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The Economic Value of Teeth

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Abstract: Healthy teeth are a vital and visible component of general well-being, but there is little systematic evidence to demonstrate its effect on labor market outcomes. In this paper, we examine the nature and magnitude of the effect of oral health on labor market outcomes by exploiting variation in access to fluoridated water during childhood. The politics surrounding the adoption of water fluoridation by local water districts suggests exposure to fluoride during childhood is arguably exogenous to other factors affecting earnings. We find that children who grew up in communities with fluoridated water earn approximately 4% more as adults than children who did not. The effect is larger for women than men, and is almost exclusively concentrated amongst those from families of low socioeconomic status (SES). We find that occupational sorting and consumer discrimination explains the mean impact of oral health on earnings, but employer discrimination explains the impact for low SES individuals.

1. Introduction

Healthy teeth are a vital and visible component of general well-being. Good dentition helps in maintaining general health and also makes a substantial and obvious contribution to appearance. Conversely, lack of teeth – edentulism – is associated with poor overall health and, anecdotally, with worse life outcomes. As recent New York Times stories documented:

> Ms. Abbott, a diabetic who is now 51, lost all her teeth and could not afford to replace them. 'Since I didn't have a smile,' she recalled, 'I couldn't even work at a checkout counter.' (May 8, 2006)

> The people who received promotions tended to have something that Caroline did not. They had teeth. Caroline's teeth had succumbed to poverty, to the years when she could not afford a dentist. (January 18, 2004)

As these anecdotes illustrate, poor dental health may make it difficult to succeed in the labor market. Moreover, as the anecdotes also note, dental health is highly responsive to dental intervention. Caries can be treated, relatively inexpensively, through filling decayed teeth[1]. If caries are not treated and tooth loss occurs, replacement teeth (dentures) cost much more, with price varying by quality of the replacements.[2]

Dental health can also be improved through public health intervention. Research in the middle of the 20th century found that communities with higher rates of naturally occurring fluoride had lower rates of dental caries. Beginning with Grand Rapids, MI in 1945, public water systems began adding fluoride to drinking water. Numerous studies since have demonstrated that local water fluoridation significantly reduces dental caries, by as much as 50%. As fluoridation rates have increased the rate of edentulism has fallen significantly over

[1] At a cost as low as $40-$50 per dental surface. http://www.affordablecare.org/dentures_prices.htm
[2] At least $860 for a complete set of upper and lower dentures. http://www.affordablecare.org/dentures_prices.htm

time as well.[3] Given the low incidence of side-effects and high cost-effectiveness, the US Centers for Disease Control has labeled water fluoridation "one of the 10 greatest public health achievements of the 20th century."

In this paper, we examine the nature and magnitude of the effect of oral health on labor market outcomes by exploiting variation in access to fluoridated water during childhood. The politics surrounding the adoption of community water fluoridation (CWF) by local water districts suggests exposure to fluoride during childhood is arguably exogenous to other factors that may affect earnings. Local water districts are established as special purpose governments (SPGs) and are fairly autonomous in their decision making (Foster (1997)). Decisions around water fluoridation are typically made independently from local preferences, especially during the time period respondents from our sample, the National Longitudinal Survey of Youth, were children (Crain et al. (1969)). The result of this political structure, as empirical evidence supports, is that the adoption of CWF is unlikely to be correlated with unobservable factors affecting wages.

We find that children who grew up in communities with fluoridated water earn approximately 4% more as adults than children who did not. These results are insensitive to adding numerous control variables, to allowing for flexible state, time, and cohort trends, and to alternative measures of fluoride exposure. We also explore these effects separately by gender and socioeconomic status (SES) to allow for differential labor market or behavioral responses to oral health, and find the effect is larger for women than men and is almost exclusively concentrated amongst individuals from families of low socioeconomic status. In exploring the potential channels through which oral health might affect earnings, we find that occupational

[3] These findings are summarized in U.S. Department of Health and Human Services (2000). The effect of water fluoridation on dental caries may be decreasing over time because fluoridation has permeated the food chain, so children are ingesting fluoride through sources other than public drinking water.

sorting and consumer discrimination explains the mean impact of oral health on earnings, but employer discrimination explains the impact for low SES individuals.

