Focus on Electronic Publishing JAMIA

Viewpoint ■

Information Economics and the Internet

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Abstract Information economics offers insights into the dynamics of information across networked systems like the Internet. An information marketplace is different from other marketplaces because an information good is not actually consumed and can be reproduced and distributed at almost no cost. For information producers to remain profitable, they will need to minimize their exposure to competition. For example, information can be sold by charging site access rather than information access fees, or it can be bundled with other information or "versioned." For information consumers, a variation of Malthus' law predicts that the exponential growth in information will mean that specific information will become increasingly expensive to find, because search costs will grow but human attention will remain limited. Furthermore, the low cost of creating poor-quality information on the Web means that the low-quality information may eventually swamp high-quality resources. The use of reputable information portals on the Web, or smart search technologies, may help in the short run, but it is unclear whether an "information famine" is avoidable in the longer term.

■ **J Am Med Inform Assoc.** 2000;7:215–221.

The information space on the Internet that we call the World Wide Web continues to grow, offering seemingly unlimited potential for the creation, storage, and dissemination of information. In health care, the Web is seen as offering an answer to everything, from the integration of our fragmented information systems to the delivery of accurate information to consumers, evidence-based medicine, and the electronic medical record.

Yet, while it is beguiling to focus on the advantages of specific technical innovations on the Internet, it is much harder to predict their ultimate utility or impact. We know, for example, that the diffusion, acceptance, and ultimate success of any technology is at least as dependent on the social system in which it is placed as on the nature of the technology itself.[1,2] Yet we still lack clear models of what it means to deliver information using a network technology like the Internet in a complex social system like health.

Surprisingly to some, economics may offer insights into the dynamics of information across networked systems. Economic models invoke not just the specific technical advantages of one product over another but the preferences and decisions of individuals who choose to use a product. In the specialist field of information economics, we find theoretic and practical models for creating, diffusing, and using information. Information economics also focuses on understanding how networks of individuals interact to exchange information and on the emergent properties of those in-

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Received for publication: 8/24/99; accepted for publication: 12/23/99.

teractions. As such, it provides informatics with a core set of theoretic results that have a wider application, beyond the specifics of the Internet.

This review introduces the basic properties of information as an economic good. Beginning with information production, the economic properties of information have substantial importance for those who publish information on the Web, whether their intent is commercial or not. In addition, this review shows that a basic economic analysis of the current growth of information on the Internet has substantial implications for information retrieval by consumers.

Producing Information: Valuing Information as a Capital Good

Economic commentators regard any information that can be given a market value, such as music, literature, or a product design, as an *information good*. Indeed, any information that can be digitized is potentially a capital good.[3] In health care, we see many examples of the capital value of information. Consumers are willing to pay for health-related information that comes directly from clinical professionals or from mass media such as magazines. Clinicians pay for subscriptions to journals or purchase texts to maintain their skills, knowledge, and professional standing. Pharmaceutical companies are happy to pay physicians for data about their prescribing behaviors so that the data can be aggregated to reveal prescribing patterns for the companies' products.

However, the characteristics of information goods differ from those of traditional traded goods in a number of ways, with interesting consequences for producers and consumers[3–6]:

- You must experience information before you know what it is. Without reading a book or listening to music, you cannot know whether it is really worth buying. In contrast, there is no need to pre-use normal goods like batteries or oranges, since we can assume that these goods will deliver what is expected of them.
- While production costs are typically high and fixed for information products, these products can be copied cheaply (and indefinitely if they are in digital form). The master copy of a book, movie, or soundtrack is expensive to produce but cheap to copy. Creating and maintaining the information content of a Web site is expensive, but making copies of the information for consumers who visit the site costs almost nothing. In economic terms, the marginal costs of reproduction for information goods are low. Worse, initial production costs are "sunk," in that they are incurred prior to mass reproduction and cannot be recovered in the case of failure.
- Since digital information can be copied exactly, it is never consumed. Furthemore, a possessor of information can transfer it to others without losing the information (unless we demand that they forget what they know!). Normal goods like apples, oranges, and houses do not behave in this way. Consequently, the laws of supply and demand that depend on the scarcity of products do not easily apply to many information goods.
- Digital information can be transported at low cost, which may approach free transmission across bulk communication networks.

