Estimated Savings in U.S. Dental Expenditures, 1979–89

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Synopsis

The American public saved more than $39 billion (1990 dollars) in dental expenditures from 1979 through 1989 in contrast to the substantial increases in expenditures in other sectors of the U.S. health care system that have pushed the system to the brink of major reform.

The dental savings were estimated after controlling for the influence of economic factors, such as changes in prices, insurance, and income, as well as noneconomic factors that could influence the extent of dental disease in the U. S. population. Results of the analysis confirm the importance of both economic and noneconomic factors in the determination of the savings in dental expenditures.

ESTIMATES BASED on recent economic research indicate that slower growth in dental expenditures resulted in savings to the American public of more than $39 billion in 1990 dollars from 1979 through 1989 (*1*). Statistical analysis shows that about two-thirds of the way through the period of 1950–89 (that is, in 1979) there was a structural change in the trend of per capita real dental expenditures. Review of relevant data and the findings of formal economic analysis point to more effective prevention of dental diseases, resulting from increased scientific knowledge of the biological and behavioral factors that cause these diseases, as a major contributor to those savings. The basis of advances in dental science has been the sustained agenda of research supported primarily by the National Institute of Dental Research (NIDR), that is part of the Public Health Service, and by other domestic and foreign research organizations.

This is a report on the data and methods used to develop the savings estimates. It reviews trends in dental expenditures since 1950, in factors that are generally understood to affect use of dental services, and in oral health since the 1960s. Also reviewed are changes in the mix of services provided by dentists, to see if they are consistent with changes in disease patterns. A comprehensive statistical model that estimates the separate influences of economic and noneconomic (epidemiologic) factors as well as of structural change on real per capita dental expenditures is described. Finally, the calculation of the savings estimate is explained.

Trends in Dental Expenditures

According to the Department of Commerce, per capita dental expenditures adjusted for inflation grew at an average annual rate of 3.3 percent between 1950 and 1978 (*2–6*). Aggregate real dental expenditures, which includes the growth in the U.S. population, grew even more rapidly, at an annual rate of 4.7 percent. Since 1978, however, growth in per capita real expenditures has been at a virtual standstill with an annual rate of 0.16 percent. Average annual growth in aggregate real dental expenditures over the same period has been approximately 1 percent, much less than the growth in medical expenditures or in the U.S. Gross National Product. Most of the growth occurred in a single year, 1981 (see table 1 and fig. 1).

Trends in Economic Factors

The flattening of the growth in dental expenditures has prompted debate about possible factors that may be driving the slowdown. Since a much larger portion of dental services is paid directly by consumers

Table 1. Total U.S. dental expenditures in billions of current and 1990 dollars and per capita U.S. dental expenditures in 1990 dollars, by year, 1950–89

Year	Total current	Total 1990	Per capita 1990
1950	$ 1.0	$ 7.4	$ 49.24
1951	1.1	7.7	51.06
1952	1.2	8.2	53.28
1953	1.3	8.7	55.48
1954	1.4	9.1	56.71
1955	1.5	9.7	59.82
1956	1.6	10.2	61.44
1957	1.7	10.6	62.96
1958	1.8	11.0	64.22
1959	2.0	11.5	65.57
1960	2.0	11.7	65.85
1961	2.1	12.2	67.31
1962	2.3	12.7	69.23
1963	2.3	12.6	67.47
1964	2.7	14.3	75.48
1965	2.9	14.7	76.54
1966	3.0	15.0	77.30
1967	3.4	16.1	82.37
1968	3.7	16.7	84.87
1969	4.3	18.2	91.37
1970	4.9	19.4	95.85
1971	5.1	19.2	93.73
1972	5.6	20.2	97.47
1973	6.6	22.9	109.36
1974	7.3	23.4	110.71
1975	8.2	24.1	112.68
1976	9.3	25.5	118.05
1977	10.3	26.3	120.69
1978	11.3	27.2	123.19
1979	12.3	27.1	121.75
1980	13.8	27.2	120.37
1981	16.2	29.1	127.71
1982	17.4	29.1	126.50
1983	18.5	29.0	124.90
1984	19.8	28.7	122.45
1985	21.5	29.3	123.94
1986	22.8	29.5	123.42
1987	25.0	30.3	125.27
1988	27.1	30.7	125.86
1989	29.0	30.9	125.37

SOURCE: U.S. Department of Commerce, Bureau of Economic Analysis, National Income and Product Accounts, 1929–1982.

compared with medical services, dentistry is more sensitive to the peaks and valleys of activity that normally occur as part of economic cycles (*7*). Examination of economic factors during the period since 1978, however, confirms that most of these factors were moving to increase use of dental services.

