicated than this. In reality, no exponential nor even convex process can continue unabated. Moreover, any form of production must involve labor and capital of some sort and these more tangible resources are clearly bounded, maybe even consumed, in the process. Therefore, any serious model of information will be bounded by tangible resources or by constraints such as bounded rationality. As a stylized abstraction,

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[2] This is under the ambitious assumption that one could access and read a page every 10 seconds, 8 hours a day, 365 days a year and that no pages needed to be revisited as their content changed.

[3] A mathematical illustration requires just a little work to recall high school calculus. Let x be an amount of information and let f(x) be any function which describes the production of new information with input x. Since f(x) creates information rather than destroying it we shall say that $f(x) > 0$ for positive values of x. We will even allow that information production exhibits diminishing returns to scale (increasing returns to scale would give even stronger results, but this might be cheating on the illustration). This means that adding more information as an input helps create more information as an output but at a decreasing rate. Thus f(x) has positive slope i.e. $f'(x) > 0$ but each new unit gives less and less marginal benefit so that $f''(x) < 0$.

Now let $x_t = g(t \mid x_0)$ give the total information x available at time t. This depends on initial information, x_0, plus anything produced up to time t. We wish to show that both g' and g'' are positive. The rate at which $g(t \mid x_0)$ changes is the rate at which we create new information minus whatever we consume as inputs to production or $g'(t \mid x_0) = f(x_t) - x_t$. But, here is the trick. If information is nonrival, we do not destroy the information used as input. We can recover the inputs afterwards so really $g'(t \mid x_0) = f(x_t) - x_t + x_t = f(g(t \mid x_0))$. The rate of change is just the rate of production at time t implying that g' is positive. So how fast is the production rate changing? By the chain rule, this is just $g''(t \mid x_0) = f'(x_t) = f'(g(t \mid x_0))g'(t \mid x_0) = f'(g(t \mid x_0))f(g(t \mid x_0))$. This means that if $f(x_t) > 0$ and $f'(x_t) > 0$ then it must also be true that $g'(t \mid x_0) > 0$ and $g''(t \mid x_0) > 0$. So the total amount of information $g(t \mid x_0)$ increases at an increasing rate. Thus nonrivalry can imply a possible information explosion.

however, this simple model reflects apparent growth in information resources surprisingly well. Two examples illustrate. Beginning in 1907, the Chemical Abstracts Society took 31 years to accumulate its first million abstracts; the next million took 18 years, and the most recent took 1.75. More articles have been published on chemistry in the last two years than all of recorded history before 1900 [22]. Broadening our focus from Chemical abstracts to published research, the same phenomenon holds (see Figure 1).

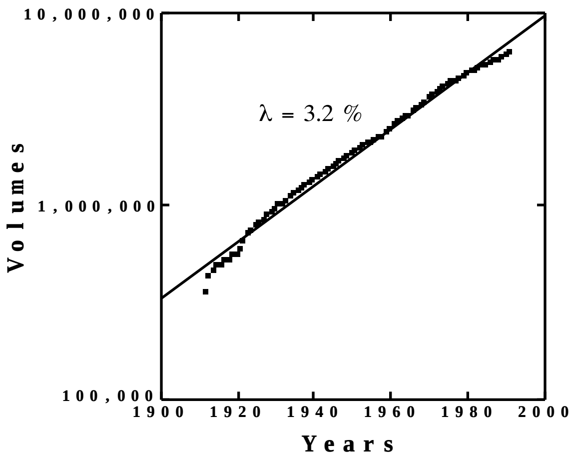

Figure 1 – Near linear growth on this log scale shows that volumes at private research libraries have grown exponentially during most of the 20th century.

Since the graph has logarithmic scale, the upward sloping line indicates increasing rates of growth over a period of more than eighty years [8]. De Sola Pool found similar exponential growth in information generated by the mass media [25].

Setting aside the modeling details, what could be the engine of information growth? Business and economic literature suggest that explicit sharing behaviors play the lead role. Speaking of "intelligent enterprises," one management scholar writes:

> ... knowledge is one of the few assets that grows most [when] shared. As one shares knowledge with colleagues, ... not only do [they] gain information ... they usually feed back questions, amplifications, and modifications, which ... add further value for the [sharer]. ... Since learning feeds knowledge back to the base, the next step (even at the same percentage increase) will spring from a higher base and be a larger absolute increment [27, p 254].

In the economics literature, Romer [28, 29] argues that knowledge spill-overs and unintentional sharing enhance the knowledge stock. Imperfect patents and labor transfers can mean that one company's research also leads to other companies' products. A case study by Annalee Saxenian [31] provides the general theory with empirical support. Beginning in 1975, California's Silicon Valley and Massachusetts' Route 128 region employed roughly the same number of people, but over the next fifteen years Silicon Valley generated three times as many net new technology jobs. Moreover, between 1986 and 1990, the market value of the Silicon Valley firms increased by more than $25 billion as compared to $1 billion along Route 128. Saxenian argues that information sharing and collaboration account for most of this difference, with several factors emerging as explanatory variables. First, a higher level of vertical integration in New England firms reduced information transfers between markets and business units. Second, more defense funding led to a premium on secret research which could not be shared. Third, engineering and technical expertise moved more freely in California's open and "spirited" environment. Adjacent to Silicon Valley, Stanford University also stimulated information transfers by hosting on-site executive education programs, charging companies $10,000 for university access, and opening a technology licensing office in 1969. In contrast, Saxenian argues, MIT inadvertently limited information transfers by requiring students to be on campus, charging $50,000 for university access, and neglecting their licensing office until the late 1980s.[4] These forces greatly increased the volume of information sharing in Silicon Valley, subsequently compounding regional wealth.