When distribution costs are low and the good itself is cheap to reproduce, producers can be drawn into ruinous price wars, driving the consumer price toward zero.[7] Consequently, information can acquire a proper market price only when some form of monopoly protects it, as through the protection of a patent or copyright, which is the usual recourse for creating value and protecting investment.

However, pirates are well able to exploit irregularities in copyright laws to their advantage, and an information good need not be digital for the enterprise to be worthwhile. In the 19th century, U.S. copyright laws did not extend to foreign works, so publishers were able to rush popular works to the United States for reproduction, where they had an almost guaranteed market. For example, in 1843, pirated copies of Dickens' A *Christmas Carol* sold for six cents in the United States, while the authorized version sold for the equivalent of $2.50 in England.[3] Competition among pirates was intense, since the first to publish might have had only a matter of days before its product, too, was copied. Modern software and music pirates operate in a similar fashion.

When free distribution of information is the goal, then this ability of information to be reproduced and distributed at minimal cost is to be welcomed. When the owner of information seeks to generate revenue from the information, it is potentially disastrous. Any document placed on the Web is subject to similar pressures, since it can potentially be copied and subsequently made available on another site. Unfortunately, copyright is weakened as a form of protection for Web documents, because information pirates can place duplicate documents on Web servers in foreign countries that do not recognize or enforce a copyright. Furthermore, the nature of the Web al-

lows consumers living in a country with well-policed copyright laws to access these foreign, pirated documents. Catching Web users who access pirated information is nontrivial and, perhaps, more trouble than it is worth.

This leads to an obvious question: How does an information producer make money publishing on the Web? If consumers expect information to be virtually free, if producing information is expensive, and if, once produced, your product can be stolen by your competitors, then it may seem a forlorn proposition (Box 1).

The answer is to avoid, as much as possible, creating information goods that must be traded in such openly competitive environments and recreate instead the characteristics of a monopoly. While these avoidance tactics may not ultimately prevent information from entering a pirate market, they delay the inevitable. With sufficient delay, the information may no longer have commercial value, or the producer may have adequately recovered enough costs and generated enough revenue.

Several avoidance tactics are commonly employed. First, unlike most commodity items, most information goods are highly differentiated.[3] Each article in a journal is different, and we would not necessarily consider one a direct substitute for another. However, information goods are similar enough for there to be competition among them. Indeed, despite some differences, consumers may not be able to discriminate. For example, a trained clinician may easily detect the difference between two self-help articles written for the general public, but a member of the public may not. In such cases, the reputation of the provider may be the only thing that helps the general public discriminate between information sources. Attaching the brand identity of a professional organization to an information site, for example, may ensure that consumers come there in preference to purely commercial information sources.

Second, it is often suggested that the Internet will herald a competitive pay-per-view model, in which consumers pay only for the information they read. For example, clinicians might pay only for the journal articles they download rather than for an annual subscription for the whole journal. Indeed, one of the big attractions of Web technologies is the potential to charge customers according to their use of a product. However, in such an environment, items of information need to compete with one another, which would drive prices down towards zero. One way to avoid this is to charge a flat fee for entry to a Web site and allow consumers to then take what they need. Comfortingly for information providers, there is theoretic and anecdotal evidence that customers may actually prefer to pay a fixed fee for entry to a Web site rather than a fee per view.[7] For example, many pay-per-view TV schemes have flopped. Three main reasons probably lead to a preference for simple and predictable

Shopping with Perfect Information

We know that prices for similar items vary across different sellers. This price dispersion is a manifestation of lack of knowledge, or ignorance, in the marketplace.[10] If everyone always knew where the best buy was, then everyone would shop there. Alternatively, all the sellers would have to drop their prices to match the lowest price. The reason people do not search exhaustively for the best deal is that search is expensive. It consumes time and effort, which are limited resources for us all. It is also the case that, on average, prolonged searches show diminishing returns over time.

In the world of online commerce, things can be very different. For example, a consumer could use a software agent, or "shop-bot," to seek the best price for a particular item.[14] Searching with the agent incurs no real cost, since Internet transactions are virtually costless, as is most information on the Internet. As a result, online sellers would be forced to match the lowest price to remain competitive in the shop-bot driven marketplace.

This is, indeed, what has happened. In one now infamous story, an online CD shopping agent offered to help customers find the cheapest CD from the online stores. As we would expect, prices started to come down among the online retailers to maintain sales. However, realizing the dilemma posed by perfect consumer information, most of the online sellers decided to block access to the shopping agent. In a single stroke they eliminated the potential for competing in a marketplace that had the potential to drive their returns down close to zero.

