NBER WORKING PAPER SERIES

CELLULAR TELEPHONE, NEW PRODUCTS AND THE CPI

Jerry Hausman

Working Paper 5982

NATIONAL BUREAU OF ECONOMIC RESEARCH
1050 Massachusetts Avenue
Cambridge, MA 02138
March 1997

Silvia Garetti and Hyde Hsu provided useful assistance. Zvi Griliches provided helpful comments on an earlier draft. This paper is part of NBER's research program in Productivity. Any opinions expressed are those of the author and not those of the National Bureau of Economic Research.

Cellular Telephone, New Products and the CPI
Jerry Hausman
NBER Working Paper No. 5982
March 1997
Productivity

ABSTRACT

Cellular telephone is an example of a new product that has significantly affected how Americans live. Since their introduction in 1983, cellular telephone adoption has grown at 25-35% per year such that at year end 1996 about 42 million cellular telephones are in use in the U.S. However, cellular telephone has not been included in the construction of the CPI, and the CPI will not include cellular telephone until 1998 or 1999. This neglect of new goods leads to an upward bias in the CPI. The analysis of the paper demonstrates that the gains in consumer welfare from a new product such as cellular telephone can be substantial. The paper also gives an approximation result which the BLS could use to calculate gains in consumer welfare from new products for use in the CPI.

The BLS telecommunications CPI estimates that since 1988, telecommunications prices have increased by 8.5% or an increase of 1.02% per year. This estimate ignores cellular service. A corrected telecommunication services COLI that includes cellular service decreased from 1.0 in 1988 to 0.903 in 1996 for a decrease of 1.28% per year. Thus, the bias in the BLS telecommunications services CPI equals approximately 2.3 percentage points per year. The neglect of new products in the CPI can lead to significant biases.

Jerry Hausman
Department of Economics
E52-271A
Massachusetts Institute of Technology
Cambridge, MA 02139
and NBER
jhausman@mit.edu

February 11, 1997

Cellular Telephone, New Products and the CPI

Jerry Hausman, MIT[1]

Cellular telephone is an example of a new product that has significantly affected how Americans live. Since their introduction in 1983, cellular telephones adoption has grown at 25-35% per year such that at year end 1996 about 42 million cellular telephones are in use in the U.S. Thus, approximately 16% of all Americans use cellular, and there are about 1/3 as many cellular telephones in the U.S. as regular (landline) telephones. The average cellular customer spends about $600 per year on cellular service. Thus, consumers and businesses have found cellular telephone to be a valuable addition to their lifestyles.

Many other new products and services also have a significant effect on consumer welfare. Approximately 10-15 million subscribers to the Internet with growth of 70%-100% per year demonstrates the importance of this new service.[2] New software products such as Windows 95 also lead to significant gains in consumer welfare. Indeed, even new products such as new cereal brands create significant increases in consumer welfare.[3]

The Bureau of Labor Statistics (BLS) does not know that cellular telephone exists, at least in terms of calculating the Consumer Price Index (CPI). Cellular telephone has not been included in the construction of the CPI, and the CPI will not include cellular telephone until 1998 or 1999 at which time over 60 million Americans are likely to be using cellular and PCS, mobile telephones based on the next generation cellular technology. This

---

[1] Dept. of Economics, E52-271A, MIT, Cambridge, MA, 02139; jhausman@mit.edu. Silvia Garetti and Hyde Hsu provided useful assistance. Zvi Griliches provided helpful comments on an earlier draft.

[2] See J. Hausman (1997) "Telecommunications: Building the Infrastructure for Value Creation" for an estimate of consumer valuation of the Internet.

[3] See J. Hausman (1996) "Valuation of New Goods Under Perfect and Imperfect Competition" where I calculate consumers welfare gains from the introduction of Apple Cinnamon Cheerios.

neglect of new goods leads to an upward bias in the CPI which the recent Boskin Committee Report (1996) found to be large and significant. Waiting 15 years to include cellular telephone in the CPI is not an isolated example; it took the BLS approximately the same amount of time to introduce room air-conditioners into the CPI. Since the price of many new products typically falls rapidly, this long delay can lead to a significant bias. For instance, the original cellular telephones sold for about $3000 in 1983 with the price to consumers now in the range of about $200, at most. Furthermore, the quality of cellular telephones has improved significantly, and the BLS typically does not adjust fully for quality in these type of products, so that another upward bias is introduced. The Boskin Committee Report estimates that the delay in introducing new goods and failure to adjust sufficiently for quality improvements creates an upward bias in the CPI of 0.6% per year. This bias is large relative to yearly changes in the CPI of approximately 3% over the past decade.

However, the Boskin Committee Report's estimate of bias is too low because the gain in consumer welfare from new products is not considered in the bias estimate. Since the BLS has stated that the CPI is designed to be a Cost of Living Index (COLI), economic theory demonstrates that increases in consumer welfare from new goods and services should enter the estimation of the CPI. A COLI approach answers the following question: how much income does a representative consumer require to be as well off this period as last period given changes in prices, introduction of new products, and exit of old products?[4] Use of an expenditure function allows estimation of this required amount which then allows the construction of an index that gives a COLI. As I demonstrate below, the gains in consumer welfare from a new product such as cellular telephone can be substantial. Thus, even if the BLS did not delay the introduction of new products such as cellular telephone into the CPI for periods of 15 years, the BLS calculation of the CPI for new products would

[4] The use of the representative consumer model is an important feature of the definition of a COLI as used here. See Pollak (1989) for the theoretical development of a COLI.

still be biased upward because the BLS does not calculate the gains in consumer welfare from new products. I demonstrate how this gain in consumer should be estimated, and I also give an approximation result which the BLS could use to calculate gains in consumer welfare from new products for use in the CPI.

II. Cellular Telephone Usage in the U.S.

Cellular telephone has been in commercial operation in the U.S. for thirteen years. Cellular telephone began operation in Chicago in late 1983 and in Los Angeles during the 1984 Olympic Games. Operation then began within the next year in the top 30 MSAs (Metropolitan Statistical Areas) and subsequently spread to the rest of the approximately 300 MSAs and more recently the RSAs (Rural Statistical Areas). Cellular telephone 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 40 years. At the time of the AT&T divestiture when it was not clear whether AT&T or the divested Bell Operating Companies (BOCs) would inherit the cellular spectrum which the FCC had granted to AT&T, an AT&T prediction for cellular subscription levels in the year 1999 was about 1 million. At year end 1996 with three years to go to reach the 1999 planning horizon, cellular subscribership in the U.S. exceeded 40 million. In Figure 1 I graph the number of cellular subscribers, with the growth rate of 25-35% a year holding for the past decade.[5] Beginning in 1996 the next generation cellular technology, PCS, has been introduced in the U.S. so that growth rates for mobile telephone usage are likely to continue at their high levels, or even increase, over the next few years.

---

[5] These data are from the Cellular Telephone Industry Association (CTIA), Washington, DC.

The average cellular subscriber spends $48.84 per month on cellular service, or about $600 per year. Thus, about $24 billion per year is spent on cellular service, with additional amounts spent by consumers on purchasing cellular telephones. In Figure 2 I graph cellular service revenue as a proportion of long distance revenue. Cellular revenue now is about 1/3 as large as long distance revenue, so cellular telephone represents a significant expenditure category in telecommunications.

Average expenditure per month for cellular service has decreased from $96.83 per month in 1987 (the first year the data were collected) to $48.84 for the first six months of 1996. However, this 50% decrease does not provide a reliable price index for cellular service, because while cellular service prices have decreased average cellular usage has also decreased. "Early adopters" of a new product or service receive the greatest value for its usage on average, so economic theory predicts that as prices decrease the "later adopters" will not use the service as much.