Interestingly, this model of knowledge compounding might also help to explain the

[4]Earlier licensing, however, might have been premature. Universities could not actually retain patent ownership of federally sponsored research until the Bayh-Dole Act of 1980. Over the course of the next decade, a nationwide stock of less than 150 university patents became an annual flow of more than 1000.

increasing inequality among cohorts of research scientists.

> ... scientific productivity is not only characterized by extreme inequality at a point in time, it is also characterized by increasing inequality over the careers of a cohort of scientists, suggesting that at least some of the processes at work are state dependent [35, p. 1204].

If the generation of new knowledge requires research resources, and access to knowledge is critical among them, then above average access might lead to above average (and growing) productivity.[5] Universities play a significant role in providing the intellectual and physical capital that make scientific research possible.

From these observations, three significant points can be taken away regarding information processes and the university. Growth in information resources has proceeded at a prodigious rate; theories of information suggest that its nonrival property facilitates growth through sharing; and university processes can affect both the distribution and sharing of information that drive these outcomes.

Specialization & Fragmentation

As a consequence of rapidly expanding information, boundedly rational processors eventually hit the limits of their capacity. As Herb Simon suggests, "a wealth of information creates a poverty of attention and a need to allocate that attention efficiently among the overabundance of information sources that might consume it" [32]. From the perspective of research and teaching, advancing the frontiers of a discipline becomes easier as you narrow your focus sufficiently to master the facts, methods, and principles of the scholarship that has preceded you. As one's own discipline becomes richer, more detailed, and more complex, Renaissance scholarship in the sense of being an authority on the latest developments in unrelated disciplines becomes more difficult. Producing frontier research in the context of rapidly expanding information thus encourages specialization.

Numerous academic disciplines exhibit increasingly narrow focus. In fact, many have progressed to the point where the specialized vocabulary that facilitates interactions within the community hinders interaction across communities. Indeed, Kuhn has observed that a widening gulf "separates the professional scientist from his colleagues in other fields" [15, p. 21]. Mathematicians unfamiliar with the theory of "elliptic curves" from the subfield of algebraic geometry, for example, cannot follow a recent proof of Fermat's last theorem. Splinter groups at academic conferences now testify to their increasing differentiation from the core. Differentiation and inbreeding has progressed to the point where expertise can mean "knowing more and more about less and less."

By increasing communications reach, information technology can compound specialization. Scholars have an incentive to keep abreast of new developments by keeping in touch with other scholars researching related topics. If IT provides a lubricant that allows for the satisfaction of preferences against the friction of geography, then more IT can imply that scholars increasingly fulfill their preferences. A preference for research contact that is more focused than contacts available locally leads to narrower interactions. Importantly, the opposite is also true. A preference for diverse contacts leads to broader interactions and more integrated communities. Technology creates options but preferences create outcomes. Preferences, in this case, significantly affect community integration with narrow preferences leading to fragmentation and broad preferences leading to integration.

Because the Internet makes it easier to find colleagues with common research interests, it can facilitate and strengthen focused communities that are dispersed geographically. Thus, sociologists, particle physicists, political scientists, and others have used the Internet to find each other and swap information.[6] Communities can also coalesce around resources. Long distance access, for example, allows inland oceanographers to read from the equipment and data sets of their coastal colleagues.

[5] This model is not a perfect fit since individual journal output appears to decline somewhat after mid-career. Still, productivity is highly concentrated in an elite cohort. The top six percent of *publishing* scientists author roughly half of all science publications [35].

[6] The same principle applies outside academia as well. Oenophiles, Star Trek fans, and members of militia groups have used the Internet to form communities of common interests.

If a mathematician increasingly works with colleagues across the continent, what happens to his or her interactions with the physicist, the biologist, and the historian who work down the hall? Figure 2 shows graphically how several local communities could be reshaped by information technology.

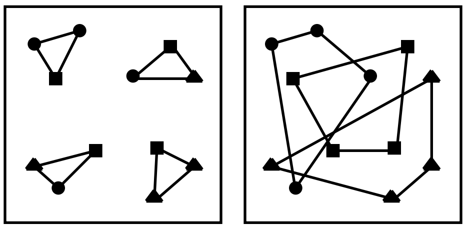

Figure 2.A **Figure 2.B**
IT can reconstitute geographic communities (2.A)
by research discipline (2.B).