Our results provide new insights to economic models of labor market discrimination. Several studies have documented labor market discrimination related to personal appearance (see, for example, Hamermesh and Biddle (1994)). Since researchers observe far less than employers about potential workers, any estimated differences in earnings could reflect inadequate controls for the numerous pre-labor market covariates. Furthermore, physical appearance is clearly amenable to spending, suggesting reverse causality. Even more elusive in this research is the ability to identify the mechanisms by which discrimination arise (see, e.g., Altonji and Blank (1999)). Audit studies where fictitious individuals who are randomly assigned into a racial group apply for jobs largely overcome omitted variable bias and reverse causality issues (see, e.g., Bertrand and Mullainathan (2004)), but are necessarily limited in the duration of follow-up (since the fictitious job seekers never actually take jobs) and only focus on employer discrimination. This paper uses situations where people are exogenously assigned to a discriminated-against category through CWF, offering an unusual opportunity to further explore the extent and nature of labor market discrimination.

The existence of interventions that can readily improve oral health also means that understanding this relationship is of significance to public policy regarding dental care. Low-income children suffer disproportionately from oral diseases, particularly tooth decay, because of inadequate access to preventable care. For example, the incidence of tooth decay is twice as common for blacks and Hispanics than whites. Numerous dental interventions, such as dental sealants and fluoride treatments, though more expensive than water fluoridation, are highly effective means for reducing tooth decay. Moreover, not all tooth loss is due to decay and preventable through fluoride; dental care in adulthood reduces tooth loss due to periodontal disease. Furthermore, restorative care, such as implants and dentures, can compensate for tooth loss. The costs of these interventions are known, but the value of the benefits is not. Our estimates of the economic value of teeth in the labor market provides evidence of a largely overlooked benefit of oral health that can be used in assessing the cost-effectiveness of a wide range of dental care interventions. Such investments have the potential to reduce disparities in dental health and thus improve the economic prospects of low-income children.

2. Background

Fluoride and Teeth

Fluoride protects teeth both systemically and topically. The ingestion of fluoride during the first 5 to 7 years of life is particularly important for the health of the four front adult teeth - the most visible components of a smile - by making tooth enamel stronger and more permanently resistant to decay (U.S. Department of Health and Human Services (2000)). Continued ingestion through the first 12 years of life, the point at which all adult teeth have typically erupted, provides the same benefits to the remaining teeth. Topical fluoride also helps to protect tooth enamel, but it is considered less effective.

Although fluoride reduces tooth decay, several negative side effects from ingestion have been considered. Excessive intake of fluoride can cause fluorosis, a slight cosmetic discoloration of the teeth. More serious – though more disputed – is the purported link between fluoride intake and other health outcomes, notably bone fractures and cancer. Although the National Research Council (2006) issued a report concluding that laboratory and epidemiological evidence does not support the hypothesis of a link between fluoride and cancer, controversy surrounding fluoride side-effects continues.

Discrimination and the Labor Market

Economic models of discrimination, beginning with Becker (1957), suggest that discrimination may occur within a competitive labor market if employers, co-workers, or customers have personal preferences about non-job related worker characteristics, such as race or gender. More recently, several studies have documented labor market discrimination related to personal appearance (see, for example, Hamermesh and Biddle (1994); Biddle and Hamermesh (1998)). For example, Hamermesh and Biddle (1994) find that better than average-looking people earn 5-10% more than average-looking people, who earn 5-10% more than below average-looking people. The effects are independent of occupation selection, and, the authors' conclude, are mostly due to employer discrimination. They find no differential effect by gender – if anything, males have a higher "return to beauty" – and find that marriage markets and labor force participation do not explain this.

In this analysis, we use teeth as a measure of physical appearance. Experimental studies indicate teeth are an important component of physical appearance. Photographs of teeth that were randomly manipulated and rated by respondents reveal that poor oral health is associated with lower esthetic, social, and professional traits (see, e.g. Eli et al. (2001)). With respect to employment, the anecdotes described above suggest that people who lack teeth may have trouble finding jobs (Shipler (2004); Eckholm (2006)). In the past, potential soldiers were rejected from military service because of missing teeth (Britten and Perrott (1941); Klein (1941)).

Hamermesh and Biddle (1994) describe several channels through which beauty might affect labor market outcomes. Consumer preferences to interact with more attractive employees may lead to greater demand, and thus higher wages, for individuals with better teeth. This could also lead to occupational sorting so that more attractive individuals choose professions with more direct customer contact. The beauty premium could also arise through employer discrimination. Employers may prefer to hire more attractive workers, indicating taste-based discrimination. In addition, oral health may also signal to a potential employer the degree of labor market success previously experienced or serve as a proxy for human capital investments, indicating statistical discrimination by employers.

