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PRICING INTERNET: THE EFFICIENT SUBSIDY

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Abstract

Pending changes to Internet (substantially expanded capacity, possible commercialization) suggest that the basis of pricing network services be carefully reviewed. Using the standard of economic efficiency, this paper concludes that:

- Moving Internet to a fully price-based system with a user subsidy (rather than a producer subsidy) will unambiguously increase the efficiency of use of our nation's scarce research resources. This may require a transition phase to acclimate users to the new regime. This transition phase should be short and have a strictly determined end-point, known to all in advance.

- Prices from primary providers of Internet to mid-level networks and to research institutions will likely be capacity-based rather than usage-based, as that is how costs are incurred. Prices that end users face from their institutions will vary significantly (i) among institutions, (ii) among user groups (students vs. administrative staff vs. assistant professors vs. full professors), and (iii) among services.

- Continued government subsidy should be tightly focused on (i) new user groups (if any) and (ii) new products and services unfamiliar to existing users (e.g., that take advantage of the new high-capacity backbone). The existing subsidy to experienced users should be phased out in favor of programs of training, development of user-friendly software, and targeted introductory pricing.

- Opening Internet to commercial and other uses is unlikely to result in much new business beyond the research community, and will likely increase the cost of the system. Significant ongoing subsidization of research users by commercial users, even if commercial demand is strong, is unlikely.

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1. Introduction

It is not for nothing that economics is known as the "dismal science;" we economists usually find ourselves giving advice which others find irksome, such as "resources are limited." The task of this chapter is doubly difficult, in that the proffered advice (i) is likely to be irksome indeed to its intended technology-oriented audience, and (ii) is based on a central tenet of economics that prices the key variable in achieving an efficient allocation of economic resources.

A common quip has it that an economist is someone who knows the price of everything and the value of nothing. To dispel that canard, the discussion in this chapter is based on the concept of value. Indeed, the role of the price system in the grand scheme of things is to enhance value. Some price strategies lead to higher national income, and some price strategies actually destroy national income. Furthermore, prices matter for all kinds of goods: private, public, things that the government produces, things that universities produce, even things that economists and technology researchers produce. Indeed,the absence of prices (zero price: "it's free;" or infinite price: "it's forbidden") matter most of all.

As used in this chapter, the term "Internet" refers to today's Internet, its backbone network NSFNet, the various mid-level networks, the institutional networks, and finally the NREN

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network toward which this complex Internet is evolving. In a subject area overfilled with acronymous names, this convention (and it only that) runs the risk of glossing over distinctions which are quite important. The author accepts responsibility for keeping the ideas straight, but not for running afoul of the acronym police.

In Section 2, a summary of results of the chapter is presented. In Section 3, the economic efficiency basis of market pricing is developed. Section 4 lays out the conditions under which market pricing can lead to inefficiencies, and which constitute the classic efficiency case for public intervention such as subsidies. In Section 5, the pricing principles are applied to the case of the Internet as it exists today. Section 6 considers efficient pricing if and as Internet seeks new users for its existing services (including commercial users) and develops new services based on its pending expansion to a 45 Mb backbone network. Section 7 summarizes and concludes the chapter.

2. Summary of Results

The starting point for all pricing analyses is the concept of economic efficiency. Simply put, an economy is *efficient* if it is creating the maximum amount of value from the resources at its command. Generally, a *market* economy works toward economic efficiency via the principle of *gains from trade*:

> Any trade in which the buyer values the good or service more highly than the seller should be consummated; all other trades should not. Since the buyer will pay a price that is less than his value, and the seller (producer) will take a price that is greater than his costs, efficiency demands a price p such that Value $\geq p \geq$ cost. Result: setting price equal to the marginal cost of production and distribution ensures that all gains from trade are exploited and the outcome is efficient.

There are, of course, situations in which a price below resource cost (say, a price of zero) can be justified; for example, introducing an entirely new product or service (subject to learning effects). Usually, however, giving things away results in far more consumption than is socially efficient.

In fact, most economists would argue that private markets, *provided they are reasonably competitive*, are the preferred mechanism for achieving efficient outcomes. There are reasons to suspect that the commercialization of certain parts of the Internet, notably the backbone network, may not yield to a competitive market. However, prices can and should be used;

there is no reason why our nation's research resources deserve to be less efficiently allocated than other resources.

The conclusions of this chapter are as follows:

- Moving The Internet to a fully price-based system with a user subsidy (rather than a producer subsidy) will unambiguously increase the efficiency of use of our nation's scarce research resources. This may require a transition phase to acclimate users to the new regime. This transition phase should be short and have a strictly determined end-point, known to all in advance.

- Prices from primary providers of Internet to mid-level networks and to research institutions will likely be capacity-based rather than usage-based, as that is the dimension upon which cost-incurring decisions are made at this level. Prices that end users face from their institutions will vary significantly (i) among institutions, (ii) among user groups (students vs. administrative staff vs. assistant professors vs. full professors), and (iii) among services.

- Continued government subsidy should be tightly focused on (i) new user groups (if any) and (ii) new products and services unfamiliar to existing users (e.g., that take advantage of the new high-capacity backbone). The existing subsidy to experienced users should be phased out in favor of programs of training, development of user-friendly software, and targeted introductory pricing.

    * Such subsidies should have a clear purpose and target, be based on serious market research on the viability of the new markets/services, and have specific target dates (or market penetration levels) at which the subsidies expire. Their *sole* objective should be to encourage new users and/or new uses, and should support a mix of activities, not just "free" service.

- Opening Internet to commercial and other uses is unlikely to result in much new business beyond the research community, and will likely increase the cost of the system (in order to upgrade Internet to commercial quality). Significant ongoing subsidization of research users by commercial users, even if commercial demand is strong, is unlikely.

It must be emphasized that these conclusions are based upon the *principles* of economic efficiency (which are not in doubt) applied to the *facts* of Internet (which are certainly subject to empirical dispute). This chapter advances no new factual evidence; the author's judgment and experience has guided the application of principles to the above conclusions.

3. The "Ought" of Pricing: Economic Efficiency

Although the starting point for all pricing analyses is economic efficiency, this is not the end; issues of social equity arise: should we charge the poor, the aged, minorities, or the handicapped less than the going rate? Usually, economists start with economic efficiency, and then see if it ought to modified to account for equity issues. In this paper, we focus on the efficiency issues and leave the equity issues to later work.

Economics is about the allocation of scarce resources, and it is with resources that we begin: human resources, capital, technology, materials, existing stocks, etc. These resources are costly, but it is not the "cost" that our accountants compute from their income statements and balance sheets. If a resource, for example fiber-optic pipes, is used to construct Internet, the "cost" of this resource is the value that this resource could produce in the best alternative use. If the social value produced by using this resource in Internet is X, and using this resource in, say, a corporate network for McDonald's produces a social value of Y, then if X < Y, the economic cost of those resources (Y) exceeds the value of the resources in Internet (X). Efficient use of this resource suggests taking the pipes away from Internet and turning them over to McDonald's![1] If X > Y, then the social value of the resource as used in Internet exceeds the cost in its next-best use (McDonald's), and efficiency is served by keeping Internet. The *economic* cost of the fiber-optic pipes to Internet is Y. Resources should be deployed in their highest-valued application. Any transaction (such as building Internet, or building the McDonald's corporate network) which attracts resources away from high-value uses to lower-value uses is *economically inefficient*. What are the criteria for economically efficient transactions?