On-campus heterogeneity can give way to off-campus homogeneity as virtual communities coalesce across geographic boundaries. This can simultaneously strengthen alliances to a professional community as it weakens alliances to the university's infrastructure. Research communities can become disembodied with respect to institutional locales. As IT improves filtering, tailoring, segmenting, and searching, the more global network can become the less local village.

There are definite exceptions. Specialization is partly a response to the problem of processing one information type more efficiently – high volume processing implied by efficient specialization. This also depends, however, on relatively low variance in processing types. Flux in the environment may favor more flexible or general skills [1] and broader interaction. Increased reach, as provided by IT, can also reverse tendencies toward community fragmentation. Any taste for diverse interactions can lead scholars into contact with new communities which could integrate rather than divide their respective disciplines. Incentives thus provide key leverage. Frequently, for example, promotion and tenure incentives favor specialization and narrow focus. Integration versus fragmentation then hinges on factors such as whether the pressure to publish at the frontier of one's own discipline is low enough to permit time for exploration in others. If keeping abreast of new developments occupies more of one's time, then less time remains for exploration leaving the net effect as increased fragmentation. IT's capacity to strengthen in-group and weaken out-group ties has been observed by communications researchers:

> Historically, the strength of an academic department rested with its resident faculty. Now it depends on the extent to which each faculty member is interconnected with other professionals – worldwide – pursuing similar interests... We now have electronic research teams and electronic water coolers. This drastically changes – weakens, in my opinion – indigenous workplace relationships and affects workplace cohesiveness.[7]

Related observations appear to hold more broadly. In describing what characterizes the emerging "Global Village," McLuhan and Powers [20] nevertheless remark on the power of satellite technology to aid "super-regionalisms" and "separatisms" like the Parti Quebeçois in Canada. As an historical example, the telephone strengthened affiliation among teenage peer groups [34]. In the field of economics, the number of out-of-state and out-of-country coauthorships in four top journals grew from 4.6% in the 1960s to 27.6% in the 1990s [10].

Overspecialization could have the effect of erecting virtual walls between scholarly communities, diminishing worthwhile interaction that currently takes place. Watson and Crick, for example, combined skills from zoology and x-ray diffraction to determine the structure of DNA [21]. Thomas Kuhn developed his ideas on scientific paradigm shifts while working at the nexus of history and physics; yet one can hardly imagine the difficulty of trying to look across paradigms from within. Once Black and Scholes recognized their formula for options pricing as a physics equation for heat transfer [4, p. 644] they could look for established parallels. Wall Street now hires dozens of physicists annually and, conceivably, reducing knowledge spillovers could have stalled the development of options markets. Similarly, the Alvarez theory that an asteroid caused the extinction of the dinosaurs emerged from a fortuitous combination of father and son skills in astrophysics and geology. Their inquiry began with the realization that iridium – an element rare on earth but common in asteroids – appears in the geological record in concentrations 20 to 160

[7] Interview with Edward Mabry of the University of Wisconsin, Milwaukee [17].

times background levels at the time the dinosaurs became extinct [3]. In significant breakthroughs, serendipity may also play a role since it is often unclear beforehand which groups need to share information. Both the heat transfer equation and knowledge of mass extinctions had existed for more than a century. The Alvarez contribution was not to discover a phenomenon but to combine phenomena, providing the best explanation consistent with multiple streams of research.

Realizing that there are benefits to collaboration, however, is not the same as encouraging it. Choices may depend on incentives. Thomas Kuhn was originally denied tenure, in part, because his contributions at the interface between disciplines were not considered central to any of them. The unspoken message to untenured faculty may not be to bridge disciplines but only to build from within. Information technology provides marvelous opportunities for intellectual exploration and community integration, but only if this is how people choose to use it.

Four key conclusions to draw from these observations are that the access properties of IT can lead to greater specialization if the pressure to focus exceeds the desire to explore, that incentives and growth in information can supply this pressure, and that research fragmentation resulting from specialization can potentially reduce information spillovers. Lastly, IT may give us new options but the level of community fragmentation differs by how we use it.

Reputation, Stratification, & Winner-Take-All Markets

The creation of great quantities of information does not mean that each data point is equally valuable. One of the strongest criticisms of the "information superhighway" is that traveling its roads collects a lot more dust than diamonds. In university research, the warehousing of numerous working papers, works-in-progress, and preprints exacerbates this problem. Specializing – learning the shortcuts and deciding for oneself which routes are most efficient – is one means of narrowing the routes on a roadmap thick with scenic distractions. A second strategy however, is to choose the popular routes, to decide based on acclamation or reputation. The volume of research published each year, for example, encourages researchers to screen their readings on the basis of author and journal reputation [35]. For better or worse, technology plays a major role in success breeding success as reputations are picked up and broadcast to larger audiences. Through technological amplification, very modest initial differences can lead to very large subsequent differences. Consider what might happen, for example, as access to the best lecturers increases with technology. Initially, everyone attends the best lecture in their neighborhood or community and most lecturers can have roughly the same number of listeners. If remote access improves, say, through video-conferencing, then slightly better lecturers can attract a majority of the listeners. With more listeners, more practice, and more feedback, the better lecturers might get better still. Figure 3 plots the case in which access improves from a purely local neighborhood to a completely global market. For the sake of concreteness, it assumes that there are twenty-five possible lectures but that bounded rationality and patience limit one's interest to no more than five lectures.