In addition to physical appearance, oral health may affect earnings through a direct impact on individual productivity. The physical pain associated with poor oral health might lead to greater absenteeism from work or school. Based on the 1996 National Health Interview Survey (NHIS), there were 1.9 days of work lost per 100 employed persons over age 18 and 3.1 days of lost school per 100 youths aged 5-17 because of dental symptoms or treatment. Physical appearance might also affect individuals' non-cognitive skills, such as self-confidence, which may have a direct effect on productivity ((Mobius and Rosenblatt (2006), Heckman (2000), Persico et al. (2004)).

3. Empirical Strategy

While existing research on the economic impact of beauty documents a relationship between appearance and earnings, physical appearance is clearly amenable to spending. For example, workers with higher wages may be able to visit the beauty salon more frequently, purchase the latest fashions, or even have cosmetic surgery to enhance their appearance. Employers may use appearance as a marker of past labor market success, rather than as an independent input into productivity. To the extent that CWF – an intervention in childhood that improves adult outcomes – is exogenously determined, it offers an opportunity to study how discrimination works in the labor market. In practice, the political structure of CWF policy reduces the likelihood that decisions about water are related to earnings.

The most important factor in determining fluoridation status is population served by a water district because of decreasing returns to scale in providing community water fluoridation. Most of the costs associated with providing community water fluoridation are fixed, and the marginal cost per person is quite low. The average costs of fluoridation per person per year are $0.50 for communities with greater than 20,000 people, $1 for communities with 10-20,00 people, and $3 if fewer than 10,000 people.

Absent population, the decision to fluoridate follows little systematic pattern. Water fluoridation policies are determined by water districts. In general, water districts are established as special purpose governments (SPGs) and their boundaries often do not correspond to the municipal boundaries that govern other types of decisions (Foster (1997)). Special purpose districts are fairly autonomous in their decision making. Only recently have SPGs attempted to incorporate citizens' input, but this input was found to have no effect on the decision making process (Heikkila and Isett (forthcoming)). Even among special purpose districts, water districts appear to be particularly independent of local conditions (Foster (1997)). Despite public concerns over water fluoridation, nearly two-thirds of decisions around water fluoridation were made without input from local constituents, with most decisions coming from various government administrators (Crain et al. (1969)). Although citizens now have more input over the process of water fluoridation, for the time period studied they had limited input.

The result of this political structure is that the adoption of CWF in communities throughout the United States follows little discernible pattern. In support of this, we highlight variation within states in the adoption of community water fluoridation in some of the largest cities in the U.S.

State	City (year fluoridated)
TN	Memphis (1970); Nashville (1953)
OH	Columbus (1973); Cleveland (1956)

MO	Kansas City (1983); St. Louis (1955)
TX	Houston (1982); San Antonio (2000); Dallas (1966), Austin (1973)

There is no obvious pattern in the timing of fluoridation, at least not one that appears correlated with wages. Similar patterns hold if we examine patterns among smaller cities.

We further illustrate the apparently exogenous adoption of water fluoridation by focusing on a specific labor market: the Chicago MSA. Figure 1 plots county fluoridation rates (described in more detail below) for Cook County and the five counties within Illinois immediately adjacent to it for the time period surrounding when the respondents in our sample were born. Before they were born, only Kane County had a considerable rate of fluoridation. Over the next 20 years, there was a considerable increase in fluoridation rates, but also considerable variation in when these areas fluoridated. The order of median family income, however, is unrelated to the order in which the areas fluoridated or the percent fluoridated as of 1979. Furthermore, by 1980, nearly all counties were mostly fluoridated, suggesting no fundamentally different oppositions to CWF. Unless these counties adopted specific programs in tandem with CWF that led to improvements in earnings and we are unable to observe them in the numerous variables we add, this variation in fluoridation identifies the causal effect on labor market outcomes.