Internet commerce also has the potential to drive prices up. If consumers can detect changes in prices more quickly than retailers, then a price drop favors the first price cutter. However, if retailers could detect price changes faster than consumers could, things would change. So, if one firm dropped its price and was immediately matched by another firm before customers could act on the change, then the first price cutter would get much less from the deal. So the incentive to cut prices is diminished. In contrast, matching upward prices is beneficial. Some evidence of a general upward drift in online prices through such price matching now exists.[15]

Box 1

flat fees for access to information. First, flat fees provide insurance against sudden large bills. Second, customers typically overestimate their potential use, so they are happy to pay more. Third, flat fees remove the worry of deciding whether downloading a specific information item is worth the money.

In addition, producers may obtain more revenue for individual information items if they bundle them with other, disparate items and then sell access to the whole package. For example, software is most profitable when it is bundled with other items into a suite and sold for less than all the items, bought individually, would cost. Even though consumers may not need the whole bundle, they are happy to pay a higher price for it than for a single piece of software. Since the cost of manufacturing software is marginal, bundling provides more revenue from individual consumers. So, buying access to a Web site or to a whole issue of an electronic journal not only may be preferred by consumers but also may be more profitable for producers.[7]

Finally, information producers can recover their fixed costs through creative pricing and marketing. It is common for different groups of consumers to pay different prices for different versions of the same information. Some consumers are happy to pay for an expensive hardback copy of a book because they can read it earlier. Others are happy to wait and read the cheaper paperback. Some investors are happy to pay a high price for real-time stock quotes and complex financial analyses, while others are happy to read free but delayed stock prices with little or no analysis. Information can be ''versioned'' along many dimensions, including delay, user interface, convenience, image resolution, format, capability, features, comprehensiveness, annoyance, and support.[8] So, while an electronic journal may make its contents available free to the public, it may provide extra services to its fee-paying subscribers, such as the ability to see articles prior to general release, advanced search and current awareness notification services, higher-resolution images, and access to links to related materials.[9]

Consuming Information: The Costs of Searching for Information on the Web

As we have seen, information can never be consumed. However, as Herbert Simon has famously noted, ''What information consumes is rather obvious. It consumes the attention of its recipients. Hence, a wealth of information creates a poverty of attention.''[6]

By all accounts, the store of information available on the Web is growing exponentially. However, the amount of information being accessed, or ''consumed,'' grows linearly at best. As Varian[3] has pointed out, this leads to a variant of Malthus' law, which showed that while the amount of food seemed to grow linearly, the number of stomaches grew exponentially (Box 2).

The uncomfortable consequence of this ''Malthus' law of information'' is that *the fraction of information that is actually consumed will, with time, approach zero*. In this case, the limiting factor is our ability to spend time consuming information. Our attention is the scarce resource.

The consequence of this ever-expanding information marketplace for information producers is that their success is increasingly dependent on their ability to compete for the attention of information consumers. The consequences for information consumers are equally problematic. First, and obviously, the demands on our attention are increasing. At the limit, information consumption has the potential to dominate all other tasks for our attention, unless individual limits to consumption are introduced.

Malthus' Law

In 19th century England, Thomas Malthus argued that a law of diminishing returns applied to the production of food, and he predicted that famine was the inevitable consequence for the human race.[16] The problem was that while the amount of agricultural land was fixed, the human population continued to grow. Even with improved agriculture, beyond some point the increased yield in food production per unit of land becomes ever smaller.

Malthus' logic was impeccable, but the human race has survived through the 20th century and into the 21st. What Malthus did not foresee was that agricultural technology would increase food yields at the rate it did. Food production per capita in 1985 was 20 times greater than it was a century earlier and outstripped the effects of a fixed supply in land and a growing population.

Some will argue that Malthus misunderstood the capacity for technology to improve food production and that as long as we develop new technologies, we will always be able to feed ourselves. Yet Malthus' logic remains valid, and if the global population continues to grow, a time will come (perhaps long into the future) when the land cannot keep up with what is demanded of it. We only evade the law if we evade the rate-limiting step—that is, the supply of land on the earth and our dependence on it.