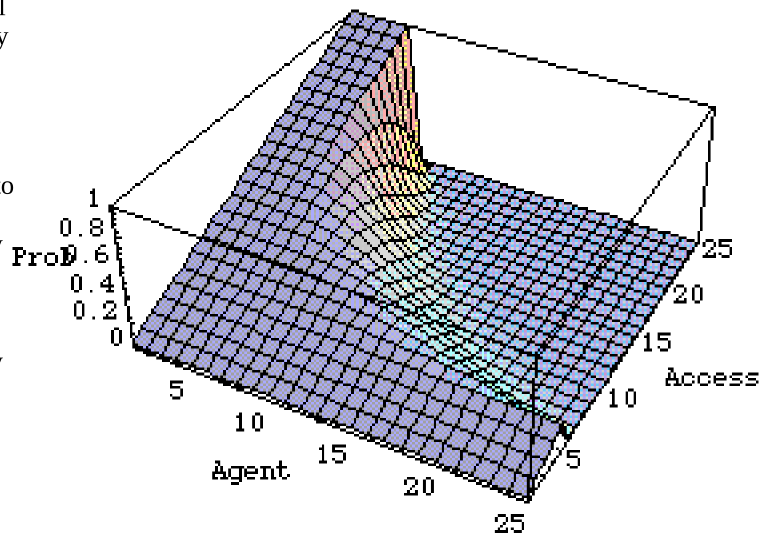

Figure 3 – As access improves, listeners might take on more virtual lectures until they can take no more. Then they choose only the very best.

This shows the probability that any one of these rank ordered lecturers would be in a listener's local choice set as access improves. With only local access, a listener is just as likely to choose any lecturer in the neighborhood. With global access, however, only the top five lecturers have an audience. Assuming bounded rationality, broadcast technology leads to the amplification of modest differences in reputation. Economists Frank and Cook [9] have called this effect a

“Winner-Take-All” market and they recount observations from a story told by author Kurt Vonnegut to illustrate its effect. Consider the life of a moderately talented musician from a hundred years ago. This performer might once have been a community treasure but the same person faces a life of diminished opportunity in a society that places him or her in global competition with the world’s best performers. How do promising new lecturers compete with Steven J. Gould on paleontology or Peter Drucker on management? At MIT, annual presentations of Richard Feynman's posthumous lectures on physics (videotapes) draw larger audiences than most physics classes.

The effects, however, of placing local professionals in global competition do not stop with changes in reputation. First, rising access can lead to falling affordability. Whether IT creates markets in academia, sports, or management, higher profiles can command higher prices. Second, availability can actually fall as demand rises. This occurs when broadcast options are limited but access is universal. Consider what might happen, for example, if everyone seeking financial advice had access to the private telephone number of Peter Lynch – clogged lines might make it impossible to reach him.

This phenomenon also occurs in research. In their efforts to find collaborators, research scholars might face the same probability distribution that listeners face when choosing lectures, namely the plot in Figure 3. The twist is that researchers are choosing from within their own community – the source and receiver are the same and both are boundedly rational. Although the lecturer can transfer information one-way to everyone, successful collaborators require two-way information transfers among partners. As a consequence, increased access allows researchers to aspire to their best partners and it allows the best partners to choose one another. Once interactive collaboration begins, members may have little time for other associations. If the top researchers in Figure 3 choose to work with one another, the result can easily be increased stratification. Although technology access has risen, scholars outside a given partnership might judge that their colleagues’ availability has actually fallen; the elite are simply too preoccupied! Telephone access can further the financial analogy. Before he became famous, Peter Lynch might have been accessible to an average investor. After his successes, however, it might take the head of Fidelity to get through.

Technology can therefore have the simultaneous effect of providing access to an elite scholar at the same time it places that scholar out of reach – high demand makes her inaccessible. This result is similar to that of the previous section in which IT and bounded rationality led to horizontal specialization. Here, they can lead to vertical stratification.

The main conclusions to draw from these observations are that reputations are one means of handling information overload, that broadcast IT can transform slight reputation differences into winner-take-all markets, and that IT combined with bounded rationality can lead to stratification.

Increased Competition versus Information Sharing

The collegiality of a university depends a great deal on an open environment and on sharing information among members of its community. Yet, the degree to which community members are willing to share ideas depends significantly on interpersonal rewards. Importantly, rewards based on absolute performance encourage free exchange while rewards based on relative performance inhibit it.

Consider two different classes with different grading policies. In one class, every student who scores above a 90 on the exam merits an “A” for the course. In the other class, only 10% of the students, regardless of the score distribution will score an “A”. Assuming that the difficulty of the test is the same in both cases, which grading policy encourages students to assist one another with preparation? The first policy is much more likely to encourage information sharing. It uncouples one student’s grade from that of another so that one student need not do badly for another to do well. Absolute performance criteria are therefore more likely to encourage study groups since students who know slightly different material can benefit one another. Here, the point is not to comment on which policy is better – a good argument can be made that the relative policy encourages students to work harder and learn more by not collaborating on preparation. Rather, the point is to emphasize that an absolute reward policy encourages information sharing whereas a relative reward policy discourages it.