On the demand side of the dental market, several economic factors stimulated per capita real dental expenditures. For one thing, higher percentages of these expenditures were covered by dental insurance, according to unpublished data from the Health Care Financing Administration's Office of National Health Statistics. Dental prices relative to general prices increased moderately (*8*). Per capita disposable income of Americans expanded during most of the period (*2–6*) (table 2).

On the supply side, the number of U.S. dentists grew substantially (*9*). More importantly, the dentist-to-population ratio increased, meaning more dentists to serve the people. During most of the time since 1978, economic factors were operating to place upward pressure on dental use, either by increasing demand or by expanding supply. Yet it was during this period that dental use (per capita real expenditures) slowed from their historical growth rates almost to a standstill.

Improvements in Oral Health

A noneconomic factor that is likely related to the slower growth in dental expenditures is improved oral health. As fewer Americans experience dental disease to begin with, and among those already with disease the severity declines, fewer and less expensive dental services are required to treat oral conditions. Comparisons of findings from four national probability surveys demonstrate that dental caries (tooth decay), the dental disease that historically has engaged the most resources to treat, has declined (*10–12*).

Two accepted measures of caries in children are the number of decayed, missing, and filled teeth and teeth surfaces (*13*). Using these indices, findings from the four national surveys demonstrate that dental caries in children ages 5 to 17 decreased immediately preceding and concurrent with the slowing in dental expenditures. A decline in dental caries among children was not observed between the Health Examination Survey conducted by the National Center for Health Statistics (NCHS) early in the 1960–62 period and the NCHS Health and Nutrition Examination Survey I conducted between 1971 and 1974 (*14*) (table 3)—a period when dental expenditures were increasing robustly. Of course, the 1960s were also an era of general economic expansion, which stimulated dental expenditures.

Significantly, a decline of approximately one-third in dental caries among children was first demonstrated between the 1971–74 survey and the NIDR survey of school children, conducted in 1980 (*11*) (table 4), the period when real dental expenditures first began to flatten. Another one-third decline was observed between the 1980 survey and the second NIDR survey of schoolchildren conducted in 1986—a period when dental expenditures remained almost constant (table 1).

The extent of the decline was dramatic. For children ages 5 to 17, the number of tooth surfaces affected by caries decreased from 7.1 in 1971–74 to

only 3.1 in 1986. Age-specific reductions were apparent among children of all ages. The largest reduction was experienced among the 17-year-olds. The number of tooth surfaces affected by caries among that age group declined from 16.9 to 8.0 between 1971–74 and 1986, representing slightly more than a 50-percent reduction in approximately 15 years.

A recent analysis demonstrates for the first time that reductions in caries also occurred among American adults during the same period (*10*). A definite birth cohort effect was observed, with caries reductions occurring among adults in their mid-40s and younger (fig. 2). Reductions in caries experience could not be demonstrated among older adults. The age groups experiencing declines in caries correspond roughly to those born after World War II. Significantly, major scientific advances in the post-war period made effective prevention of dental disease possible.

Trends in Factors that Affect Dental Caries

An important reason for the improvement in oral health is likely to be changes in factors that cause dental caries (*13,15*). Research has identified three factors necessary for caries to develop—dental plaque, which harbors appropriate bacteria; a diet containing carbohydrates, particularly refined sugar; and susceptible tooth surfaces. Specifically, dental caries results when acid-producing bacteria colonize an organic film (dental plaque) that adheres to the surfaces of teeth. These bacteria ferment sugar and other carbohydrates to produce organic acids that demineralize the enamel of susceptible teeth. If demineralization progresses, clinically detectable dental caries develops.

Caries is prevented by reducing or eliminating one, or any combination, of these factors. For example, dental caries can be diminished by reducing the amount of plaque adhering to teeth. Periodic prophylaxes (teeth cleanings) by dentists or dental hygienists help control plaque; however, day-to-day control of plaque is best accomplished through regular brushing and flossing. As figure 3 indicates, the number of diagnostic and preventive procedures per capita increased since 1979, and most Americans' personal oral hygiene practices have improved over the past several decades.