To more formally assess whether CWF status is exogenous, we also examine several characteristics of the parents of the NLSY sample and county level measures by CWF status in Table 1. Urban residents are more likely to have fluoridated water than rural residents, which is consistent with the increasing returns to scale in providing CWF due to high fixed costs. Because wages and occupations are likely to differ by urban residence, we also perform analyses using only urban areas. Other than this difference, however, there are no obvious patterns between people with high and low fluoride exposure. For example, parental education – an established factor related to children’s wages as adults – moves up and down across the fluoridation categories. County level income and housing prices – also important factors affecting adult wages – do not vary systematically across fluoridation rates. The supply of dentists as of 1974 does not vary systematically across the categories either. Our fundamental identification assumption is that the unobservable factors affecting wages are uncorrelated with fluoridation status conditional on the included covariates. Although we can never directly test this assumption, these patterns are encouraging.

4. Data

Sources

The data we use in this study combines several secondary data sets in order to capture information on fluoridation status, earnings, and background demographics.[4] The 1992 Water Fluoridation Census compiled by the CDC contains detailed information on the fluoridation status of every public water system in the United States. Each state provided information to the CDC for each water system within the state, including the date fluoridation began, whether the fluoride was naturally occurring or chemically adjusted, the county served, and the population within the county served as of 1990.

For demographic data, we use the geocoded version of the National Longitudinal Study of Youth (NLSY) for information on earnings. The NLSY follows a nationally representative sample of over 12,000 men and women born between the years 1957 and 1964. The survey, which began in 1979, follows individuals every year until 1994, and every other year since then. The NLSY collects detailed information on economic and social behaviors at various points in time. For a measure of earnings, we use the hourly rate of pay from the current or most recent job, a question consistent with CPS questionnaires.

[4] We are unaware of data containing information on earnings, childhood location, and oral health.

A particularly attractive feature of the geocoded version of the NLSY is the availability of the county of each respondent's residence at birth, at age 14, and at the current survey wave. These variables enable us to link individuals with childhood community water fluoridation status from the fluoridation census. County of birth could reflect the county of the hospital rather than residence (this distinction was not made clear in the NLSY questionnaire), so we compute various measurements of exposure, discussed below.

Although we control for individual level characteristics using the NLSY, there may be county level factors that are correlated with fluoridation status and earnings. For example, fluoridated areas may implement other programs simultaneously or dental practices may respond to the local prevalence of tooth decay. We merge numerous county level variables from the 1960 and 1970 City and County Data Books (CCDB) to account for area demographics and from the 1974 County Business Patterns (CBP) to account for the availability of dentists and other health care services during childhood.

In order to detect the channels though which physical appearance affects earnings, we merge data from the Occupational Information Network (ONET), which provides detailed information on attributes of workers in each occupation listed in the 2000 Standard Occupation Classification (SOC) system. For example, occupations that require frequent interactions with consumers are more likely to experience consumer discrimination, so we use data from ONET to identify occupations that meet this criterion. We create a crosswalk from the 2000 SOC to the 1980 Census Occupations Codes provided in the NLSY to assign these attributes to the occupations of the individuals in our samples.

Assigning fluoride exposure

In order to assign childhood fluoride exposure to each individual in the NLSY, we must first determine the percent of each county in the U.S. with access to fluoridated water for the childhood years of our sample. To determine this, we merge the Fluoridation Census data with total population estimates of each county from the 1990 Census of Population and Housing to compute the percent of the county with fluoridated water in 1990. To determine county fluoridation rates for prior years, we assume the percent of the population served by each water system is constant over time. Using the date fluoridation began, we then assign this same percent fluoridated to the county for all years after fluoridation began (and zero to all years prior to fluoridation). If there are multiple fluoridating water districts within a county, as is often the case, we average the percent fluoridated using the population served as of 1990 as weights. To compute cumulative exposure for an individual over a period of years, we compute the mean level of exposure over a specified period of time relevant for oral health. Based on the timing of the effects of water fluoridation, we compute two measures of cumulative fluoride exposure: the mean over the first 5 years of life and the first 12 years of life.

To clarify this assignment, consider a county with only one water district that fluoridates, and began doing so in 1960. As of 1990, this water district served 1000 people within the county and the total population of the county was 5000, suggesting a fluoridation rate of .2 (=1000/5000). The following chart displays how we compute the 5-year cumulative fluoride exposure for individuals from the NLSY cohort.