A similar distinction may affect faculty collegiality. It costs very little to share intellectual credit either through coauthorship or citation. In many ways, citing another scholar's work strengthens one's own contributions. It demonstrates familiarity with material, lays the foundation for common discourse, and outlines the research gaps one hopes to fill with new contributions. Thus, the traditional practice of scholarship is comparatively open in that it encourages sharing through dialogue and publication. Loosely speaking, authors are rewarded for their absolute performance in terms of their number and quality of publications.[8]

An alternate reward structure is possible which compensates not for the publication of ideas but for their economic value – a trend suggested by an increasing tendency to seek corporate research sponsorship. Sharing credit, however, is easier than sharing dollars. Possible reward structures based on the sale of information assets can have a chilling effect on dialogue. Dividing the proceeds from the sale of an idea, method, or formula is a zero sum game: the more one contributor gains, the more another contributor loses. The relative performance of each contributor must be assessed in very precise terms, creating an incentive to hoard information and deny it to others lest attribution become ambiguous. In the sharing of credit for scholarship, questions of attribution for fractions of an idea are less common. In the sharing of proceeds from a sale, attribution problems, bargaining costs, and the loss of information sharing can impose systemic costs.

The ability to sell information also depends heavily on its non-availability to the general public; if it is freely available it is probably free. A strategy of selling information is likely to limit sharing for three reasons. First, sharing creates a second possible supplier. Bertrand, or price competition,[9] between perfect substitutes (i.e., the same information from an alternate source) cannot sustain a market with positive prices. Second, if new research is patentable, the developer cannot legally disclose it before filing an application without risking loss of its patentability. This could introduce disclosure delays. Finally, if new research is not patentable but it has market value, it is more likely to remain a trade secret to increase its value to potential buyers or to improve the competitive status of the research sponsor. This could eliminate disclosure entirely. Evidence suggests that the privatization of information due to its high economic value is an increasingly common phenomenon. Scientific knowledge and production know-how in the form of software, genetic codes, and protein manufacturing, for example, are being patented and copyrighted at unprecedented rates [5].

Research also provides evidence that relative versus absolute reward effects of information sharing occur in industry. A study of groupware introduced into a consulting firm observed this phenomenon [24]. In a competitive up-or-out atmosphere, consultants below the level of principal would vie for a limited number of promotions largely on the basis of individual competency. Revealing unique knowledge or expertise risked shrinking any relative advantage over less qualified candidates or growing the advantage of more qualified candidates if the beneficiary did not respond with at least as much valuable information. Under the relative reward structure, competing consultants refused to share information.

Ironically, the same firm provided evidence of both absolute and relative objective functions in different contexts. At the firm's highest level, principals enjoyed permanent tenure and focused more on absolute rather than relative maximization. Their interests lay with the absolute performance of the firm and not their relative advantage over other principals. Among principals, collegiality and information sharing prevailed. Different incentives and behavior indicated the existence of their separate agendas: "Consultants feel little incentive to share their ideas for fear that they may lose status, power, and distinctive competence. Principals, on the other hand, do not share this fear and are more focused on the interests of ... the firm than on their individual careers [24, p. 367]."

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[8] Another interpretation of an absolute performance system is a "priority" based system. Reputation points accrue to the first to publish a result, a system which encourages early disclosure and discourages shirking because, in an open environment, others might obtain similar results [35]. The absolute bar for recognition is the information frontier since duplication of a result inside the frontier contributes much less to social welfare. Competition certainly exists among researchers but, in general, absolute or priority reward systems promote disclosure.

[9] Another alternative is Cournot, or quantity competition, which leads to output restrictions. This assumption is harder to justify given nonrivalry.

Despite the introduction of groupware technology to facilitate information sharing, it did not alter behaviors. Again, the point is that IT creates options but preferences, uses, and choices determine results.

Implications – Where do we go from here?

How then should higher education respond to the issues raised by applying theories of information and technology? The answer depends on one's purpose and whether one takes the perspective of the social planner setting educational priorities or the perspective of a single institution competing for resources. Let me conclude with three suggestions; two focus on the information asset while the third focuses on information processing.

From the perspective of a social planner, if the purpose is to foster growth in information resources, then subsidizing education and encouraging interdisciplinary cooperation is perhaps one of few realistic solutions. The reason is that, due to its nonrival character, information exhibits "positive externalities."

In economic terms, a positive externality is a benefit to nonparticipants when a consumer engages in some transaction. Buying telephone service, for example, benefits you and the telephone company but it also benefits friends and relatives who gain access to you even though they bear none of your costs for service. Considering the university as an information processor, such externalities include the social benefits of an education that a student does not consider when paying tuition and information spillovers that a sponsor does not capture when buying research. Benefits falling outside pairwise transactions with a university are not received by buyers and therefore rarely valued. An analogy to a familiar negative externality, pollution, will help to illustrate the nature of the social investment problem.