Caries can also be reduced by the ingestion of small, controlled amounts of fluoride compounds. Fluoride lessens the susceptibility of enamel to dissolution by the acids produced by bacteria; it also is thought to interfere with the metabolism of the

Figure 1. Rates of growth in real aggregate and per capita dental expenditures, 1950-89

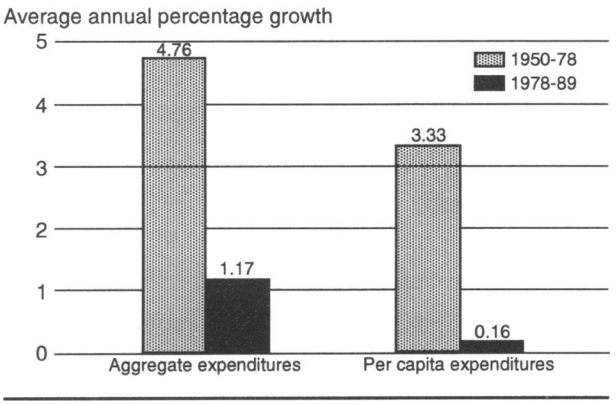
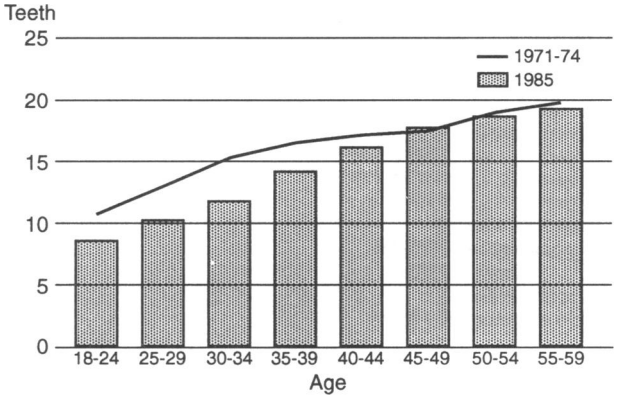


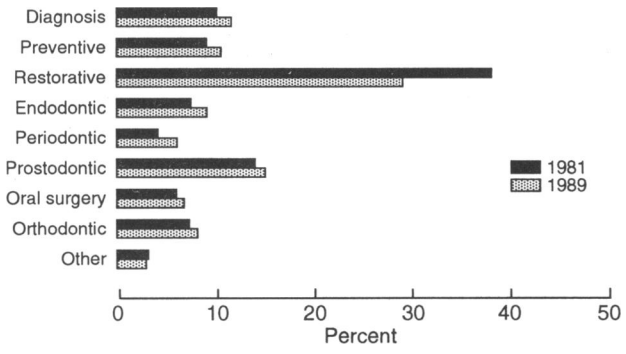
Figure 2. Mean number of decayed, missing, and filled teeth in U.S. employed adults, 1971-74 and 1985, by age



bacteria, diminishing their potential to cause caries. Between 1978 and 1989, the percentage of the U.S. population living in communities with fluoridated water supplies rose from 48.4 percent to 58 percent (*16*) (table 5). The rate of increase did not particularly accelerate during this period but was similar to the steady increase in water fluoridation that has occurred since the mid-1950s. Fluoridated toothpaste also became available during the 1950s and has now almost totally replaced nonfluoridated toothpaste in the American marketplace (*17*). This change had also largely occurred before the 1980s.

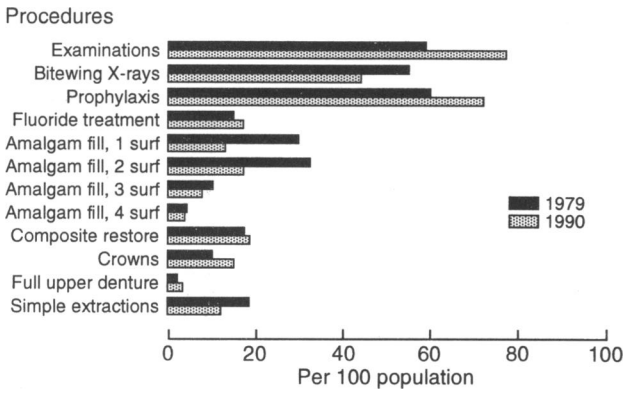
Finally, diets low in refined sugars are less likely to be associated with high rates of dental caries. Since the 1950s, research has led to the development of noncaloric sweeteners that substitute for refined sugar. These sweeteners cannot be used by bacteria to produce acid and therefore are not cariogenic. Between 1978 and 1989, per capita consumption of noncaloric sweeteners increased from 6.9 to 21 sugar pound-equivalents, up more than 200 percent in 11

Figure 3. Percentage of dentists' time, by procedure category, 1981 and 1989



SOURCE: American Dental Association: Survey of dental practice, 1982, 1990

Figure 4. Completed dental procedures per 100 persons in U.S. population, 1979, 1990



SOURCE: American Dental Association: Survey of dental practice, 1982, 1990

years (*18–21*). During the same period, the per capita consumption of refined cane and beet sugar fell from 91.4 pounds to 62.2 pounds, a 32-percent decline (table 5). Refined sugar is almost entirely sucrose, a very cariogenic form of sugar. Consumption of corn sugar, used mainly to sweeten liquids, increased over the last decade. Because it contains less sucrose, many experts do not consider corn sugar as cariogenic as cane sugar.