year	fluoridation start date	population in county served by fluoridated water district as of 1990	county population as of 1990	contemporan-eous fluoride exposure	5-year cumulative fluoride exposure by birth year
1990	1960	1000	5000	0.20	
1968	1960	1000	5000	0.20	
1967	1960	1000	5000	0.20	
1966	1960	1000	5000	0.20	
1965	1960	1000	5000	0.20	
1964	1960	1000	5000	0.20	0.20
1963	1960	1000	5000	0.20	0.20
1962	1960	1000	5000	0.20	0.20
1961	1960	1000	5000	0.20	0.20
1960	1960	1000	5000	0.20	0.20
1959	1960	1000	5000	0.00	0.16
1958	1960	1000	5000	0.00	0.12
1957	1960	1000	5000	0.00	0.08

Since fluoridation began in 1960, the contemporaneous fluoridation rate is .2 for 1960 and later and 0 for 1959 and earlier. Cumulative fluoride exposure for the first 5 years of life for an individual born in 1957 is the mean of contemporaneous fluoridation rates for the years 1957-1961, which is .08 (=(0 + 0 + 0 + .2 + .2)/5). For an individual born in 1964 it is the mean of contemporaneous fluoridation rates for the years 1964-1968, which is .2 (=(.2 + .2 + .2 + .2 + .2)/5).

Since we do not know an individual's county at every single point in time during childhood, a potential concern with this approach for determining exposure is measurement error. We assess the potential extent of this misallocation by performing analyses using only respondents who report the same county of residence at both birth and age 14 in the NLSY, which is roughly 60% of our sample.

Given that fluoride has topical benefits that endure throughout life, it is also essential that we approximate individual's current exposure to fluoride. Since fluoridation status within a community is correlated over time, we do not want to falsely attribute the effect of fluoride exposure during childhood to exposure during adulthood. The fluoridation census ends in 1992, so we assume fluoridation rates are constant after that year. The overall percentage of population receiving fluoridated water has only changed from 56.1% in 1992 to 59% in 2002, the last year for which data is available in the NLSY, suggesting this is not a major concern

Construct validity

Given the concern regarding noise in fluoridation exposure, it is crucial that our method for assigning fluoridation exposure to individuals contains enough signal. To assess this, we examine the effect of fluoridation on adult dental health using the Behavioral Risk Factor Surveillance System (BRFSS). The BRFSS is an annual survey designed to elicit prevalence of major behavioral risks among adults. Beginning in 1995, the survey asked respondents the number of permanent adult teeth missing due to tooth decay or gum disease, and not due to injury or orthodontics. Respondents were given 4 categories to choose from: 1) none; 2) 1-5; 3) 6 or more but not all; and 4) all teeth missing. For assigning fluoridation exposure, the BRFSS only has current county of residence. Although there is considerable mobility in the U.S. – over half of the respondents in the NLSY lived in a different county in the last wave of the survey (when they were between the ages of 37 through 44) than during childhood – our only alternative is to assume current location is the same as the location during childhood to merge the BRFSS with the fluoridation census.

It is important to note several reasons why our estimates may differ from previous studies of the effect of fluoridation on oral health. One, the measurement error by assuming zero mobility throughout life is likely to attenuate estimates if mobility is unrelated to fluoridation status. Two, other studies look at the effect of childhood fluoridation exposure on oral health during childhood, so we are extending this research one step further by looking at oral health during adulthood. Finally, most studies use tooth decay as a measure of oral health. Our use of tooth loss is a more severe outcome than tooth decay, so that it may be more difficult to detect an effect.

Nonetheless, our results suggest that assigned fluoridation status has a strong effect on tooth loss, consistent with the existing dental literature. Table 2 provides estimates from a linear regression of tooth loss against childhood fluoridation exposure, age, race, gender, and state and year dummies for individuals in the same cohort as the NLSY. Because the dependent variable is a categorical variable, we assign individuals the mean tooth loss within the category. The results indicate that water fluoridation significantly reduces tooth loss, which is consistent with previous evidence documenting the benefits of water fluoridation. Changing from a non-fluoridated to fluoridated community results in roughly one-half less tooth loss. Importantly, this establishes that the effects of dental health via water fluoridation may persist into adulthood, and that our measure of fluoridation exposure is valid.

Two other patterns emerge to support our assignment of fluoridation exposure. First, fluoridation should affect oral health by gender similarly. As Table 2 confirms, we find the effect of fluoridation on tooth loss are virtually identical for men and women. Therefore, any differences in the effects of fluoridation by gender would represent differential effects of the labor market rather than differential effects of fluoridation on oral health. Second, low SES children are less able to respond to health shocks than high SES children, so water fluoridation should have a greater impact on tooth loss for low SES children. Table 2 supports this: the effect of water fluoridation on tooth loss is greater for blacks.