To construct a price index for cellular service, I have surveyed cellular companies in the top 30 MSAs since 1985. The top 30 MSAs comprise about 41% of the total U.S. population. To account for changes in cellular usage, I calculate the lowest price subscriber plan for 160 minutes per month of cellular usage with 80% peak and 20% offpeak usage.[6] I then use this plan to compute a price index. In Figure 3 I graph the price index for cellular service, with a base of 100 in 1985. By 1996 the index had decreased to 0.78 so that cellular prices had decreased by about 22% over the period. The price index calculated in real dollars, using the CPI-U, declines to 0.53 over the same period. Combined with the significant decrease in retail cellular telephone prices, which I graph in Figure 4, the failure of the BLS to include cellular telephone in the CPI creates a significant bias. An overall index of the cost of cellular service and the cost of cellular telephones is graphed in

[6] These minutes were the approximate average usage when I began the survey; average minutes of usage are now significantly less.

Figure 5 where the overall decrease from the base of 100 in 1985 is 48%.[7] When the BLS finally includes cellular telephone in the CPI in 1998 or 1999 with the price index likely to be at 0.60 or below, the BLS will begin its index at the 1998 or 1999 service and handset prices, neglecting the previous 40% or more decrease that had occurred. This neglect causes a bias in the CPI as well as measures of standards of living and U.S. economic performance. I strongly recommend that the BLS speed up its inclusion of new goods and services in the CPI. A 15 year delay is much too long.

However, even if the BLS had not waited 15 years to include cellular telephone in the CPI, in terms of a cost of living index (COLI), the above index would still lead to a significant upward bias. The gain in consumer welfare from new products or services must also be included in a COLI. I discuss the theory of inclusion of new products and services in a COLI in the next section.

III. New Products and Services in a COLI

According to the BLS, the CPI serves as an approximation to an ideal cost of living index (COLI). A cost of living index answers the question of how much more (or less) income does a representative consumer require to be as well off in period 1 as in period 0 given changes in prices, changes in the quality of goods, and the introduction or new goods (or the disappearance of existing goods). However, the BLS omits the effect of the introduction of new goods in its calculation of the CPI, thus imparting an upward bias. I first explain the theory of cost-of-living indices and demonstrate how new goods should be included using the classical theory of Hicks (1940) and Rothbarth (1941) and then derive an approximation which should be useful for the BLS in including the effect of new goods in the CPI.

---

[7] To create the combined index I assume a "churn" (customer drop) rate of 0.33 which has been the approximate rate for the past decade.

The correct price to use for the new good in the pre-introduction period is the "virtual" price which sets demand to zero. Estimation of this virtual price requires estimation of a demand function which in turn provides the expenditure function which allows exact calculation of the COLI. Given the demand function I can solve for the virtual price and for the expenditure function (or indirect utility function) and make correct evaluations of consumer welfare and the change in the COLI from the introduction of a new product or service. In period 1 consider the demand for the new good, x_n, as a function of all prices and income, y:

$$x_n = g(p_1, \ldots, p_{n-1}, p_n, y). \tag{3.1}$$

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:

$$0 = x_n = g(p_1, \ldots, p_{n-1}, p^*_n, y). \tag{3.2}$$

However, instead of using the Marshallian demand curve approach of Hicks (1940) and Rothbarth (1941) in equations (3.1) and (3.2), I instead would use the income compensated and utility constant Hicksian demand curve to do an exact welfare evaluation.[8] In terms of the expenditure function I solve the differential equation from Roy's identity which corresponds to the demand function in equation (3.1) to find the (partial) expenditure function:[9]

$$y = e(p_1, \ldots, p_{n-1}, p_n, u^1). \tag{3.3}$$

---

[8] In equation (3.2) income, y, is solved in terms of the utility level, u^1, to find the Hicksian demand curve given the Marshallian demand curve specification.

[9] Hausman (1981) demonstrates how to solve the differential equation which 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 non-parametric specification of demand is specified and estimated.

The expenditure function gives the minimum amount of income, y, to achieve the level of utility u^1 which arises from the indirect utility function which corresponds to the demand function of equation (3.1) and the expenditure function of equation (3.3). 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 (3.3) to calculate:

$$y^* = e(p_1, \ldots, p_{n-1}, p^*_n, u^1). \tag{3.4}$$

The exact cost of living index becomes $P(p, p^*, u^1) = y^* / y$.[10] Note that to use this approach one must estimate a demand curve as in equation (3.1) which in turn implies the expenditure function and the ability to do the exact welfare calculation of equations (3.3) and (3.4). Thus, the only required assumption is to specify a parametric (or non-parametric) form of the demand function.

Estimation of the expenditure function in equation (3.4) as well as y^* typically requires significant amounts of data and a parametric or non-parametric estimation of a demand curve. Compared to the usual BLS procedure in estimating the CPI, this approach using features of a demand function is considerably more complicated. However, estimation of the demand function for a new product (or equivalently a utility or expenditure function) is a necessary approach to estimation of y^*, so that traditional Laspeyres index number formula or superlative formulae such as a Fisher index will not suffice in this situation. I now propose a conservative approach which decreases the information requirements and should provide a "lower bound" estimate. In Figure 6 I graph an estimated demand curve D_1 which could be either an uncompensated or compensated demand curve. The virtual price of this demand curve is vp_1 which has the disadvantage of often being outside the range of

---

[10] As with any index number calculation, I could use the pre-introduction utility level u^0 to calculate the cost of living index. However, almost no change would occur in y^* / y because of the relatively small percentage of expenditure on cellular telephone compared to income y.

observed prices. However, an approximation can be used by taking the supporting hyperplane at the observed price and quantities, (p_1, q_1), which then leads to a virtual price of vp_2. Now I claim that this estimate is conservative because $vp_2 < vp_1$, unless the "true" demand curve D_1 is concave to the origin, which while theoretically possible would not be expected to occur for most new products and services. The change in expenditure to hold utility constant with the introduction of the new product, $y - y^*$, is the compensating variation which again can be approximated by the area under the approximate demand curve D_2 above the observed price. This amount is easily computed as:

$$y - y^* \approx CV = (0.5\ p_1\ q_1)/\delta \tag{3.5}$$

where CV is the compensating variation (consumers surplus) from the introduction of the new product and δ is the own price elasticity of demand. To estimate equation (3.5) current revenue $R = p_1\ q_1$ is required. However, these data are typically available from scanner data which the BLS should begin to use, rather than its outmoded price checking approach, or from industry sources. The only econometric estimate needed is for the price elasticity δ, and this parameter appears to be the irreducible feature of the demand curve that is needed to estimate the change in the COLI from the introduction of a new product or service. Again, estimation of an own price elasticity is straightforward using modern scanner data. The data allow estimation with a high degree of precision. Other approaches using alternative sources of data could also be utilized.

IV. A COLI-Based Index for Cellular Telephone

I now turn to the econometric estimation to implement the expenditure function approach of equations (3.3) and (3.4) and the approximation approach of equation (3.5). To do so, I collected price and subscribership data for

the period 1989-93 from a (confidential) survey of cellular operators. I use these 5 years of data to run a regression of cellular prices in the top 30 MSAs. These top 30 MSAs contain about 107 million pops (population), or about 41% of the entire U.S. population.[11] In Table 1 I do 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 for 160 minutes along with variable for log of income, log of population, log of commute time, regulation, and year. The year variable allows for a diffusion curve effect and changes in prices of competing services, e.g. 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.

