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Maximizing efficiency and effectiveness of Information Data Banks

by

Y.M.Braunstein

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MAXIMIZING EFFICIENCY AND EFFECTIVENESS
OF INFORMATION DATA BANKS

by

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MAXIMIZING EFFICIENCY AND EFFECTIVENESS
OF INFORMATION DATA BANKS

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SUMMARY

This paper examines several of the principles underlying the efficient and effective production, transfer, and use of information. The first sections examine the cost savings and benefits that accrue to users from increased cooperation among the participants in the information transfer process. This discussion covers both cooperation between producers, intermediaries, and users ("vertical cooperation") and cooperation among the producers or among the intermediaries ("horizontal cooperation"). Next, the impact of networking on information services is discussed. Here the distinctions are made among computer networks, communications networks, and information networks. Each is analyzed in turn. The final sections deal with the effects of charges for information. Particular attention is paid to the transactions costs associated with any pricing and collection mechanism and to the economic impact of the use of copyright protection for information products and services.

1. EFFECTS OF INCREASED COOPERATION ON THE VALUE AND COSTS OF INFORMATION

1.0 Introduction

Over the years economists have developed a simple means of classifying the interactions between firms - whether one is discussing market transactions, contracts, or mergers. In this classification a distinction is made between vertical interactions - those that occur between suppliers and users of information (or any other good or service) and horizontal interactions - those that involve organizations at the same "level." We shall use this taxonomy in the following discussion of the benefits of increased cooperation among the organizations involved in information transfer and the operation of information data banks. As will be seen, this cooperation can increase both the value of information and reduce the costs of providing and using information.

1.1 Vertical Cooperation

There are several economic benefits that can result from increased vertical cooperation.* This cooperation may be as complete as the merger of a supplier and its customer or be less complete in nature as would be the case with increased standardization of products and services and cooperation between providers and users. The possible gains include a reduction in cost from the elimination of some of normal costs of doing business and relying on the marketplace, a lowering of the risk and uncertainty involved in any transaction, and an elimination of the need for each separate stage of the process to be self-supporting.**

The abstracting and indexing operations of publishers of scientific journals can provide an example of the cost savings. For instance, Parisi [2] describes one publisher which uses a simple keyboard entry of indexing information to produce all of the following in correctly formatted camera-ready copy:

1. monthly abstracts of all articles published
2. bimonthly abstracts of all articles and papers (in a different format)
3. bimonthly permuted key work subject index
4. bimonthly author index
5. annual conventional subject and author indices
6. cumulative five-year subject and author indices.

The development costs of this computer assisted abstracting and indexing system were approximately U.S. \$25,000 in 1970. The monthly costs now are less than \$2000 for the input of 100 items - papers, discussions, etc. (See Parisi [3].)

Another publisher uses a standard format for titles, authors' names, abstracts, and references to facilitate later use by abstracting and indexing services. There is essentially no increase in the composition costs from this standardization. There are, of course, additional costs associated with production of the magnetic tapes containing this information. These can be minimized by using optical character recognition (OCR) elements when typing the abstracts and indexing information, OCR readers, and the appropriate equipment and programming. The tapes, containing the information on articles published each month, are sold to computer system operators, the publishers of abstracts and indices, etc.

This movement toward automation by the primary publishers leads to more efficient access by researchers and others to the information contained in their journals. The individual scientist or engineer may first become aware of a particular piece of research either through the print medium or via the computer-based bibliographic reference systems. In addition to being useful for its own reference products, the information on titles, authors, citations and abstracts can also be utilized by the abstracting and indexing services in their products. Both these services and the computer system operators may benefit from the standardization and machine readable outputs that are utilized by the primary publishers themselves.

* For a complete survey of the recent work in the economics of vertical integration, see Williamson [1].

** Another benefit of vertical mergers that is often cited is that the increased firm size may improve access to capital markets. This will be ignored here.

The secondary services often provide the information to the user in different modes or formats. This "repackaging" may take the form of an entirely different index (e.g., a citation index or an augmented key word index) or make use of special thesauri. These additional channels can help meet the needs of different groups of users by addressing their particular needs or research methods. In general, one need not worry about over-proliferation or needless duplication of products and services if each must meet the test of the market. Those products or services that are useful will be demanded by individuals, institutions, or libraries, unless their prices are excessive.

What we have is a situation where the usefulness of one product (a citation index and its data base, for example) is predicated on the existence of another product (here the primary journals). And the usefulness of the basic product (the journals) is enhanced by the availability of the "downstream" product (the index). Formally, this is similar to what Samuelson [4] calls the "Pareto-Georgescu" definition of "complementarity". Whatever the technical description, it is obvious that there is an inter-dependency between the values of the primary sources of information and of the products that provide alternate classification schemes or modes of access. And this relationship between the values is in addition to the relationship between the costs described above.

1.2 Horizontal Cooperation

There is at present little standardization across information data bases or the systems used to access them. This lack of standardization is apparent to the user of information data banks from the start. On one level there are differences in the structures of data bases, of their thesauri, and so on. On another level the commands, logical structure and computational, logical, and storage capabilities of the computer systems on which the data bases are maintained also differ.

It is commonly held that to require the designers of the data bases or of the computer systems to adhere to certain standards will stifle creativity, possibly resulting in losses to the systems users. On the other hand, increased standardization may make the data contained in an assortment of data banks both more accessible and more useful.

Currently there is no one simple solution to this conflict. However the MARC II format for bibliographic reference data encoded on magnetic tape has achieved a fair degree of acceptance. (See Avram, et. al. [5] for details on MARC II.) But many producers of tape output do not use this standard. This is true even for some of the systems developed after 1968.

