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Valuing the Effect of Regulation on New Services in Telecommunications

THIS PAPER DEALS with how to value the introduction of new services in telecommunications. Much public discussion has centered on the evolving "information superhighway" as well as on the many new services that may be offered as high-capacity fiber optic transmission networks are extended into the telecommunications infrastructure. The Federal Communications Commission (FCC) has decided to tax long-distance users to subsidize Internet access to schools and libraries. The cost is estimated to exceed $2 billion a year. Numerous cable companies, such as Time Warner, have announced plans to upgrade their current coaxial-based networks to combined fiber-coax networks. This increased transmission capacity will allow many more channels of entertainment, high-speed access to information, and new interactive services.

How can society establish the value of these new services and increased choices? This question has potentially important economic consequences and equally important public policy implications. Because of the network structure of telecommunications, public policy has always played a large role in its production and regulation. In countries such as the United States and Canada, very strict regulation (which is only slowly being loosened) has limited the ability of companies to compete freely in telecommunications. By demonstrating how to value new telecommunications services, I allow for a more reasoned approach to the necessary benefit-cost calculations; this approach can help both

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to guide public investment in telecommunications infrastructure and to evaluate the effects of regulation.

To value new telecommunications services, I apply the method first introduced by the Nobel prizewinning economist Sir J. R. Hicks.[1] The basic idea underlying the economic approach to valuing new goods or services is the recognition that until these goods actually come on the market, consumers are unable to purchase them at any price, no matter how much they would like to buy them. Thus, in some sense, the price of the new good or service might as well be infinite.

A more refined economic approach estimates the ''virtual,'' or ''reservation,'' price that sets demand for the new good or service to zero. At this virtual price, demand is zero, so a ''virtual equilibrium'' exists between demand and supply (which is zero). Estimation of the virtual price along with the expenditure function (demand curve) for the new good or service gives the economic value.

The actual price of the new service will usually be well below the virtual price. The quantity consumed multiplied by the difference between the virtual price and the market price (multiplied by one-half) approximates the fundamental gain in value, also called the consumer surplus, from the new service.[2] This economic approach uses market demand to value new goods and services because the market establishes what consumers are willing to pay.

The introduction of new telecommunications services can lead to very large gains in consumer welfare. Consider voice messaging services introduced by local telephone companies in 1990; I estimate that the gain in consumer welfare from these new services was $1.27 billion a year by 1994. Similarly, the introduction of cellular telephone services has led to estimated gains in consumer welfare of about $50 billion a year.

Introduction of a new telecommunications service is typically much different from the introduction of a new good in an industry that is not regulated. If Kellogg or General Mills wants to introduce a new brand of cereal, it manufactures the cereal and convinces supermarkets to

1. Hicks (1940). I recently used this methodology to value new varieties of consumer goods; see Hausman (1996a).

2. This estimate is the calculation of the well-known welfare triangle, which measures consumer surplus and approximates the gain in consumer welfare.

stock the new brand on their shelves. Consumers then decide whether the new brand will be successful by voting with their consumer expenditure. Regulation makes introduction of new telecommunications services much different. In the United States telecommunications companies must typically file an application with the FCC and state regulators. Potential competitors of the new service have economic incentives to attempt to stop or delay introduction of the new service. While regulators review the applications and attempt to sort out these claims, the new service can be delayed for many years, even decades. My approach allows estimation of the cost of these regulatory delays by valuing the economic gains that consumers would have had if the service had been available during the period of regulatory delay.

To assess the economic costs of regulatory delay, I first consider the particular example of voice messaging services offered by the Bell operating companies. AT&T initially proposed to offer these services in the late 1970s. The FCC first delayed its decision and then refused to allow the Bell operating companies to offer these voice messaging services on an integrated basis with the rest of their telecommunications services. In 1986 the FCC reversed its decision. By then, however, the AT&T divestiture decree, the Modification of Final Judgment (MFJ), forbade the Bell operating companies to offer voice messaging services. Two years later, in 1988, the MFJ court vacated the restriction on information services, which included voice messaging services, and the Bell operating companies began to offer the services the next year, more than ten years after they were first proposed to be offered. The services have been available since 1990, and about 16 million consumers bought them in 1996. If, as I estimate, the consumer value from these services was $1.27 billion in 1994, then the approximate ten-year regulatory delay cost consumers billions of dollars. Applying the methodology to the cost of regulatory delay in the introduction of cellular telephone service, I estimate the cost to consumers to be closer to $100 billion in total, with more than $25 billion lost in a single year.

This cost of regulatory delay in the introduction of new telecommunications services has not received the attention it deserves. Although the potentially adverse effect of regulation on "dynamic economic efficiency" is often mentioned, the literature on the effects of regulation has largely ignored the actual effects of regulatory delays in new services.[3] I calculate the loss in consumer surplus and also the effect on the telecommunications consumer price index from the introduction of these new services. Either alternative measure of consumer welfare demonstrates the significant consumer gains from the introduction of new telecommunications services and the very large cost imposed by regulatory delay in the introduction of these services.

Last, I consider the effect of current regulation on the future introduction of new telecommunications services. The FCC is aware of the cost of regulatory delay, which was widely discussed in the regulatory proceedings leading up to the FCC's decision to auction spectrum for personal communications services in 1994. In 1996, however, the FCC adopted new regulations to force local exchange companies to unbundle their networks and sell their services at very low prices to competitors. The pricing rules are being challenged in federal court, but if they are permitted to take effect, they will retard innovation and the future introduction of new services by telephone companies. Once again regulation will likely cost consumers billions of dollars.

The Economic Valuation of New Goods

Sir John Hicks made one of the first attempts to develop a theory for valuing new goods. In 1940 he valued social income and economic welfare using index number theory to analyze the effects of rationing and the introduction of new goods. Hicks correctly saw his approach as the basis for evaluating real income under these changes. Without completely working out the mathematics, he stated that for rationed goods the index numbers needed to be altered so that the price used in the index number calculated would lead to the amount of the ration being demanded. This higher price can be considered the "virtual price," which, when inserted into the demand function, leads to the observed amount of rationed demand.[4] For new products Hicks stated

3. See, for example, Joskow and Rose (1989) for a review of the effects of regulation. Oster and Quigley (1977) did find that regulation in the construction industry retarded diffusion of techniques, but they did not estimate the loss to consumer welfare from the regulation.

4. See Neary and Roberts (1980) for a modern treatment of rationing using this approach.

that the virtual price for periods in which the goods did not exist would "just make the demands for these commodities (from the whole community) equal to zero."[5]

Modern economists recognize this price as the shadow, or reservation, price that is used in the demand function to set demand equal to zero. Of course, new products in a sense are a special case of rationing where the demand for the good is zero. Given the demand function, I can solve for the virtual price and for the expenditure function (or the indirect utility function) and correctly value social welfare without using the index number formulas discussed by Hicks.[6]

Rothbarth, in a 1941 paper on rationing, put the subject on firm mathematical footing and introduced the notion that a virtual price arises from the "price system with respect to which the quantities actually consumed are optimum . . . the 'virtual price system.' "[7] I use his approach to demonstrate the effect on the price index, or real income, of the introduction of a new good. In period 1 consider the demand for the new good, x_n, as a function of all prices and income, y:

$$x_n = g(p_1, \ldots, p_{n-1}, p_n, y). \tag{1}$$

Now if the good were not available in period 0, I solve for the virtual price, p_n^*, which causes the demand for the new good to be equal to zero:

$$0 = x_n = g(p_1, \ldots, p_{n-1}, p_n^*, y). \tag{2}$$

The index number approach, used by both Hicks and Rothbarth, then considers the change in real income to be the ratio $(p_n^*)(x_n) / (p_n)(x_n)$. Although this approach is approximately correct, it does not account for the need to change income y as the price is increased in order to stay on the same indifference curve so that the marginal value of income does not change. Thus, instead of using the Marshallian demand curve in equations 1 and 2, I instead would use the income-compensated and utility-constant Hicksian demand curve to do an exact welfare evalua-

5. Hicks (1940, p. 144).
6. See Hausman (1980, 1981), who uses this approach in the context of female labor supply to make welfare calculations.
7. Rothbarth (1940–41, p. 100).

tion.[8] To find the (partial) expenditure function, I solve the differential equation from Roy's identity, which corresponds to the demand function in equation 1:[9]

$$(3) \qquad y = e(p_1, \ldots, p_{n-1}, p_n, u^1).$$

The expenditure function gives the minimum amount of income, y, to achieve the level of utility u^1 that arises from the indirect utility function, which corresponds to the demand function of equation 1 and the expenditure function of equation 3. To solve for the amount of income needed to achieve utility level u^1 in the absence of the new good, I use the expenditure function from equation 3 to calculate:

$$(4) \qquad y^* = e(p_1, \ldots, p_{n-1}, p_n^*, u^1).$$

The change in consumer welfare when the price decreases from the virtual price level, p_n^*, to the actual price level, p_n, keeping utility at the level u^1, is $y^* - y$.[10]

Note that to use this approach, one must estimate a demand curve as in equation 1, which in turn implies the expenditure function and the ability to do the exact welfare calculation of equations 3 and 4. Thus,

8. In equation 3, income, y, is solved out in terms of the utility level, u^1, to find the Hicksian demand curve given the Marshallian demand curve specification. Hausman (1981) demonstrates this solution procedure.