Changes in Dental Services

Changing disease patterns with resultant improvement in oral health have influenced the dental services provided to Americans. The American Dental Association recently reported that U.S. dentists are spending less time on restorative care and are performing fewer restorative treatments than ever before (*22*).

The percent of time spent providing restorative dentistry by the average dentist declined from 37.5 percent in 1981 to 29.5 percent in 1989 (fig. 3). This represents an average annual reduction of approximately 3 percent in the amount of time spent restoring teeth. Among general practitioners, the dentists who provide the most restorative treatment, time spent providing restorative services declined from 42 percent to 35 percent over the same time period.

In contrast, dentists are spending significantly more time providing diagnostic and preventive services. The percent of time spent by dentists providing those services increased from 18.2 percent in 1981 to 21.3 percent in 1990 (fig. 3). General practitioners increased their time in those categories of care from 19.3 percent to 24 percent during the 1980s.

Services provided by U.S. dentists increased from the early 1980s by about 1.5 percent annually. An estimated 940 million dental services (422 per 100 persons) were provided in 1979, compared with about 1.1 billion (444 per 100 persons) in 1990. A major source of this increase was the number of diagnostic and preventive procedures provided, which increased from 62 per 100 persons in 1979 to 72 per 100 persons in 1990 (fig. 4).

In contrast, the number of restorative services decreased from an estimated 233 million (104.5 per 100 persons) in 1979 to about 202 million (81.5 per 100 persons) in 1990, a decline of 31 million restorative procedures over 11 years (fig. 4). This translates to an average annual decline of 2.23 percent. Within the general category of restorative services, the number of amalgam restorations, long the most common restorative procedure, decreased most dramatically. Total amalgam restorations declined from 160 million in 1979 to 96 million in 1990, a 40-percent decline in 11 years. When the change in the U.S. population between 1979 and 1990 is considered, the number of amalgams provided per 100 persons declined even more dramatically from 71.8 in 1979 to 38.1 in 1990. These trends in the services provided by dental practitioners are consistent with the declines in dental disease detected by epidemiologic surveys over roughly the same period.

Statistical Analysis

Assessment of the possible causes of the slowdown in per capita real dental expenditures is difficult when each variable is considered separately. A statistical multiple regression model that allows a simultaneous assessment of the impact of economic and non-

Table 2. U.S. civilian population's per capita disposable income, the Consumer Price Index in 1990 dollars, percentage of expenditures covered by dental insurance, and the number of U.S. dentists, 1950–89

Year	U.S. Civilian population (millions)[1]	Per capita disposable income[2]	Consumer Price Index 1990 dollars[2]	Dental component Consumer Price Index 1990 dollars[3]	Percent of dental expenditures paid by insurance[4]	Number of U.S. dentists[5]
1950	150.79	$1,368	$18.4	$13.5	0.0	89,700
1951	151.60	1,475	19.9	14.0	0.3	91,302
1952	153.89	1,528	20.3	14.3	0.6	92,932
1953	156.60	1,599	20.5	14.7	0.9	94,591
1954	159.70	1,604	20.6	15.2	1.2	96,280
1955	162.97	1,687	20.5	15.4	1.5	98,000
1956	166.06	1,769	20.8	15.7	1.8	99,399
1957	169.11	1,833	21.5	16.1	2.0	100,820
1958	172.23	1,865	22.1	16.5	2.3	102,260
1959	175.28	1,946	22.3	17.0	2.6	103,720
1960	178.14	1,986	22.7	17.3	2.9	105,200
1961	181.14	2,034	22.9	17.4	2.9	106,600
1962	183.68	2,123	23.1	17.9	2.9	108,020
1963	186.49	2,197	23.4	18.4	2.9	109,460
1964	189.14	2,352	23.7	18.8	2.9	110,920
1965	191.61	2,505	24.1	19.4	3.2	112,400
1966	193.42	2,675	24.8	20.1	4.5	113,150
1967	195.26	2,828	25.5	21.1	7.6	113,910
1968	197.11	3,037	26.6	22.2	9.3	114,670
1969	199.15	3,239	28.0	23.8	9.2	115,430
1970	201.90	3,489	29.7	25.2	9.2	116,200
1971	204.87	3,740	31.0	26.8	9.8	118,210
1972	207.51	4,000	32.0	27.9	10.6	120,250
1973	209.60	4,481	34.0	28.7	11.2	122,330
1974	211.64	4,855	37.7	30.9	13.1	124,450
1975	213.79	5,291	41.2	34.1	17.5	126,600
1976	215.89	5,744	43.5	36.3	21.8	129,700
1977	218.11	6,262	46.4	39.0	23.4	132,700
1978	220.47	6,968	49.9	41.8	25.3	135,500
1979	222.97	7,682	55.5	45.3	29.6	138,400
1980	225.63	8,421	63.0	50.6	34.8	141,300
1981	227.87	9,243	69.6	55.5	38.5	144,400
1982	230.12	9,724	73.8	59.8	41.6	147,200
1983	232.29	10,340	76.2	63.8	41.8	150,300
1984	234.40	11,257	79.5	69.0	42.4	153,000
1985	236.57	11,861	82.3	73.3	41.9	155,600
1986	239.08	12,469	83.9	77.4	42.8	158,100
1987	241.52	13,094	86.9	82.7	43.3	160,600
1988	243.91	14,123	90.5	88.3	44.6	164,000
1989	246.80	14,973	94.9	93.8	45.2	168,000