Below are two of the many statements that decry the lack of standardization and cooperation, those by Adkinson [6] and Gechman [7]:

The scientific and technical information activities in the United States will never gain the stature nor develop the necessary services so long as the participants view this area as an arena of competition instead of a platform for hard headed realistic cooperation and coordination ... individual biases in technical presentation and organization cannot be tolerated ...

The lack of standards is probably the greatest deterrent to the accelerated use of machine-readable bibliographic data bases. It is not possible (in the author's opinion) to realize the full potential of this powerful tool without establishment and adoption of uniform data elements, tape formats, coding conventions, etc. The dilemma exists because most suppliers market magnetic tape data bases as a byproduct of their publication activities. The suppliers' production problems are numerous and they have varied motivations. There are a host of problems associated with standardization that can only be overcome through cooperation of producers, users and processors.

In addition to the development of standards, two systems that may be technically and economically feasible in the near future have been proposed as solutions to this problem. One involves a "front-end" plain language processor that would serve as an interface between the user and the computer system. But this type of processor or "intelligent terminal" must still confront the possible differences in formats of the various source files. It is this ability that is the key; the natural language capability is, of course, useful but is not necessary.

The other system is based on the use of a mini-computer to store the appropriate parts of the data bases in a manner that would facilitate later usage. With this type of system, the user could develop one set of protocols to search through several data bases and then pool the outputs of the individual searches. If this system were to be adopted, it is possible that certain copyright or other property rights questions would arise. These are discussed below in section 3.3.

Each of these, and other efforts to promote standardization, have associated with them certain costs that will have to be borne by the users. But the benefits may be considerable; for example, increases in standardization when coupled with advances in technology could enable (and possibly would cause) the following improvements in the dissemination of scientific and technical information:*

1. Coordinated organization of data bases and improvement in retrieval techniques.
2. Nationwide organization and consequent improvement of standardization and user-provider interfacing.
3. With on-request programming feature, highly specialized material receives wider visibility. Enhances awareness outside specialized discipline areas.
4. Introduction of compatible "viewer" response adds feedback feature and tends to improve overall quality and response to user needs.
5. Improvement in profile definition for Selective Dissemination of Information, and better match of data supplied to data desired.

*This list is adapted from one in [8].

2. IMPACTS OF NETWORKING ON INFORMATION SYSTEMS*

2.0 Introduction

Because "networking" is such an amorphous concept it is possible to discuss it from a variety of viewpoints. Each viewpoint can result in a different set of conclusions regarding the economy of services to be offered and the impact on end users.

There are three general types of networks that are relevant to this discussion and likely to impact on information services in the near future. These include:

- communication networks
- computer networks
- information networks

A more complete description of each category of network is presented elsewhere [9]. The primary advantage to viewing networks in these three categories is that the impacts can be evaluated at a more specific level. Communication networks, for example, have received a great deal of publicity recently and promise to change pricing policy to a distance independent structure. This, however, does not mean that information services as we know them will be significantly cheaper. The total cost for these services consists of many other elements.

Communication networks are made up of transmission lines, concentrators, switching mechanisms and non-data processing components. This is the view traditionally taken by the Federal Communications Commission. With the increased competition in the communications industry as a result of new specialized common carriers and value-added networks, current regulatory policy may need to change to view not only the communication network but also the data processing equipment linked by that network.

Computer networks are often the most confusing to identify. Most definitions imply multiple computers linked together via some means (possibly a communication network). As terminals become more intelligent and acquire internal capabilities equivalent to small computers, a single central mainframe linked to such terminals may become a true computer network.

Information networks in their broadest sense can be any formalized system for information exchange. Current interest is in highly formalized information exchange using today's technology to link libraries, specialized data resources or individuals to the person or institutions in need of information.

Combinations of these three network types offer the most interesting and challenging areas for impact evaluation. Information services delivered within an information network (where duplication is removed) using a computer network (to resource share specialized software, data bases, or processing power) and transmitted via a communication network (to reduce transmission cost) will be tested in the marketplace during this decade. Their survival will depend upon a thorough understanding of the function and economics of each of the component networks. Their survival will depend even more upon a thorough understanding of the user community to be served and its needs and economic resources.

The fact that one component cost (e.g., communication costs) has dropped considerably, may have less influence than expected when viewed in a total context. The real challenge to economic evaluation will come in the development of a suitable product/service "mix" to be delivered via the "network".

In the following sections a brief discussion of the cost/price trends for each network type will be discussed. Because in this case the whole is different from the sum of the parts, the problem of suboptimization must be considered. We cannot assume that optimizing individual components of the system will optimize the overall system made up of several network types.

The final section of this chapter provides some suggestions on possible gains/trends for the overall systems configured from these component networks.

2.1 Communication Networks

The latest buzzword is "packet switching" a result of ARPANET-developed technology which has reached the marketplace in the U.S. and abroad with a promise of greatly reduced and distance-independent cost for communication.** The technology is proven and the application in the commercial sector through such enterprises as TELENET Corporation holds great promise. But the reality is that the communication cost is a relatively small portion of a data processing budget (about 10% according to Martin [10]) and presumably even less for an information service in which processing involves much more than computer processing, storage and retrieval. Therefore, even a significant savings in communication costs via technology such as packet-switched networks might have relatively little impact on an information service required to recover full costs (i.e., not partially subsidized).

In addition, within the U.S. the emergence of commercial packet switched value-added networks and other long-line common carrier networks has created a competitive market where there had previously been no challengers. This will result in a downward trend in communication costs until the marketplace shakes out and regulatory policies are clearly defined.