9. Hausman (1981) demonstrates how to solve the differential equation that arises from Roy's identity in the case of common parametric specifications of demand. Hausman and Newey (1995) demonstrate how to do the analysis when a nonparametric specification of demand is estimated.

10. It is sometimes asked whether consumers who buy the new product and discontinue their purchases of substitute products "lose consumer surplus" from not purchasing the older product, thus causing the consumer benefits from the new product to be overestimated. This calculation demonstrates that no "lost consumer surplus" arises so long as the older product continues to be available at its previous price. To the extent that other prices change, the changes in consumer welfare are incorporated straightforwardly into the welfare calculations because equations 3 and 4 are based on the expenditure function (for example, compensated demand curve) and are therefore path independent of price changes. Only when the older products disappear from the market do significant complications arise. Also, the analysis takes the representative consumer approach, which means it is not complicated by consumer switching from one product to another product because the representative consumer continues to purchase all products. Of course, one might prefer a discrete choice approach to the analysis if the data were available; see, for example, Berry, Levinsohn, and Pakes (1995). A discrete choice approach requires distributional assumptions on preferences, however, that may not be satisfied in the data.

the only assumption required is to specify a parametric (or nonparametric) form of the demand function. Once the demand function has been specified and estimated, the expenditure function can be estimated and the standard errors calculated.[11]

Estimation of the Demand Curve and Expenditure Function for Voice Messaging

In 1996 demand for voice messaging services from local telephone companies in the United States exceeded 16 million subscribers. Local companies offer advanced voice mail features through their local central office switches. In addition to the usual voice mail features, other features include the ability to receive messages while the line is otherwise in use, partitioned mailboxes for various family members, and a broadcast facility to a group of numbers, which is useful for businesses, schools, and other organizations. Voice messaging, along with on-line information services, is one of the great success stories of enhanced telecommunications services offered in the past fifteen years.

To estimate the demand curve for voice messaging, I used aggregate state-level panel data from 1991 through 1994. Data on demand for BOC voice messaging was available over a four-year period, 1991–94, for eighteen states in the Midwest, Southwest, and West.[12] The left-hand-side variable is the log of demand in units of subscription, while the primary right-hand-side variables, log of price and log of income, were deflated using the consumer price index. The price used is the state-specific price for the standard voice messaging service in each year. Prices vary in the sample from $2.80 to $11 a month. A log linear demand specification was used. Fixed effects for each state were included, as well as national and state-specific time trends, to allow for the price of substitute products, in particular telephone answering machines, and to allow for the differential growth in demand for voice

11. The expenditure function can be estimated using the techniques of Hausman (1981) or Vartia (1983) in the parametric case or of Hausman and Newey (1995) in the nonparametric demand function case. The standard errors are calculated using the techniques of Hausman (1981) and Hausman and Newey (1995).

12. Although I do not have price data on other states, penetration data (sales per telephone line) from other states are similar to my sample of eighteen states, so the results should be applicable to other states.

messaging across states as more and more potential customers become aware of the service. The price of telephone answering machines decreased over the period, a phenomenon that the national time trends capture in the demand specification.[13] Voice messaging was also introduced at different times, so each state could be at a different point along a diffusion curve, a factor that is captured by the state-specific time trends. Thus, the demand curve specification takes into account the price of substitute products as well as different diffusion rates in the different states.

To account for potential joint endogeneity of demand and price, I use the Hausman and Taylor approach of prices from different markets as instruments for prices in a given market.[14] The approach assumes that the price in each state is determined to a significant extent by the cost of technology, which is determined in a national market. Because the states do not regulate the price for voice messaging, the price in each state is determined by this common cost of technology as well as by local demand conditions. Using a price index from other states (after removing state fixed effects) as an instrument for a given state removes state-specific effects while still capturing the cost element of voice messaging.

The results for a fixed effects specification estimated by both ordinary least squares (OLS) and instrumental variables (IV) are given in table 1. The value of the demand elasticity for the IV estimate is greater (in magnitude) than that for the corresponding OLS estimate by about a factor of two. This increase in the demand elasticity is consistent with the use of an instrument that removes joint endogeneity of the price variable. The IV fixed effects specification fits quite well with the standard error, estimated to be 0.256.[15] The estimated price elasticity is -1.61, with an asymptotic standard error of 0.52. Thus, the estimated (asymptotic) t-statistic is 3.09, which indicates quite precise estimation.[16]

13. The price of a telephone answering machine is the same across different states except for different sales tax rates, which will be accounted for in the state fixed effects.

14. Hausman and Taylor (1981).

15. The R^2 measure for an OLS regression would be 0.999, although this measure is not appropriate for an instrumental variable estimator.

16. A Hausman-type specification test would marginally reject the OLS estimates in favor of the IV estimates; see Hausman (1978). I use the IV estimates in the following consumer welfare calculations.

Table 1. Voice Messaging Demand Estimates

Variable	*Regression method* — *Ordinary least squares*	*Instrumental variables*
Log of monthly price	−0.821	−1.607
	(0.243)	(0.523)
Log of income	4.912	4.795
	(0.407)	(0.423)
Log of population	0.945	0.961
	(0.066)	(0.068)
Intercept	6.790	7.343
	(0.541)	(0.662)
Number of observations	61	61
Standard error	0.2185	0.2557
R^2	0.9998	—

Source: Author's calculations.
Note: Standard errors in parentheses.

To estimate exact consumer welfare arising from a new telecommunications service, I also need to estimate the income elasticity. To do that, I use the estimated fixed effects for each state and a two-stage estimation approach (minimum chi square estimation).[17] Here, average family income was used for each state in each year of the data.[18] The results are given in table 1. The estimates are 4.80 (0.42) for income elasticity and 0.96 (0.068) for population elasticity. The relatively high income elasticity is to be expected because voice messaging is likely to be a superior good, and the consumer welfare results are not particularly sensitive to the estimate, as I demonstrate subsequently.

Once the demand function for voice messaging is estimated, I turn to the expenditure function to estimate the value of voice messaging to

17. Minimum chi square (or minimum distance) estimation is similar to GLS (generalized least squares) estimation; see Malinvaud (1971) or Rothenberg (1973). I estimate the model in two steps to ensure that the price elasticity, which is the primary parameter needed for consumer welfare calculations, is consistently estimated. The use of a fixed estimator in the first stage guarantees consistency, given the correct specification. The second-stage estimate is similar to "between" estimation in panel data, but it attempts to correct for possible nonorthogonality of unobserved state-specific factors. See Hausman and Taylor (1981) for a further discussion. Other variables such as the ratio of business to residential access lines were included in the state-level specification, but they did not significantly affect the results.

18. Both households and small businesses purchase voice mail, so the family income variable can be interpreted partly as a disposable income measure as well.

consumers. To estimate the overall effect on consumer welfare, I adopt an exact consumer surplus approach using the expenditure function for the log linear demand curve. I begin with the following expenditure function:[19]

$$(5) \qquad e(p, \bar{u}) = \{(1 - \delta)[\bar{u} + Ap^{1+\alpha}/(1 + \alpha)]\}^{1/(1-\delta)},$$

where A is the intercept of the demand curve, α is the price elasticity, and δ is the income elasticity estimate. The compensating variation is calculated from equation 6 where y is income:

$$(6) \qquad CV = \left[\frac{(1 - \delta)}{(1 + \alpha)} y^{-\delta} (p_1x_1 - p_0x_0) + y^{(1-\delta)}\right]^{1/(1-\delta)} - y.$$

For a new good, the expenditure function from equation 5 is used to calculate the compensated (Hicksian) demand curve, and the reservation, or virtual, price is calculated.[20] This price can be used in the expenditure function of equation 5 to calculate consumer surplus from the introduction of the new good. Equation 6 has a straightforward interpretation in the case of a new good. The term p_0x_0 is the revenue spent on the new good in period 0 (before it is introduced). This term will be zero because $x_0 = 0$ so long as the product converges.[21] For the simplest situation of no income effect, $\delta = 0$, equation 6 reduces to expenditure on the new service divided by the price elasticity minus 1. Thus, if a new good produces a large demand, x_1, the consumer surplus, or value to society of the new good, will be substantial.