Also, in Table 1, in the right hand column, I re-estimate the demand model using instrumental variables. This estimation methodology takes into account of possible joint endogeneity of price and demand. When I use instrumental variables in the model, I estimate the demand elasticity to be -0.51 (standard error = 0.17). Thus, I find a somewhat higher elasticity estimate than before which will yield a somewhat smaller effect for the gain in consumer welfare from the introduction of cellular. When I do a Hausman specification test, I do not reject the elasticity estimate from the initial model. Note that the parameter estimates for the other variables, e.g. population, remain virtually the same.[12]

To calculate the expenditure function of equation (3.4) I now use the results of Hausman (1981) to calculate

---

[11] Note that no truncation or sample selection bias is introduced by using the top 30 MSAs since population is an exogenous variable.

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

$$e\ (p, \overline{u})\ =\ [\ (1-\delta)\ \ (\overline{u}+Ap^{1+\alpha}/(1+\alpha))\ ]^{1/(1-\delta)} \qquad (4.1)$$

where A is the intercept of the demand curve, α is the price elasticity, and δ is the income elasticity estimate in Table 1. The compensating variation is calculated from equation (4.1) where y is income:

$$CV = \left\{\frac{(1-\delta)}{(1+\alpha)}\ y^{-\delta}\ [p_1x_1 - p_0x_0]\ +\ y^{(1-\delta)}\right\}^{1/(1-\delta)} - y \qquad (4.2)$$

I then use equation (4.2) to calculate the CV for the introduction of cellular telephone using the average revenue and subscribership data from the CTIA which I 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 (asymptotic standard error = 22.6B) In Figure 7 I graph the resulting price index for a COLI based on these results. Note that using a basis of 1988, the COLI index for cellular telephone decreases to about 0.13. Note that the index of 0.13 is well below the price index which I calculate in Section II to be 0.78, or 0.53 in inflation adjusted dollars. Thus, use of a COLI index rather than a price index can have significant effects for new products and services.[13]

A question which often arises in discussion of introducing new goods into the CPI is evident from Figure 7 when viewed in conjunction with Figure 1. The exact cost of living index for cellular decreases rapidly in Figure 7, but Figure 1 demonstrates that if cellular had been included in the CPI in an early year, say 1985, it would have a small weight. Does the year of introduction affect the importance of a new product or service in a correct

[13] The index correctly captures the overall gain in consumer welfare from the introduction of cellular telephones. Since both individual and business use of cellular is present, some proportion of the welfare gain would be placed in the CPI while the rest would appear in the PPI. The relative proportions are straightforward to estimate given household expenditure data.

COLI? The correct answer is no, as equations (3.3) and (3.4) demonstrate. For an earlier year of introduction, y^* from equation (3.4) is smaller, but once cellular is introduced into the COLI the demand curve continues to shift outwards as the year indicator variable coefficients in Table 1 demonstrate. This outward shift in the demand curve caused by increased quality and diffusion creates additional consumer welfare which would be incorporated into a COLI through equation (4.2). Thus, in each year two effects are present: a decreased price for the given demand curve and an outward shift of the demand curve holding price constant. Because of the use of Hicksian compensated demand functions and expenditure functions in equations (3.3) and (3.4) the combined effect of the two economic factors is path (year of introduction) independent. Introduction of new goods and improved quality of existing goods are actually similar economic effects which enter a COLI in a similar manner. This discussion demonstrates why in the presence of the introduction of new goods and quality improvement (or quality deterioration) of existing goods both prices and quantities (or revenues) must be used to calculate a correct COLI. The BLS approach of only using prices and ignoring the information in quantity data will never allow for a correct estimate of an exact COLI in the presence of new goods and improvements in existing goods.

I now calculate the approximate COLI based on the approximation of equation (3.5). I use the larger of the two estimated price elasticities in Table 1, -.51 to yield a lower bound for the approximation. Thus, for this calculation I need only an estimate of the demand elasticity as well as price and quantity in each year to position the supporting hyperplane to the demand curve. Here the lower bound approximation to the gain in consumer welfare from the introduction of cellular using equation (3.5) is $24.2 billion (asymptotic standard error = $8.1B). In Figure 8 I graph the results of this approximate COLI calculation. The COLI estimate decreases from a base of 1.0 in 1989 to 0.14 in 1996. As expected, the exact calculation of 0.13 and the conservative approximation of 0.14 give approximately the same results which are both much less than the pure price index estimate of 0.77. The

approximation approach, because it estimates the gain in consumer welfare from the introduction of a new good, is much closer to the exact calculation than the measure which ignores this effect. The gain in consumer welfare measured as the compensating variation from cellular is in the range of $24-49 billion per year which demonstrates the substantial value to consumers from the introduction of cellular telephone.

V. Estimation of a Corrected Telecommunications Services CPI

The BLS calculates a telephone services CPI each month. The three components of the telephone services CPI are local access charges, intrastate long distance (toll) charges, and interstate long distance (toll) charges. Cellular telephone is not included in the telephone services CPI. Overall, the telephone services CPI is approximately 1.7% of the overall CPI.

I now estimate a corrected telecommunications services CPI where I include cellular service. I take into account the decline in cellular service prices, e.g. Figure 3, and also the gain in consumer welfare from the introduction of cellular service. Thus, I approximate a COLI based telecommunications services CPI.

To construct the corrected telecommunications services CPI I use yearly expenditures weights based on total local and long distance expenditure.[14] In Figure 9 I graph the BLS telecommunications services CPI along with the corrected COLIs for telecommunications services. Note that the BLS telecommunications CPI estimates that since 1988, telecommunications prices have increased by 8.5% or an increase of 1.02% per year. This estimate ignores cellular service. A corrected telecommunication services COLI that includes cellular service decreased from 1.0 in 1988 to 0.903 in 1996 for a

[14] 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 which would need data on consumer expenditure shares to become a superlative index.

decrease of 1.28% per year. Thus, the bias in the BLS telecommunications services CPI equals approximately 2.3% per year. Over the period 1988-1996, the BLS telecommunications services CPI is biased upwards by about 20%. This bias will not be removed when the BLS includes cellular in the telecommunications CPI in 1998 or 1999.

Lastly, I do similar calculations using the lower bound approximation to the COLI using equation (3.5). In Figure 9, this approximate telecommunication services CPI that includes cellular service is essentially unchanged since 1988. Thus, the BLS telecommunications index would still have a bias of approximately 1% per year with respect to the lower bound approximation.

VI. Conclusion

I have demonstrated how a new product such as cellular telephone should be included in a COLI. The BLS attempts to estimate a COLI, but it fails to account for the gains in consumer welfare from the introductions of new products and services. Thus, even if the BLS introduced new products much earlier into the CPI, a significant bias would remain from the neglect of the gain in consumer welfare as the calculations have demonstrated.

I find it interesting that many people, including some economists, do not feel intuitively that new goods should be included in a COLI. They accept the fact that substitution among existing products when relative prices change should be included. However, they continue to have in mind a static choice set without accepting the implication that new products and services that gain significant demand often lead to large gains in consumer welfare that should be included in a COLI. To respond to the observation that many new goods are very much like existing goods, the economist's answer is that the own price elasticity tells us how similar the products are. A high own price elasticity, together with a high cross price elasticity which arises from the Slutsky equation, will arise for new products that are similar to old

products. Equation (4.2), or even easier equation (3.5), demonstrates that in the situation of a high price elasticity that only a small gain in consumer welfare will occur. Thus, introduction of a new "brand" of milk will have almost no effect because it will have a high price elasticity. However, cellular telephone with a relatively low price elasticity and high demand has a large effect on consumer welfare. Even using the conservative approximation of equation (3.5), the gain in consumer welfare in 1996 from the introduction of cellular telephone service is approximately $24 billion per year.

