PRICING THE NET: WHAT ECONOMISTS DO

Gerald R. Faulhaber*

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* Professor, Department of Public Policy and Management, Wharton School, University of Pennsylvania. 19104.
Tel. 215-898-7860
fax: 215-898-9463
e-mail: faulhaber@wharton.upenn.edu

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1. Introduction

This paper is organized around three topics that "support and surround" the subject of network pricing: the market structure of the emerging information infrastructure, considerations of cross-subsidy in pricing, and the real-life pricing issues that are likely to occur if and when the info*bahn* ever gets up and running.

I will take it as given that the reason for our gathering here today is to look forward to the possible futures of data networks, to the various complementary and often conflicting visions of the National Information Infrastructure. Data networks of the last decade bear a strong resemblance to computers of the 1960s and 1970s; raw-edged beasts roughly controlled by their keepers to do the world's heavy lifting: tracking satellites and enemy missiles or managing payroll and accounts payable. High-powered back office work, conducted under the vigilant eye of a few experts who knew their machines and their colleagues at the other end of the digital pipe. Data networks of the next decade or two will bear a strong resemblance to PCs, faxes, and VCRs; in other words, consumer electronics, which better be idiot-proof because that's who is running the equipment. With Internet and the promise of the Info*bahn*, data networks are becoming front office. It is in this spirit that I approach the network pricing problem.

What this *isn't* is a paper in which I propose the really-cool-pricing-scheme *du jour*. We economists have been at this long enough so that we know each other's tricks, but I am hoping to be surprised by my colleagues today. Even more, I am hoping to be *really* surprised by the engineers; my years at Bell Labs, when I actually did something socially useful, taught me how clever engineers can be. Today I prefer to be delighted by your ingenuity rather than compete with it.

Economists (usually) and engineers (almost always) tend to study pricing of goods and services in the abstract. A normative criterion is established, the cost and demand structure defined, and optimal prices are determined. In fact, how we see the pricing problem, or even *if* we see it, often depends upon the structure of the markets in which the goods and services are sold. In Section 2, we explore how industry structure issues affect not only prices, but what the pricing question is. In Section 3, the concept of subsidy-free pricing is developed; rather than focus on what the *optimal* price should be, based on some normative criterion, this strain of the literature focuses on what we might call *admissible* pricing: sets of prices (or price functions) that satisfy competitive and/or equity constraints. Lastly, in Section 4, some likely pricing outcomes are laid out and related to how the data network industry will evolve. If we think network pricing is a complex topic today, we ain't seen nothin' yet!

2. Pricing and Market Structure

The pricing problems of a regulated monopolist, such as a local telephone company or a cable TV company, are quite different from pricing problems in industries with, say, many firms and much product differentiation. The pricing problems of a regulated industry with many firms and perhaps several technologies, such as transportation pre-1980 are different still.

Before describing why they are different, let me motivate this discussion for the conference at hand by admitting up front that I haven't the foggiest idea what the market structure of the emerging NII will actually be, much less how it will evolve over time. Let me also assert, perhaps more contentiously, that no one else knows, either. However, we know what some of the possibilities are, and how we might get there.

Virtually every government in the world, and certainly ours, has seen fit to grant virtually every public telecommunications network some form of monopoly franchise, generally in return for regulation or outright public ownership. While many have characterized the Internet as an anarchic, free-spirit network, beholden to no corporation or regulatory agency, the fact is that all the transmission facilities of the Internet are leased from local and interexchange telephone companies. At the facilities level, this is pretty much a regulated industry. [1] It is unlikely that this fundamental fact of political economy is about to change with the NII . Two informal measures of the likelihood of this outcome are : (i) both Democrats in the administration and Democrats in Congress have indicated a strong interest in the NII; (ii) note that all reference in the popular press refer to the Info*bahn* as "the" Info*bahn* , or "the" NII; this suggests to me that the expectation is franchise monopoly . In a country presumably committed to competition as a national economic policy, how can we fall so easily into the monopoly model? Some will argue that the investment to build the NII is so great that only one firm can be profitable; the natural monopoly argument. Others will argue that it is a right of all citizens to have the new world of information access (and 24-hour video on demand) available to them, and this may require internal subsidies to achieve this; the universal service argument. We can therefore expect political demands and public pressure for a single Info*bahn*, regulated to protect against monopoly abuse and to ensure universal service.