To make the calculation corresponding to equation 6 and to area A in figure 1, I use the estimate of the voice messaging demand curve. The main parameter of the demand curve is the estimated price elasticity of -1.61 (0.52). Using the compensating variation formula from equation 6, I estimate the consumer welfare from voice messaging services provided by the local exchange carriers to be \$1.27 billion.[22] On aver-

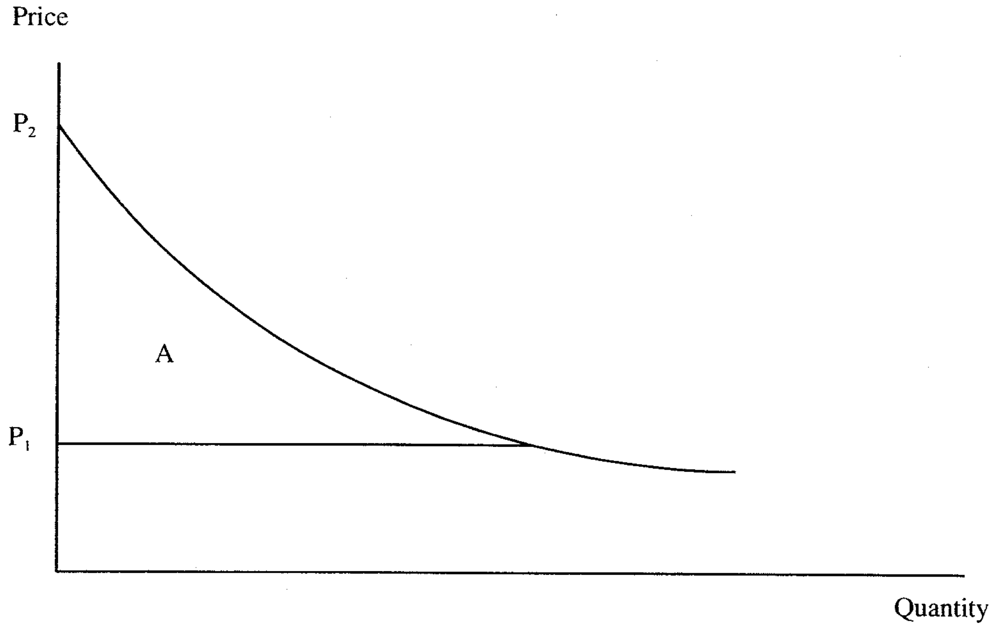
19. Hausman (1981, eq. 3).

20. Hausman (1996a).

21. The price required to cause zero demand approaches infinity for the log linear demand function. The product, p_0x_0, converges to zero, however, if the price elasticity exceeds 1.0.

22. The asymptotic standard error is 0.61. The term denotes the estimated standard error based on the estimated asymptotic normal distribution. The distribution was adjusted for values of the price elasticity equal to -1.0 where equation 2 was not defined.

Figure 1. Gain in Consumer Welfare from Introduction of a New Good



Source: Author's calculations. See text for explanation of terms.

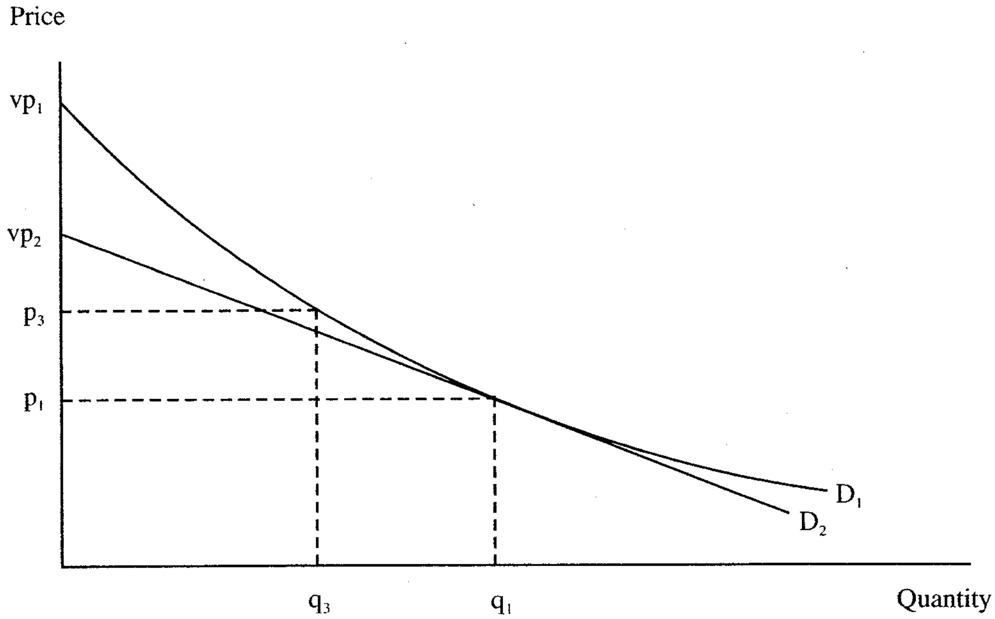
age, each subscriber receives approximately the same amount in compensating variation as the subscriber pays for the voice messaging services. Note that the economic efficiency gain to the U.S. economy is even larger than \$1.27 billion because the calculation ignores the profit (producer surplus) from voice messaging services.

I now explore the range of results for the consumer welfare estimate. If the estimated income elasticity is replaced with a value of 1.5, the gain in consumer welfare rises to \$1.37 billion; if the income elasticity is reduced to 0.5, the estimated gain in consumer welfare is \$1.40 billion.[23] Thus, the results are not very sensitive to the estimated income elasticity.

A more serious concern may be the use of a log linear demand specification. Given the choice of a log linear demand curve, the virtual price, which sets demand to zero, approaches infinity. Thus, I use the following approximation as demonstrated in figure 2. I use the linear demand curve, which is tangent to the estimate demand curve at the mean of the data. The compensating variation estimated with this de-

23. The asymptotic standards of error are 0.57 and 0.56, respectively.

Figure 2. Linear Approximation to Consumer Welfare Gain



Source: Author's calculations. See text for explanation.

mand curve should be a lower bound estimate because the estimate at the mean of the data is always less than any other demand curve with the same elasticity unless the other demand curve is convex to the origin, which is counter to the usual intuition and experience with demand curves.

If a linear, rather than log linear, demand function is used, the estimate of consumer welfare from voice messaging would be about $480 million a year.[24] The estimated virtual price, at which there would be zero demand, is about $13 a month. This is about $5 higher than the actual population-weighted average price of $8 in 1995. If anything, this virtual price estimate seems to be on the low side. For a small business (or residence) that uses voice messaging and does not want to lose calls, the savings from not having to purchase a second incoming line is about $25 a month plus the cost of an answering machine (which

24. The asymptotic standard error is 156. One could further consider variations in the estimates using the linear approximation because of uncertainty about the demand elasticity parameter. For instance, a 95 percent confidence interval would go from about $235 million up to $1.1 billion. The resulting compensating variations estimates remain quite significant.

would be small). Using this value as the virtual price in the log linear demand specification leads to an estimate of consumer welfare of about $2.1 billion a year, which is above the log linear compensating variation estimate.[25]

Thus, I find that the range of the compensating variation estimates, about $480 million to $2.1 billion, is most likely centered around the log linear demand curve estimate of about $1.2 billion. Clearly, new telecommunications services can create significant value for consumers, and government actions that either speed up or delay the introduction of these new services can affect the economic welfare of its citizens substantially.

Regulatory Delay and the Introduction of Voice Messaging

Voice messaging using central office-based telephone technology was sufficiently developed to begin operation in the early 1980s.[26] AT&T applied to the FCC in 1981 for permission to provide "Custom Calling II" services, which included voice messaging services, on an unseparated basis, that is, these services would have been integrated with basic local exchange service. The FCC rejected AT&T's request.[27] AT&T stated that a redesigned system for structural separation would take three years to introduce, and the additional costs would be substantial. Because it was "technically possible" to provide structurally separated voice messaging, the FCC decided to bar AT&T from providing it on an integrated basis. The additional economic costs that AT&T said it would incur if it were forced to separate the two kinds of service played only a minor role in the FCC decision.

A few months later, the court judgment divesting AT&T of the Bell operating companies prohibited those companies from providing "in-

25. The asymptotic standard error is 0.37.

26. See Rey (1983) for an early description of the development of AT&T's custom calling services.

27. AT&T Petition for Waiver of Section 64.702 of the Commission's Rules and Regulations ¶18, 88 F.C.C. 2d 1 (1981). AT&T had claimed that it would need to redesign its network equipment to provide voice messaging on a structurally separated basis. Rejecting the claim, the FCC recognized the presence of economies of scope in voice messaging (¶17) but feared a "slippery slope" regarding possible cross-subsidies that would create regulatory uncertainty.

formation services,'' which included voice messaging. The combined effect of the FCC decision and the court judgment was to preclude the Bell operating companies from offering voice messaging to small business and residential customers. Despite the FCC's stated belief that competing service providers would offer voice messaging, they never did so. Thus, residential and small business customers did not have the opportunity to purchase voice messaging services.

In March 1988 the judgment was modified to permit the Bell operating companies to transmit information services (although they were still prohibited from providing content for those services).[28] In 1988 the FCC also began approving comparably efficient interconnection plans that allowed the operating companies to provide individual enhanced services, such as voice messaging, on a structurally integrated basis. These regulatory changes permitted the operating companies to offer the voice messaging services they had originally petitioned to provide in 1981. In practice, they introduced voice messaging services in 1990, five to seven years later than they would have been introduced had it not been for the FCC and the court delays. How much did that delay cost consumers?

For the initial case of similar demand and price in 1988 as 1994, I estimate the lost consumer welfare to be $1.27 billion (in 1994 dollars). This calculation is based on the demand curve for voice messaging estimated above as well as on the formula for compensating variation in equation 6.