1. The producer of the goods in question (firm, government, university) uses a minimum of resources to produce the goods (no waste);

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[1] That the reader may see one use (Internet) as having a serious social purpose while the other use (McDonald's) seems frivolous, this example drives home the point that *all* uses, public and private, compete for resources. Other readers (for example, McDonald's employees) may approach this example with different values.

2. the producer uses a cost-minimizing resource mix (if capital is dear and labor cheap, use more labor than capital);

3. the right mix of goods is being produced (the shoe factory produces half right shoes and half left shoes);

4. the goods are consumed by those who value them most (if I like hiking boots and you like wingtips, make sure the hiking boots go to me and the wingtips to you, not vice-versa).

The first two criteria are called *technical efficiency,* and at least the first should be familiar to all. The third and fourth criteria are called *allocative efficiency* and are familiar mostly to economists. The first two relate to resource conservation; the last two to social value. It should now be clear where "social value" come from: the value *to the consumer* of the good or service in question. Not the value to economists, or to engineers, or even to the government (except insofar as we are consumers) but to the person who actually derives benefits from the good or service (directly or indirectly). If our citizens prefer Madonna concerts to the Philadelphia Orchestra and Riccardo Muti, then Madonna is producing the higher social value.

How is it that our economy ensures that all economic transactions meet these apparently stringent efficiency criteria? Who is in charge? In market economies, the answer is "No one and everyone." It is the price system that ensures that the economy is a self-correcting system which tends in the direction of economic efficiency. Individual economic agents (firms, consumers, and producers) ensure that efficiency-enhancing transactions are effected for the simple reason that *it is in their self-interest to do so.* It might be thought that our economy could do better if we had social planners with supercomputers running it, rather than all these individual, uncontrolled transactions occurring! For an object lesson in how well such a central planning system works, consider the planned economies of the Soviet Union or Eastern Europe.

How is it that prices perform their function?

Price as Signal: To Consumer, to Producer

Implicit in the above analysis is that the *global* principle of social value maximization from limited resources must be realized transaction by transaction. Each transaction must satisfy a *local* principle in order for global value maximization to be realized, and this is the principle of gains from trade, mentioned above. Clearly, price plays a central role in informing individual economic agents so that they can realize these gains from trade, thereby achieving economic efficiency.

Price, then, acts as a *signal*. It tells the consumer how much of each good to consume: so that the last (marginal) unit purchased has a value to him/her just equal to its price. It tells the producer how much of each good to make: so that the last (marginal) unit produced has a cost to the producer just equal to the selling price.

Price also performs a *market-clearing* function. If price is "too low," consumers will demand more than is being produced; in order to ration the now-scarce resource, sellers will raise prices. Demand reduces and more sellers, induced by higher prices, enter the market. If price is "too high," sellers cannot get rid of their stock; they must lower price in order to do so. Demand increases and sellers leave the market, induced by lower prices. In either event, the price level eventually stabilizes at the point where supply equals demand, and the *market clears*.

It is in this sense that prices are signals that lead to behavior by consumers and producers that produce economically efficient outcomes. In short, prices can induce economically efficient behavior.

Just as clearly, prices that do not reflect costs can induce inefficient use of resources. The continued rapid growth of traffic on Internet is no surprise when the user price of zero is taken into account. The prevalence of mail reflectors in the network reflects this pricing anomaly: adding a name (or a thousand names) to a distribution list is literally costless to the user, but nevertheless can consume significant resources. Of course, one can think of rationing schemes to help solve this problem, but why not try the rationing scheme most prevalent in our economy: prices, specifically prices that the user faces for his/her use of Internet. If users must pay real money for all the messages (plus copies) they launch into the network, users would only initiate messages that had a value to them greater than the price they were charged. If prices were set to reflect the long-run marginal cost of providing the service, then all messages, and only those messages, whose value to the user exceeded the cost of the resources consumed to send the message would be sent. Prices would correctly reflect resource costs, and the socially efficient level of usage would result.

Now if this were the end of the story for Internet, the conclusion would be obvious: let private markets supply the broadband network, and all users, including researchers, would pay for the service, either from corporate budgets or from NSF grants. After all, that's how most of the goods and services we use are allocated: books, word processors, office space, secretarial support, etc. Why should broadband services for the research community be different from these other goods and services? Let the market reign, even for broadband services, and the economically efficient outcome is assured!

Many would view this as a wildly optimistic statement about the functioning of an economy characterized by deep budget and trade deficits, lagging productivity and savings, and the S&L crisis. The theoretical construct of the efficient market is just that: a theoretical construct, and it only holds under some very specific assumptions. As those of you with some mathematics background will appreciate, local properties imply global properties only under special circumstances, and that is certainly true here. What are the assumptions under which a market with a price system leads to economically efficient outcomes? More important, is Internet a case in which the assumptions hold?

Assumptions:

i) Benefits and costs are all private: no externalities (spillovers).

ii) Full information on both sides of the transaction.

iii) Constant or decreasing returns to scale in production.

iv) Costless entry and exit (no sunk costs).

If any or all of these assumptions are violated for Internet, then the case for cost-based pricing for Internet is not so clear. The standard economic dictum of price-equals-marginal-cost may not be the most effective in efficiently allocating resources for broadband services to the research community. If not, what *are* efficient prices for Internet? We look at each of the assumptions above, and see what happens when they are violated.

4. Pricing in Imperfect Markets.

Spillovers

Spillovers, or externalities, occur when a transaction between two parties inadvertently affects third parties. The best-known example of a negative spillover is pollution: when consumers (party 1) purchase electricity from a utility (party 2) that pollutes the air or water in its production process, then third parties, such as people who breathe and drink water, are affected by these transactions. Positive spillovers also exist; the first purchaser of a new software product in my department enables others to learn easily from the purchaser's experience, so the "pioneer" consumer's learning efforts affect third parties (the purchaser's colleagues) positively. In either case, the price at which the transaction occurs does not convey information about spillovers and their social value. With only prices as a guide, we tend to over-produce negative spillovers and under-produce positive spillovers, since their value is not captured in the market pricing calculus.

Two rather different spillovers occur with Internet: a macro spillover and a micro spillover. To understand their relationship, let's look for a moment at the macro spillover, which pertains to the overall production process of research. The research process uses **inputs**: primarily human capital in the form of our brainpower, secretarial support, travel and living expenses, and the use of broadband services for communicating with our colleagues. It produces **outputs**, which is (presumably) new knowledge, or *information*, generally in the form of scholarly papers. Now the production and distribution of information as an economic good has rather different properties than the distribution of, say, detergent or Italian sports cars. Once the information is produced, (i) the cost of supplying it to more consumers is (essentially) zero; (ii) the producer cannot (and usually does not want to) exclude anyone from using it; and (iii) giving it to someone else does not deny the giver continued to use of the information.

(i) The marginal cost to supply a Lamborghini to an additional customer is considerable; the marginal cost to tell an additional researcher about a new idea is essentially zero.

(ii) The producer of the Lamborghini can exclude anyone from using its products until they pay the asking price; the researcher cannot (indeed does not want to) exclude others from using the researcher's new idea.

(iii) When the owner of the Lamborghini sells the vehicle another, the original owner can no longer use it; however, the researcher can continue to use his ideas, even after conveying them to many others.

It should be no surprise that the price system does not work well in research. After all, one cannot "sell" an idea since exclusive use cannot be conveyed to the new owner. [2] Yet we all know research creates social value. The solution? Public subsidy of research, usually from general tax revenues.