The development of packet switching emerged in part from two observations---

1. Many user-computer or computer-computer interactions have fairly short holding times, and

* The following four sections on networks were written by W.D. Penniman, Battelle Columbus Laboratories, Columbus, OH 43201, U.S.A.

** Although some tariffs are distance-independent, at this time it is difficult to determine if the costs are truly distance-independent or if the tariffs represent rate-averaging or "postalization".

cannot tolerate a lengthy connection time (such as in a transaction application, where a machine wants to quickly report a single activity). The dial-up phone system (circuit switching) is geared for longer times to connect, and the tariffs are based upon longer minimum holding times.

2. In those situations where there is a lengthy holding time, communication tends to be bursty in nature: long periods of inactivity followed by a burst of traffic (that is, a high peak/average load figure).

Packet switching will allow many users to share the same facilities, while still providing adequate response time and capacity when necessary. An idle user generates no traffic, and need not be paying for an otherwise unused dedicated line. Thus, this approach is particularly well suited for user interaction with a computer, or for situations where one user process wishes to communicate with many other machines. (It is worth noting that this approach is not well suited to those applications where one simply wants to sustain a specified data transmission rate between two pre-determined hosts -- a circuit switched line would most likely be more appropriate.) In addition, a packet switched network can also provide a sufficient degree of standardization, making it possible to communicate with differing computer systems.

Recent data indicates that packet switched component costs are not likely to fall below 50% of circuit switched costs and this in turn will be only about 30% of the total communication system costs.* The greatest advantage of packet switched networks is in applications where the ratio of peak to average loads is high and where the distance involved is great. Information services involve relatively large amounts of data for bibliographic or full text retrieval. The distance advantage does apply to these applications more clearly.

In another study (Blanc [12]) a cost analysis model was developed to evaluate alternative communication methods for linking terminals and hosts. The analysis, among other conclusions, indicated economies of scale with increased network size where the host to terminal ratio is fixed and also where the number of terminals per host is increased. Therefore, greater cost savings and lower per user costs can be realized (as expected) in larger networks or through the linking of currently separate computer networks and their associated communication systems.

In the future, the advantage of packet switching may be magnified as computer costs drop relative to communication costs. The real total cost of information services, however, is still comprised of many more facets than this, and tends to be labor intensive. Just as Johnson [13] concludes for total data processing systems that packet switching will provide savings but not reduce total costs, the same should be noted for information services. The labor intensive elements are going to increase in cost and will account for a much greater portion of information service budgets.

During early stages of information service development and promotion where subsidy (via government for example) is available, it is common to charge the end user for communication costs or terminal rental, or computer connect time. This cost becomes associated in the user's mind with the cost of information. As reduced communication costs are publicized, the user will expect significant reductions in the cost of information services. This is not likely to occur in the open marketplace where subsidy of input and processing costs is not present.

In summary, communication costs are decreasing due to advancing technology and the competitive aspects of a previously monopolistic or highly controlled marketplace. While this trend holds great promise for one component of the information service economic structure, total costs are not likely to be significantly influenced in the near future.

2.2 Computer Networks

A discussion of the economics of computer networking is similar in many respects to that of communication networks. We are currently experiencing drastic reductions in the cost of raw computing power. This, coupled with inexpensive communication costs, encourages remote delivery of computer resources to a wider variety of users creating economies of scale which further reduce computing costs.

Finding the successful product mix and marketing strategy for operation of a single-host computer/remote terminal network or a computer network with several large hosts is a complex problem. Several groups have discussed this area (see Penniman et. al. [14]) and evaluated different strategies and several government subsidized tests of shared resource networks have been conducted in university settings (Weingasten and Whitley [15]). Ultimately, computer networks should be regarded in a free, dynamic market consisting of suppliers (computing centers), middlemen (service and/or sales centers) and end users.

In addition to economies of scale, economies of specialization are being recognized where it is more economical to provide access to specialized resources remotely than to transfer hardware, software and technical expertise (Stefferd [16]). Stefferud also provides an excellent analysis of the network marketplace issues including the wholesale/retail concept.

A recent microeconomic analysis of the market for computer services (Cotton [17]) points out the highly competitive nature of undifferentiated services. In addition, for new services the reduction of cost "has been a major factor in promoting the continued development of those applications".

Current trends indicate another powerful force in the economics of computer networking. The advent of the relatively powerful and inexpensive minicomputer offers the possibility for highly decentralized computer resources. Whereas the large centralized computer installation has provided the most economic approach to date, decentralization now offers technical, if not managerial, advantages.

The advantages and disadvantages of each approach (centralization vs. decentralization) are once again a topic of much discussion in the literature (e.g., Keider [18]; Wagner [19]). Whatever the result

* C.f. Johnson [11].

of this debate - and it is likely to vary from application to application, less expensive computing should result.

However, a total economic analysis must consider rising staff costs at the same time that the raw processing costs are decreasing. For information service applications this, again, is likely to be the most significant factor.

2.3 Information Networks

By the definition previously presented, this is the area with the greatest direct impact on information service efficiency and effectiveness. Certainly those information networks which utilize communication and computer networks will reap the benefits and face the problems of them. In addition, information networks, per se, will have their own blend of problems and advantages. Some of the likely benefits and disbenefits of information networking for scientific and technical information services were evaluated recently by Battelle (Penniman, et. al. [20]) and are excerpted in Table 1. While these potential impacts are presented out of context, they indicate the far-reaching influence of the information service sector as it embraces networking.