Suppose that the FCC had not delayed, but instead had allowed the operating companies to provide voice messaging services starting in 1984 on an integrated basis. For illustrative purposes, suppose that technology had not been as advanced or that competition from other forms of voice messaging equipment, such as answering machines, had been less.[29] Assume, as a result, that price would have been 50 percent higher with a corresponding decrease in quantity demanded. Consumer welfare would decrease by about $170 million. The regulatory delay

28. Opinion of Judge Harold Greene on the First Triennial Review, September 10, 1987, Section V.

29. Indeed, in the early 1980s the technology would have been based on a mainframe computer system, whereas the technology is now based on personal computers. Thus, the price could have been 50 percent higher in the earlier period.

Table 2. Estimated Lost Consumer Welfare in 1988 because of Voice Messaging Delay (1994 Dollars)

Scenario	*Penetration*	*Assumed price*	*Lost welfare*
Similar to 1994	1994 level	1994 price	$1.27 billion
Higher price	1994 level	50% higher	$1.0 billion

Soruce: Author's calculations.

still would have cost consumers $1.10 billion in lost welfare in 1988 (table 2).

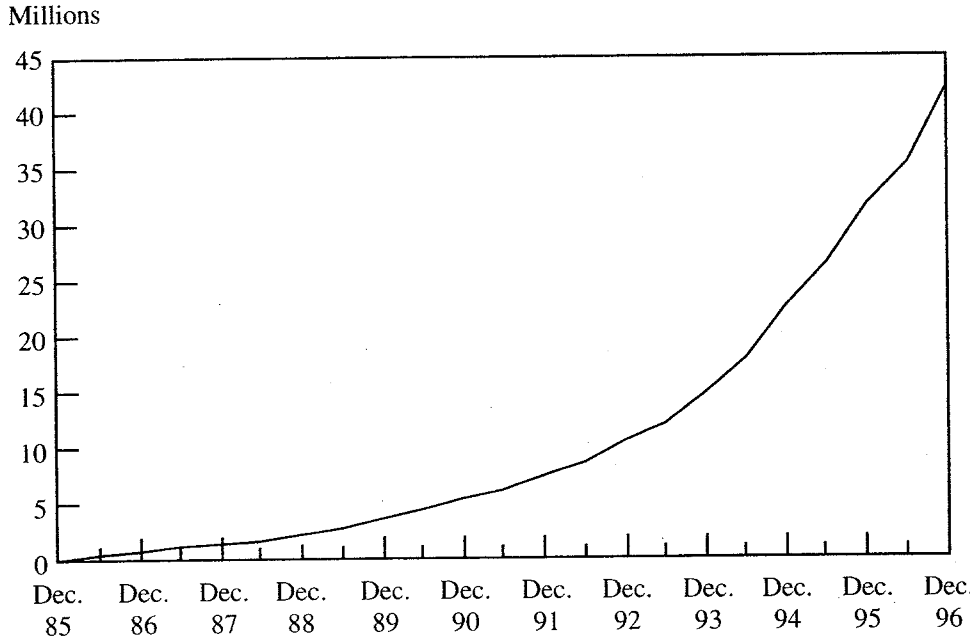
These calculations demonstrate a very important result in economic analysis. Consumer welfare gains from the introduction of a successful new product are usually quite large. In the theory of international trade such gains explain why a tariff is superior to a quota.[30] In public finance theory these gains explain why, in times of shortage, tradable ration tickets are superior to a nontradable framework. The gain in consumer welfare here is even larger because when regulation holds up the introduction of a new good or service, it is equivalent to a quota or a ration having a zero value.

Why, then, would regulators impose such a large loss on U.S. consumers? The FCC's stated concern was that a cross-subsidy from the local exchange service might occur if AT&T were permitted to provide voice messaging services on an unseparated basis. Although this concern had some merit given the use of rate of return regulation at the time, regulators never made the fundamental calculation of comparing lost consumer surplus from not permitting introduction of voice messaging with the possible consumer harm from some amount of cross-subsidy.[31] No rational calculation about consumer benefit was ever made. A "public interest" consumer welfare standard seems far from the FCC's actual decision process, although such a standard is supposed to guide FCC decisions.

30. See Romer (1994) for a theoretical discussion of welfare costs from trade restrictions.

31. A discussant of my paper, Dr. Greg Rosston, who recently served as an economist at the FCC, stated that the commission may have used permission to offer voice messaging as a "bargaining tool" or "pawn in the game" to attempt to force AT&T to open its network to competitors. This quite revealing remark fails to recognize that consumers are the ultimate pawns in the regulatory game, because it is consumer welfare that is reduced when the FCC delays the introduction of new services in an attempt to achieve other regulatory goals.

Figure 3. Number of Cellular Subscribers: 1985–96



Source: Cellular Telephone Industry Association.

The situation worsened considerably once the federal court became involved in working out the plan to break up AT&T; until the Supreme Court required otherwise in 1994, the federal court judge followed a legalistic approach to regulation rather than one that explicitly considered consumer welfare or the public interest.

The Effect of Regulatory Delay on the Introduction of Cellular Telephone

Cellular telephones are an example of a new product that has significantly affected how Americans live. Since cell phones were introduced in the United States in 1983, demand has increased 25–35 percent a year (figure 3). By the end of 1996, about 42 million cell phones were in use—about one-third the number of regular (landline) telephones. About 16 percent of all Americans used cellular telephones.

Cellular telephones were introduced first in Chicago in late 1983 and then in Los Angeles during the 1984 Olympic Games. Within the next year operations began in the other top thirty metropolitan statistical areas (MSAs) and subsequently spread to the rest of the country. Cellular telephone service is now available almost everywhere within the United States.

Cellular telephone has been, along with 800 telephone service, the great success story of new telecommunications services offered in the past forty years. At the time of the AT&T divestiture when it was not clear whether AT&T or the divested Bell operating companies would inherit the cellular spectrum that the FCC had granted to AT&T, an AT&T prediction for cellular subscription levels in the year 1999 was about 1 million. By the end of 1996 cellular subscribership had already reached 42 million (figure 3).[32] In 1996 the next generation of cellular technology, PCS, was introduced in the United States, so growth rates for mobile telephone usage were likely to continue at their high levels, or even increase, during the next few years.

The average cellular subscriber spends $48.84 a month on cellular service, or just under $600 a year; altogether about $24 billion a year is spent on cellular service, with additional amounts spent by consumers on purchasing cellular telephones. Revenue from cellular service in 1996 was about one-third as large as revenue from long-distance service, so cellular telephone represents a significant expenditure category in telecommunications (figure 4).

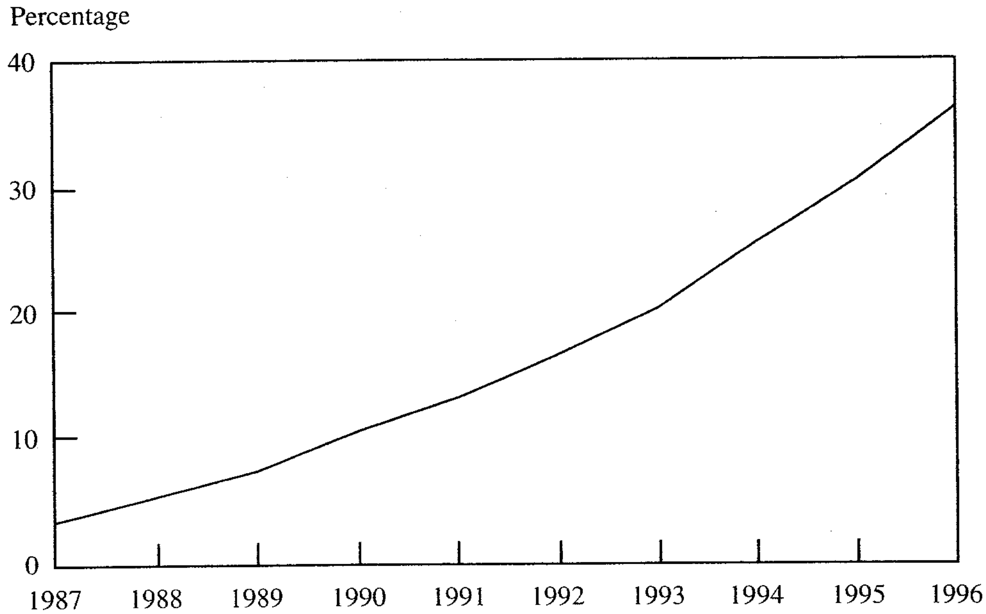
Cause of Regulatory Delay in the Introduction of Cellular Telephone

Cellular telephone technology was sufficiently developed to begin operation in the early 1970s. In practice, however, cellular service did not begin in the United States until 1983.[33] The delay in providing cellular telephone was caused by regulatory indecision and the subsequent licensing procedure used by the FCC, which was in charge of the cellular spectrum. The FCC could not decide whether to give AT&T an exclusive right to provide cellular service, to give that right to non-AT&T companies such as paging companies, or to allow competition

32. These data are from the Cellular Telephone Industry Association (CTIA), Washington, D.C.

33. See Lee (1982) and Calhoun (1988) for histories of the development of cellular telephone. The FCC began its inquiry to reallocate additional spectrum for mobile telephone service in 1968.