5. Methods

<u>Behavioral Model</u>

To highlight the mechanisms whereby oral health affects wages, we provide a brief behavioral model where workers sort into occupations and make investments in oral health, and both employers and consumers discriminate in the labor market. Consider a labor market where wages (w) in occupation j are determined by productivity (q_j), oral health (oh), and human capital of the worker. Some of human capital is affected by oral health (hc), such as absenteeism and self-esteem, and some is not (x). Workers are paid wages according to:

(1) $w_j = f(oh,\ q_j(oh,hc,x))$

Workers invest in oral health, which is affected by CWF and other inputs into dental care (d), such as dentist visits. Their ability to make investments in oral health depends on their total income.

Oral health may affect earnings through several channels. Employers with a taste for more attractive workers offer them higher wages ($\delta f/\delta oh > 0$). Consumers with a preference to deal with more attractive workers results in higher output ($\delta q_j/\delta oh > 0$) and thus higher earnings. If better oral health makes workers more productive by reducing absenteeism or improving self-esteem, then oral health indirectly leads to higher wages ($\delta q_j/\delta hc \cdot \delta hc/\delta oh > 0$). Based on earnings in each occupation, workers sort into occupations that provide the highest wage ($w_j > w_{-j}$).

Four immediate insights arise from this model. One, because CWF and d are substitutes into the production of oral health, workers without access to CWF purchase more d, implying unobserved compensatory behavior is likely in our analysis. For the time period studied, the primary source of compensatory behavior is through the use of dentists. We are fortunately able to control for the number of dental practices per capita to account for the availability of dentists.

Two, if oral health is a normal good, then workers with higher wages purchase more of *d*, giving rise to a simultaneity bias. We alleviate this concern by using an intervention in childhood so that temporal precedence is clearly established.

Three, because consumer discrimination can only arise in occupations where workers interact with consumers, some occupations may have a higher appearance premium than others. Using data from ONET, we identify occupations with frequent interactions with external customers to test this.

Four, the effect of oral health on earnings may vary across individuals. Differences may arise by gender if men and women are held to different standards regarding physical appearance. For example, Wolf (1991) argues that women are judged against appearance standards set forth by the media while men are not, which may generate greater employer discrimination against less attractive women. Different effects by gender may also arise because of selection into gender-traditional occupations where the importance of physical appearance varies. For example, men are more likely to work in construction and manufacturing industries, where workers do not interact with consumers, while women are more likely to enter occupations, such as wait staff, cashier, or teacher, where consumer interaction is the norm. If consumer discrimination is important, women may choose particular occupations depending on subjective views of their physical appearance.

Empirical testing of the various mechanisms involves the following regression:

(2) $$y = \beta_1 oh + \beta_2 x + \beta_3 occ + \beta_4 oh*occ + \beta_5 hc + \varepsilon$$

where y is the log of hourly earnings and *occ* is an occupation where appearance matters for earnings. Evidence that $\beta_1 > 0$ implies employer discrimination; $\beta_3 > 0$ implies occupational sorting; $\beta_4 > 0$ implies consumer discrimination – wages are higher for individuals given their occupational choice; and $\beta_5 > 0$ implies productivity effects.

Although fluoridation is a community level treatment, Figure 1 also demonstrates the considerable spatial variation in fluoridation rates within a small area. Given their close proximity, this gives rise to varying rates of oral health within a given labor market such that an equilibrium with a beauty premium can arise.

Structural model

We unfortunately do not observe oral health in our data, so we must estimate a reduced form relationship between earnings and childhood water fluoridation. To guide the interpretation and specification of our econometric model, we provide a basic structural model. First we focus on a model to determine whether oral health has an impact on earnings by removing the potential mechanisms from equation (2):

(3) $y = \beta_1 oh + \beta_2 x + \varepsilon$

Note at this stage we exclude endogenous choice variables that may be affected by oral health (*hc*), which is consistent with approaches taken elsewhere (Persico et al., (2004); Neal and Johnson (1996); Heckman (1998)).