Pollution creates costs that we share collectively because neither buyers nor sellers bear the costs of cleaning up. Goods that pollute are discounted from their true price leading buyers to overconsume them. The opposite is true for information. If ideas spilling into the market create benefits that we share collectively, a positive externality, then buyers underconsume them because buyers do not profit from ideas the rest of us use. For goods with negative externalities, a buyer receives all the benefits for a fraction of the costs. For goods with positive externalities, a buyer pays all the costs for a fraction of the benefits. The result for universities is underconsumption, underinvestment, and undervaluation. Positive externalities make research and education prime candidates for government support.

Alternatively, if we collectively decide that public funding for education is too expensive, then an alternate solution is to sell the information which universities warehouse and produce. In essence, universities might earn considerable revenue by privatizing their information assets. This already occurs when universities charge tuition for credit or contact hours in the classroom, that is for information transfers. This also occurs when universities engage in technology licensing, contract research, and equity arrangements, which are also increasingly common. Similarly, there is almost no reason why universities ought not capture certain revenue streams currently captured by publishers. University faculty already author, edit, review and purchase the journals for which publishers act largely as distribution channels. Distribution, however, offers negligible value-added in the age of the Internet.

There is a sense, however, in which the privatization of information detracts from knowledge as a public good. If universities share information in neat packages with preferred sponsors, then positive externalities decline because ideas do not diffuse as rapidly. This can also lead to information stratification in which the information rich become information richer. Presumably, anyone with valuable information can choose to exercise his knowledge in a way that gains him access to others with valuable information – an advantage which snowballs over time – Peter Lynch, for example, is likely to have much better access to knowledgeable financiers and economists than he had two decades before his investment successes. Governments need to decide whether they are as comfortable with the privatization of information and knowledge as they appear to be with the privatization of education and research; the two are closely related. For the most part, suggestions one and two are mutually exclusive alternatives. There is little reason to subsidize the privatization of information capital if subsidies are used to reduce positive externalities.

There is a third possible response to the problem of changing environments. Universities may focus on information processes rather than information products, which implies that universities need to improve their capacity for handling complex information.

One measure of information complexity is the amount of data necessary to describe the states in a system. For universities, state variables might include students, faculty, tuition, business sponsored research, and numerous others. This information description also needs to include the relationships of numerous combinations among these variables. By most accounts, complexity, broadly interpreted, is increasing because the state variables and their relationships are changing more rapidly. Government funding priorities are different; new student constituencies are emerging among the adult population and from abroad; technology places distant colleges in local competition; and regulation has lifted mandatory retirement.

If different structures process information differently, then which ones can improve complex information processing? One that arguably handles complexity better than others is a "network organization." These are collections of cospecialized assets whose members share a common purpose and exercise joint control [1]. Networks help flexibly cope with rising complexity and rapidly changing information .

By considering two extreme organizational forms, archetypal markets and hierarchies, we can better determine how different structures handle complexity.

A market handles complexity rather well. It matches buyers and sellers in a wide variety of possible asset combinations. In fact, the number of possible relationships is combinatorially explosive. Hypothetically, potential students, interested researchers, and available educators might each seek one another. Each could mix and match from a huge variety of combinations and secure from a pattern of private transactions what they could not find at an institution with fixed resources. The trouble with this view of a market system is that it entails huge search and coordination costs, it lacks economies of scale from specialization, and individual members have trouble establishing and maintaining reputations since transactions are rarely repeated. New combinations can flexibly emerge to handle dynamic complexity but the amount of work to attain one is not necessarily efficient.

At the other extreme, a hierarchy assembles a specific collection of assets in order to obtain a consistent and efficient result. A central authority also tends to make decisions on behalf of the rest of the organization. This structure has limited search costs, can achieve economies of scale, and can establish credible long term contacts. The trouble with hierarchies is that their rigid combination of assets is not very flexible and their centralized decisions often omit important decentralized information.

With respect to handling change, one important principle binds both organizational structures: the complexity of factors considered in a decision cannot exceed the complexity of the decision process. In a market, everyone decides on their optimal course of action and a combinatorial explosion of possible structures is conceivable. Complex processing ability is high. In a hierarchy, a central authority makes decisions for the organization and allocates transactions over a fixed asset combination. Complex processing ability is low. My point is not to argue that universities are hierarchies; they are neither rigidly configured nor centrally controlled. However, if a university exhibits a degree of hierarchy that is well adapted to a given level of complexity, then a rise in complexity suggests that a more market-like structure could help process more information.

Network organizations might play this role. Their characteristics – cospecialization, common purpose, and joint control – imply higher levels of autonomy and self-sufficiency than more traditional structures. They also imply a high degree of organizational modularity as distinct from vertical integration. With a network structure, organizational boundaries are more flexible and ties to other organizations are more likely. The research on network organizations suggests that they perform better than traditional structures at managing information since this is what helps to provide members with distinctive competence. Networks also gather and process information in a distributed rather than a centralized fashion [1, 23, 26]. They handle complexity rather well.