I also find a bias in the BLS estimate of the telecommunications services index of between 1.0-2.3% per year. Rather than telecommunications service prices increasing at about 1% per year, the correct calculation has them decreasing at about 1.3% per year. Difference of this magnitude are significant and likely arise from other new goods and services such as Internet services. Now that data are increasingly available, I will find it interesting to see whether the BLS incorporates the correct measure of consumer welfare for new products in its estimate of the CPI, or whether it continues to neglect this potentially important component of a COLI.

References

Boskin, M. et. al. "Toward a More Accurate Measure of the Cost of Living," Final Report to the Senate Finance Committee, December 4, 1996.

Diewert, W.E., "Exact and Superlative Index Numbers," Journal of Econometrics, 4, 1976.

Hausman, J., "Specification Tests in Econometrics," Econometrica, 46, (1978).

Hausman, J., "Exact Consumer Surplus and Deadweight Loss," American Economic Review, 71, (1981).

Hausman, J., "Valuation of New Goods Under Perfect and imperfect Competition", in T. Bresnahan and R. Gordon, eds., The Economics of New Products, Univ. of Chicago Press, 1996.

Hausman, J., "Telecommunications: Building the Infrastructure for Value Creation", forthcoming in S. Bradley and R. Nolan eds., Sense and Respond, Harvard Business School Press, 1997.

Hausman, J. and W. Newey, "Nonparametric Estimation of Exact Consumers Surplus and Deadweight Loss," Econometrica, 63, (1995).

Hausman, J. and W. Taylor, "Panel Data and Unobservable Individual Effects," Econometrica, 49, (1981).

Hicks, J.R., "The Valuation of the Social Income," Economic Journal, (1940).

Pollak, R., The Theory of the Cost-of-Living Index, Oxford University Press, 1989.

Rothbarth, E., "The Measurement of Changes in Real Income under conditions of Rationing," Review of Economic Studies, pp. 100-107, (1941).

Figure 1
Number of Cellular Service Subscribers: 1985-1996

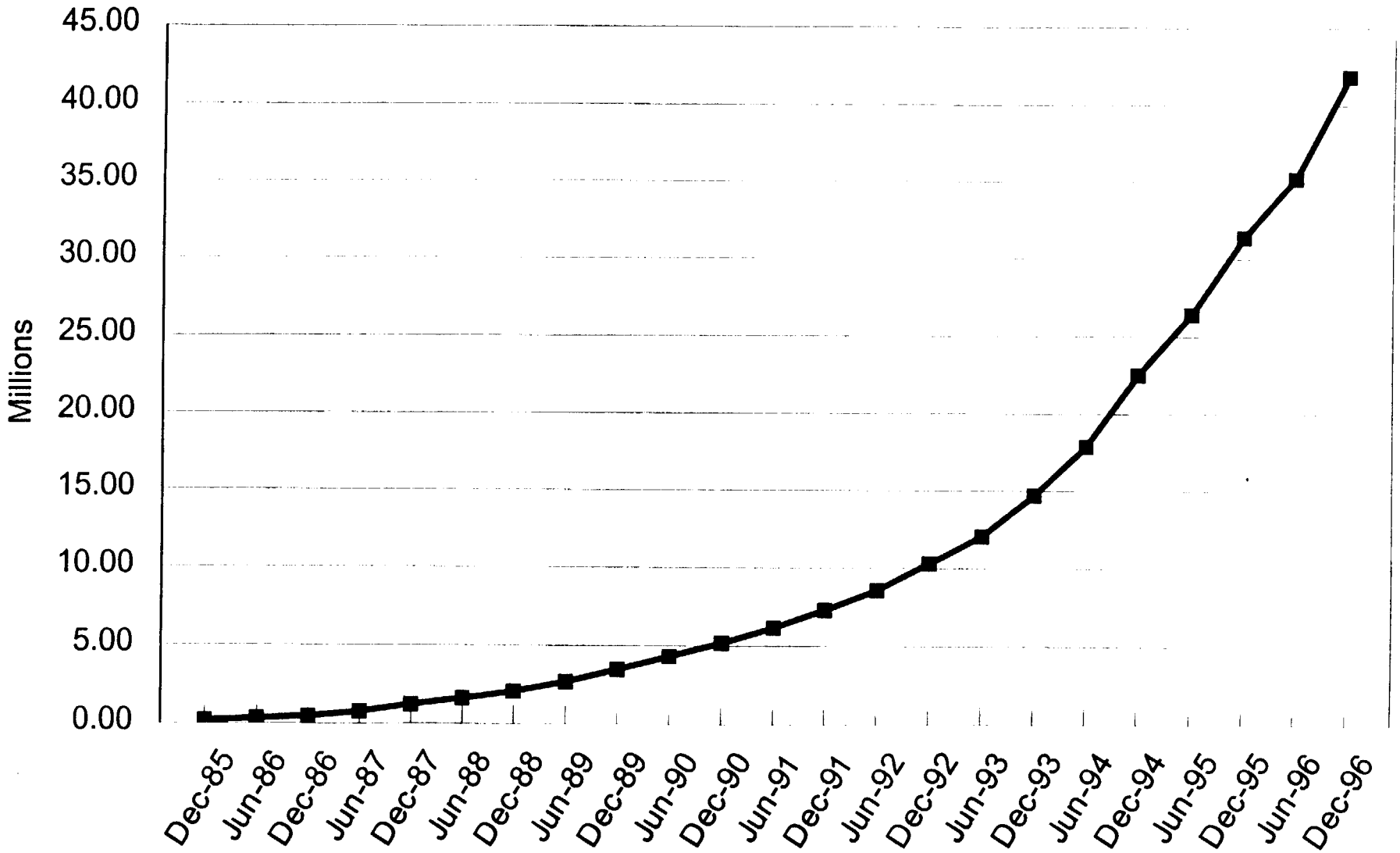

Figure 2
Cellular Service Expenditures as a Percentage of Long Distance Expenditures: 1987-1996