Oral health is determined by:

(4) $oh = \alpha_1 wfc + \alpha_2 wfa + \alpha_3 d + \eta$

where *wf* indicates fluoride exposure during adulthood (*a)* and childhood (*c*) and *d* are substitutes for water fluoridation, such as the use of formal dental care through dentists.[5] α_1 represents the direct effect of childhood exposure to water fluoridation on oral health because fluoridation exposure during childhood helps developing teeth become permanently resistant to decay. The

[5] Note that fluoridated toothpaste and dietary fluoride drops were unavailable for the population studied, so the use of formal dental care is the main substitute technology available.

dental literature implies that $\alpha_1 > \alpha_2 > 0$: the ingestion of fluoride during childhood has a larger effect on adult oral health than ingestion as an adult.

Substituting equation (4) into (3) yields the following reduced form relationship:

(5) $y = \pi_1 wfc + \pi_2 wfa + \pi_3 d + \beta_2 x + v$

where π_1 $(= \alpha_1 \cdot \beta_1 = \delta oh/\delta wfc \cdot \delta y/\delta oh)$ represents the reduced form effect of childhood water fluoridation on earnings. Since we excluded *wfc* from equation (3) on the assumption that water fluoridation does not directly affect labor market outcomes, fluoridation only affects earnings indirectly through its impact on oral health. If we observe *x* and *d* and find that $\pi_1 > 0$, this implies that better oral health leads to higher wages ($\beta_1 > 0$).

Although we use the rich covariates available in the NLSY and merge numerous county level variables to capture *x* and *d*, it is unlikely that we can observe all covariates. We are particularly concerned about unobserved compensatory behavior because the demand for alternative dental services likely depends on CWF, as our behavioral model highlights. For example, it is possible that unfluoridated areas have more dentists, which lowers the price of dental care and increases the use of fluoride substitutes. Although we control for the number of dentists available in each county, to the extent that we do not adequately capture compensatory behavior our estimate of π_1 instead is $\beta_1 \cdot (\alpha_1 + \alpha_3) = \delta y/\delta oh \cdot (\delta oh/\delta wfc + \delta d/\delta wfc)$. Given that the correlation between *wfc* and *d* is likely to be negative, this implies that our estimates understate the effect of water fluoridation on wages.

Furthermore, we expect compensatory behavior to vary by SES if wealthier families are better able to afford or are more knowledgeable about substitute care. Data from the 1986-87 National Survey of Oral Health in U.S. School Children indicate that 68% of white children residing in unfluoridated communities supplement their diets with fluoride tabs or drops, while less than 46% of blacks and Hispanics do. The percent of decayed teeth that are filled is also considerably higher for white children. Furthermore, table 2 indicates that the effect of water fluoridation on tooth loss is greater for blacks. Therefore, we expect π_1 to be larger for low SES individuals, though we can not necessarily distinguish whether this is due to α_1 or β_1.

If we find that $\pi_1 > 0$, as our results suggest, we then explore the mechanisms by which oral health affects wages. To do this, we substitute equation (4) into equation (2) to get:

(6) $$y = \pi_1 wfc + \pi_2 wfa + \pi_3 d + \beta_2 x + \beta_3 occ + \pi_4 wfc{*}occ + \beta_5 hc + \varepsilon.$$

As we successively add *hc* and *occ* to our model, we attribute the degree to which π_1 obtained from equation (5) changes to that channel. For example, if we find that adding *oh*occ* to the regression lowers our estimate of π_1 by 0.25, this implies consumer discrimination explains 25% of the effect of oral health on earnings. After adding all potential mechanisms, any residual effect of π_1 reflects employer discrimination.

<u>Empirical model</u>

To determine the effect of water fluoridation on labor market outcomes, we estimate the following statistical model:

(7) $$y_{ijtcs} = \pi_1 wfc_{jcs} + \pi_2 wfa_{tcs} + \pi_3 d_{jcs} + \beta_2 x_{ijcs} + \delta_s + \varphi_t + \sigma_j + \upsilon_{ijtcs}.$$

y_{ijct} is the (log) hourly wage of individual i in cohort j at time t, who resided in county c of state s during childhood. For d and x, we include numerous individual level and county level demographics, shown in Table 1. States with higher rates of fluoridation may have other generous programs that affect health and wages, so we include state fixed effects (δ_s) to limit comparisons to counties within the same state. φ_t is a time fixed effect that non-parametrically controls for lifecycle earnings profile. σ_j are cohort fixed effects to account for the increasing prevalence of water fluoridation over time. υ is an error term that includes an individual specific effect (we observe individuals multiple times), a county of birth specific effects (fluoridation is assigned at the county level), and an idiosyncratic term. Given this structure of the error term, we cluster standard errors at the county of birth to allow for arbitrary heteroskedasticity and serial correlation within a county.[6]

Our main test regards the parameter π_1. Given that *wfc* lies in the range of 0 to 1, we can interpret π_1 as the effect on earnings from living in a fluoridated area relative to living in a non-fluoridated area. Although we cannot determine whether individuals residing in an area with fluoridated water are necessarily consuming that water, there were few alternatives to public drinking water during the period studied. If we find that $\pi_1 > 0$, this suggests that individuals with greater fluoride exposure earn higher wages. Given that water fluoridation improves oral health ($\alpha_1 > 0$), this implies that better oral health leads to higher wages ($\beta_1 > 0$).