[1]Statistical Abstracts of the United States, 1991. U.S. Department of Commerce, Bureau of the Census.
[2]Economic Report of the President, February 1991
[3]Consumer Price Index Detailed Report. January Issues 1951–90, Bureau of Labor Statistics, U.S. Department of Labor.
[4]Office of National Health Statistics, Health Care Financing Administration, Department of Health and Human Services, August 1992.
[5]Bureau of Health Professions, Health Resources and Services Administration, Public Health Service, 1990.

economic factors, as well as a possible structural change in dental expenditures, is used to estimate the separate influence of these factors. Specification of the final model proceeds in several stages.

First, underlying the demand-side of the analysis is a microeconomic model of dental consumer behavior. Utility of the consumer is assumed to depend on oral health status and the consumption of nondental goods and services. Consumers are thought to seek dental services not because they directly provide utility, but because they maintain or improve oral health status. Oral health status also is influenced by certain noneconomic factors (exposure to fluoridation and dietary factors such as consumption of refined sugar, corn sugars, and noncaloric sweeteners), which are assumed to be exogenous in this framework. Consumers are assumed to maximize utility, subject to a personal budget constraint.

Within this framework, the resulting individual demand for dental care (q_d) depends on the economic factors that enter into the budget constraint (income, the price of dental care, the dental coinsurance rate, and the price of other goods) as well as the noneconomic factors that may influence the need for dental services. One of the principal advantages of specifying the underlying microeconomic model is that it provides a theoretically consistent framework for incorporating both economic and noneconomic

Table 3. Mean caries experience (decayed, missing, and filled teeth) among children ages 6–17 in two national surveys conducted between 1963 and 1974

Ages (years)	NCHS [1]1963–70	NCHS 1971–74
6–11	1.4	1.7
12–17	6.2	6.2

[1]The 1963–65 survey sampled children ages 6–11, the 1966–70 survey, children ages 12–17.
NOTE: NCHS = National Center for Health Statistics.
SOURCE: Reference *14*.

Table 4. Mean caries experience (decayed, missing, and filled surfaces) among children ages 5–17 in three national surveys conducted between 1971 and 1986

Age (years)	NCHS 1971–74	NIDR 1979–80	NIDR 1986–87
All ages	7.06	4.77	3.07
5	0.15	0.11	0.07
6	0.41	0.20	0.13
7	0.69	0.58	0.41
8	1.86	1.25	0.71
9	3.59	1.90	1.14
10	4.14	2.60	1.69
11	4.58	3.00	2.33
12	6.36	4.18	2.66
13	8.67	5.41	3.76
14	9.60	6.53	4.68
15	11.67	8.07	5.71
16	15.12	9.58	6.68
17	16.90	11.04	8.04

NOTE: NCHS = National Center for Health Statistics; NIDR = National Institute of Dental Research.
SOURCE: "Recent Trends in Dental Caries in U.S. Children and the Effect of Water Fluoridation," by J.A. Brunelle and J.P. Carlos. Journal of Dental Research 69 (Special issue) :723–727, February 1990.

determinants of the demand for dental care. Typically, these factors have been studied in isolation. A more detailed discussion of this hybrid approach is given by Beazoglou and colleagues (*1*). A dummy variable (T) also is introduced to allow for the possibility of a structural shift in demand. The civilian population (N) times q_d gives the aggregate demand for dental services (Q_d).