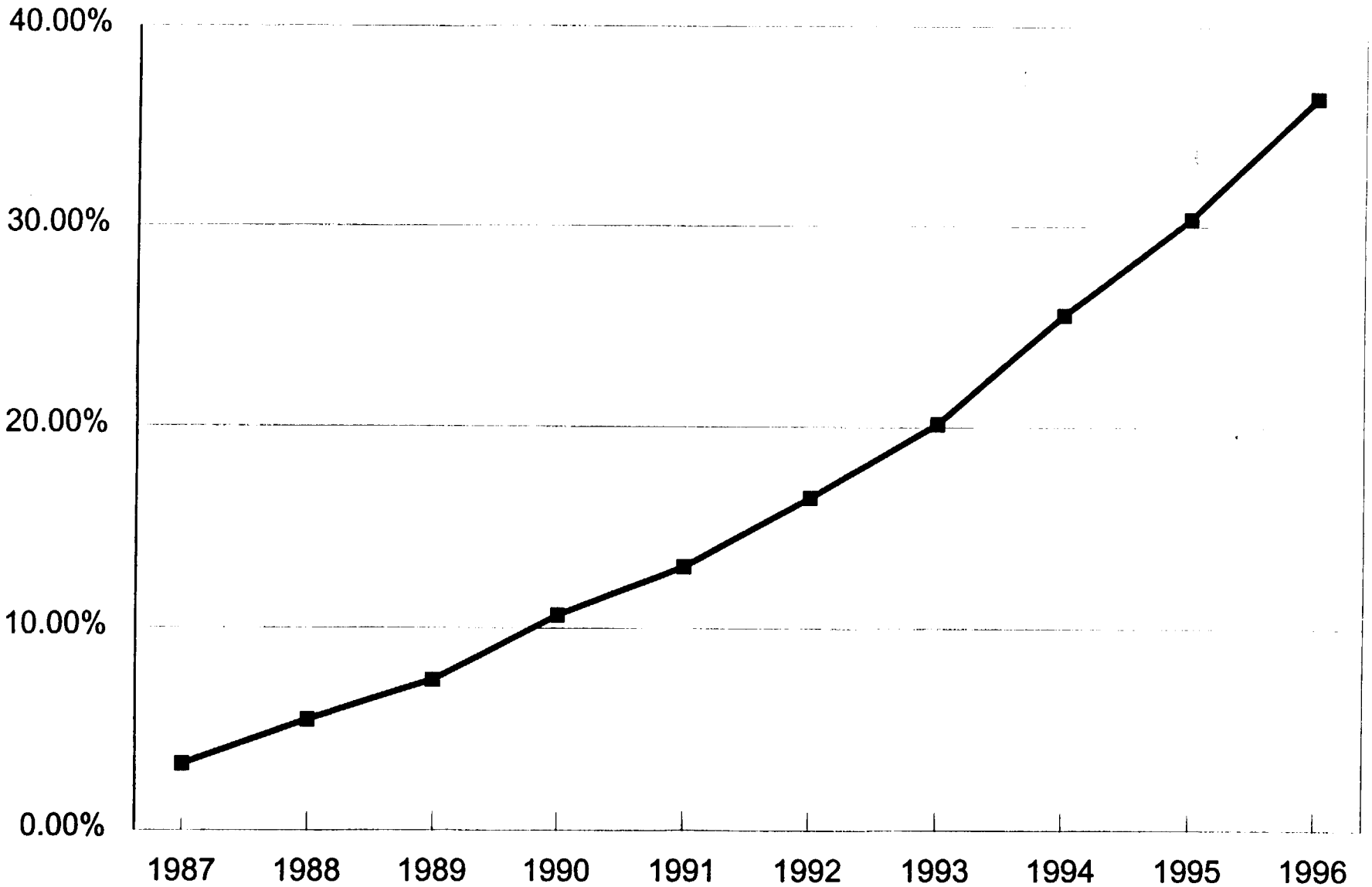

Figure 3
Cellular Average Price Index for Top 30 MSAs: 1985-1996
(Base: 1985 = 1.00)