Figure 4. Cellular Service Expenditures as a Percentage of Long-Distance Expenditures: 1987–96



Source: Cellular Telephone Industry Association, Federal Communications Commission.

between the two groups. AT&T had invented cellular and argued that only one provider should be present in each MSA because of significant economies of scale in spectrum usage. Potential entrants into cellular service argued that AT&T should be barred from the market because cellular telephones could compete with AT&T's landline local monopoly at some time in the future. This delay led to extremely large losses in consumer welfare.

Initially the FCC made one decision and then another. Finally, in the early 1980s it decided to allow two cellular providers in each MSA. This duopoly situation was a departure for the commission, which previously had not allowed competition (although competition did exist in the provision of "Improved Mobile Telephone Service," the car telephone service that preceded cellular service). Interestingly, most other nations followed the U.S. lead in initially allowing for two cellular companies. The FCC decided to award 20 megahertz (MHz) of spectrum to each of the two cellular providers, with 10 MHz of spectrum kept in reserve. In 1986 the FCC awarded 5 MHz of additional spectrum to each of the two cellular providers so that each had 25 MHz of spectrum.[34]

The FCC awarded the B block, or ''wireline,'' cellular frequency to the wireline telephone company in each MSA. Of course, this company was usually a Bell operating company except for areas where GTE or an independent telephone company was awarded the spectrum. In several MSAs two or more wireline companies formed a partnership to operate the so-called wireline network.[35] To award the A block, or nonwireline, cellular frequency, the FCC originally decided to conduct ''comparative hearings'' to decide who proposed the best cellular network. This procedure soon threatened to create a morass of evidentiary and legal wrangling, so the FCC encouraged contenders to form partnerships. Companies such as Communications Industries, MCI, Metromedia, the Washington Post, and LIN Broadcasting became partnership members and were awarded these nonwireline franchises.

Because of procedural delays in awarding the nonwireline franchises, the wireline networks typically began operation a year or two earlier than the nonwireline networks. The exceptions were Boston and Washington, where regulators delayed operation of the wireline network until the nonwireline network could begin operation. The headstart given the wireline networks elsewhere had no adverse effect on subsequent competition, however, and consumers had the advantage of earlier use of cellular telephones. Because the nonwireline networks were able to resell the wireline carrier's service until they began operation, most consumers did not realize that they were using the wireline network. By 1996 the nonwireline carrier in numerous MSAs had significantly surpassed the wireline carrier in subscribers, notwithstanding their delayed beginning of operations, by offering innovative service packages better suited to customer demands.

After realizing the problems of comparative hearings, the FCC sub-

34. The relatively small amount of spectrum awarded for cellular service in the United States led to severe capacity problems in MSAs such as Los Angeles and New York in the late 1980s and early 1990s. The demand for cellular was considerably greater than any forecasts that I have seen by either cellular companies or equipment manufacturers.

35. For instance, in New York NYNEX owned 54 percent, Bell Atlantic owned 36 percent, and Sprint owned 10 percent. NYNEX and Bell Atlantic subsequently merged their cellular operations.

sequently used lotteries to award the nonwireline licenses in smaller MSAs and in rural areas, but it continued to award the wireline license to the wireline carrier. Overall, FCC indecision delayed the provision of cellular telephone in the United States by seven to ten years. This regulatory indecision made a new good, cellular telephone, unavailable in the United States when it was being offered in Scandinavia and Japan using equipment invented by AT&T Bell Labs.

Estimating the Cost of Regulatory Delay

To approximate the consumer welfare loss caused by the FCC delay, I begin with the econometric estimation to implement the expenditure function approach of equations 5 and 6 and the linear approximation approach of figure 2. To do so, I collected price and subscribership data for the period 1989–93 from a confidential survey of cellular operators and used the data to run a regression of cellular prices in the top thirty MSAs. These MSAs contain about 107 million people, or about 41 percent of the U.S. population.[36] Table 3 presents an econometric analysis of cellular demand. Here the left-hand-side variable is the log of the number of subscribers, and the right-hand-side variable is the log of price along with variables for log of income, log of population, log of commute time, regulation, and year. The price variable is based on the monthly access charge and per minute charges for 160 minutes a month (the approximate average usage) for the least expensive plan available for 160 minutes of usage in each MSA.[37] Monthly prices for average usage varied in the MSAs from a high of $125 in New York City to a low of $55 in Buffalo, with cellular carriers in Portland, Oregon, and Chicago also offering very low monthly prices. The price of the cellular telephone is also included, using a three-year amortization period based on an observed churn rate of 0.33 a year. The year variable allows for a diffusion curve effect and changes in prices of competing services,

36. Note that no truncation or sample selection bias is introduced by using the top thirty MSAs because population is an exogenous variable.

37. Cellular consumers typically have a variety of linear and nonlinear price schedules to choose from. I use the most economical plan for the average usage per month, consistent with my approach of using a representative consumer model. In calculating the consumer surplus measure, nonlinearities in the price schedules can be taken into account by the use of a "virtual income" measure, as in my previous research (Hausman, 1985), but no significant change occurs because of the very small size of virtual income compared with overall consumer income.

Table 3. 1989–93 Demand Regression for Top Thirty Cellular Markets

	Regression method	
Variable	*Ordinary least squares*	*Instrumental variables*[a]
Intercept	0.852	1.101
	(2.475)	(2.478)
Log of price[b]	−0.406	−0.506
	(0.151)	(0.169)
Log of income[c]	0.184	0.193
	(0.302)	(0.302)
Log of population[d]	0.948	0.953
	(0.064)	(0.064)
Log of commute time[e]	0.977	0.984
	(0.356)	(0.355)
Regulation	−0.161	−0.147
	(0.065)	(0.066)
Year 89	−1.234	−1.217
	(0.090)	(0.091)
Year 90	−0.830	−0.817
	(0.078)	(0.078)
Year 91	−0.566	−0.559
	(0.071)	(0.071)
Year 92	−0.310	−0.306
	(0.069)	(0.069)
Number of observations	196	196
Standard error	0.315	0.315
R^2	0.982	—

Source: Author's calculation.

Notes: Standard errors in parentheses. Left-hand-side variable = log of subscribers.

a. Price is endogenous. Instruments include average price across other top thirty metropolitan statistical areas, an indicator variable for state regulation of paging, maximum marginal state income tax rates, state taxes as a percentage of personal income, and construction costs.

b. Minimum monthly bill is based on 128 minutes of peak calling and 32 minutes of off-peak calling.

c. Log of per capita personal income. Source: NPA Data Services, Inc., April 1994.

d. Log of population. Source: NPA Data Services, Inc., April 1994.

e. Mean commute time from home to work. Source: 1990 U.S. Census, Tape File 3c.

such as paging. The least squares estimate of the price elasticity is −0.41, which is estimated quite precisely (standard error = 0.15). Note that the population variable estimate is 0.95, which is not statistically different from 1.0, as would be expected. A significant effect of commuting time in the MSA is also found to be important.

The right-hand column of table 3 shows a reestimation of the demand model using instrumental variables. This estimation methodology takes into account possible joint endogeneity of price and demand. When instrumental variables are used in the model, the demand elasticity is estimated to be −0.51 (standard error = 0.17).[38] This somewhat higher elasticity estimate yields a somewhat smaller effect than the initial model for the gain in consumer welfare from the introduction of cellular. A Hausman specification test does not reject the elasticity estimate from the initial model.[39] Note that the parameter estimates for the other variables, such as population, remain virtually the same.[40]

The expenditure function of equation 6 is calculated:[41]

$$(7) \qquad CV = \left[\frac{(1-\delta)}{(1+\alpha)} y^{-\delta} (p_1 x_1 - p_0 x_0) + y^{(1-\delta)}\right]^{1/(1-\delta)} - y.$$

This equation is then used to calculate the compensating variation for the introduction of cellular telephone using the average revenue and subscribership data discussed earlier as well as the econometric estimates of the parameters of the demand function and associated expenditure function. The gain in consumer welfare from the introduction of cellular telephone is estimated to be \$49.8 billion a year (asymptotic standard error = \$22.6 billion).

Next, the gain in consumer welfare is calculated using the linear approximation used previously for voice messaging. This approximation provides a lower bound estimate for the compensating variation. The larger of the two estimated price elasticities in table 3, −0.51, is used to yield a lower bound approximation to the gain in consumer welfare from the introduction of cellular of \$24.2 billion a year (asymptotic standard error = \$8.1 billion). The gain in consumer welfare measured as the compensating variation from cellular is in the range of

38. One of my discussants raised the point of possible errors in variables from using the price for average cellular usage in the estimated demand equation. The instrumental variable procedure should eliminate the possible problem of errors in variables. Note that estimated price elasticity is a *market* (not firm) price elasticity, so an estimate of −0.51 is not "too low" given the limited substitute services to cellular telephone.

39. Hausman (1978).

40. I have done IV estimation to allow both price and regulation to be jointly endogenous. I find results similar to the previous estimates.

41. The results of Hausman (1981) are used to calculate the compensating variation. Here because the estimated price elasticity is less than one, the integral of the compensated demand function does not converge. To calculate the compensating variation from the introduction of cellular, I use the area under the compensated demand curve between the year in question, for p_1x_1, and 1985, for p_0x_0, which is the beginning year of the CTIA data. This calculation slightly underestimates the gain in compensating variation.