Box 2

Equally worrying, it should, theoretically, become ever more expensive to find information. Searching for and evaluating information in particular have the potential to become increasingly expensive over time. If the amount of information is growing exponentially, then, by implication, so too should the number of documents that match any particular search. Another way of stating this is to say that, for a given amount of search effort, the probability a finding a document on the Web will decrease with time. In other words, the seemingly inevitable consequence of a global growth in information supply is actually an ''information famine,'' in which we cannot find what we need. The haystack just keeps growing, making it ever harder to find the needle.

The costs of searching for, evaluating, and then purchasing any good are all *transaction costs*. Although they may not be factored into the final price we pay for an item, they are a real part of the cost of doing business. So, while information on the Internet may become virtually free to obtain, the transaction costs in obtaining that information will not disappear. We can summarize by noting that the cost of an information transaction on the Internet is related to the amount of information placed on the Internet. Such costs are an example of a *negative network effect* or *negative externality* (Box 3).

It can be seen from this that searching for information on the Web is subject to the same economic constraints that apply to searching for goods in a physical marketplace (Box 1). A traditional way in which consumers minimize the search costs for goods is to seek out a trusted supplier who usually delivers a high-quality product at a good price. A department store, for example, can be seen as an organization whose main value is to search for superior goods for its customers and then guarantee that they are of good quality. A store's good reputation results in consumer loyalty. Such a reputation is a valuable item in itself, since it economizes on search for customers[10] and therefore can be translated into a price added to the base cost of a good.

On the Web, information consumers can similarly minimize search costs by constraining their search to known areas that produce high-quality information that usually suits their needs. Such information portals thus act like traditional department stores. Unsurprisingly, there is already fierce competition among Web portals for consumer attention and the consequent opportunity to attract what is most economically valuable to them—consumer loyalty maintained through reputation.

Externalities

An *externality* is a cost or benefit that falls on people who are not directly involved in an activity.

The Internet exhibits what are know as *positive externalities*, or *network effects*, where the value of a good depends on the number of other people who use it. Thus, the more people who join the Internet, the more valuable an individual connection to the Internet becomes.[6] Other networks exhibit similar positive externalities. The value of the fax or telephone changed enormously once the network of individuals owning one grew, resulting in a sustaining positive feedback cycle of network growth. So, with positive network externalities, the actions of others enhance the value of joining the network.

In contrast, pollution arising out of the production of a commodity is an example of a *negative externality*. It affects not just those who manufacture or consume the product but society as a whole.[16] Since externalities are, by definition, not factored into prices, there is no economic incentive to deal with them by producers. The problem then is that negative externalities impose additional costs on others but can be ignored by the producer. If one could somehow internalize the externality—by factoring the cost of pollution into taxation, for example—then an incentive to minimize the negative effect would be introduced. So a tax based on the amount of pollution a producer generates has the effect of providing an incentive to minimize pollution.

The Internet also exhibits negative externalities. For example, when the number of users on the network exceeds its transmission capacity, congestion results. The resulting delay in the transmission of e-mail or retrieval of documents imposes a cost on individual users. As long as the cost remains external to the system, there is no incentive for individual users to deal with the problem. However, if Internet use became expensive at times of congestion, then the negative externality would become internalized into the calculations of consumers and they would have an incentive to use the system less at congested times.[3]

Box 3

An issue related to the growth of information is that of information quality. If the main cost of creating and selling information online occurs at the time of production, then producers with low production costs are in a position to swamp high-quality producers. For health care there are particular implications. For example, producing high-quality evidence-based guidelines for clinicians or clear and accurate information for consumers is resource intensive. Consequently, the rate at which good-quality health information can be

produced cannot match that at which poor-quality information is produced. Thus, producers of poor-quality information may be at an advantage on the Internet, where they can flood the entire information market with their product.[11]

Solutions to this problem of information quantity include the use of legislation to limit the ability of producers of poor-quality information to publish on the Web, but the international reach of the Internet limits the effectiveness of any single nation's efforts. Alternatively, quality labels could be used to identify information that meets a high standard.[12] Many consumers solve the quality problem in the same way that they solve the search problem. They seek information from portals that seem to them to deliver good-quality information. Consequently, one of the Internet's challenges to health care is for us to find economic ways to provide sources of information on the Web that consumers trust.[13] Failure to do so leaves the health information market open to opportunists who may not share the same standards for information production or the same goals for its dissemination.

Despite all our best efforts, however, over time the rigid logic of the Malthus law of information should, theoretically, swamp all the benefits to information producers of creating high-quality sites. And for consumers, it should swamp the benefits of ''contracting out'' information search costs to a trusted portal, labeling information, or using search agents. Information will continue to increase exponentially, but our capacity to find what we need will not.