This macro spillover leads to the conclusion that research *output* should be subsidized, and indeed it is, generally through cash grants to researchers via institutions. These cash grants can be used by the researcher to purchase inputs, such as secretarial support, in competitive markets. The importance of subsidizing research does not lead to the conclusion that the government should actually provide one of the inputs, such as broadband network services. After all, no one would suggest that the special nature of research warrants the government hiring and supplying secretarial services for research. [3] What is it about an electronic broadband network that makes it worthy of government provision?

This brings us to the micro spillover, the so-called *network externality.* This term was first used in connection with the voice telephone network back in the early 1970s to describe the fact that the value of a communications network to each user depends upon how many other users are connected to it. A telephone network with only one user is of absolutely no value to that user.

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[2] There are intellectual property rights for some forms of "new ideas:" an inventor of a new device can obtain a patent granting him/her exclusive rights to that device for a fixed period of time, and an author of a written work can obtain a copyright granting exclusive rights to his/her text.

[3] A related issue is that the dissemination of research results is actually far from costless (although the *marginal* cost is small). Indeed, our nation's research library system exists to serve this purpose, and justifiably receives government support to do so. The traditional vehicle for getting research to the user (or library) is the scholarly journal, usually funded through a combination of (differentiated) subscription fees and page charges to authors (see William J. Baumol and Yale Braunstein, "Empirical Study of Scale Economies and Production Complementary: The Case of Journal Publication," *Journal of Political Economy,* **85**(5), October 1977, pp. 1037-1048, for a discussion of the economic properties of scholarly journals). Ultimately, journals use the U.S.Postal Service as the conduit for physical distribution. Internet has the potential to be an electronic conduit for scholarly material; however, this is not a reason for direct subsidies for the operation of the network. Subsidizing researchers directly would enable them to make the best choice among potential distribution mechanisms for their scholarly material, rather than provide one such mechanism (Internet) at no cost.

In choosing whether or not to connect to a network, each subscriber considers both the price of connection as well as who else is already connected. Further, if the subscriber chooses to connect, the value of being connected to all other actual or potential users has thereby increased. Each connect decision generates a (positive) spillover, and this is certainly the case with the Internet.

How does this change the efficient pricing rule? During the start-up period of a service subject to network externalities, below-cost pricing may be economically efficient. In fact, this was the rationale for subsidizing connection to the telephone network for many years. Only today, when telephone penetration rates have stabilized at around 94% of households are we slowly doing away with this subsidy.

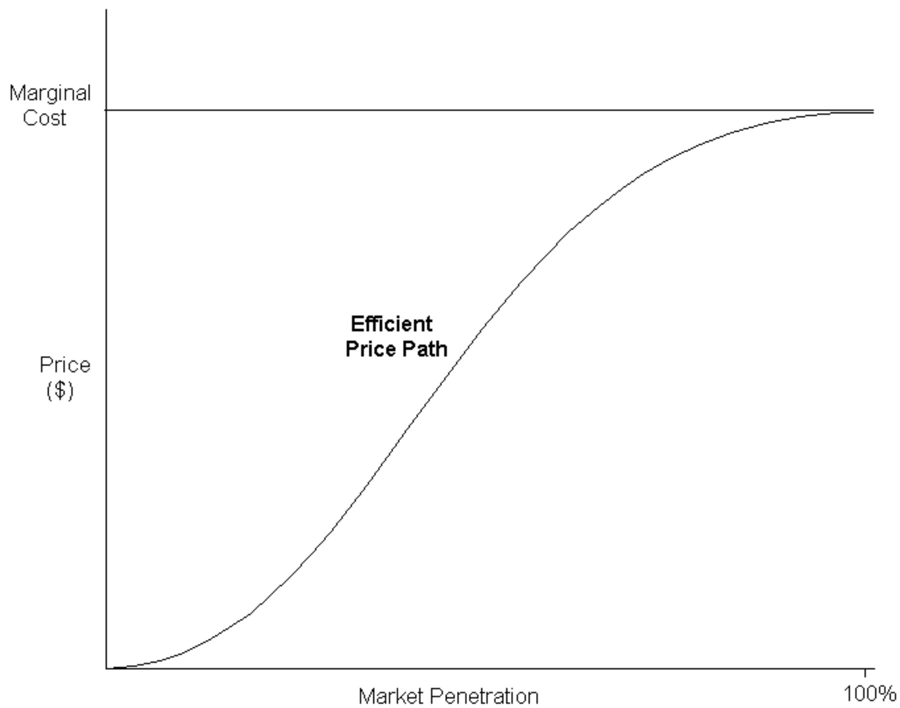

Figure 1

Figure 1 shows a typical efficient price path as a function of market penetration. It suggests that the service may have to be given away at low values of penetration, but that positive prices could be charged at relatively low levels of development. It also suggests that it is not necessary to be at 100% penetration (of the available market) before charging a price equal to marginal cost. Once a "critical mass" of a user community adopts, there are sufficient incentives for the rest of the community to adopt, without the need for below-cost price incentives.

How does this translate to Internet? If everyone in a particular discipline is on the Internet and communicates via e-mail, then the benefits to a researcher in that discipline of being on the e-mail network are both obvious and high. If all your colleagues congregate in the seminar room at 4:00 PM for tea and gossip, then that's where you'd better be. If all your colleagues are on the Internet, then that's where you'd better be. Conversely, if no one in a particular discipline is on Internet, then the benefits to a researcher in that discipline are both obvious and low. The relevant penetration rate is interest-group specific: most all econometricians are on e-mail, most all economic theorists are not.

To summarize, the two forms of spillover effects, macro and micro, lead us to two rather different departures from a market pricing solution: (i) the macro spillover associated with the production of new knowledge leads to the efficiency rationale for financial support of basic research (but not government provision or subsidy of Internet), and (ii) the micro spillover of the network externality leads to the efficiency rationale for supporting low-penetration broadband services until a "critical mass" develops.

Information Deficiencies

Two ways[4] that the "full-information" assumption can fail are:

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[4] Another type of failure, not particularly relevant here, occurs when there is asymmetric information between consumers and producers. In general, this can be a particularly nasty problem, resulting in the failure of private markets. For example, owners (producers) of used cars know more about the quality of their product than potential buyers. Since buyers know only the average quality, they are willing to pay a price that reflects only that average quality. Owners of high-quality used cars may be unwilling to put their autos on the market at such a low price, so only the "lemons" show up on the market. Consumers know this, and so are willing to pay less for the goods, thereby driving all high-quality suppliers out of the market. Groucho Marx said it best 50 years ago: "I wouldn't join a country club that would admit the likes of me!"

i) The production technology is not fully understood; producers learn what can be produced and how to produce it cheaply as they gain experience in production (the "learning curve").

ii) Consumers do not know how the service can be of value to them, because of their unfamiliarity with it. Further, they need to learn both the technical and economic parameters of the system: What will it do? What support can be expected? What happens on weekends? Will these guys be in business in a year? etc. The more consumption that takes place, the more consumers learn, and the higher their demand for the service.

In the case of Internet, both these problems were present at the time ARPANET was established, and it is possible that some forms of these problems still remain. The problem is a learning problem; solving it involves making investments in consumer and producer information, or learning. In the case of consumer learning, there are several types of investments that can overcome this information deficiency: good and extensive training, developing user-friendly systems, advertising, and below-cost ("introductory") pricing. Many consumers would hesitate to buy a new service with all its attendant start-up costs (of which learning is often the largest) at full cost.