On the other hand, there are forces heading in the direction of oligopolistic, if not competitive, supply. Telephone companies and cable companies appear eager to get into each other's markets, and direct broadcast satellite firms appear willing to take on the cable companies. This corporate jockeying reflects an underlying technological difference in competing visions of the Info*bahn:* will it be primarily an entertainment distribution system, an extension of today's cable networks or will it be interactive

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[1] Clearly, the extent of regulation in the interexchange market is substantially less than it was five years ago, and substantially less than it is in local exchange markets. AT&T is subject to price cap regulation, with many of the facilities in question in the "Tariff 12" basket. MCI and Sprint are subject only to filing requirements. Nevertheless, it is still regulated.

multimedia, binding the nation together education, information, and interaction ? The first calls for a network that is primarily a one-way, one-to-many system; the second calls for a two-way, many-to-many interactive system. This suggests at least two Info*bahns*, each designed to meet different needs, but with some competitive functional overlap. If direct broadcast satellite is also considered, then the U.S. could well have three (or more) Info*bahns*. It is possible that political demands for government intervention will bring some or all of this structure under some form of regulation.

In the end, proliferating options for consumers may drive government regulation out of this business. There are precedents, including the full deregulation of CPE in the telephone business in the late 1970's as well as transportation deregulation in the late 1970's (airlines) and early 1980's (trucking and railroads). There is also the possibility that a market-friendly Congress may adopt a competitive policy from the beginning, precluding even the start of pervasive regulation. Again, there is a precedent; the FCC's treatment of the cellular market and more recently PCS suggests that the government can play an enabling role without playing the coercive regulatory role as well. Should this occur, the market will see many firms and much product differentiation.

Another industry structure issue is the separation of content and conduit. In telephone, the legal concept of a common carrier enjoins the phone company from any control over the content of the messages moving through its pipes. In cable, we accept that the cable company has the right to decide what we can see, and also has the right to own upstream entertainment production firms. Today, we are choosing sides as to whether America On-Line has the right to censor on-line forums. The Electronic Frontiers Foundation has eloquently argued for ensuring that the facilities providers supply merely an open platform, to which anyone else can plug in and do business. Just as any trucking company can use the Intestates, so any information vendor should be able to use the NII on terms equivalent to any other vendor, *including the platform provider.* In fact, this is the identical issue that the AT&T antitrust case turned on: equal access by competitors to bottleneck facilities.

What difference does industry structure make to defining the pricing issues? Let me first note that virtually all of the contributions of economists to pricing have been in regulatory economics. Our earliest contribution was the control of monopoly power via regulation, but our more interesting contributions came later, when the multiproduct nature of regulated firms was taken into account. The extensive literature on Ramsey pricing, cross-subsidy, non-uniform pricing, and sustainability of natural monopoly was the high-water mark of economists' pricing contributions to pricing and regulation. I also include in this literature pricing methods to control for congestion of fixed costs, a problem which occurs in telephone and electric power, and certainly occurs in data networks. There are several strains to this literature, including peak-load pricing, load-limit pricing, and so-called Vickrey pricing. This latter form of real-time pricing never attracted many advocates in the telephone business, but Varian and MacKie-Mason (1994) are strong proponents of this "smart pricing" for the Internet, which appears to be its natural *métier.*

Economists have also made significant contributions to the theory of access pricing, much of it driven by the AT&T divestiture issues. These include (among many others) Laffont and Tirole (1994) and Economides and Woroch (1993), and Baumol's (1993) "Efficient Component Pricing" rule. This has been one of economists' few successful forays into pricing in regulated industries with many firms. Some pricing work in the transportation field emerged in the late 1970's, particularly relating to competing transportation modes. Generally economists have thrown up their hands at the thought of achieving any kind of efficient pricing in a regulated oligopoly structure.

Surprisingly, economist have had little to say about pricing in product-differentiated markets[2] with competitive entry. One measure of this lack of attention to such markets is that the extensive literature on peak-load pricing and congestion pricing in public utilities made no references at all to competitive markets in which the same problems arise, such as hotels and rental cars. In these markets, pricing mechanisms naturally arose to handle these problems, a fact which virtually all *regulatory* economists overlooked.