However, as with Malthus' prediction about the production of food, advances in technology might help us avoid catastrophe in the short term (Box 2). If we can increase the accuracy of information search technology at a rate greater than the rate at which information grows, then we can avoid our information famine. At present, a large research effort is focused on Internet search technologies. For example, personalized search agents can not only help find information but filter it according to the likelihood that it matches a consumer's needs. An agent could do this by learning from past experience. By building a computational model based on the documents that satisfied previous search criteria, the agent over time builds up knowledge about its users needs. Since the rate-limiting step we identified is human attention—specifically, the time it takes to sift through the results of a particular search—anything that makes it easier to specify exactly what is needed will improve the situation.

In a sense, we are entering a period of an escalating technologic arms race between the production of information and our capacity to find information, and the ultimate outcome is not at all clear. However, even if improved search technology cannot change underlying economic principles, it can confer a relative advantage to individuals. When the possession of the best information is critical to an endeavor's success, then possessing a superior search technology confers an advantage over one's competitors.

Conclusion

Information economics provides us with a challenging analysis of the future for information publication on the Internet. It shows that the growth in information has profound consequences for both information producers and consumers. It will be harder for producers to push the information they create to the audience they want. Consumers, on the other hand, are faced with parallel problems arising out of information oversupply and the limits of human attention. While technologic innovation can be cast as our savior, in truth we still know very little about its power to help. Right now, it is very hard to know whether we are heading for an information feast or famine.

References ■

1. Rogers EM. Diffusion of Innovations. 4th ed. New York: Free Press, 1995.
2. Coiera E. The impact of culture on technology [editorial]. Med J Aust. 1999;171:508.
3. Varian HR. Markets for information goods. Apr 1998 (rev Oct 16, 1998). Available at University of California, Berkeley, School of information Management and Systems Web site, at: http://www.sims.berkeley.edu/~hal/people/hal/papers.html.
4. Morris-Suzuki T. Capitalism in the computer age and afterward. In: Davis J, Hirschl TA, Stack M. Cutting Edge: Technology, Information Capitalism and Social Revolution. London, UK: Verso, 1997.
5. Davis J, Stack M. The digital advantage. In: Davis J, Hirschl TA, Stack M. Cutting Edge: Technology, Information Capitalism and Social Revolution. London, UK: Verso, 1997.
6. Kelly K. New Rules for the New Economy. London, UK: Fourth Estate, 1998.
7. Fishburn P, Oklyzko AM, Siders RC. Fixed fee versus unit pricing for information goods: competition, equilibria and price wars. First Monday [online serial]. 1997;2(7). Available at: http://www.firstmonday.dk/issues/issue2_7/odlyzko/.
8. Shapiro C, Varian HR. Information rules: a strategic guide for the network economy. Cambridge, Mass: Harvard Business School Press, 1998.
9. Varian HR. Pricing electronic journals. D-Lib Magazine [online serial]. Jun 1996. Available at: http://www.dlib.org/dlib/june96/06varian.html.
10. Stigler GJ. The economics of information. J Polit Econ. 1961; 69:213–25. Reprinted in: Lamberton DM (ed). Economics of

Information and Knowledge. Harmondsworth, UK: Penguin, 1971.
11. Coiera E. Information epidemics, economics and immunity on the Internet [editorial]. BMJ. 1998;317:1469–70.
12. Eysenback G, Diepgen TL. Towards distributed quality management of medical information on the Internet. BMJ. 1998;317:1496–502.
13. Coiera E. The Internet's challenge to healthcare provision [editorial]. BMJ. 1996;311:2–4.
14. Kephart JO, Greenwald A. Shopbot economics. Proceedings of 5th European Conference on Symbolic and Quantitative Approaches to Reasoning with Uncertainty; London, UK; Jul 6, 1999. Available at IBM Research, Information Economies Project Web site, at: http://www.research.ibm.com/infoecon/researchpapers.html.
15. Varian HR. Market structure in the network age. Apr 1999 (rev Aug 30, 1999). Available at University of California–Berkeley, School of Information Management and Systems Web site, at: http://www.sims.berkeley.edu/~hal/people/hal/papers.html.
16. Frank RH. Microeconomics and Behavior. 3rd ed. New York: McGraw-Hill, 1997.