For a new product or service, the usual pricing rules may not apply. If the service is different enough from anything that consumers or producers have seen before, then both parties are in a state of information deficiency: consumers don't really know what this service is for or how they would use it, and producers are still trying to figure out how to make it most efficiently (or most in tune with the as-yet- unstated needs of consumers). In the early stages of production and distribution, producer and consumer learning are going on. This learning constitutes an **information investment** for both demanders and suppliers. During this period, costs are likely to be high, the product imperfect, and consumers indifferent or suspicious; hence demand is likely to be low. As learning progresses, consumers learn the value of the service (and the quality of the supplier), the producer learns exactly what service it should be providing, and eventually how to do it cheaply. In general, the more production and consumption that takes place early on, the faster learning is on both sides of the market. On the production side, this is the well known *learning curve* effect; the more the cumulative production , the lower is the unit cost. Note that this is *not* economies of scale, which relates to declining average costs with respect to an increasing scale in a single period. Learning curve effects have to do with how much a producer has produced over the lifetime of the service, not the per-period scale.

It should be noted that the service in question need not be completely new in order that learning effects are important. It could be an old service that is being introduced to a new group of consumers, in which case consumer learning is relevant. If this new group of consumers demands somewhat different characteristics in a product or service, then producer learning may take place as well, as producers struggle to ascertain the best way to serve this new market.

Whatever can be done to encourage consumption and production in the somewhat unfavorable early period can be thought of as an investment in learning. Heavy advertising, free training sessions, readily available technical support, providing user-friendly software, encouraging user groups, and lower prices constitute a *promotion* cost, which lowers the barriers to learning for consumers, increasing their learning and thereby their consumption, ultimately lowering the producer's costs as the producer works down the learning curve. With all these introductory offers, the provider is not making money: it is investing in learning in hopes of realizing higher demand and lower costs in subsequent periods. The time pattern of price and cost may look something like this:

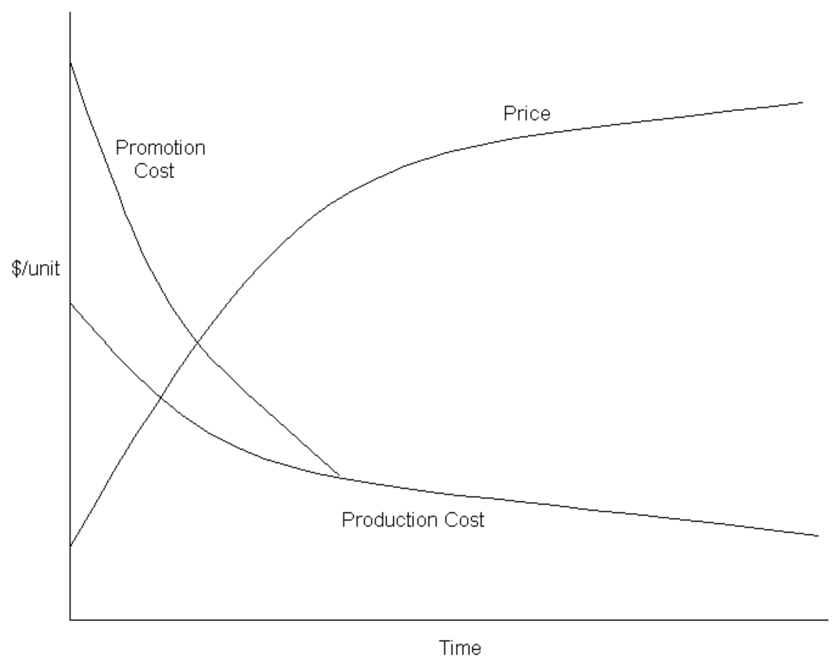

Figure 2

The discrepancy[5] between price and cost in the early stages of the product lifecycle results in a cash flow loss. This is often thought of as a "transaction cost" of entering a new market. The view taken here is that this cost is best viewed as an investment which results in lower costs in later stages, and increased demand as well, permitting higher subsequent prices. The resulting profits may justify the initial investment.

However, the role of learning in private markets is significantly different than its public role. Learning, either by the producer or the consumer, may be *appropriable*, in which case the learning is unique to the producer and the product. The producer "owns" the learning, in that it cannot be easily transferred to other producers or products. Another producer that entered the market would have to go through the same learning process (on the production side) and teach its consumers its own system, with little transference from prior learning. More likely, the learning is *non-appropriable*, in that other producers can easily imitate what the first producer has learned, or can take advantage of what the first producer has already taught consumers. This may occur if a producer educates consumers to use a new product (such as a new form of women's makeup) and other producers take advantage of consumers' new awareness to sell products without incurring the consumer education costs, thereby permitting them to undercut the original producer. If the pioneer producer anticipates this, it will not make the original information investment.

This problem can occur with producer learning as well. The first producer in a market must work its way down the learning curve, eventually realizing lower costs. What happens when a new producer enters? Must it too work its way down the same learning curve? Usually, this is not the case. The information exists in the heads of the engineers and production people of the existing producer, and they can be hired away by new entrants.

If learning is non-appropriable it may not pay a private producer to bring it to market, even though the innovation is socially efficient product, since the innovator may not reap the rewards before others appropriate these rewards in the market. However, if it is the

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[5] The similarity of Figures 1 and 2 suggests that the network externality and consumer learning may be related. In fact, both effects can be present in the same market, as was likely the case in the early ARPANET. However, there are markets which exhibit network externalities but no consumer learning (e.g., telephone) and market which exhibit consumer learning but not network externalities (e.g., women's cosmetics *circa* 1970, when eye makeup first gained popularity).

government, a public producer, undertaking to provide a new technology (such as ARPANET), then one purpose of such an undertaking is to demonstrate to the private sector how it can be done. In this case, non- appropriability makes the government's job easier, and it is just such situations of non-appropriability that call for government to take the lead in developing a new technology.

Suppose now that the product in question is quite new and untried, but shows much promise as an aid to an activity of great national importance. Say, for example, that the product in question is broadband electronic networking *circa* 1965, with its attendant promise to increase the productivity of the research community. No private producer would see this as profitable, because of the high "transactions costs." However, the government may indeed be interested in undertaking the learning investment, both to teach academics this wonderful new way of communicating and to show potential suppliers how it is done.

NSF, of course, can let others reap the benefits of this learning; that's what it's for. Its optimal price/cost path may look more like this:

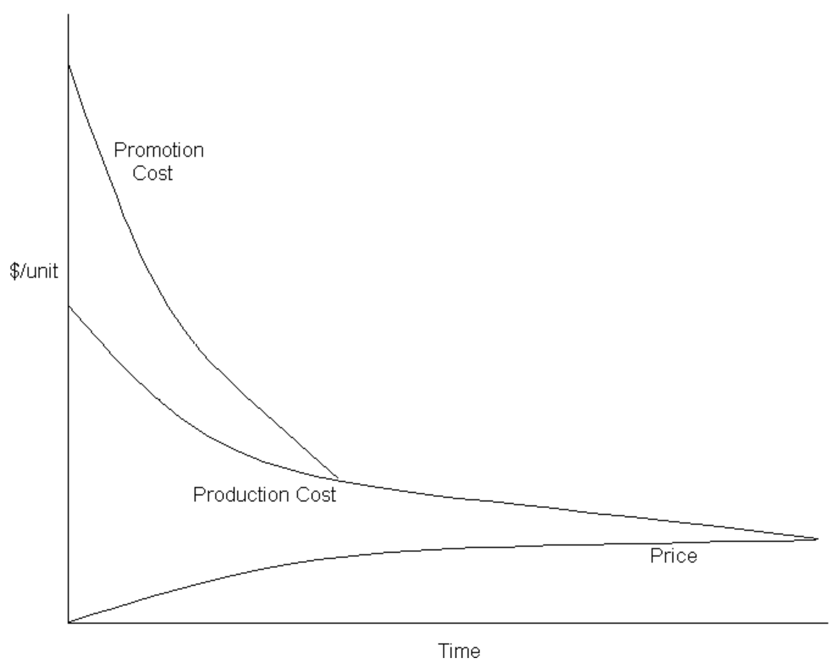

Figure 3

In the very early stages, the government gives the service away in order to induce learning. However, as costs decreases get smaller and smaller (the unit cost curve is convex here), less and less learning is going on, and the investment in learning (below-cost pricing) also gets less and less. When unit costs reach their asymptote, no more learning is occurring and price should cover these operating and investment costs. Any higher price would discourage efficient usage of the system. In addition, since learning (in the narrow sense we use it here) is now finished, the role of the government in generating information is also finished. This project could now be turned over to the private sector.

During the initial learning period, the government subsidy of learning (per unit, at each point in time) is equal to the difference between the cost curve and the price curve of Figure 3. This constitutes a public investment in the generation of new knowledge, and under this illustrative circumstances may be efficiency enhancing.

Does this argument apply to the anticipated services that will take advantage of the capabilities of the pending 45 Mb network and the proposed gigabit network that many hope will follow? In principle, yes; but the author's experience suggests that there are two critical caveats:

Caveat 1: The 45 Mb network is *not* a service; it is a "platform" which can power real services to real customers. Ultimately, it is these real services to real customers that can properly lay claim to a new-service subsidy, not the underlying engine. Are there any such services? Videotelephony and medical imaging are mentioned, but apparently there has been no empirical work (either market research or econometric estimation) to determine if there are actual customers who might be interested in these services. Those of us who lived through the Bell Laboratories' PicturePhone fiasco of the late 1960s, as well as the SBS broadband corporate satellite network of the late 1970s, are suspicious of slick technology in search of an application that real people will use and pay for.

Caveat 2: The "new-technology" argument is often used to attempt to involve the government in building and operating ARPANET or some other leading edge system. In some cases, this is quite legitimate; what is learned from such projects creates knowledge that private firms can appropriate if in fact it is cost-effective. It should be no surprise that private firms often champion government intervention in these areas; it effectively subsidizes them at public expense. The classic case was the SST debate of 1970; this technology was "too risky" for the private sector, involved "too much capital commitment," but was "critical to our nation maintaining its technological edge." Ultimately, the question is, If it's too risky for Boeing, why isn't it too risky for the American taxpayer? If it's important to America, why isn't it even more important to Boeing?[6] In the event, it is obvious that the SST was not a worthwhile technology, as France and Britain have found out to their loss. There are many current examples of apparently uneconomic government support of "new technology:" France's Minitel, California's Sematech,[7] and Japan's fifth generation computer project. [8] The historical record of government subsidy for *commercial* high technology speaks more to the lobbying effectiveness of special interests than it does of the public interest served.

What are the lessons from these observations? New-service (or new-user) subsidies should be tightly focused on very specific learning objectives. The services and consumers whom they are designed to assist should be explicitly identified, and the subsidy program designed around their needs, and not the needs of existing users. The design of such subsidy programs should have a " sunset"provision, in the form of an explicit expiration date, reflecting the fact that learning is not forever.

Economies of Scale and Other Economic Myths

The classic rationale for government intervention in the marketplace is pervasive economies of scale. If an industry's cost function is characterized by declining average cost up to the full extent of market demand, then the largest producer will always have an advantage over smaller ones. The natural result of the competitive market is monopolization; hence, the phrase "natural monopoly." Firms such as public utilities are generally thought to be natural

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[6] The long-term success of Boeing in the postwar era in the technology-intensive airframe industry suggests that appropriability is not a major problem. No doubt some technology "leakage" occurs in this highly competitive business, but it has not been enough of a problem for Boeing, traditionally an innovator, to lose its longstanding competitive edge in this market.

[7] Note that without government subsidy, the idea of a research consortium fell apart (U.S. Memories).

[8] For a brief description and recent assessment, see Michael Cross, "Japan's Fifth generation Computer Project: Successes and Failures," *Futures*, **21**(4), August 1989, pp. 401-403.

monopolies; in keeping with this classic rationale for government intervention, [9] public utilities are either publicly owned or publicly regulated. Examples are electric power distribution systems and the post office.

Indeed, the logic that "bigger is better," or at least cheaper, is quite appealing. Technologists particularly, whose professional bias is often that "the system is the solution," [10] tend to see scale economies as ubiquitous. However, many (but by no means all) economists consider scale economies to be on a par with "predatory pricing" and "foreign dumping:" phenomena commonly believed to be prevalent, but when subject to careful analysis appear to be rare. The reason: bigger systems involve bigger organizations, more coordination, more paperwork, and greater bureaucratization, among other things. Scale has definite economic disadvantages which are behaviorally based, not engineering-based. Further, these diseconomies of scale are inherent in managing large organizations, not because people are inept. The following perspective on economies of scale only mildly overstates the case:

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[9] Recent work on the theory of contestable markets casts doubt on this classic rationale, focusing instead on the significance of sunk costs (*infra*). See William J. Baumol, John C. Panzar, Robert D. Willig, *Contestable Markets and the Theory of Industry Structure*, New York : Harcourt Brace Jovanovich, 1982.

[10] This phrase originated as a public relations slogan for the Bell System in the 1970s. Traditionally, telephone service was viewed as the quintessential natural monopoly, regulated and protected from entry. At this time, many questioned this assumption of pervasive economies of scale, and the public policy rationale for continued monopolization of the entire industry eroded. Events in the long distance telephony market (especially the successful deployment of nationwide fiber optic networks by U.S. Sprint and MCI) since the 1984 divestiture of the old Bell System suggest that this skepticism was not without basis.

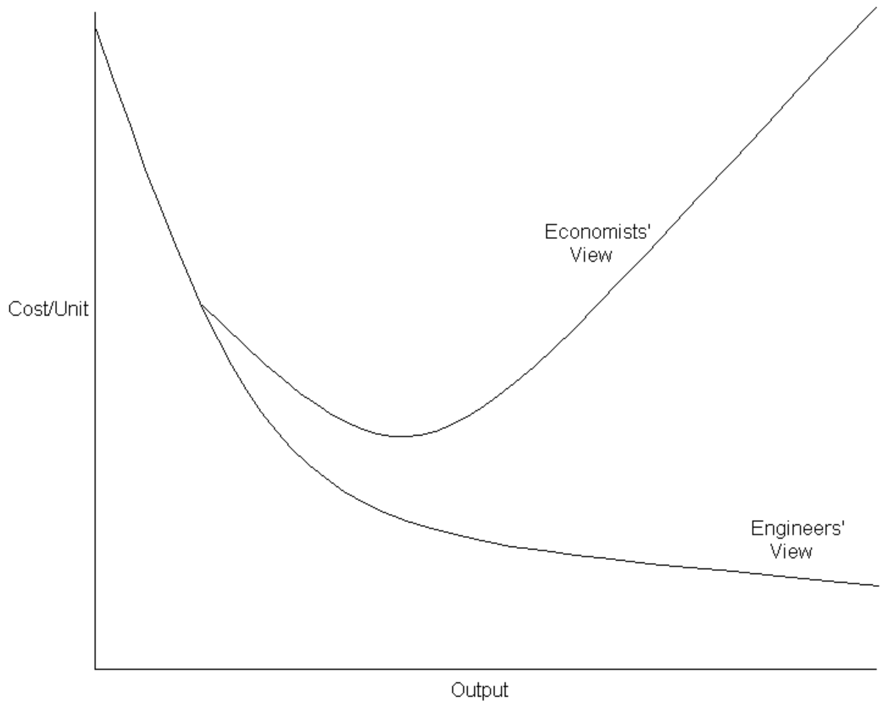

Figure 4

Engineers are smart enough to understand the technical details of the system and develop computer-based design models which optimize the hardware and figure its costs. Economists aren't smart enough to do that, so we are forced to look at the results of implementation: what has actually happened when these systems have been put in place? How much money actually gets spent?