Table 4. Estimated Lost Consumer Welfare in 1983 Because of Cellular Telephone Delay (1994 Dollars)

Scenario	*Penetration*	*Assumed price*	*Lost welfare*
Similar to 1994	1994 level	1994 price	$49.8 billion
Higher price	1994 level	50% higher	$33.5 billion
Lower demand	50% 1994 level	50% higher	$16.7 billion

Soruce: Author's calculations.

$24 billion to $50 billion a year, which demonstrates the substantial value to consumers from the introduction of cellular telephone.

The $24 billion estimate is likely to be quite conservative, however. The linear approximation implies a virtual price of $97.09 at current demand levels, which seems quite low for the monthly fee for users who achieve high utility from the mobility feature of cellular telephone. Indeed, the data set shows actual monthly fees as high as $125, with substantial demand occurring at these prices. Holding other parameters constant, a virtual price of $125 a month would lead to a lower bound estimate of consumer welfare of $31.2 billion a year. Thus, a more refined estimate of the gain in consumer welfare from cellular telephone is in the range of $31 billion to $50 billion a year.

The same approach used for voice messaging can now be used to determine how much consumer welfare was lost by the ten-year delay in the introduction of cellular telephone caused by FCC indecision. I attempt to approximate this welfare loss by asking the question: If in 1983 cellular had already been available for ten years—as it would have been were it not for the FCC delays—but if, because of more limited and higher cost microprocessors and other semiconductor chips, it cost twice as much (in 1983 dollars) as it did in 1994, and correspondingly, if demand were lower because of the higher price, what was the lost consumer welfare? I estimate that the annual lost consumer welfare was approximately $24.3 billion in 1983 dollars or about $33.5 billion in 1994 dollars (table 4). Thus, the lost compensating variation was about $76 per subscriber per month, which is equivalent to an average monthly service price (with the assumed 50 percent increase) of about $120 per month. Even if I assume that demand for cellular would only have been half as great in 1983 as it was in 1994 because of decreased functionality, I still estimate an annual welfare loss of approximately $16.7 billion.[42]

42. Rohlfs, Jackson, and Kelley (1991) earlier estimated a welfare loss of about $85

These findings reinforce a fundamental point: the consumer welfare cost of holding up the introduction of a new good is much larger than the effects of higher prices or other regulatory effects on demand, because the entire compensating variation is lost when regulatory delays cause demand to be zero. The welfare loss from the delay in the introduction of cellular is considerably larger than the delay in voice messaging, in part because the demand for cellular is approximately four times as large as the demand for voice messaging.

As these two studies show, regulatory delay can have potentially large negative effects on the U.S. economy. Why then did the FCC impose such harm on consumers and the economy? It appears that delay in cellular service was the commission's way to avoid confronting a very difficult decision. Potential losses in consumer welfare did not appear to figure into the FCC's regulatory approach. Indeed, the delay might have been even longer had cellular service not begun in other countries, which placed additional pressure on the FCC to reach a decision.

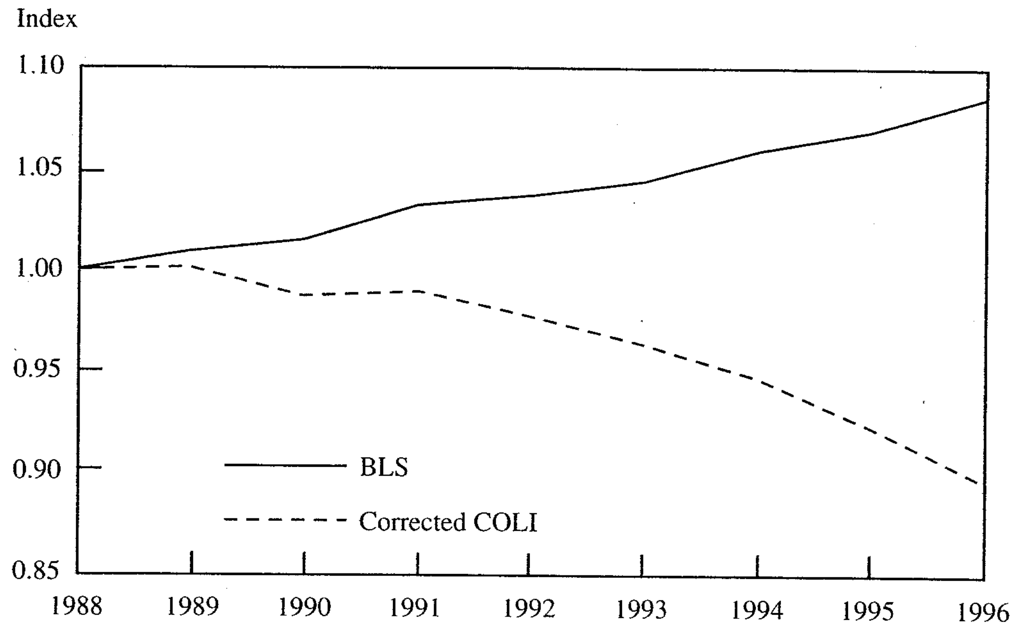
Estimating a Telecommunications Price Index That Includes New Services

An alternative approach to valuing these new telecommunications services involves calculating a cost-of-living index (COLI) for telecommunications services that includes cellular telephone and voice messaging services and then comparing this index to one that excludes these services. Because a cost-of-living index is a monotonic transformation of the expenditure function in the representative consumer model, its calculation determines the percentage improvement in utility for a sub-utility function of telecommunications services.

The Bureau of Labor Statistics (BLS) calculates a consumer price index for telephone services each month. Its major components are local access charges, intrastate long-distance (toll) charges, and interstate long-distance (toll) charges. The telephone service index is 1.7 percent of the overall consumer price index, but the telephone service index

billion from the delay in introducing cellular telephone in the United States, assuming the delay to be ten years.

Figure 5. Telecommunications CPI: BLS and Corrected Cost-of-Living Increase (COLI) Calculations



Source: Author's calculations; Bureau of Labor Statistics.

does not include cellular telephone and does not account for the gain in consumer welfare from the introduction of voice messaging services (although it takes the price change for messaging services into account).

To estimate an augmented price index that includes both these services, I take into account the decline in prices for cellular and voice messaging services as well as the gain in consumer welfare from the introduction of both services. To construct the augmented index, I use yearly expenditure weights based on total local and long-distance expenditure.[43] Figure 5 shows both the BLS index and my augmented one. Note that the BLS index estimates that telecommunications prices have increased by 8.5 percent since 1988, an increase of 1.02 percent a year. The augmented index shows a decline, from 1.0 in 1988 to

43. To the extent that the proportion of consumer usage of cellular is approximately equal to consumer usage of local and long-distance services, these weights create a superlative price index; see Diewert (1976). Otherwise, the calculation leads to an approximation to a telecommunications CPI that would need data on consumer expenditure shares to become a superlative index.

0.897 in 1996, for a price decrease of 1.35 percent a year.[44] Thus, the bias in the BLS index equals approximately 2.37 percentage points a year. Over the period 1988–96, the inclusion of these new telecommunications services decreases the change in the BLS index by about 20 percent, a significant amount both for a price index and as a measurement of the utility derived from telecommunications services.

The Current FCC Approach to Regulating New Investment in Services

"It's no fun to be a regulator unless you get to regulate."

Anon.

The Telecommunications Act of 1996 was the first basic change in the regulatory framework for telecommunications since 1934. It called for less regulation, more competition, and the most modern telecommunications infrastructure possible; its purpose was "to provide for a pro-competitive, de-regulatory national policy framework designed to accelerate rapidly private sector deployment of advanced telecommunications and information technologies and services to all Americans by opening all telecommunications markets to competition."[45] The FCC has instituted numerous regulatory rulemakings to implement the 1996 Telecommunication Act. The most important so far has been the Local Competition and Interconnection Order of August 1996.[46] If implemented in its current form, this order will likely have serious negative effects on innovation, the introduction of new services, and new investment in the local telephone network.

Most economists agree that regulation should be used only when significant market power can lead to unregulated prices well above competitive levels. In these cases, the goal of regulators should be to

44. Approximately 95 percent of this change is due to the introduction of cellular telephone; the other 5 percent arises from the introduction of voice messaging services.

45. *U.S. House. Conference Report to the Telecommunications Act of 1996, S. 652. 104 Cong. 2d sess., 1996, H. Rept. 104–458.*

46. FCC, "First Report and Order, CC docket No. 96-98 and 95-185," August 1, 1996. The local exchange carriers are challenging the FCC order in federal court. Two questions are at issue: whether the FCC improperly usurped the rights of states to set regulated rates for local competition; and the validity of the pricing framework the FCC used to set the rates. Only the latter issue is considered here.

set prices at "competitive levels." Economists are much less explicit, however, about how these competitive levels of prices can be estimated, particularly for telecommunications networks with large fixed costs. Most economists would agree that perfect competition cannot yield the appropriate standard because prices set at marginal cost will not allow a privately owned utility to earn a sufficient return on capital to survive. The large fixed costs of telecommunications networks thus do not allow the price-equals-marginal-cost standard of perfect competition to be used.