Historically, information services have been heavily subsidized. The extent of subsidy required has long been a topic for discussion and has been addressed by those who have felt the stark realities of the economic system (e.g., Hyslop, [21]). More recent ventures involving computer and communication technology in delivery of information services have been relatively successful (e.g., Firschein and Summit, [22]). The apparent financial viability of bibliographic search services offered by such organizations as Lockheed and SDC indicates that bibliographic searching via a terminal is now the standard for consumers who can afford it.

Of perhaps greater impact in the library arena is the resource sharing of cataloging offered by such networks as the Ohio College Library Center (Kilgour, et. al. [23] and Hewitt [24]). In this form of network a labor-intensive function is shared. It also reduces cost at the front end of the processing system and represents a parallel to the resource sharing of computing power.

One of the major barriers to evaluation of the economic impact of technology such as networking in the information service sector is the establishment of value for the end product. While this problem is not peculiar to networking it is worth attention here because networking influences the availability of information which increases the need for measures of value and better approaches to economic evaluation of information as a commodity (Braunstein [25]).

At the theoretical level, research such as that by Yovitz and Abilock [26] and Sheridan [27] could result in practical measures of value for information required by decision makers. If such research is successful, then a full economic analysis of network delivered information services could be accomplished. In the meantime, attempts at justifying information networks by looking at cost reduction of operations or increased availability of information are too limited in perspective.

2.4 Networks - Concluding Comment

The total environment in which networks are evolving is complex and multifaceted and includes technical, legal, economic, policy and humanistic aspects (see Penniman, et. al. [28]). Only a few of these aspects have been addressed in this brief discussion. One of the most interesting information networks currently evolving links people to people via computer conferencing (Turoff [29]), and it may well surpass the more formal information exchange mechanisms of traditional information services.

In addition, new broadband telecommunication services, are being discussed which could bring to each household a wide range of unique services (Hammer [30]). The way in which we work, play, plan and even dream could well be influenced by the networks and services of this next decade. The data banks of that decade may consist of people linked together to share their individual resources, knowledge, and aspirations in a real-time fashion.

TABLE 1:

PROJECTED BENEFITS AND DISBENEFITS OF NETWORKING
WITHIN THE INFORMATION SERVICE SECTOR

<u>Benefits</u>	<u>Disadvantages</u>
<u>Functional</u> <ul style="list-style-type: none"> o Engineers/scientists spend less time in getting new information o State of the art reports easier to produce o Decrease lag time between production and use of information o Standardization of form of presentation of S&T information 	<u>Functional</u> <ul style="list-style-type: none"> o Reduction in quality of research and competition of ideas as a result of standardized information sources o Overt or covert screening and elimination of information deemed less worthwhile because it differs from the bulk of material in the system. "Least common denominator" effect o Increased demand for intermediaries due to expanded network activity could place information collection/screening in the hands of poorly trained workers
<u>Organizational</u> <ul style="list-style-type: none"> o Managerial aspects of networks promote information as a national resource 	<u>Organizational</u> <ul style="list-style-type: none"> o Tendency toward monopolies in network development o Growth of network bureaucracies with overwhelming power in ability to control information o Inadequate guarantees for protection of sensitive information
<u>Technological</u> <ul style="list-style-type: none"> o Competitive market for network hardware could accelerate technological development 	<u>Technological</u> <ul style="list-style-type: none"> o Network hardware cost demands may prevent efficient/cheap operation o Network can become "locked in" to particular hardware and errors in design become prohibitively expensive to correct
<u>Financial</u> <ul style="list-style-type: none"> o Increased productivity of S/E personnel could decrease cost of scientific research and applications o Employment increase in selected sectors or information-intensive industries 	<u>Financial</u> <ul style="list-style-type: none"> o Information businesses which compete with networks must join or shrink o Too rapid development of network will waste money because of technological or organizational immaturity o Above results in inflated costs for network services
<u>Social/Psychological</u> <ul style="list-style-type: none"> o Increased communication capability as a result of easier flow of information o Ability to confront national problems using information as a resource for new solutions o Increased education alternatives via information networks and CAI. 	<u>Social/Psychological</u> <ul style="list-style-type: none"> o Overreliance on network as information source limits scientists' perspective to that of network gatekeepers o Browsing and serendipitous discovery will decrease o Fear of loss of privacy via network monitoring could curtail communication o Pressure to continue poor networks because of "technological mandate" o Widened gap between the information-rich and the information-poor.

3. EFFECTS OF CHARGES FOR INFORMATION

3.0 Price-Quality Relationships and Different Charging Mechanisms*

The economic issues of public policy arising in the production and dissemination of scientific information are best examined by first considering pricing and allocation questions in general, for economists hold that the main reasons public policy must concern itself with the production and dissemination of scientific information is that, left to itself, this sector of activity can be expected to suffer from resource misallocation and non-optimal pricing. The discussion starts with the simple case of a single-product firm producing a common public good.

Starting with the most general type of economic considerations, we can examine the pricing structures that can be expected to apply to a public good characterized by economies of scale. By considering the consequences of these different pricing policies, we shall discover the type of regulatory of market structure that is implied. (Here it is assumed that the reader has some general background in economics and some familiarity with terms such as *marginal cost* and *marginal revenue*. This background, although very helpful, is not necessary to the understanding of what will be presented below.)

It is widely held that a fundamental issue for public policy in this area is the issue of public good attributes in the information dissemination process. Public good attributes often mean a) that private enterprise simply cannot provide such a service on *any* sort of financially viable basis, and b) it is often undesirable for private enterprise to do so. In fact, most of the standard examples of public goods--national defense, environmental protection, etc.--are commodities which are supplied largely or exclusively by government. That, of course, is why they are called "public goods".