The experience in telecommunications suggests that the *minimum efficient scale* of national networks, though large, does not support the natural monopoly argument. Any assertion that Internet, or its backbone network, requires continued government intervention because it is a natural monopoly deserves very close scrutiny.

Sunk Costs

The usual story of competitive markets is one of easy entry and exit. Resources freely flow to their most valued use: if a producer finds a particular market uncongenial, that producer can move resources to another market. Picking up your marbles and going to play in the next game down the street is a crucial part of the competitive market story. However, in some cases, suppliers and/or consumers cannot pick up their marbles and move on. Producers may have "sunk costs:" costs which are specific to a market and cannot be moved, either physically or economically, to another market. Example of a sunk cost: a local electric power distribution network. Example of a cost that is not sunk: a fleet of trucks. [11]

Asset specificity, a more formal and precise term for sunk costs, leads to non-competitive markets, and often calls for regulation or government ownership, even if all else in the market suggests competition. Note that socially efficient pricing is still marginal cost pricing; however, an open competitive market may not be a good way to achieve efficient outcomes. [12]

Can we learn from these private market examples anything that applies to research facilities? There are many examples in which the government actually (or effectively) owns the research facility, such as large facilities for the study of high-energy physics (from the early days of the cyclotron to tomorrow's superconducting supercollider) and supercomputers. Such facilities exhibit asset specificity: highly specialized to a specific discipline and use, and capable of serving many researchers.

Is today's Internet or tomorrow's NREN likely to be subject to asset specificity? Only if the resources used to provide it have no other use, once committed to Internet. Telecommunications and computer technology have today advanced to the point where the building blocks for Internet, especially the backbone network, can be readily deployed for other services. Broadband facilities are available from local and long-distance common carriers and switching systems are available from a variety of vendors (although the new switches for NSFNET's 45 Mb network apparently were designed specifically for this application). Further, should an entrant into the backbone business later find its venture unprofitable, it can rid itself

[11] Some resources are "sunk" in the physical sense of unmovable capital assets, but not in the economic sense. An example is a nuclear power generating station. With cheap "wheeling" (long distance transmission of volume power), the operator of this station can sell its power output anywhere in a 1,000 mile radius, not just to the local power distributor. The power station is "sunk" physically, but not economically.

[12] In the presence of scale economies, marginal cost pricing is efficient, but has the undesirable property that the total revenues of the enterprise do not cover total costs. An extensive literature has developed on "second-best prices:" efficient prices subject to a total budget constraint. The seminal article in this field is William J. Baumol and David Bradford, "Optimal Departures from Marginal Cost Pricing," *American Economic Review*, **63**(3), September, 1970, pp. 265-283.

of its investment in physical capital relatively easily. On the other hand, software which is developed specifically for Internet may be a sunk cost, in that it has no use in any other application.

While asset specificity may have been a justification for ownership of the broadband facility in the early days of network deployment, it does not seem to provide a justification in today's or tomorrow's technology-rich environment. It is possible that switch and software development for tomorrow's NREN may not be forthcoming from our nation's private sector electronics industry because of the asset specificity risk entailed, and that government support of *development* activities for the projected gigabit network is required. There is no evidence that the extraordinarily innovative and risk-taking private-sector electronics industry is not up to the job, however.

5. Efficient Pricing for Internet: Today's Environment

With some overgeneralization[13], *today's* Internet can be characterized as:

- *Stable Primary Products*: e-mail, file transfer (FTP), and remote login. Some experimental products developed by high-end users.

- *Stable Primary Customer Markets*: physical and mathematical scientists and engineers, located in universities, research institutes, and private technology firms.

- *Production Technology (Hardware)*: leased telecommunications facilities and computer-based switches, with some hardware unique to broadband network.

- *Production Technology (Software)*: distribution and support services provided chiefly by member institutions; highly variable across institutions.

- *Growth Prospects*: volume of traffic of current services growing rapidly; capacity upgrade from 1.5 Mb to 45 Mb currently pending.

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[13] For a balanced view of the present and the future of broadband networks from a technology policy perspective, see M. Kapor, "Designing for Openness and Freedom in the National Public Network," Electronic Frontier Foundation, Cambridge, MA.

Comparing the nature of Internet as presently constituted to the criteria of the previous section, it can be seen that:

1. Experienced user groups appear to have learned to use the existing product set. The consumer learning argument for subsidization does not appear to be compelling, at least for Internet in its current configuration.

2. The primary customer groups enjoy high penetration; with some notable exceptions, institutions are not currently targeting user groups for which current Internet offerings have low penetration. The network externality argument for subsidization appears to be weak, at least for the current Internet customer groups.

3. For current services, hardware, and operations, the production technology seems well in hand, no longer subject to learning curve effects. Today's operation has evolved from the early experimental days of ARPANET to something like a mature business. Certainly there continue to be problems (as with any business), principally associated with rapid growth and the deployment of T3. It may be the case that certain areas of operating a large and rapidly growing broadband network still constitute researchable issues, in which case subsidies (or grants) for studying such problems are appropriate. However, subsidizing the general operations of Internet is difficult to justify on the basis of producer learning and the experience curve.

4. Neither economies of scale nor sunk costs appear to be a significant issue for Internet.

In brief, Internet *as it is today* provides little justification for continued direct subsidy, at least on the basis of economic efficiency. [14] At the time ARPANET was established, however, the picture was considerably different; network externalities and both consumer and producer learning were compelling arguments for direct subsidy. Today's government subsidy is perhaps best seen as a relic of Internet's experimental past. Efforts to place today's Internet on

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[14] It is perhaps worth repeating that this in no way suggests that today's Internet is not an extremely valuable national resource, and that it is an essential input to America's research community. However, America has many such valuable national resources, most of which are neither provided by nor subsidized by the government. In fact, it is this value which makes Internet eminently self-sustaining; since it is so important, of course researchers and their institutions will be willing to pay for it.

a self-financing basis constitute good (if overdue) public policy. As the efficiency rationale for subsidy erodes, so should the subsidy (absent non-efficiency reasons).

Self-financing of Internet does not imply that the nation's research support should in any way be lessened. It does argue that our research resources can be more efficiently deployed by providing researchers with the resources, and letting the various communications media, including Internet, work to earn them on the basis of service provided.

Price Structures for Internet

Efficient pricing of today's Internet involves many elements, as there are many transactions involved. The backbone network, now provided by ANS, provides connection capacity to both mid-level networks and end-institutions; the mid-level networks provides connection capacity as well as services to their participating institutions. Finally, the institutions provide Internet primary services to individual researchers, the ultimate end users.