A number of organizations have taken this approach, from real estate ventures to fashion textiles, and from biotechnology startups to multinational chain stores. Certain non-profit consumer advocacy groups also use network structures. This does not imply that academia should copy commercial practices; greater positive externalities, for example, skew the comparison. Still, examples are informative. Coalitions of engineering and business schools can offer programs in technological innovation superior to those offered independently. Schools of law, economics, and public policy can teach their graduates cooperatively to design regulatory mechanisms that are constitutionally sound and economically efficient. The division of labor might also be by function rather than by discipline. For example, by dividing information tasks into creation, transfer, storage, and certification, one can imagine structures that warehouse the most complete information on chemistry, but that also rank and certify individual contributions among these huge resources – a function that libraries typically do not perform. Another type of institution might have few warehoused resources but might offer unique skills in delivering the best lectures via telecommunications; thus it focuses on information transfers. Valuable partnerships, or network organizations, could then link the delivery institution with the warehousing institution or even the research institution. Network organizations combine positive attributes of other structures with some attributes of their own. Among multiple strengths, one critical skill is proving adept at the process of self-design. They adapt well in complex environments.

Certain strategies mentioned earlier also motivate the adoption of network structures, particularly modular specialization. Given the falling price of IT, recall that one strategy is to avoid IT substitutes and to emphasize IT complements. Codified, algorithmic, and rote training are aspects of education that might well pass to self-learning and IT instruction. Traditional universities enjoy no particular advantages over industry in providing efficient service in these areas [12, 19]. Rote forms of student certification might also be handled by IT. In contrast, non-algorithmic insight, Socratic discursive dialog, and peer review (i.e. information certification) remain aspects of education and information exchange at which universities remain unsurpassed. By lifting the geographic barriers to information exchange, IT may complement the delivery of educational services in which universities enjoy a comparative advantage even as it substitutes for those in which they do not. Pursuing IT complements argues for specializing in areas of comparative advantage, that is, aspects of creating, teaching, caching, and accrediting information that require sophisticated rather than simple processing.

Specialization appears to be the sine qua non of future success. In education as in other fields, the increased reach of IT helps create an environment in which the best drive out the merely good [19] and the winners will indeed take most if not all of these markets. The question that follows is “How specialized is specialized?” In their efforts to become world class experts on selected topics, for example, doctoral students have been known to choose theses so narrow that they sacrifice relevance for precision. Certain academic disciplines have even been criticized for being too far removed from practice. They are neither accountable nor even recountable to the general public [7].

One potentially useful guideline is to choose that level of specialization that makes one an attractive expert partner. Accountability to a partner helps ensure relevance. Complexity and change in the environment can lead the specialist in one period to become a relic in the next. Change imposes a need to balance specialized skills with more general skills in order to adapt. Partnering helps share risk, provide diverse information input, and distribute decision authority in ways that can potentially increase joint viability. In complex environments, the trick is to partner for complementary skills rather than invest in imitating the talents more expertly deployed by others. This avoids the opportunity costs associated with performing tasks at which one is second rate. Market opportunities and educational niches may themselves change and require a new partner’s complementary resources in order to exploit them. In attracting partners, however, one needs to be an attractive partner. To develop a program in product innovation, for example, a first rate business school is less likely to partner with a second rate engineering school if the market offers better options. IT also complements network cooperation and more market-like structures because it enhances coordination [18]. The resulting cospecialization, common purpose, and coordinated control leads to network forms of organization.

Conclusions / Bottom Line

From an institutional perspective, the greatest rewards are to be derived from anticipating the need to specialize and focusing on departments and clusters of departments that collectively provide the greatest value. In any given environment, the degree of specialization should be influenced by factors that make one an attractive partner. Too little specialization leaves a school with too little to offer. Too much specialization leaves one without much occasion to contribute. A more complex environment implies a need for more partners and more resource coordination. This implies specializing within disciplines and information roles, and balancing specialization with complementary partnerships and resources. To a university, it also implies providing departments with greater autonomy and the ability to seek complementary resources outside the core institutional structure. Information processing pressures suggest a move toward network structures.

Given the university's role in creating, teaching, caching, and accrediting information, educators can benefit significantly by applying a model of the university as an information processor to their strategic thinking. Such a model captures the public good versus private capital tradeoff and recognizes the tension between rewarding information sharing versus rewarding information sales. It also provides important insights into evolving phenomena including specialization, fragmentation, incentive competition, winner-take-all markets, and intensification of reputations. Using this framework also suggests how increasingly rapid changes in the environment can increase the need for improved information processing capacity.

As information complexity rises, our colleges and universities will need to adapt even as they continue to play an essential role in shaping our information institutions. Half the information challenge is to predict the consequences of information pressures. Then, given that no future scenario is inevitable, the other half is to seek such leverage as can lead to the futures we want. The only real tragedy would be to treat these trends as inescapable. Information and technology create opportunity – they give us new choices with which to seek the more attractive futures, and avoid the less attractive alternatives.

Bibliography

1. Alstyne, M.V., *The State of Network Organization: A Survey in Three Frameworks.* Journal of Organizational Computing, 1997. **7**(3 (forthcoming)).