Baumol and Sidak have proposed an alternative competitive standard, the "perfect contestability" standard. Under this standard regulators would require firms to set prices as if "the competitive pressures generated by fully unimpeded and costless entry and exit, contrary to fact, were to prevail."[47] Costless entry and exit, however, presumes no sunk costs, that is, costs that cannot be recovered upon exit by a firm. This assumption is extremely far from economic and technological reality in telecommunications where the essence of most investments is an extremely high proportion of sunk costs. Consider the investment by a local exchange carrier in a new local fiber optic network that can provide new broadband services and high speed Internet access to residential customers. Most of the investment is sunk because it cannot be recovered if the broadband network does not succeed. Thus, when either technological or economic uncertainty exists, "perfect contestability as a generalization of perfect competition" cannot provide the correct competitive standard.[48]

In a perfectly contestable market, if the return to an investment decreases below the competitive return, the investment is immediately removed from the market and used elsewhere. The actual economics of telecommunications investment could not be further from a perfectly contestable market, however. When fiber optic networks are constructed, they are almost entirely sunk investments. If their economic return falls below competitive levels, the firm cannot shift them to other uses because of their sunk and irreversible nature. Thus, the use of a perfectly contestable market standard fails to recognize the important

47. Baumol and Sidak (1994, pp. 28, 31 ff.).

48. This feature of sunk and irreversible investment has been widely recognized by economic research in the past ten years. See MacDonald and Siegel (1986) and, for a recent and comprehensive treatment, Dixit and Pindyck (1994).

feature of sunk and irreversible investments—they eliminate costless exit.

Because of its failure to take into account the sunk and irreversible nature of investments, the contestable market model has nothing of interest to say about competition in telecommunications. An industry cannot be expected to behave in a manner that is fundamentally inconsistent with its underlying technological and economic characteristics. Thus, just as the large fixed costs of telecommunications networks do not allow the price-equals-marginal-cost standard of perfect competition to be used, the large sunk costs of telecommunications networks do not allow the costless-entry-and-exit standard of perfect contestability to be used.

Another way to consider the problem of setting regulated prices is to allow for the existence of the (all-knowing) social planner, an approach well known to graduate students through the Second Fundamental Theorem of welfare economics. Suppose the social planner were considering a new investment in a telecommunications network where sunk and irreversible investments are the norm. The social planner wants to maximize the value of the social welfare integral over time subject to uncertainty. The investment, however, is subject to both technological and economic uncertainty, so the cost of the investment may (randomly) decrease in the future, and demand uncertainty means that the social planner does not know whether the investment will be economic. In making an optimal decision the social planner will take into account the sunk and irreversible nature of the investment because the investment cannot be shifted to another use if the new service fails. In this case, assuming that sunk costs do not exist, which is the perfect contestability standard, will lead to incorrect decisions and decreased economic efficiency. Unfortunately, the FCC has adopted the contestability standard in determining regulatory prices for unbundled network elements.

FCC-Mandated Costs for Unbundling

Under the Telecommunication Act of 1996, the FCC required local exchange carriers to sell their unbundled facilities to their competitors at cost-based prices.[49] The FCC did not permit any markup over cost;

49. The FCC decision is currently under appeal. In the FCC proceeding I provided testimony on behalf of the local exchange carriers.

instead, it used an approach that attempts to estimate the total service, long-run, incremental cost on a forward-looking basis.[50] TSLRIC, as it is called, attempts to solve the perfect competition problem that price cannot equal marginal cost by allowing for the fixed costs of a given service to be recovered. Although it allows for recovery of the cost of investment and variable costs of providing the service over the economic lifetime of the investment, TSLRIC makes no allowance for the sunk and irreversible nature of telecommunications investment, so it adopts the perfect contestability standard. The distinction between "fixed" costs, which are recoverable, and "sunk" costs, which are not, is crucial. By concluding that TSLRIC (TELRIC) is economically efficient because it allows the recovery of the fixed costs of investment, the FCC has chosen the incorrect standard for setting regulated prices. TSLRIC in this case will lead to less innovation, decreased introduction of new services, and decreased investment below economically efficient levels.

The TSLRIC Standard and Investment in New Services

The first and easiest example of the negative effect of the use of TSLRIC on the introduction of new services is investment in new services. Many new telecommunications services do not succeed. Recent failures include Picturephone services (AT&T and MCI in the 1990s) and information service gateway services offered by many local exchange carriers. These new gateway services required substantial sunk costs in research and development to create the large databases necessary to provide information services. Now if a local exchange carrier introduces a successful new service, under proposed FCC rules, a competitor can buy the service at a price determined using the TSLRIC approach. At most, the local carrier will recover its cost—and not enough to cover the sunk investment in any unsuccessful services. If the FCC rule were applied to the pharmaceutical industry, pharmaceutical companies would be required to sell or license their successful products to generic producers or resellers at incremental cost. They would recover their R&D and production costs on their successful new

50. The FCC chose a variant of TSLRIC, called TELRIC for total element, long-run, incremental cost. The essential economic problem of TSLRIC also exists in TELRIC, however.

drugs, but that is not enough to cover the costs of any unsuccessful attempts.

Because innovative projects in telecommunications have a significant probability of failure, this truncation of returns on successful new services decreases economic incentives for regulated telecommunications companies to innovate. By eliminating the right tail of the distribution of returns, the FCC has decreased the mean of the expected return of a new project. For example, consider a project with returns, y, that follow a normal distribution with mean μ and standard deviation σ. The expected value of the return when it is truncated at cost c is:

$$E(y \mid y < c) = \mu - \sigma M(c), \tag{8}$$

where $M(c)$ is the inverse Mills ratio evaluated at c.[51] Thus, the tighter the cost standard, the lower are the incentives to innovate, as expected. More important, note that as the returns to the innovation become more uncertain, the expected return and the incentives to innovate also decrease. Indeed, for any symmetric distribution of returns, including the normal, the FCC's TSLRIC approach could stop all new investments in uncertain services because for any service a local exchange carrier would undertake in the absence of regulation, $E(y) > c$, so truncation of the distribution at c will cause $E(y) < c$, and no new investment may occur.

Thus, the issue of sunk and irreversible investments aside, the FCC pricing policy decreases the economic incentives for investment in innovative services and may eliminate them altogether. Consider the likely outcome if the FCC had used a TSLRIC approach to regulate the price of cellular telephone service. If cellular carriers had been required to sell their services to competitors (resellers) at a TSLRIC cost-based price, it is unlikely that they would have risked the billions of dollars of investment in cellular networks when the future of cellular was highly uncertain and many industry analysts did not forecast much success for cellular. The consumer welfare gains that have been derived from the success of cellular telephone would not have existed; indeed, a TSLRIC-based rule would likely have led to tens of billions of dollars of lost consumer welfare.

51. The inverse Mills ratio is the ratio of the density function and distribution function of the standard normal distribution evaluated at $(c - \mu)/\sigma$. The inverse Mills ratio $M(c)$ increases monotonically as c decreases for given μ and σ.

The FCC could apply something similar to patent protection for new services to give the local exchange carriers economic incentives to innovate in the presence of the TSLRIC-based pricing approach.[52] But this policy option is a recipe for delay. Currently, the Patent Office takes more than two years to grant a patent, and longer time periods are not uncommon. No opponent of the patent is allowed to be part of the process, however. In an FCC setting, where competitors presumably would be permitted to participate, as they are now, and would likely attempt to delay the introduction of new services as they did with both voice messaging and cellular telephone, I would expect much longer delays. Thus, the patent approach will not solve the problem. A better approach would be to leave new services unregulated. The gains in consumer welfare from successful new services would lead to significant gains for consumers. Attempting to "fine-tune" prices of new services through cost-based regulation will lead to overall consumer losses. Regulators, however, find it extremely difficult not to regulate any new service of a regulated company.

The Effect of Sunk and Irreversible Investments

TSLRIC assumes that all capital invested now will be used over the entire economic life of the new investment and that prices for the capital goods or the service being offered will not decrease over time.[53] With changing demand conditions, changing prices, or changing technology, these assumptions are not necessarily true. Thus, TSLRIC assumes a world of certainty when the actual world is one of uncertainty. Significant economic consequences can arise from the effect that the sunk nature of investment has on the calculation of TSLRIC.

Consider the value of a project under no demand uncertainty with a risk-adjusted discount rate of r, and assume a known exponential economic depreciation at rate δ. This assumption on depreciation can be thought of as the price of the capital decreasing over time at this rate due to technological progress. Assume that price, net of the effect of economic depreciation of the capital goods, is expected to decrease

52. The FCC chief economist Dr. Joseph Farrell recently considered this option; see Farrell (1997).

53. This discussion follows Hausman (1996b). See also Laffont and Tirole (1996).

with growth rate $-\alpha$.[54] The initial price of output is P. The value of the project is

$$(9) \qquad V(P) = \int_0^\infty \lambda \exp(-\lambda t)\, P \,\frac{1 - \exp(-\delta t)}{\delta}\, dt = P/(\lambda + \delta),$$

where $\lambda = r + \alpha$. Note that δ is added to the expression to account for the decreasing price of capital goods. This term, omitted from the FCC's TSLRIC calculations, accounts for technological progress in equipment prices, which is one economic factor that leads to lower prices over time. Suppose that the cost of the investment is I. The rule for a competitive firm is to invest if $V(P) > I$. Equivalently from equation 9, $P > (\lambda + \delta)\, I$. The economic interpretation of this expression is that the price (or price minus variable cost) must exceed the cost of capital, which includes the change in price of the capital good to make the investment worthwhile.[55] Note that the net change in the output price and the price of the capital good both enter the efficient investment rule. The FCC's TSLRIC calculation ignores the basic economic fact that when technological change is present, (quality-adjusted) capital goods prices tend to decline over time. This economic factor needs to be taken into account, or economic inefficiency will result.