The public goods issue, then, is considered critical by many economists for two fundamental reasons: first, because certain types of public goods attributes effectively *preclude* private financing and supply, and second, there are some grounds for the belief that public good attributes characterize some components of virtually all information dissemination activities.

Higher education has often been used for an example because it is widely familiar and has been analyzed thoroughly by economists. However many of the same principles apply to the transfer of information. In Figure A, line DD represents the normal downward sloping demand curve. The average cost curve (labeled AC) indicates the behavior of cost per unit (the total production and distribution costs divided by the output) as the scale of output changes. In our graph, this curve is declining everywhere, meaning, roughly, that we are dealing with economies of scale. By a standard mathematical theorem, the marginal cost curve (MC), the cost of producing each *additional* unit, is therefore always below the average cost curve. The graph also shows the marginal revenue curve (MR) which is important in the consideration of alternative pricing strategies.

It is probably reasonable to hypothesize that education or information transfer is characterized by decreasing average costs for many organizations. We can therefore take Figure A to represent either of these cases and use it to consider some of the alternative structures for the production and pricing of education or information.

The first structure that we shall assume will be production by a *profit-maximizing monopoly*. A monopolist will produce at the quantity where the marginal cost equals the marginal revenue so as to maximize profit. This is quantity q_1 on Figure A. It can be sold for price p_1 as can be seen by the demand curve. So the profit-maximizing monopolist will charge p_1 for q_1 units of education, and will make a profit. (For those who want to get into the mechanics of this type of diagram, the profit can be computed by finding the distance between the average cost curve and p_1 , and by multiplying this by quantity q_1 .) In a normal situation, if there were no barriers to entry--if one did not have to obtain a license or a franchise, the existence of this profit might lead to the entry to additional firms and cause some change in the structure of the market. But with the declining average cost curve, one should remember that the larger the producer--the larger the organization, the cheaper per "use" it is to provide the product or service. Consequently, the firm with the initial monopoly will be able to produce at a lower cost than any smaller entrant. It will, therefore, be able to drive any such entrant out of business by charging prices that cover its own costs but are below those of the entrants. The scale economies thus produce the problem of "natural monopoly"--a state of affairs in which competition is not viable, so that society cannot rely upon the forces of competition to protect consumer interests.

A second pricing option is commonly called average cost pricing or full cost recovery. This would lead to production where the average cost curve crosses the demand curve. The firm would produce q_2 units and the price charged would equal the cost (or p_2 on Figure A). With this price-output pair, the firm exactly breaks even and makes no profit. This possibly characterizes those institutions whose private non-profit status requires them to recover their full costs of operation, but prohibits them from earning any net return.

However, a basic theorem in economics tells that an optimal allocation of resources is generally inconsistent with average cost pricing, and that optimality instead requires *marginal cost pricing*. That is, the price of each item must equal the value of the amount of resources that go into producing an additional unit. This condition can be stated as:

$$MC_i = p_i \text{ for all } i. \quad (1)$$

*Sections 3.0 and 3.1 are adapted from "Public Policy and Research on the Economics of Information Transfer," a paper presented at the 1976 annual meeting of the American Society for Information Science [31].

It can be seen that (because of the presence of scale economies) with marginal cost pricing, the quantity produced (q_3) will be greater than that under average cost pricing, and the price (p_3) will be lower. The problem of marginal cost pricing when there are scale economies is that it requires a subsidy to the producer. This is because it costs almost p_2 to produce each unit but the price per unit is p_3 , and therefore some subsidy is required.*

In schooling and information (and other goods and services) there is often still another alternative pricing option; this is the pricing scheme that is adopted if one believes in universal free provision. Universal free provision can be characterized on our diagram by the price equal to zero (p_4) the quantity produced being q_4 . Here a very large subsidy, equal to the average cost at quantity q_4 times q_4 units, is required. (This discussion of alternative pricing structures applies not only to education and information, but to all goods and services whose average cost curve slopes downward in the relevant portion.)

In any of these situations, the pertinent considerations are not quite as simple as the preceding discussion has made them seem. We have said that, in general, an optimal allocation requires the marginal cost of good i to be equal to the price of good i for all such goods [Eq. (1)]. But this requirement cannot be met by a subsidy if marginal cost pricing is required for *every* good. The reason is that society must raise the money for the subsidy from somewhere--by some form of taxation. And this means that even if pre-tax prices are equal to marginal costs, after-tax prices cannot be; thereby the optimal pricing problem becomes an optimal taxation problem. How are we to raise the money for the subsidy? The taxes have to be charges on something. We can have a charge on income or on labor, or we can have charges on the consumption of various goods such as value added taxes or sales taxes. Any type of system of raising this revenue, other than a lump sum tax, causes prices to differ from marginal costs somewhere. And therefore we cannot have universal marginal cost pricing.