2. Alstyne, M.V. and E. Brynjolfsson. *Communication Networks and the Rise of an Information Elite -- Do Computers Help the Rich get Richer?* in *International Conference on Information Systems*. 1995. Amsterdam:

3. Alvarez, L.W., *et al.*, *Extraterrestrial Cause for the Cretaceous-Tertiary Extinction -- Experimental Results and Theoretical Interpretation.* Science, 1980. **208**(4448): p. 1095-1108.

4. Black, F. and M. Scholes, *The Pricing of Options and Corporate Liabilities.* Journal of Political Economy, 1973. **81**(3): p. 637-654.

5. Branscombe, A.W., *Who Owns Information?* 1995, Cambridge, MA: MIT Press.

6. Brynjolfsson, E., *The Productivity Paradox of Information Technology.* Communications of the ACM, 1993. **96**(12): p. 67-77.

7. Cassidy, J., *Department of Disputation: The Decline of Economics.* The New Yorker, 1996. : p. 50.

8. Cummings, A., *et al.*, *University Libraries and Scholarly Communication*. 1992, Virginia: Association of Research Libraries.

9. Frank, R.H. and P.J. Cook, *The Winner-Take-All Society*. 1995, New York: Free Press.

10. Gaspar, J. and E.L. Glaeser, *Information Technology and the Future of Cities*1996, NBER: May, 5562

11. Hoffman, C., *Federal Support for Education. Fiscal Years 1980 to 1995*1995, US Government Printing Office: Nov.,

12. Ives, B. and S. Jarvenpaa, *Will the Internet Revolutionize Business Education and Research?* Sloan Management Review, 1996. **Spring**: p. 33-42.

13. Kaufer, D.S. and K.M. Carley, *Communication at a Distance: The Influence of Print on Sociocultural Organization and Change.* 1993, Hillsdale, NJ: Lawrence Erlbaum Associates. 474.

14. Krugman, P., *White Collars Turn Blue,* in *New York Times Magazine*1996, New York. p. 106-107, 199.

15. Kuhn, T., *The Structure of Scientific Revolutions*. 2nd ed. 1970, Chicago: University of Chicago Press.

16. Lenzner, R. and S.S. Johnson, *Seeing Things As They Are*, in *Forbes*1997, p. 39.

17. Leslie, J., *Mail Bonding,* in *Wired*1995, p. 42-48.

18. Malone, T.W., J. Yates, and R.I. Benjamin, *Electronic Markets and Electronic Hierarchies.* Communications of the ACM, 1987. **30**(6): p. 484-497.

19. Massy, W.F. and R. Zemsky, *Using Information Technology to Enhance Academic Productivity*1995, National Learning Infrastructure Initiative: June,

20. McLuhan, M. and B.R. Powers, *The Global Village -- Transformations in World Life and Media in the 21st Century.* 1989, New York: Oxford University Press.

21. Moffat, A.S., *New Meetings Tackle the Knowledge Conundrum.* Science, 1993. **259**: p. 1253-55.

22. Noam, E., *Electronics and the Dim Future of the University.* Science, 1995. **270**: p. 247-249.

23. Nohria, N. and R.G. Eccles, ed. *Networks and Organizations.* 1993, Harvard Business School Press: Boston, MA. 544.

24. Orlikowski, W. *Learning from Notes: Organizational Issues in Groupware Implementation*. in *Proceedings of the Conference on Computer Supported Cooperative Work (CSCW)*. 1992. Toronto, Canada: ACM.

25. Pool, I.d.S., *Tracking the Flow of Information.* Science, 1983. **221**(4611): p. 609-613.

26. Powell, W.W., ed. *Neither Market Nor Hierarchy: Network Forms of Organization.* Research in Organizational Behavior, ed.^eds. B.M. Staw and L.L. Cummings. Vol. 12. 1990, JAI Press: Greenwich, CT. 295-336.

27. Quinn, J.B., *Intelligent Enterprise*. 1992, New York: Free Press. 473.

28. Romer, P., *Increasing Returns and Long Run Growth.* Journal of Political Economy, 1986. **94**(5): p. 1002-1037.

29. Romer, P., *Endogenous Technological Change.* Journal of Political Economy, 1990. **98**(5): p. S71-S102.

30. Rowe, K., *At Conference, Dertouzos Discusses Links to the Past,* in *MIT Tech Talk*1996, Cambridge. p. 4.

31. Saxenian, A., *Lessons From Silicon Valley.* Technology Review, 1994. **97**(5): p. 42-51.

32. Simon, H., *Applying Information Technology to Organizational Design.* Public Administration Review, 1973. : p. 268-278.

33. Simon, H.A., *Models of Man*. 1957, New York: John Wiley & Sons.

34. Sproull, L. and S. Kiesler, *Connections -- New Ways of Working in the Networked Organization.* 1991, Cambridge: MIT Press. 212.

35. Stephan, P.E., *The Economics of Science.* Journal of Economic Literature, 1996. **34**(4): p. 1199-1235.