- Transactions among *institutions* are most efficiently based on *capacity per unit time*. We would expect ANS to charge mid-level networks or institutions a monthly or annual fee that varied with the size of the electronic pipe provided to them. If the cost of providing the pipe to an institution were higher than to a mid-level network (because of increased service levels, etc.), the fee would be higher. Mid-levels could face a "wholesale" price for capacity, while individual institutions face a "retail" price. In turn, mid-levels would also price capacity to participating institutions on a retail basis; this capacity might be bundled with services provided by the mid-levels to the institutions. If mid-level networks are unable to provide services that are valued by the participating institutions, we would expect most such institutions would buy direct from the backbone provider(s).

- Transactions between a participating institution and its end users should show a high degree of variation among institutions. Some institutions may decide, as a matter of university (or firm or agency) policy, that Internet should be treated like the library: a no-charge service to the university community. Other institutions may treat Internet more like telephone service, in which departmental and research budgets are charged on the basis of *usage*; the price per minute would vary, depending upon the capacity (and other services) demanded. Institutions desiring to encourage the use of Internet throughout their community may offer free e-mail to, say, students and junior faculty, with other services and other users priced to recover costs.

- Individual institutions, mid-level networks, or end users ma y develop software packages that are of general interest throughout the Internet community. Originators of such software may choose to sell it or to make it available on a shareware or public domain basis.

Efficient pricing of today's Internet on the institutional level is most analogous to the pricing of mainframe computer services. Institutions lease capacity from suppliers (or distributors) and resell it within their institution (and occasionally outside of it) to end -users employing a variety of charging mechanisms that reflect the objectives of that institution for computing. Although internal pricing is usually usage-based (or free), more complicated schemes, such as two-part tariffs and priority pricing, may also be used.

What happens to the support for research? In this model, the support shifts from providing a needed input at below-cost prices (producer subsidy) to providing researchers and/or their institutions cash with which to pay the bill (user subsidy). In fact, most support to research is delivered in exactly this way. If the researcher needs to use the telephone or fly on an airline as part of his research effort, these expenses are including as a line item in the researcher's budget proposal and commercially available services are then purchased. In some cases, the cash can be used to purchase government services, such as census tapes. This support may go directly to the university or it may go to the individual researcher. In the former case, researchers will have access to the Internet even if they don't happen to have a grant, and this approach may be preferable. But again, this is a decision best left to the individual institutions.

It is also important that in making grants to researchers, cash for Internet usage should not be a totally separate budget item which can only be spent on Internet. A cash account constrained for one specific type of expenditure up to a fixed level is equivalent to giving the researcher X free Internet usage, with no option to trade off Internet usage against any other use for this cash, such as telephone or fax. The idea here is to induce users to make rational decisions among competing uses of their funds, one of which is Internet. Limiting certain user funds to one budget category (Internet) defeats the purpose of pricing. A better approach would be to have the researcher's Internet usage budgeted under a "Communications" category, so that the user can trade off the benefits and costs of different media.

6. Efficient Pricing for Internet: Tomorrow's Prospects.

Internet (and its predecessors) has traditionally been a vision as well as a reality for the computing community. Current prospects for the National Research and Educational Network

(NREN) foresee a national, perhaps international, broadband network far beyond today's Internet, in terms of users and in terms of services. What pricing policy leads to the most efficient deployment of the Internet of the future?

There are several directions in which Internet can grow:

- Present traffic volumes can continue the rapid growth of the past year; efficient pricing of existing services should help curtail this growth to usage which has positive value (Value > price) to the user.
- T3 connections to end users promise entirely new uses of Internet, as institutions and users invent services that can only exist on a 45 Mb pipe.
- Institutions can reach out to new user groups within their community; for example, Carnegie-Mellon University requires that all incoming students become computer-literate with their systems, including use of Internet.
- Universities/colleges not now on Internet can be connected.
- Other institutions, such as high schools, libraries, and municipalities can be connected.
- Commercial users could be encouraged to connect to Internet.

The pricing implications:

Rapid Growth: The continued rapid growth of Internet volumes can be seen as a consequence of existing inefficient pricing; substantial resources are being committed to producing a good that is being given to end users "for free." The appropriate response is higher (than zero) prices to end users, in order to bring some sense of the cost of the scarcity of resources to those whose decisions affect usage.

T3 Network Yields New Services: The expansion of Internet to an end-to-end 45 Mb network suggests that new network services and uses could arise that are not possible with the present system. The availability of a truly high capacity network, it can be argued, makes feasible brand new services, and such services may best be introduced with below-cost pricing to aid in consumer learning. There are two models as to how this might happen:

Specific Service Candidates: it is unlikely that the expansion of Internet to a 45 Mb capacity has been undertaken without having some specific end user services in mind, although exactly what these envisioned services might be does not appear to be well-documented. If specific service candidates exist, the nature of these services should be fully developed and specific markets for these services identified. [15] Empirical analysis should then be undertaken to determine which customers have an interest in these services, and what is the value of the service to them. It is critical that such a market assessment be grounded in actual customers who would be actual users of the proposed services; either survey data or empirical estimates based on observed market behavior are needed. Asking engineers who they think might be (even worse, "should be") interested does *not* constitute empirical market analysis.

If specific services and specific customers can be identified, then a subsidy to encourage customer learning of these new services may indeed be appropriate. This subsidy may involve introductory pricing ("free" service) but must also include training, user-friendly software, good documentation, and technical support services. Typically, these services are provided (or not provided, as the case may be) by the user's home institution, and the subsidy needs to be directed there. Note that in order for a subsidy to be efficient, it must be directed at the target market, and the target service. It also must include not just a price break, but a package of services aimed at making the new service easy to use. Providing old services for free is no way to encourage learning of new services; it is simply using the "customer learning" rationale as an excuse to maintain the status quo.

"Go fishing:" the existence of a sophisticated user group that is capable of developing new end user services to take advantage of new technology is a unique advantage of the Internet. One innovation strategy is to "go fishing" for new applications: build the 45 Mb network and see if users find new ways to use it. If this is the strategy, subsidies for entrepreneurial rewards (such as prizes for the "Best New Internet Product of the Year") are clearly more appropriate to

[15] For a discussion of the demand for integrated broadband networks from the public (both consumers and firms) as a whole, see Robert Pepper, "Through the Looking Glass: Integrated Broadband Networks, Regulatory Policies, and Institution Change," OPP working Paper 24, Federal Communications Commission, Washington, D.C.,November, 1988. This paper also provides an excellent discussion of the extraordinarily complex regulatory and institutional issues associated with broadband.

this end than subsidies for price breaks. As the expected new services come on line, subsidies as outlined above may be needed to ensure customer learning.

New User Groups: to the extent Internet institutions seek to expand their on-campus users to those who are at present unfamiliar with its joys, a subsidy specifically targeted at these user groups may be appropriate. This would certainly include (but not be limited to) extensive training programs, development of easy-to-use [16] software, support of Internet on LANs, well written and readily available manuals, and perhaps introductory pricing for these new users. After all, if CompuServe can do it, why not Internet? While some experienced users may reap some benefit (for example, from the use of software developed for new users), subsidized programs should be designed entirely around the needs of the targeted new users.

Other Nonprofit Institutions Not Now on Internet bringing entirely new institutions into the Internet community is a risk. Currently, Internet is built to serve the research community; seeking to add non-research institutions may move Internet away from its basic mission of research support toward a more broadly based public broadband network mission. Clearly, expanding the base of users expands the political support that Internet can call upon to ensure, for example, continued subsidy. However, an efficient subsidy designed to encourage new institutions to join Internet would be directed at those new institutions, not the existing Internet infrastructure.