Second, to control for the influence of supply-side factors, the individual dentist's supply of dental services (q_s) is assumed to be positively related to the price of dental services and negatively related to the price index for residential space (a proxy for the price of office space and other inputs). The aggregate supply of dental services (Q_s) is then D times q_s where D is the total number of dentists.

In the following Equations 1 and 2, nonlinear functional forms are used to represent q_d and q_s. In the third stage, aggregate demand and supply are equated and solved for the market-clearing price of dental services (p), given by Equation 3. The log-linear version of this equation, which contains both demand and supply-side influences, then is fitted to annual data by the method of ordinary least squares (OLS).

Equation 1. $$Q_d = N\, q_d = N\, a_o\, (cp \div P)^{a1}\, Y^{a2}\, S^{a3}\, K^{a4}\, L^{a5}\, F^{a6}\, (\exp)^{a7(T)}\, U_d$$

Equation 2. $$Q_s = D\, q_s = D\, b_o\, p^{b1}\, R^{b2}\, U_s$$

Equation 3. $$p = (b_o \div a_o)^{1 \div (a1-b1)} (D \div N)^{1 \div (a1-b1)} R^{b2 \div (a1-b1)} (c \div P)^{-a1 \div (a1-b1)} Y^{-a2 \div (a1-b1)} S^{-a3 \div (a1-b1)} K^{-a4 \div (a1-b1)} L^{-a5 \div (a1-b1)} F^{-a6 \div (a1-b1)} (\exp)^{-a7T \div (a1-b1)} U_p$$

Where

- Q_d = Aggregate demand for dental care;
- q_d = Per capita demand for dental care;
- Q_s = Aggregate supply of dental care;
- q_s = Per dentist supply of dental care;
- N = U.S. civilian population;
- D = total number of dentists;
- p = dental component of the consumer price index;
- P = consumer price index (all goods and services);
- c = coinsurance rate (fraction of dental expenditures paid by consumer;
- Y = Per capita disposable income;
- S = per capita consumption of refined sugar (cane and beet);
- K = per capita consumption of corn sugar;
- L = per capita consumption of non-caloric sweeteners;
- F = percent of U.S. population with fluoridated water;
- T = dummy variable (after 1978 = 1);
- R = price index for residential space (a proxy for the price of office space and other inputs); and
- U = the stochastic term in each equation.

In the final stage of the modeling procedure, predicted values of the price variable ($\hat{p}$) from the regression analysis of Equation 3 are used in the individual demand function (Equation 4). OLS regression analysis of this function, again in log-linear form, is used to obtain consistent estimates of the demand-side parameters (a_i, i = 0,1, ... ,7). Each parameter associated with a particular independent variable can be interpreted as the elasticity of individual demand with respect to that variable. For example, a_2 provides an estimate of the percentage change in q_d associated with a one percent change in per capita disposable income.

Equation 4. $q_d = a_o\ (c\hat{p} \div P)^{a1} Y^{a2} S^{a3} K^{a4} L^{a5} F^{a6} (exp)^{a7T} U_q$

For savings to occur as a result of prevention, the structure of the model must change over time. The dummy variable (T) in Equation 4 serves to capture the effect of a possible structural change. It was hypothesized that the shift, if any, occurred after 1975. To test for this, a sequence of preliminary regressions were run, assigning T a value of *zero* for each year before the structural change and a value of *one* for each following year. Structural change was hypothesized to occur in 1975, 1976, ... , and 1985, successively. Each of the preliminary models was estimated using time series data for the period 1950 through 1989. Evaluation of these successive runs revealed that a significant structural change occurred in 1979, roughly coincident with the observed slowdown in the growth of per capita real dental expenditures. Once the point of structural change was detected statistically, the final form of the demand model was specified, in which $T = 0$ for 1950–78 and $T = 1$ for 1979–89.

Results of the final regression model are shown in table 6. The regression, corrected for autocorrelation, explains more than 99 percent of the variation in per capita real dental expenditures. Parameter estimates for price and income are consistent with economic theory—increases in the quantity demanded are associated with a reduction in the net price of dental care or an increase in per capita income. The size of the price and income elasticities are generally consistent with cross-sectional studies of the demand for care, and both coefficients are statistically significant.