Now, a TSLRIC calculation does not include δ but instead assumes that the price of capital goods does not change over time. This assumption is extremely inaccurate. Take a Class 5 central office switch, for example. In the late 1980s an AT&T Class 5 switch was sold to a Bell operating company for approximately \$200 a line.[56] Today, these switches are priced at \$70 a line or lower. A TSLRIC calculation would be based on the \$70 price. A Bell operating company that paid \$200 a line made the efficient investment decision when it purchased its central office switch. But TSLRIC, by omitting economic depreciation caused by technological progress, leads to a systematically downward biased estimate of costs. Indeed, I estimate the economic depreciation of central office switches to be near 8 percent a year over the past five years, while the cost of fiber optic carrier systems has decreased at approxi-

54. This factor arises because of changes in demand and total factor productivity.

55. For simplicity, I assume only capital costs and no variable costs in this calculation. Variable costs can be included by reinterpreting P to be price minus variable costs, which will lead to the same solution.

56. Hausman and Kohlberg (1989, p. 204).

mately 7 percent a year during the same period. Technological progress can make the omitted economic factor δ quite large relative to r for telecommunications switching or transmission equipment.

TSLRIC calculations assume that the investment is always used at full capacity, that the demand curve does not shift inward over time, and that a new technology does not appear that lowers the cost of production. Of course, these conditions are unlikely to hold true over the life of the sunk investment. Thus, uncertainty needs to be added to the calculation.

Given the fundamental uncertainty and the sunk nature of the investment, a "reward for waiting" occurs because over time some uncertainty is resolved. The uncertainty can arise from uncertainty about demand, price, technology, or interest rates.[57] Now the fundamental decision rule for investment changes to

$$P^S > \frac{\beta_1}{\beta_1 - 1}(\delta + \lambda)\, I, \tag{10}$$

where $\beta_1 > 1$ so that $m = \beta_1/(\beta_1 - 1) > 1$. The parameter β_1 takes into account the sunk cost nature of the investment coupled with inherent economic uncertainty.[58] Parameter m is the markup factor required to account for the effect of uncertain economic factors on the cost of sunk and irreversible investments. Thus, the critical cutoff point for investment is $P^S > P$, from equation 9.

To see how important this consideration of sunk costs can be, I evaluate the markup factor m. The parameters β_1 and m depend on

57. The FCC incorrectly assumed that taking into account *expected* price changes in capital goods and economic depreciation is sufficient to estimate the effect of changing technology and demand conditions; see the FCC "First Report and Order," para. 686. Thus, the FCC implicitly assumed that the variances of the stochastic processes that determine the uncertainty are zero, that is, that no uncertainty exists. Under the FCC approach the values of all traded options should be zero (contrary to stock market fact), because the expected price change of the underlying stock does not enter the option value formula. It is the uncertainty related to the stochastic process as well as the time to expiration that gives value to the option, as all option pricing formulas demonstrate; the Black-Scholes formula is one example.

58. I do not derive this equation here because it is the solution to a differential equation. For a derivation, see, for example, Dixit and Pindyck (1994, pp. 254–56, 279–80, 369). The parameter β_1 depends on the expected risk-adjusted discount rate of r, expected exponential economic depreciation δ, the net expected price $-\alpha$, and the amount of uncertainty in the underlying stochastic process.

several economic factors. As uncertainty increases, that is, the variance of the underlying stochastic process, β_1 decreases and the *m* factor increases. Also, as δ increases, β_1 increases, which means that the *m* factor decreases. As *r* increases, β_1 decreases, so the *m* factor increases. MacDonald and Siegel and Dixit and Pindyck calculate $m = 2$, so, for instance, $V^S = 2I$.[59] A TSLRIC calculation that ignores the sunk cost feature of telecommunications network investments would thus be off by a factor of two.

Using parameters for local exchange carriers and taking into account the decrease in capital prices caused by technological progress (which Dixit and Pindyck assume to be zero in their calculation) and because the expected change in (real) prices of most telecommunications services is also negative given the decreasing capital prices, I calculate the value of *m* to be 3.2–3.4.[60] Thus, a markup factor must be applied to the investment cost component of TSLRIC to account for the interaction of uncertainty with sunk and irreversible costs of investment.[61] Depending on the ratio of sunk costs to fixed and variable costs, the overall markup on TSLRIC will vary, but it will be significant given the importance of sunk costs in most telecommunications investments. Note that this same markup over TSLRIC would be used by the hypothetical social planner to choose optimal investment in a telecommunications network because the social planner would face the same inherent economic and technological uncertainty over future demand and cost factors.

59. MacDonald and Siegel (1986) and Dixit and Pindyck (1994, p. 153).

60. Because of the expected decrease in the price of capital goods, even if the standard deviation of the underlying stochastic process were 0.25 as high as a typical stock, the markup factor would still be 2.1. For a standard deviation 0.5 as high, the markup factor is 2.4. I have also explored the effect of the finite expected economic lifetimes of the capital investments in telecommunications infrastructure. Using expected lifetimes of ten to fifteen years leads to only small changes in the option value formulas; for example, for a project with a twelve-year economic life, the markup factor of 2.0 changes to 1.9.

61. It is the advent of competition that requires correct regulatory policy to be applied to the markup. Previously, when regulatory policy did not allow for competition, regulators could (incorrectly) set prices based on historic capital costs. Given the onset of competition arising from the 1996 Telecommunication Act and regulatory removal of barriers to competition, regulators must now account for changes in prices over time. Otherwise, local exchange carriers will decrease their investment below economically efficient levels because their expected returns, adjusted for risk, will be too low to justify the new investment.

By failing to apply a markup to TSLRIC, the FCC has set too low a regulated price for telecommunications services from new investment, and the result will be a decrease in new investment in telecommunications services and network infrastructure below economically efficient levels, contrary to the stated purpose of the Telecommunications Act of 1996. If a goal of the FCC is to achieve facilities-based competition in local telecommunications, it has failed in its task. It has set prices that will decrease the incentives of potential competitors to construct their own networks because TSLRIC always makes it more attractive to "rent" than to "buy" a telecommunications network. Similarly, the FCC has decreased the incentives for new competitors to invest in innovative services because they can wait for the local incumbents to invest and then demand access to successful new services at cost. Through its focus on static cost efficiency considerations in setting regulated prices equal to TSLRIC, the FCC has missed the negative effect on dynamic efficiency that TSLRIC-based prices will cause. The examples of voice messaging and cellular telephone demonstrate the large dynamic efficiency effects in telecommunications that will be lost if the FCC's use of TSLRIC to set regulated prices is permitted to go forward.

Conclusions

New telecommunications services can create very large gains in consumer welfare. For voice messaging services I estimate consumer welfare gains of about $1.27 billion a year based on current levels of demand and price. For cellular telephone those gains are about $50 billion a year. Regulation, which has led to lengthy delays in the introduction of new telecommunications services, thus causes very large losses in consumer welfare. Note that these losses in consumer welfare cannot be regained in subsequent periods.[62]

62. I have considered possible consumer losses due to possible cross-subsidy from other regulated services in Hausman and Tardiff (1995). Using the demand function parameter estimates from Hausman, Tardiff, and Belinfante (1993), the possible welfare losses are quite small because the estimated price elasticities for these regulated services are very near to zero. I estimate the potential welfare loss to be less than $100,000, compared with the welfare gain of more than $1 billion. Thus, consumer gains from new services are very large compared with possible consumer losses. Further details of these calculations will be provided upon request.

Unfortunately, regulators do not seem to have recognized the large consumer welfare losses from past regulatory delays and pricing distortions. The FCC's recently adopted TSLRIC approach to pricing creates significant negative economic disincentives to investment in new services or new infrastructure by regulated telephone companies or by their competitors. The FCC has based its pricing framework on an incorrect economic model that neglects the important role of sunk and irreversible investments in telecommunications. Thus, the FCC has once again focused on static cost efficiency questions and failed to account for the demonstrated large gains in dynamic economic efficiency that arise from new investment. Through its regulatory actions, the FCC has decreased the chances that U.S. residential customers will have access to broadband fiber networks in the near future, whether offered by local exchange carriers or by competitive new entrants. By setting network prices below competitive levels, the FCC has discouraged the local exchange carriers from new investments in infrastructure. It has also discouraged new entrants from investing in their own infrastructure because they can buy the services at below-competitive prices and less risk from the carriers.

Regulation, as currently implemented, may well be unable to keep up with the fast-paced changes in telecommunications technology. Consumer welfare losses are likely to be quite large because of regulatory delays and pricing distortions. Past welfare losses have been in the billions of dollars per year, and the FCC's current approach may well lead to comparable consumer welfare losses in the future.

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