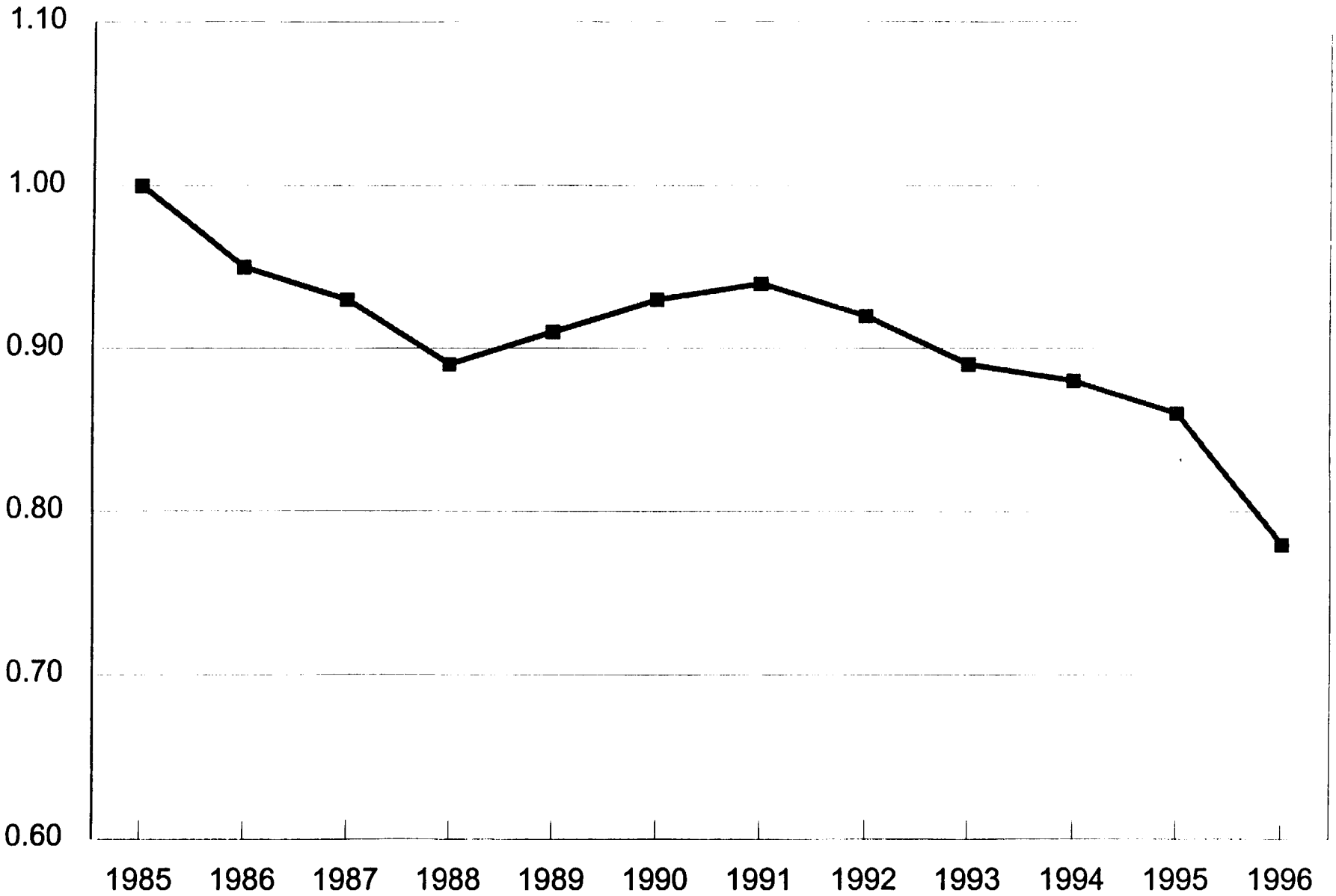

Figure 4
Cellular Telephone Average Prices: 1984-1996

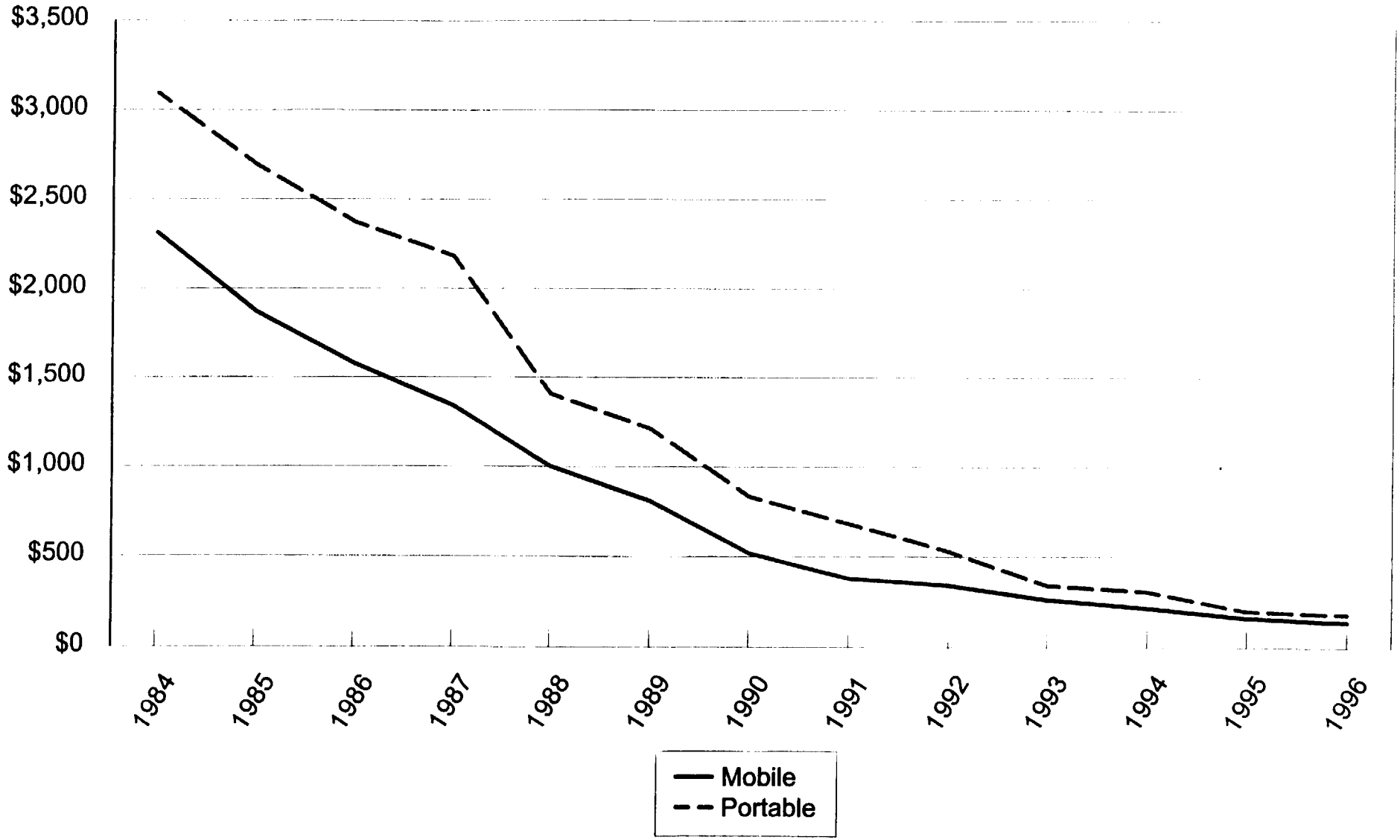

Figure 5
Combined Cellular Service and Equipment Prices: 1985-1996
(Base: 1985 = 1.00)