So, does industry structure matter for defining the pricing problem? And is industry structure an issue in data networks? This brief look at the history of how economists have defined the pricing problem suggests that structure does indeed matter. The brief look at possible industry structures toward which the NII could evolve suggests that this issue is still very much up in the air. What will end up being the important pricing issues will be highly context-dependent, and what that context will be is still not known.

3. Subsidy-Free Prices [3]

While most of the world looks at prices as a means to recover costs and make some profits, economists view prices as signals which ensure that producers make, and consumers consume the "efficient" amounts of goods and services. Therefore, our approach to pricing has been that of ensuring, to the extent feasible, efficiency in production and consumption, taking account of all costs (including congestion) and all benefits (including the network externality). Since this is a normative exercise, our answer is usually cast in the form of the "optimal," or "efficient" price. It is in this spirit that much of the recent economic work on pricing the Internet has been conducted. [4]

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[2] There is actually a large and rather specialized literature on pricing in markets that can be characterized as spatial, either geographic space or product space. This tradition goes bank at least to Hotelling in the 1930's.

[3] The material in this section is drawn from Faulhaber (1975) and Faulhaber and Levinson (1981).

[4] See Faulhaber (1992) for an early attempt to frame the pricing issue for the Internet (or NREN, as the NII was then referred to).

However, there is another strain to this literature, which focuses more on the "fairness" of prices: subsidy-free prices. The question this literature sought to answer is: are some customers paying too much for their service while others are paying too little? Is one product or service priced too high, while another is priced too low? That is, does the price structure result in cross-subsidy?

The problem is posed in the context of a production technology characterized by cost subadditivity: it is cheaper to supply all services with a single supplier rather than multiple suppliers. This is a strictly technological on the cost function $C(\mathbf{Q})$, where $\mathbf{Q} = (Q_1,\ldots,Q_n)$ is the vector of outputs of n services:

for any set of quantity vectors $\mathbf{Q}^1,\ldots,\mathbf{Q}^k$,

$$C\left(\sum \mathbf{Q}^j\right) < \sum C(\mathbf{Q}^j).$$

We assume that a price vector $\mathbf{p}$ is set, either by the market or by a regulator, which ensures that the enterprise just breaks even, including all economic costs, so that $\mathbf{p}\cdot\mathbf{Q}(\mathbf{p}) = C(\mathbf{Q})$. A price vector $\mathbf{p}$ is *subsidy-free* if and only if, for all subsets $S \subseteq N = \{1,\ldots,n\}$ the total revenues from that subset are no greater than the costs of that subset if that subset were provided on a "stand-alone" basis:

$$\mathbf{p}_S \cdot \mathbf{Q}_S(\mathbf{p}) \le C(\mathbf{Q}_S). \tag{1}$$

Equivalently, prices are subsidy-free iff, for all subsets $T \subseteq N$, revenues are no less that the incremental costs of that subset:

$$\mathbf{p}_T \cdot \mathbf{Q}_T(\mathbf{p}) \ge C(\mathbf{Q}) - C(\mathbf{Q}_{N-T}). \tag{2}$$

With the assumption that revenues equal cost, conditions (1) and (2) are equivalent.

What does this have to do with fairness? In the presence of cost subadditivity, there are gains to all from cooperating in producing one big enterprise. Prices are the way we share these gains; if one big network is cheaper (and more beneficial) than several small ones, then everyone should be able to share in those gains. If, however, one product or group of products is paying more than its stand-alone costs, then it is not sharing in the gains, and it would be better off if it had not joined in the larger enterprise.