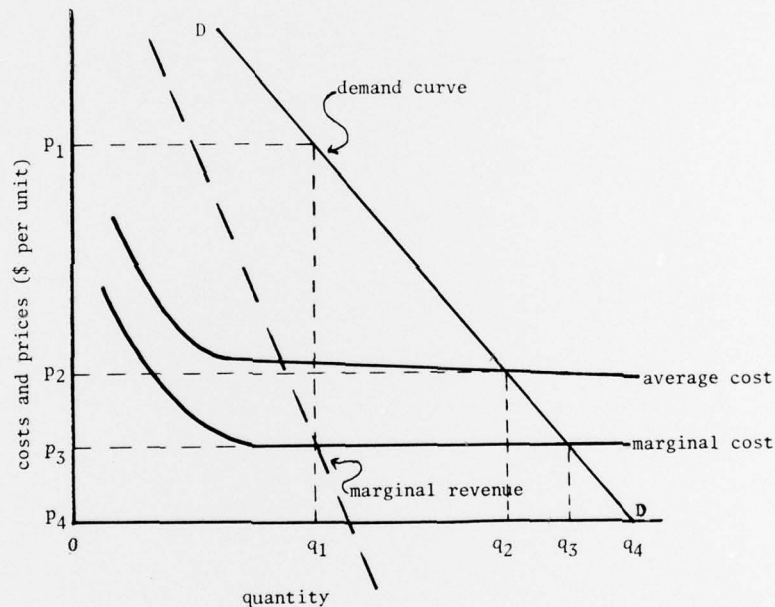


Figure A

Alternatives in Pricing and Allocation

Four Different Cases

1. Profit-maximizing monopolist -- profit made
2. Average-cost pricing (full cost recovery) -- no profit
3. Marginal-cost pricing (optimal allocation of resources)-- subsidy needed
4. Universal free provision (price = 0) -- large subsidy needed

* DeiRossi [32] covers some of this in more detail and provides an example in which he calculates the welfare-maximizing Prices of computer services, especially bibliographic searches.

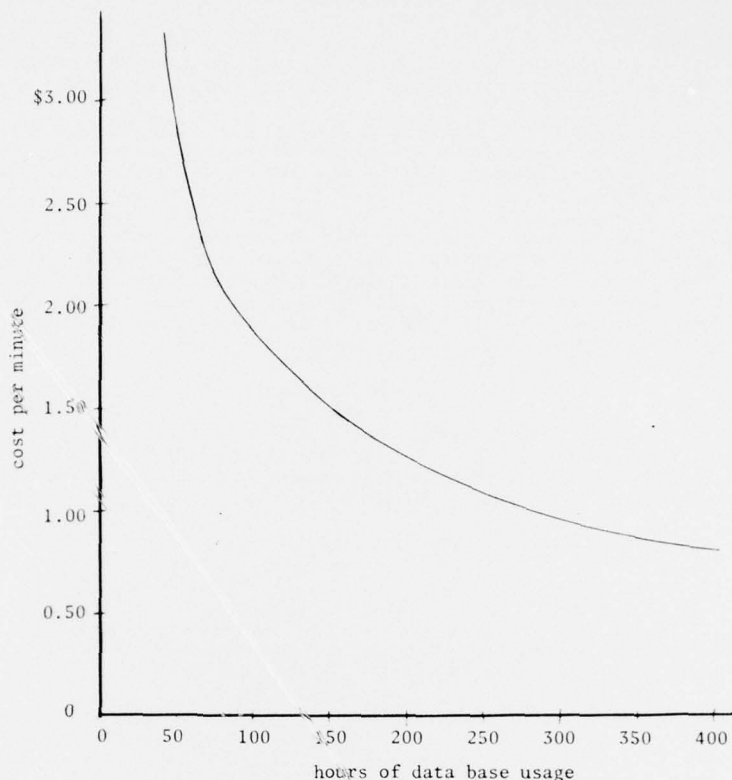


Figure B

*Cost Per Minute to Maintain a Data Base on a Computer Information System
(exclusive of charges for the data base)*

The formula that Ramsey derived for this problem in his pathbreaking paper of 1927 [33], and which has been resurrected and revitalized by Baumol and Bradford in their 1966 paper [34], asserts that there should be a new rule, calling for "optimal departures from marginal cost pricing," which is characterized by Eq. (2):

$$\frac{(p_i - MC_i)/p_i}{(p_j - MC_j)/p_j} = |E_j|/|E_i| \quad (2)$$

for all i and j , and where $|E_i|$ is the absolute value of the price elasticity of demand of good i .*

In Eq. (2) the price for each good should depart from the marginal cost in a way that it is proportional to the inelasticity of the demand for that good. The reason for the inelasticity term is that we want to minimize the quantity effects of these departures from marginal cost pricing. We have seen that as we raise the price, the quantity that gets produced and consumed tends to drop, and we try to minimize the sum of these quantity effects across all the goods.

3.1 Multi-Product Production: The Case of Information

The rule, as stated in Eq. (2), applies strictly only in the case where the two goods have independent demands and costs. For the situation where the demands are not independent but are in fact inter-dependent (i.e., the consumption of one good changes the demand for another good), we have to modify the equation by adding more terms to the right side. For the case where the costs are inter-dependent, we have to worry about the partial derivatives of the total cost with changes in quantities of each of the outputs of the firm. At this point, we have now introduced some of the multi-product considerations, because we may seek optimal prices in the case where a firm produces more than one product. This is the situation in every industry, and I shall now draw my examples from the science information fields. For an academic journal

*Price elasticity of demand for good or service i (E_i) is defined as the percentage change in quantity of i demanded divided by the percentage change in price, *ceteris paribus*; or, $E_i = (\Delta Q_i/Q_i)/(\Delta P_i/P_i)$.

producer who produces more than one journal and sells them to different audiences (say libraries and individual scholars working in the field), we have a very complex calculation to determine the pricing scheme that brings about an optimal allocation of resources. In a recent theoretical paper, Baumol, *et al.* [35] have shown that the optimal pricing rule is the sustainable one--that the firm will, in fact, be able to break even and stay in business with optimal pricing. In another recent theoretical paper, Ordovery and Willig [36] explicitly consider the case of the pricing of a journal that has both library and individual subscribers. They analyze the relationship between the library and individual subscriber to determine how they influence each other, and therefore the optimal prices can be calculated.