Economic factors, however, are not the only sources of variation in dental expenditures. The decline in per capita consumption of refined sugar appears to be an important noneconomic factor related to the change in per capita dental expenditures. Finally, the estimated coefficient for the structural change variable, which also is statistically significant, indicates average annual real (1990) savings of $12.28 per person, or about 10 percent of the total per capita dental expenditures. The use of this estimate to construct estimates of the annual savings in total dental expenditures that occurred from 1979 through 1989 is described subsequently.

Calculation of Savings in Dental Expenditures

The regression analysis, previously described, suggests that a significant structural shift in per capita real dental expenditures occurred sometime in the late 1970s; 1979 is our best estimate. This shift is evident even after controlling for a variety of economic and noneconomic factors that might influence the consumption of dental services. That is, the shift captured by the dummy variable (T) in the regression analysis cannot be attributed to changes in the price of dental care relative to the price of other goods and services, the level of dental insurance, per capita income, fluoridation, or the level and mix of sweetener consumption, since the regression analysis statistically controls for variation in these other factors. Even certain supply-side factors that might

Table 5. Percentage of the U.S. population living in communities with fluoridated water supplies and the per capita consumption of noncaloric sweeteners (in sugar-pound equivalents) and of refined cane and beet sugar, and corn sugar (in pounds) per year, 1950–89

Year	Fluoridated water	Noncaloric sweetners	Refined sugar	Corn sugar
1950	1.0	0.0	100.6	8.8
1951	1.8	0.0	94.0	9.2
1952	3.2	0.0	97.1	9.2
1953	5.4	0.0	97.2	10.0
1954	9.4	0.0	95.6	10.5
1955	16.1	0.0	96.3	10.9
1956	17.3	0.0	97.8	11.4
1957	18.6	0.0	95.0	11.9
1958	20.0	0.0	96.8	12.5
1959	21.5	0.0	96.4	13.0
1960	23.1	2.2	97.6	13.6
1961	24.5	2.5	97.8	13.9
1962	26.0	2.9	97.3	14.9
1963	27.6	3.7	96.7	16.0
1964	29.4	4.8	96.6	16.7
1965	31.2	5.7	96.6	16.9
1966	32.8	6.4	97.6	17.1
1967	34.4	6.9	97.3	16.9
1968	36.2	7.2	100.1	17.7
1969	37.9	6.9	100.1	18.4
1970	39.7	5.8	101.8	19.3
1971	40.4	5.1	102.1	20.8
1972	41.3	5.1	102.3	21.1
1973	42.2	5.1	100.8	23.4
1974	43.2	5.9	95.7	25.1
1975	44.3	6.1	89.2	27.5
1976	45.6	6.1	93.4	29.7
1977	47.0	6.6	94.2	31.2
1978	48.4	6.9	91.4	33.7
1979	49.9	7.3	89.3	36.3
1980	51.3	7.7	83.6	40.2
1981	52.0	8.2	79.4	44.5
1982	52.8	9.4	73.7	48.2
1983	53.6	13.0	71.1	52.2
1984	54.4	15.8	67.6	57.8
1985	55.2	18.0	63.3	66.5
1986	56.0	18.5	61.0	67.3
1987	56.0	19.0	62.8	68.6
1988	57.0	20.0	62.0	69.6
1989	58.0	21.0	62.2	69.7

SOURCES: "Fluoridation Census, 1985," Centers for Disease Control, U.S. Department of Health and Human Services, July 1988.
"Food Consumption, Prices, and Expenditure, Annual Report 1950–1989," Economic Research Service, U.S. Department of Agriculture.

Table 6. Regression results for per capita demand for dental care (Equation 4)

Variable	Coefficient	Standard Error	Probability >t
Intercept	–6.23	1.73	<0.01
Log income	0.85	0.21	<0.01
Log predicted price	–0.56	0.22	0.01
Log CPI90	–0.14	0.19	0.46
Log noncaloric sweetener	–0.001	0.003	0.67
Log cane sugar	0.57	0.16	<0.01
Log corn sugar	0.068	0.14	0.63
Log PCT fluoridation	0.040	0.012	0.01
Structural shift dummy	–0.10	0.032	0.01
Rho	0.19	0.16	0.23

N = 40
Adj R^2 = 0.99
F Stat = 761.7
Log income = Log of per capita disposable personal income.
Log predicted price = Log of coinsurance * estimated dental price from Stage 1: price equation (equation 3).
Log CPI90 = Log of consumer price index (base 1990).
Log Noncaloric sweetener = Log of per capita consumption of noncaloric sweeteners in sucros-pound-equivalents per year.
Log cane sugar = Log of per capita consumption of cane and beet sugar in pounds per year.
Log corn sugar = Log of per capita consumption of corn sugar in pounds per year.
Log PCT fluoridation = Percent of U.S. population with fluoridated water.
Structural shift dummy = Indicator variable for an exogenous shift in demand for dental care.
Rho = Auto-correlation coefficient.

influence the price, and hence the consumption, of dental services were taken into account in the estimation procedure.