Of course, this has implications for competitive entry. Absent legal restrictions and barriers to entry and exit, the presence of cross-subsidy would generally be a signal for competitive entry. In fact, the contestability literature of the late 1970's-early 1980's was built upon precisely this observation. However, the institutions associated with the network may make entry infeasible. Then cross-subsidy becomes simply the exploitation of one product (or product group) for the benefit of others, based on the inability of the exploited group to do much about it. Certainly, consumers of the exploited products would not have joined in the first place had they realized their fate. In this sense, cross-subsidy is unfair because it may be viewed as abrogating the

implicit contract by which the one big network was put together in the first place: to realize the benefits of scale. [5]

There are several features of subsidy-free prices of economic importance:

- with cost subadditivity, there is usually a set of subsidy-free prices; they are not unique;
- to determine which prices are subsidy-free, it is necessary to examine all subsets of products, not just each product singly;
- efficient, or so-called Ramsey prices need not be subsidy-free;
- for some cost functions, there may be no subsidy-free prices.

A compelling criticism of this definition is that the basic unit of analysis is the product and not the consumer. Fairness, after all, has to do with people, not products. This suggests an extension of this analysis to consumers. Let $M=\{1,\ldots,m\}$ be the set of consumers of the network products, with $Q^j(\mathbf{p})$ the j^{th} consumer's demand function. For any subset of consumers $V \subseteq M$, define $\mathbf{Q}^V = \sum_{j\in V} \mathbf{Q}^j(\mathbf{p})$. Then the price vector $\mathbf{p}$ is *consumer subsidy-free* iff no group of consumers is paying revenues in excess of their stand-alone costs;

$$\mathbf{p}\cdot\mathbf{Q}^V(\mathbf{p}) \le C(\mathbf{Q}^V(\mathbf{p})), \quad \text{for all } V \subseteq M. \tag{3}$$

Equivalently, prices are subsidy-free if no group of consumers is paying less than their incremental costs:

$$\mathbf{p}\cdot\mathbf{Q}^W(\mathbf{p}) \ge C(\mathbf{Q}(\mathbf{p})) - C(\mathbf{Q}^W(\mathbf{p})), \quad \text{for all } W \subseteq M. \tag{4}$$

Introducing consumers does indeed change the conclusions. Depending upon demand patterns, consumer subsidy-free prices constitute a larger set than product subsidy-free prices, may be identical to the set of subsidy-free prices, or may be smaller than the subsidy-free set. Examples:

- if the demand vectors of all consumers are proportional ($\mathbf{Q}^j = a^j\mathbf{Q}$) for some scalar a^j), then *any* price vector is consumer subsidy-free, whether it is product subsidy-free or not;

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[5] The astute reader may note that subsidy-free prices correspond to the *core* of the appropriately defined game. The core is a set solution concept from cooperative game theory which has had some application in economics, especially general equilibrium theory. Subsidy-free prices are not the only contribution that cooperative game theory has made to the pricing literature. In the early 1980's, several papers appeared on "axiomatic cost allocation," which used the Shapley value of this game to set prices, appealing to the alleged fairness of the Shapley value algorithm.

- if costs are affine ($C(\mathbf{Q}) = F + \mathbf{c} \cdot \mathbf{Q}$) and for each product i there exists at least one consumer that consumes only that product, then $\mathbf{p}$ is consumer subsidy-free iff it is product subsidy-free.

In Faulhaber (1981) a peak-load pricing example is given in which there is a unique consumer subsidy-free price but an entire set of product subsidy-free prices.

Unfortunately, the consumer subsidy-free concept is of limited usefulness, as observing actual consumer demand patterns and performing these calculations is at best onerous (even with computers) and is usually impossible. A more useful and a more general concept is that of *anonymous equity*; a price vector is anonymously equitable if it is consumer subsidy-free for any possible subset of consumer demand. More formally, the price vector $\mathbf{p}$ is *anonymously equitable* iff

$$\mathbf{p} \cdot \mathbf{q} \leq C(\mathbf{q}), \text{ for all vectors } \mathbf{q} \leq \mathbf{Q}(\mathbf{p}), \tag{5}$$

or equivalently.

$$\mathbf{p} \cdot \mathbf{q}' \geq C(\mathbf{Q}) - C(\mathbf{Q} - \mathbf{q}'), \text{ for all vectors } \mathbf{q}' \leq \mathbf{Q}(\mathbf{p}). \tag{6}$$

Note that anonymous equity (and subsidy-free) does not dictate a specific price vector. [6] Rather, in most cases the concept maps out a *range* of prices that satisfy the constraints of (5) and (6), such that all prices within this set are fair in the sense that all (possible) groups of consumers are sharing in the benefits of having one big network.