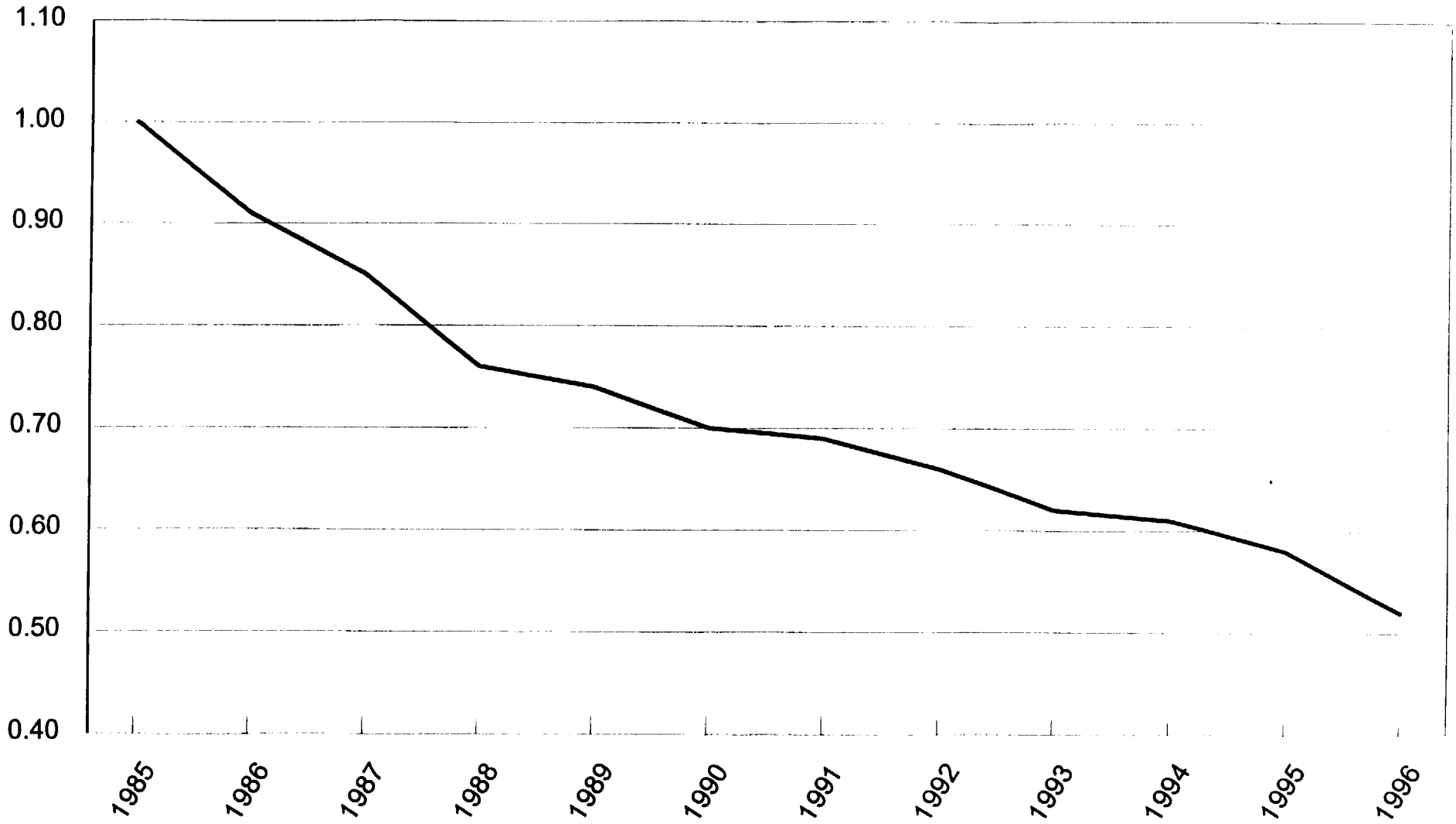

Figure 6
Exact and Approximate Consumer Welfare Approach

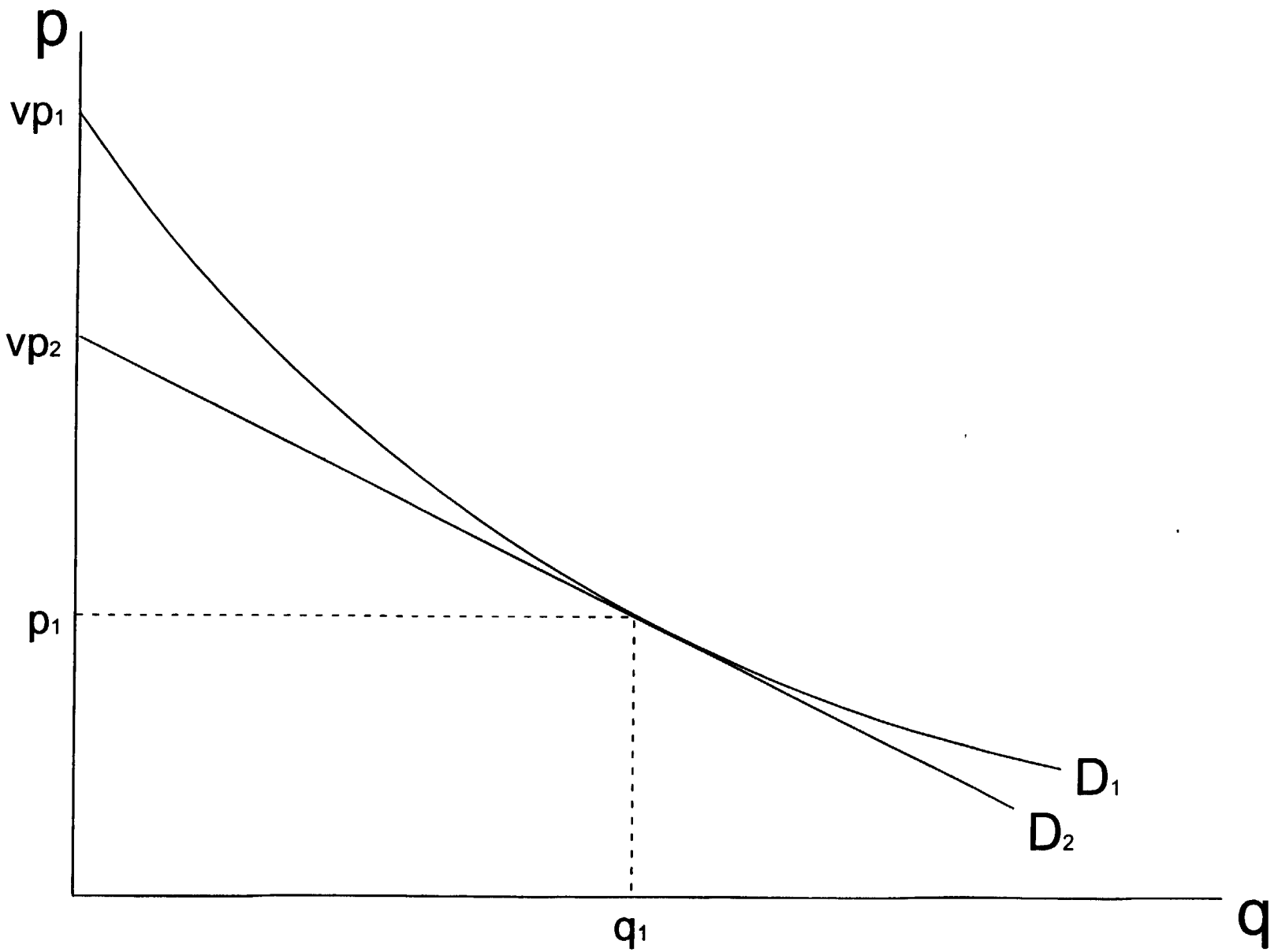

Figure 7
Exact Cost of Living Index: 1988-1996

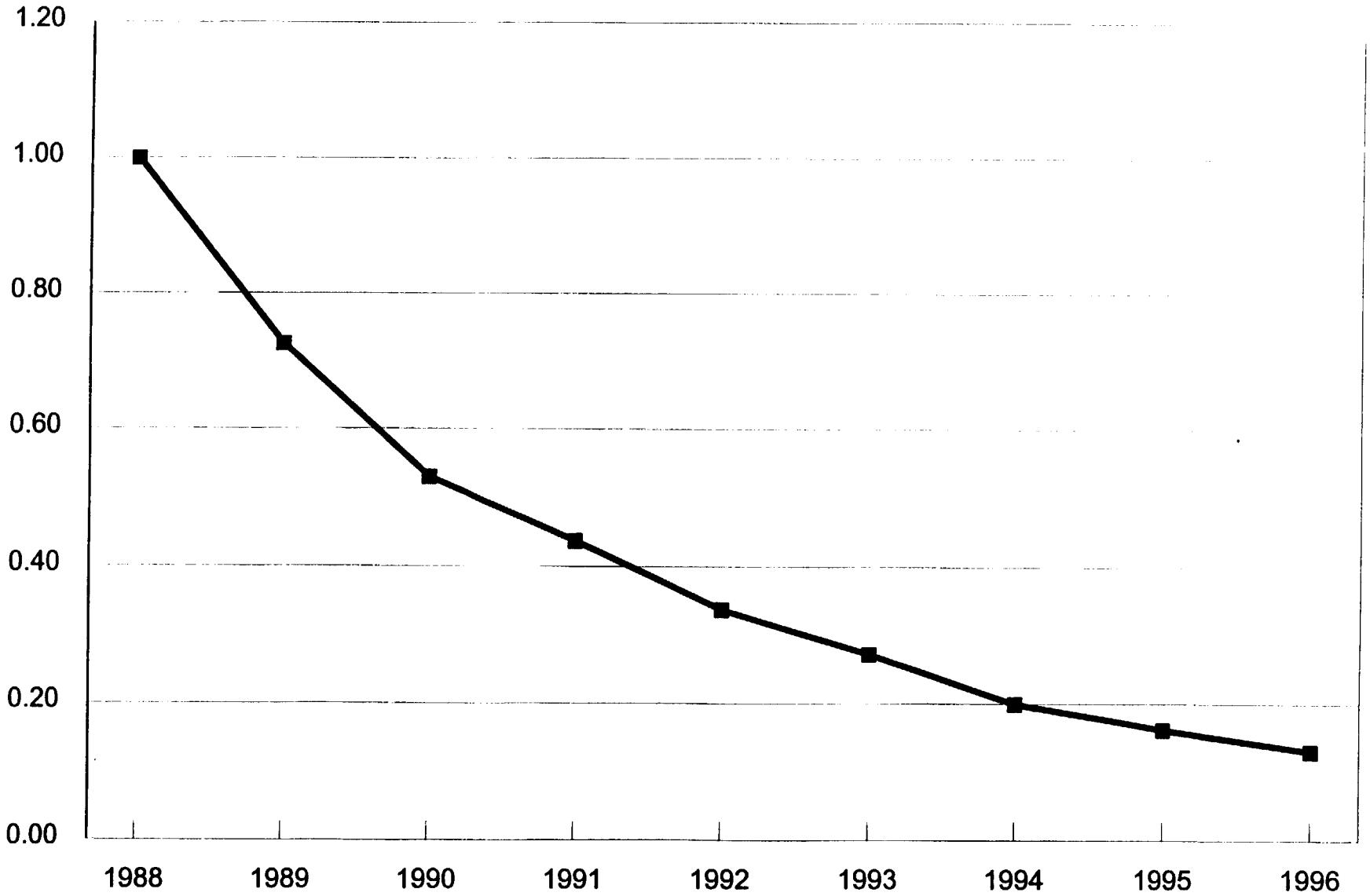

Figure 8
Approximate Cost of Living Index: 1988-1996

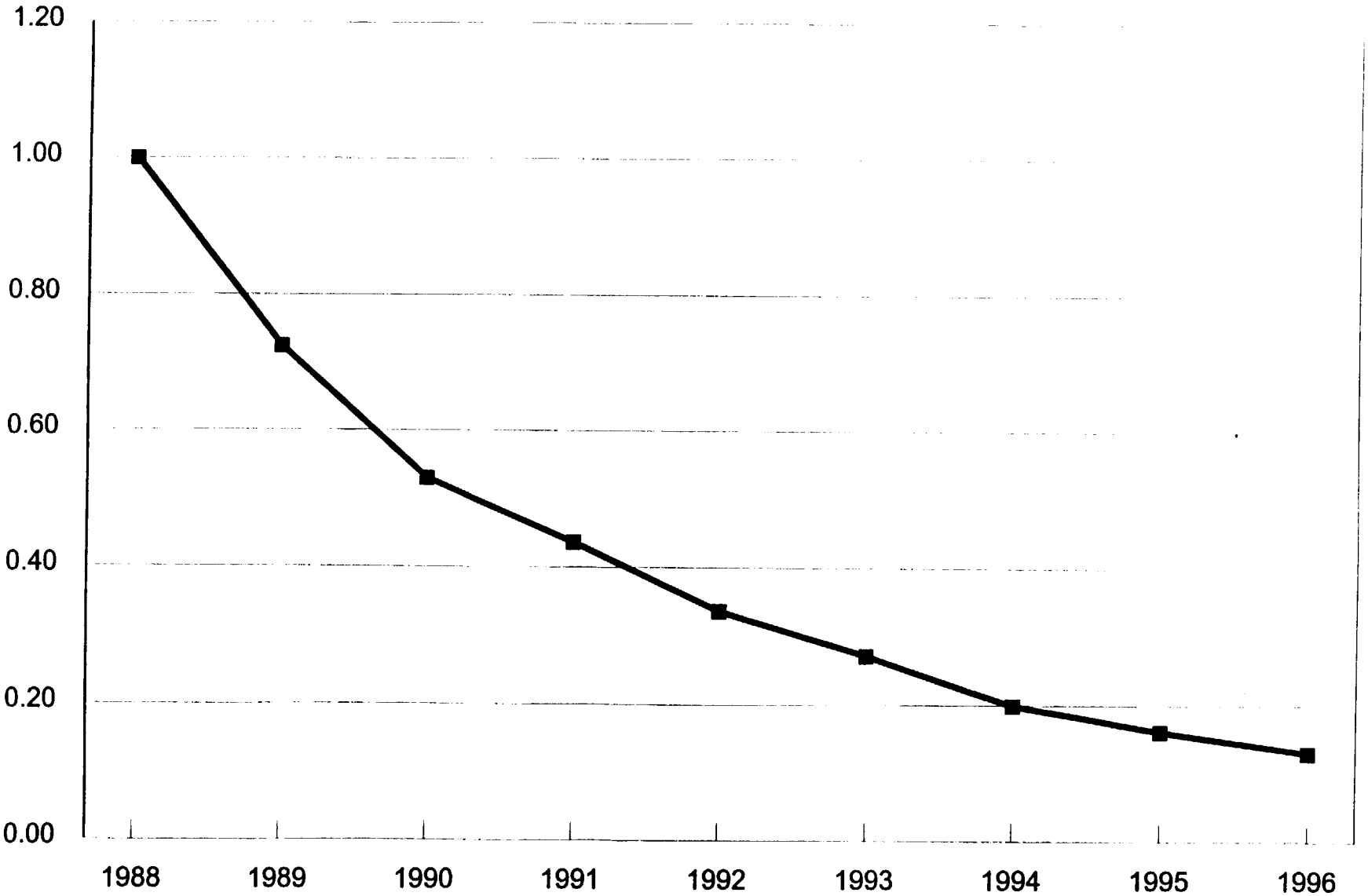

Figure 9
Telecommunications CPI:
BLS Calculations and Correct COLI Calculations

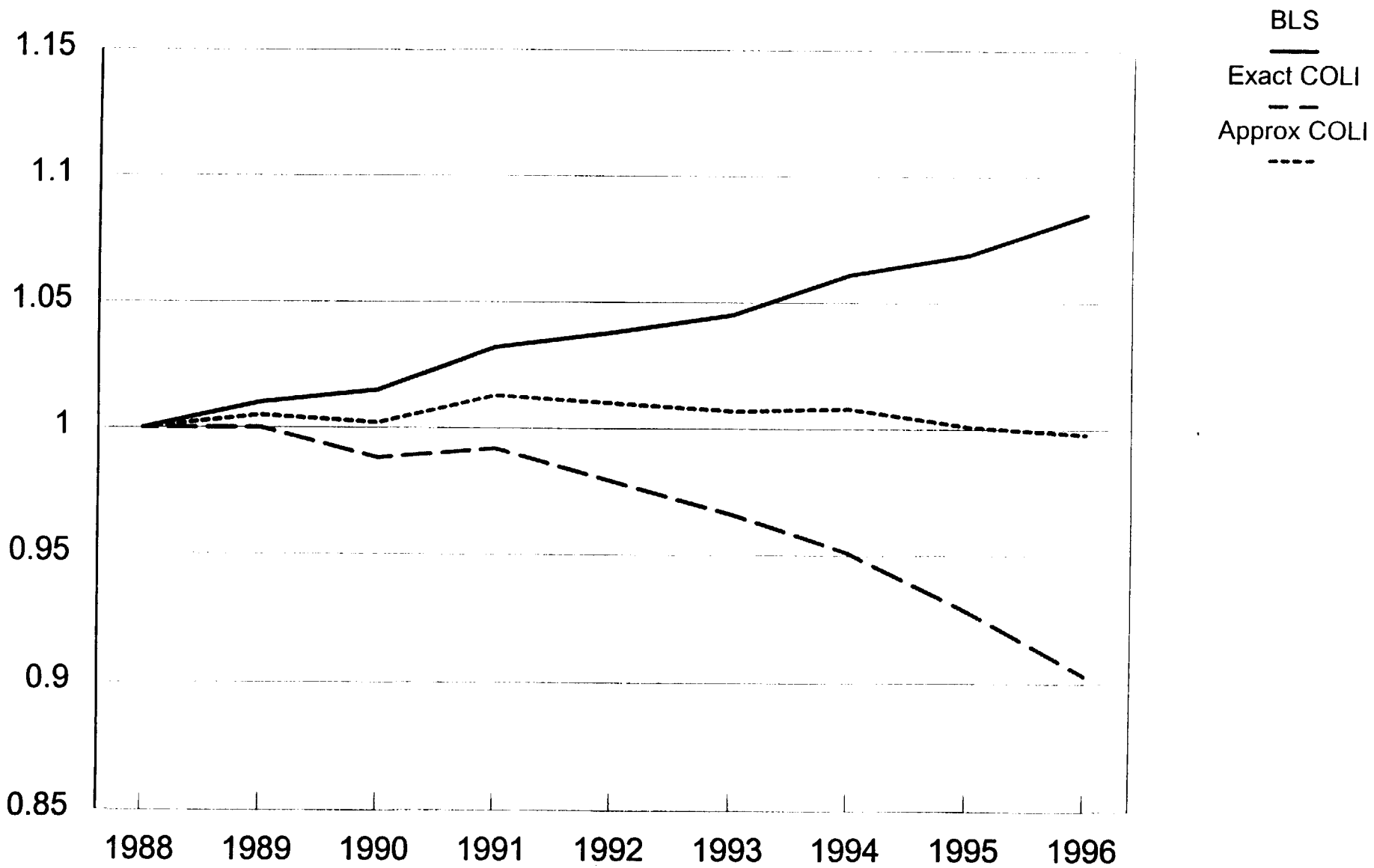

Table1
1989-1993 Demand Regression for Top 30 Cellular Markets <1
Left Hand Side Variable: Log of Subscribers

Variable	OLS	IV <2
Intercept	0.852 (2.475)	1.101 (2.478)
Log of Price <3	-0.406 (0.151)	-0.506 (0.169)
Log of Income <4	0.184 (0.302)	0.193 (0.302)
Log of Population <5	0.948 (0.064)	0.953 (0.064)
Log of Commute Time <6	0.977 (0.356)	0.984 (0.355)
Regulation	-0.161 (0.065)	-0.147 (0.066)
Year 89	-1.234 (0.090)	-1.217 (0.091)
Year 90	-0.830 (0.078)	-0.817 (0.078)
Year 91	-0.566 (0.071)	-0.559 (0.071)
Year 92	-0.310 (0.069)	-0.306 (0.069)
Number of Obs.	196	196
Std. Error of Reg.	0.315	0.315
R Squared	0.982	---

Notes:
1> Standard errors in parentheses.
2> Price is endogenous. Instruments include average price across other Top 30 MSAs, 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.
3> Minimum monthly bill is based on 128 minutes of peak calling and 32 minutes of off-peak calling.
4> Log of per capita personal income. Source: NPA Data Services, Inc., April 1994.
5> Log of population. Source: NPA Data Services, Inc., April 1994.
6> Mean commute time from home to work. Source: 1990 U.S. Census, Tape File 3c.