Similar considerations also apply to the case of computerized information systems. Here there may be more than one data base on the computerized information system, and one needs to determine the prices to charge for computer time and for access to each of the bibliographic data bases. Here the outputs emerge at various stages in the production process, giving rise to the issue of vertical integration. Again using journals as an example to calculate optimal prices, we must determine the costs of designing the journal copy in such a way that it is very easy to retrieve certain information for abstracting and indexing. The marginal cost of producing titles, abstracts, authors, and references in machine readable form can be calculated. Then one can compute the optimal price for the sale of that information to an abstracting and indexing service. In the computerized information area we can then calculate the optimal price for the Medlar's bibliographic data base, the price for access to it through the Medline system, and the prices to be charged the purchasers of the tapes themselves (such as the SUNY System, SDC, and Lockheed).

Each of these cases involves the production and distribution of information by multi-product firms; but they also involve problems of production and distribution of public goods in general. Often these are lumped together in the statement that information is inherently risky--for one to purchase it, one has to have information about the product itself, yet the obtaining of better information about the product itself is costly. (And there is the paradox that when one has good information about the product or service, one may no longer need to purchase anything more.)

As an example, Figure B describes the variation with the volume of use in the actual average cost per minute required to operate a computer information system and maintain one data base on the system. Here is the classic declining average cost situation: the more users or usage of the system, the lower the cost per minute. If we encourage all of the usage of and access to the data base to be channelled through one computer system so as to take advantage of the declining costs, we are encouraging a monopoly. (This monopoly may develop naturally without any outside encouragement.) It is then necessary to consider possible regulatory measures to prevent the monopoly pricing and restriction of output described above.

There may also be similar economies in the production and distribution of the data bases themselves. Our regulatory and market structure problem is therefore more complex. We must consider the effects on each stage of the production and distribution process.

There are also other special problems in the science information field. To some extent these come about because the government is a very large producer or subsidizer of the production of this information and the government is also one of the largest purchasers of this information. It may well be that instead of bringing about some kind of standardization by legislation, we could have a standardization by government purchasing practice as one saw in the case of micro-fiche. There, the government simply said a firm can produce any type or any size of micro-fiche it wished but we shall purchase only micro-fiche of certain dimensions. One can imagine a similar situation in the information field. Whether one deals with these questions by regulation or by government fiat does not eliminate the fact that they are important considerations which are important public policy issues.

Before one can measure the properties of the costs of the information firm, one must determine exactly what its outputs are and what are the best methods of characterizing those outputs. Some of this work has already been accomplished, e.g., the Berg [37] and Barzel [38] articles on scientific journals, and Baumol and Braunstein [39].

The results so far indicate that there are considerable savings from multi-journal production. Using data collected by Fry and White [40], analysis shows that (average) costs for a typical journal produced by a large publisher with over 30 journals were on the order of 80% of those of a publisher producing only one journal. And we have seen above (p. 1) that there are savings from producing multiple outputs.

3.2 Fixed Costs and Transactions Costs

The analysis by Ordovery and Willig [41] shows how optimal prices for information products that can be used in a variety of modes should be calculated. In particular they examine the pricing of scientific journals for which one mode of usage is the "public" mode in libraries and the other is the "private" mode via individual subscriptions. Their discussion assumes economies of scale in production and in increased cost (or inconvenience) to the user if the public mode is utilized. The optimal prices for the two types of subscriptions were found to depend "on the ratio of the price elasticities of library and personal subscription demand, the ratio of library to personal subscriptions and, the newly identified variable, the average number of potential personal subscribers who are users of the marginal libraries." In this context the "marginal library" is one that is just indifferent between subscribing or not subscribing to the journal.

There are several practical applications of this analysis. For instance Ordovery and Willig show that having library subscription rates greater than those for personal subscriptions (as opposed to having equal prices) will increase economic welfare without reducing the profits of the publisher [42].

Similar considerations apply to information data banks. This is true whether the operator of the data bank and the systems used to access the information contained therein is a profit-making firm or a not-for-profit organization subject to either a break-even constraint or maximum permitted loss constraint. Although low prices encourage usage, one must remember that to permit prices to be below average costs, a subsidy will be required and that subsidy will have to be paid by someone (by taxation, membership fees,

etc.)

The operation of information data banks, like the publishing of journals is characterized by economies of scale. For computerized systems, there are high fixed costs associated with the purchase and maintenance of hardware and software and with the inputting and storage of the information. This is true whether the information is bibliographic, numeric, or whatever.

One large on-line retrieval system (but not the data base itself) cost approximately U.S. \$1,000,000 (in 1970 prices) over a three-year period for systems development and related hardware acquisition. This development cost can be further allocated into five categories. (The approximate percentage of the total development costs follow each.)

Software Design/Implementation	5-10%
Hardware Acquisition	60-70%
Maintenance	5-10%
Testing and Experimentation	10%
Marketing and Education	10%

The development of the data base itself has large start-up and fixed costs. Figure C shows the time profile of the annual total costs of a highly-computerized information data bank. One should note that fixed costs enter this discussion in two ways. One is the set-up costs - the development and other early investment that is required. The other is that there is a fixed component in the operating costs. This was illustrated above in Figure B and is also discussed by DeiRossi [43].

These fixed costs and the resultant scale economies cause marginal cost pricing to fail - to not recover all of the costs of a firm or organization. The "second-best" solution is the modified pricing rule in Eq. (2) above. Using this Ramsey-Baumol-Bradford approach, we could conclude that it is desirable, from society's point of view, to charge for all the outputs of information data banks, even if some or all the marginal costs were zero. But there are certain caveats to this conclusion. Possibly the most important of these is the imposition of a pricing scheme requires that some resources must be devoted to collecting the charges from the users. These "transactions costs" that are associated with the pricing of resources may be a negligible or a significant sum relative to the charges that are collected.