Does subsidy-free pricing matter to the owners and managers of the network? As it turns out, it does matter; *why* and *how* it matters, however, depends upon the industry structure:

- If the network is a regulated monopoly, then any cross-subsidy is likely to lead to consumer complains that their group is paying more than their "fair share," demanding immediate redress in the form of lower prices. [7]

- If the network is not price-regulated but there are significant barriers to entry, then any cross-subsidy is likely to lead to demands that price regulation be imposed so

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[6] The analysis is based on the assumption that that all prices are uniform. It is straightforward (but tedious) to generalize these results to the case in which non-uniform price structures are employed. The analysis is also based on the assumption that the definition of the outputs is clear and unambiguous; this has proven to be not so in the context of regulatory proceedings in the telephone industry, and is even less likely to be the case in the NII.

[7] It is to be expected that such claims will be made whether or not a subsidy in fact exists. If consumers (or anyone) believes that asserting a claim may lower their price, and the costs of asserting the claim are lower than the expected benefits of possibly lower prices, we should expect to hear such claims. This analysis develops a clear framework in which such claims can be judged and demonstrated to be valid or not.

that the demanding group can gain some rate relief from its cavalier treatment at the hands of the network owners.

- If the network business has relatively low barriers to entry, then cross-subsidy will not lead to any political demands, but it will lead to entry and loss of business from the network. Prices which are not subsidy-free are generally not sustainable in a market with low entry barriers.

- If the network supplies not only the platform but also services across the network, then competitive service suppliers are likely to claim that the network providers are providing themselves a subsidy in the form of preferential low-cost access.

Therefore, in all the cases above, any failure to keep prices subsidy-free is likely to end up changing the network's business in ways which the owners are likely to be unhappy with. The particular form of that unhappiness varies substantially across industry structures, but unhappiness there will be.

4. Conclusions: Thinking About Prices

As a practical matter, we often find ourselves thinking about problems, pricing problems included, based on familiar reference points. Since many economists, myself included, cut their teeth on telephone pricing, we often see the NII in telephone terms: Ramsey pricing, congestion pricing, access pricing, etc. Likewise, many in the cable industry came at their pricing problem from the context of video entertainment; the broadcast model was to provide programs "for free." Recently, they have moved toward a pay-per-view model, closer to that of movie theaters and video rentals. Those from the Internet world are perhaps using a library or academic model; information is a public good, and somebody ought to provide it for free. In this model, pricing of any sort is an outrage that must be resisted strongly.

Let me suggest another model: the network as a distribution channel of goods and services. In an economy increasingly dominated by electronic products, the NII could become the mall of the 21^{st} century, and the network owners then become the equivalent of the mall developers. Yes, it may be the future of catalog shopping, with L.L. Bean a major network presence. But as our consumption moves from goods to electronic services, the network becomes the point of consumption, not just the point of ordering. Games, interactive libraries, movies, special interest group discussions, and other mind candy become what's consumed, and the network is where you consume it. Kids (and adults) that hang around the newgroups will be the new "mall rats," "stores" will entice you in with slick home pages (storefronts).. Different places on the network will cater to clientele of different incomes and taste.

In this model, pricing for the network itself is likely to be zero for consumers logging into the mall, but very substantial for electronic stores that locate in desirable network "real estate." The prices charged by electronic providers must, of course, cover these costs, but they may not be marginal for the browsing shopper. The relevant telephone

concept is 800 service; the seller covers the cost of the buyer to get to the front door. This is not to say that delivering a movie or an interactive game is not a costly use of network time and bandwidth. However, in this model the customer pays the vendor for the service delivered and the vendor pays the network operator for what no doubt amounts to the bulk of its marginal cost

At the end of the day, which will predominate: the telephone model, the movie model, the library model, or the shopping mall model? The answer, of course, is yes. I expect to see all of these models deployed in some form within the next decade. I also expect that our marketing colleagues will have as much or more to say about pricing than either economists or engineers. In the real world of competitive markets, it is they who have the final word, and unless the NII becomes a fully regulated entity, I suspect it is they who will have the final word on pricing the NII.

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