It is not possible to identify with certainty all possible sources of this structural shift, but the shift is consistent with the general improvement in oral health documented by recent epidemiologic surveys. In turn, the improvement in oral health reflects the development of more effective preventive methods that emerged from a sustained agenda of dental research, and the adoption of these methods by dental professionals and their patients. Reductions in dental diseases and tooth loss have both contributed to the savings.

Estimated annual savings in dental expenditures have been calculated by multiplying the estimated annual real per capita savings associated with the structural shift ($12.28) times the corresponding U.S. population in each of the years 1979 to 1989. To calculate the value in the year 1990 of the cumulative savings between 1979 and 1989, the value of each year's savings was adjusted by adding the interest that would have accrued to each year's savings if it had been placed in a bank account drawing 2 percent interest from the year the savings occurred until 1990. Two percent real interest is a conservative adjustment to the value of savings. The following table shows the estimated savings (unadjusted and adjusted) in billions of 1990 dollars for each of the 11 years. The unadjusted cumulative estimated savings from the 1979–89 period is $34.8 billion. The cumulative estimated savings adjusted to their value in 1990 is $39.1 billion.

Year	Unadjusted savings	Savings adjusted with 2 percent interest
1979	$2.928	$3.641
1980	3.005	3.663
1981	3.115	3.723
1982	3.086	3.616
1983	3.110	3.572
1984	3.143	3.540
1985	3.083	3.404
1986	3.198	3.353
1987	3.261	3.461
1988	3.388	3.525
1989	3.534	3.605

Discussion

The dental sector of the U.S. health care system is unique. Recent increases in expenditures in other parts of the system (hospital care, physician services, long-term care, and pharmaceuticals, for example) have pushed the system to the brink of major health care reform. By contrast, increases in dental expenditures have been remarkably modest, especially during the 1980s. Following an extended period of relatively steady increase (3.3 percent per year), per capita real dental expenditures flattened out and grew at an annual rate of 0.16 percent from 1979 to 1989. This report is a summary of the findings of a study designed to isolate the sources of this significant departure from the long-term trend in dental expenditures and from the recent experience of other sectors in the health care system.

To control for the variety of economic and noneconomic factors that influence dental expenditures, a multivariate linear regression approach was adopted. The structure of this statistical model was based on a conventional microeconomic model of the demand and supply of dental services, modified to allow for the potential influence of certain noneconomic factors. Results of the regression analysis confirm the important roles that both economic and noneconomic factors (notably the consumption of refined sugar) play in the determination of dental expenditures. Beyond these observed factors, however, there is strong evidence that a significant structural shift in per capita real dental expenditures occurred in about 1979. This structural shift reduced per capita dental expenditures by roughly 10 percent, leading to an estimated cumulative savings of $39.1 billion over the period 1979–1989, measured in 1990 dollars.

The estimated savings are both credible and conservative. They were derived after controlling for the influence of economic factors such as changes in prices, insurance, and income, as well as epidemiologic factors (various types of sweeteners and fluoride). The estimates also take into account changes in the number of dentists and practice costs. Although the statistical model suggests that the reduction in the consumption of cane and beet sugar also may have significantly reduced dental expenditures, this source of savings is not included in the estimate of savings attributed to dental research because it could partly result from changes in technology not directly related to dental research. Nevertheless, it seems likely that dental research has contributed to the adoption of less cariogenic diets and improved oral health.

In the current discussion of health care reform, concerns are often raised about the possible adverse effects of cost containment on health status. It is important to note that the estimated savings in dental expenditures from the 1979–89 period occurred while the oral health status of the U.S. population was improving significantly and without major reform of the dental delivery system. In addition to the documented reduction in caries, edentulism (total toothlessness) has declined, resulting in important benefits that are difficult to measure. Millions of people who have retained their natural teeth can chew more effectively, have better appearances, and better self images than if they had become edentulous. Such intangible benefits are important but have not been included in the estimate of savings. For all these reasons, the estimate of $39 billion in cumulative savings in dental expenditures from prevention and research is likely to understate the full value of these activities.

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