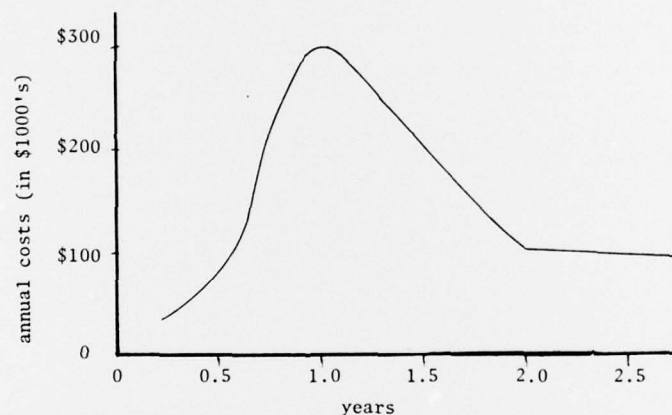


Figure C

The pricing, collection, and enforcement tasks are all part of the "exclusion mechanism" - the procedures by which one can determine who is using or consuming a good or service and then collect for that usage. The difficulties of establishing such mechanisms is one of the rationales for the collective provision of public goods. (Remember that economies of scale was another such rationale.)

In the case of information data banks there are a variety of formulae and mechanisms on which the creator of the data base and the operator of the accessing system rely to collect fees from their customers. Blanket charges, per-use charges, and combinations of both (two-part tariffs) are currently employed. The transactions costs of any system will of course depend on the exact nature of its pricing schemes and exclusion mechanisms.

Two examples of the magnitude of the transactions of computer-based information data banks have been obtained. In one, with a large "service-bureau" type of operation for which the information data bank was

but one part, the costs of monitoring use, accounting, billing, and so on were approximately 15 to 18 per cent of total costs. The other organization operated only an on-line information retrieval system. They estimated the costs of monitoring and recording usage to be on the order of 10 to 15 per cent of total costs.

While these estimates of transactions costs are significant fractions of the total costs of each of the information systems, most people would not believe that they are excessive or by themselves preclude charging for the outputs of the systems.

3.3 The Role of Copyright in Scientific and Technical Information Systems

Historically copyrights have been used to protect the interests of the owners. This protection is limited in that the owner of copyrighted material does not have the right to refuse to sell his work. This limitation is based on the premise that the owner of the copyrighted work has a monopoly and can earn monopoly profits.* However copyright is not the only method of protecting property rights that is used in information data banks. In their dealings with computer system operators the producers of several of the computer-readable bibliographic data bases rely more on their being the sole source of periodic updates than on copyright.

But being the sole source of supply is another name for being a monopolist. But both sources of monopoly power - copyright and being the sole source of updates - are limited. First there are substitutes for the various data bases, although they may be imperfect substitutes. And second, the potential for entry exists, therefore limiting the power of existing firms to earn excessive profits.

The existence of economical electronic storage of textual and reference material makes the problems of monitoring usage and charging fees more difficult than otherwise would be the case. Let us adopt the (sometimes imperfect) analogy that is often made between a computer data bank and a "conventional" library. In each input, storage, and retrieval exist as identifiable functions. In the library situation, payment is made for the material - books, serials, etc. - as the ownership of a tangible item changes once on input. (There is some pressure for payment of an additional sum to copyright holders based on the borrowing of "their" works from public libraries. The United Kingdom has recently been adopted such a system on a limited scale.) However in computer systems there need not be the purchase of any tangible items to obtain material for the input operation. Although the technical and economic realities permit detailed monitoring and record-keeping for the computer systems, the difficulties of enforcement are greater.

Suitable contract arrangements have been developed to cover, for instance, the agreement entered into by an abstracting and indexing service and a computer system operator such as Lockheed or SDC. These vary considerably - some include payments from the computer system to the abstracting and indexing service for each citation the user obtains on-line or off-line in addition to the payments for the data base and updates. But as the number of commercial and private computer-based systems increases, it may be beneficial from a cost and efficiency basis to standardize the basis for payments to the generators of the data bases. One obvious possibility is the expansion of copyright protection. But this will require agreement on whether input, storage, or retrieval and output should be the basis for the royalties associated with usage.

Another part of the copyright quandary revolves around the abstract itself. For example, the American Institute of Physics asserts that it owns the copyright of all the abstracts published in its journals. There have been several recent discussions of the effects of and problems associated with universal enforcement of these proprietary rights. (See Omnibus Copyright Revision [46] and Weil [47].) Weil concludes:

....it seems to be generally agreed that even informative abstracts of copyrighted works prepared by other than "authors" are not "derivative works," i.e., are not "abridgments" in terms of the copyright law if they are not so detailed that they eliminate the need to refer to the copyrighted works for complete information, and if they do not employ an unfair amount of the actual text of the original documents.

3.4 Conclusion

We have discussed how a reliance on the market mechanism can, in some situations increase the efficiency in the production, transfer and use of information. However, the economics of information data banks may necessitate either a subsidy or prices above marginal cost. In many cases the subsidies or the prices (or both) can be reduced by producing and selling multiple outputs. And the increased variety of information products and services can further benefit the users of the information.

In addition to the pricing problem, there are the further questions associated with standardization, networking, transactions costs, copyrights, and market power. We have tried to shed some light on each of these.

*Legally this is known as "an entitlement protected by a liability rule." See Calabresi and Melamid [44], or Braunein and Ordover [45].

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