Commercial Users: perhaps the most tempting of all options is to open Internet to commercial use. Generally, there are two arguments advanced for this:

Spread the fixed costs this is a common variant of economies of scale; by adding new users, the overhead cost per unit is reduced, thereby leading to lower prices for all.

Discriminatory pricing in this view, commercial users would be willing to pay prices sufficiently high that academic users could continue to be subsidized via low (or zero) prices.

Both of these arguments seem appealing; both in my view are wrong. Fixed costs do not seem to be a major element of Internet. The current high growth rate is not contributing to lower

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[16] This observation from M. Kapor, *op. cit.*: "On most Internet systems...newcomers find themselves what John Perry Barlow calls a 'savage user interface.'"

costs; the opposite is more likely. Further, adding commercial users who are not similar in demands and expectations to the current user base would require substantial change in how Internet service is distributed and supported. In fact, this would add to average costs, not reduce them. "Spreading the fixed costs" is a siren song that has led many an enterprise into foolish (and unprofitable) excursions away from their core business. Internet can ill afford such an excursion.

Discriminatory pricing appears to offer a painless way to maintain subsidy support for Internet; corporate users, happy to have access to this far-flung network, are willing to pay a rate above their costs. The difference can be used to subsidize academic users. The fact that there are a number commercial users, primarily research-oriented firms, already on Internet and paying higher fees is taken as evidence for the viability of this approach. In this case, the evidence is misleading, and attempts to charge commercial users rates above costs are likely to meet with very limited success, for several reasons:

- For research-oriented firms, access to Internet is very valuable, in that it gives access to the academic research community which is an important input to their production process. These firms would indeed be willing to pay prices above costs, because they are buying access to a key resource: the research community. However, this base of firms constitutes a small fraction of U.S. firms, and most of them are already on Internet. The untapped market is likely to be small.

- For mainstream firms (Proctor and Gamble, Citicorp, GM, etc.), by far the lion's share of corporate America, access to the research community is of little value. [17] Internet could only be sold to mainstream firms as a *public* broadband network.

  * Many of the Fortune 100 firms have already invested heavily in *private* broadband networks,[18] specially designed to fit their particular needs. In some cases these networks may include supplier or client firms. It is unlikely that these firms will be much interested in Internet.

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[17] Many such firms have a research laboratory (e.g., GTE Laboratories, a subsidiary of GTE Service Corp.) which is connected to Internet. This is usually the only corporate facility so connected.

[18] See, for example, John Foley, "The Net Connection," *Communications Week*, December 3, 1990.

* For existing services (e-mail, e.g.), corporate America has stayed away from public networks (MCI Mail, CompuServe) in droves. These networks offer well-designed services and are successful at reaching certain niche markets. Should Internet attempt to serve a corporate market, these networks constitute the competition, and they have yet to show themselves as money-spinners. Private e-mail networks seem to meet the needs of most corporations, for the simple reason that most of a firm's communications take place within the firm or with a very limited set of suppliers and customers. External (between firm communication) is much more formal, and does not lend itself to the informality of e-mail.

* Corporations have shown little enthusiasm for *public* broadband service networks generally, despite the promise of new services. The abortive Satellite Business Services' foray into broadband in the 1970s indicates that (i) firms are willing to test the market; and (ii) the market doesn't seem to be there. Of course, it is always possible that the *next* attempt to woo corporate customers to public broadband networks may work, and commercializing Internet may be wildly successful. The author is unaware of a single piece of evidence that would support this scenario, however.[19]

* Most important, corporate (non-research) users would be unwilling to pay prices above costs in order to subsidize anyone, including academics. Competitive alternatives are available; if Internet attempted to charge prices higher than the competition, they would lose the business. Only if the commercial user has a specific need for access to the academic research community would above-cost pricing be feasible. Yet most such users are already on Internet.

A current fad among management consultants is to advise firms to "stick to their knitting;" to keep tightly focused on what they do well, their "core competence." It would appear that Internet's core competence is serving the research community with leading-edge computer network technology. Within this broad mandate, there is much room for future growth: bringing new research communities on to Internet (students, new faculty groups), and

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[19] See Pepper, *op. cit.*

developing new services which take advantage of the pending 45 Mb network upgrade. In this context, there is ample rationale for subsidies narrowly targeted to achieve these ends: training, software development, "marketing" the service to its intended audience, and perhaps introductory pricing for new users and new services.

7. Is There An Efficient Subsidy?

Let us summarize the points thus far:

- Continued provision of the backbone network (NSFNET) for *today's* Internet without charge cannot be justified on grounds of efficient use of our nation's scarce research resources.

- Efficient use of today's Internet is fostered by setting prices for Internet services that reflect the costs of the resources thus consumed. Universities or individual researchers could pay these costs as they currently pay for other telecommunications services: out of departmental or research budgets.

- If new user groups and new broadband services are developed for delivery on the Internet, tightly focused programs specifically designed to educate new users, or educate old users about new services, may justify a subsidy in order to overcome problems of consumer learning.

- Expansion of Internet to unfamiliar markets in the hopes of generating new subsidies (either from cross-subsidies or continued public funding) are likely to be unproductive, and possibly dysfunctional.

Existing users, asked to give up a subsidy which they may view as a right, may find this policy unduly harsh. A similar situation occurred in the 1970s as telephone companies moved away from providing directory assistance calls for "free." At the time, many telephone customers were outraged that their "right" to free calls to directory assistance was being taken away. Today, few would argue that customers who place resource-using demands on the system should pay for the cost of those resources.

The prospect of these short-term costs from the subsidy withdrawal suggests a transition plan to help existing users adapt. The purpose of such a plan is not to continue the subsidy indefinitely, but to help users make the transition. Therefore, the plan should be explicit about precisely who pays what, and for exactly how long. Ambiguity in the transition plan would undermine the purpose of the transition itself.

8. Conclusions

Applying the standard of economic efficiency to the deployment of Internet, we find that:

- Moving Internet to a fully price-based system with a user subsidy (rather than a producer subsidy) will unambiguously increase the efficiency of use of our nation's scarce research resources. This may require a transition phase to acclimate users to the new regime. This transition phase should be short and have a strictly determined end-point, known to all in advance.

- Prices from primary providers of Internet to mid-level networks and to research institutions will likely be capacity-based rather than usage-based, as that is the dimension upon which cost-incurring decisions are made at this level. Prices that end users face from their institutions will vary significantly (i) among institutions, (ii) among user groups (students vs. administrative staff vs. assistant professors vs. full professors), and (iii) among services.

- Continued government subsidy should be tightly focused on (i) new user groups (if any) and (ii) new products and services unfamiliar to existing users (e.g., that take advantage of the new high-capacity backbone). The existing subsidy to experienced users should be phased out in favor of programs of training, development of user-friendly software, and targeted introductory pricing.

    * Such subsidies should have a clear purpose and target, be based on empirical analysis (either market research or econometric estimation) on the viability of the new markets/services, and have specific target dates at which the subsidies expire. Their *sole* objective should be to encourage new users and/or new uses, and should support a mix of activities, not just "free" service.

- Opening Internet to commercial and other uses is unlikely to result in much new business beyond the research community, and will likely increase the cost of the system. Significant ongoing subsidization of research users by commercial users (except by commercial *research* user), even if commercial demand is strong, is unlikely.