6. Results

<u>Main results</u>

Table 3 shows our main results in which we assign fluoride status based on county at age 14 and measure fluoride exposure as the average over the first 5 years, the point at which the front 4 teeth develop. To assess if gender differences exist, in all analyses we estimate (7) separately by gender. Furthermore, given that urban residence is an important predictor of fluoridation status, we also eliminate rural areas by estimating (7) only for counties within an MSA. We also assess sensitivity of estimates of π_1 to variables included in *x* and *d*. We begin with models that do not include these variables, and then assess how estimates for π_1 change to the inclusion of these variables. If we find little evidence that it changes, this suggests our model is less likely to suffer from omitted confounding.

[6] Note that the individual effect is nested within the county effect, so clustering at the county accounts for this.

Using only the NLSY covariates for *x* and *d*, we find a positive effect of CWF on earnings of 3.7% for all individuals, with effects slightly stronger for women than men, though the differences are not appreciable. In the second column we add county level variables from the 1960 CCDB, and results fall to just over 2% for all groups. In the third column, we add 1970 CCDB variables, and estimates are comparable to column (2). We repeat this same set of specifications for urban counties in columns (4)-(6), and find our estimates are generally unaffected by the inclusion of controls, which suggests the variation in estimates for columns (1)-(3) is due to additional covariates capturing the degree to which an area is urban. Estimates from our preferred specification (column (6)), indicate that water fluoridation has a statistically significant effect on earnings of roughly 4% overall, with the effect slightly larger for women than for men.

Table 4 shows further sensitivity analyses of our results. Column (1) repeats results from our preferred specification, and the next 4 columns assess the sensitivity of our estimates to various trends. For example, although we are including state and age fixed effects, it is possible that earnings profiles within states vary over time. Adding cohort-age dummies (column 2), age-state dummies (column 3), cohort-state dummies (column 4), and cohort-age-state dummies (column 5) have virtually no effect on the estimates.

As another specification test, we limit our analysis to only counties that eventually fluoridated as of 1992, the last year of the fluoridation census. This eliminates the concern that counties that never fluoridate are systematically different than counties that do. In a sense, this specification check presents a model that does not simply exploit the cross-sectional variation in water fluoridation but also exploits the timing of CWF adoption. The results, shown in column (6), reveal a smaller effect for men but the effect for women is virtually unchanged. In the last column, we eliminate counties with greater than 1 million people as of 1960 for fear that these influential areas are driving our results.[7] Results for women are again unaffected, and results for men are now close to zero.

In the second panel of Table 4, we examine the sensitivity of our results to alternate measures of fluoride exposure. Column 1 repeats the results from our preferred specification in Table 3. In column 2, we use county of birth to assign fluoride exposure, and find the effect on earnings are smaller when compared to column 1, though the difference is not statistically significant. This change might be due to mobility that is correlated with earnings and fluoride or to mismeasurement of county of residence at birth. The third column, which reports results for the sample that did not move between birth and age 14, suggests that mismeasurement is the more likely reason for the weaker results for county of birth: the magnitude of effects for women using this measure are larger than either the county of birth or county at age 14 measures, suggesting that our preferred estimates are attenuated. In the last column, we measure fluoridation exposure through the first 14 years, the point at which all adult teeth are formed. These results are also comparable to the preferred results.

In sum, the results from Tables 3 and 4 suggest that fluoride exposure in childhood has a robust, statistically significant effect on hourly earnings of women. The effect for men is less robust and is often statistically insignificant. The higher effect for women is consistent with our hypotheses that 1) women may be more greatly affected by consumer or employer discrimination and 2) that women may be more likely to select into occupations based on their physical appearance. The lack of sensitivity of our estimates to numerous county level variables, various

[7] Counties (major cities) with population over 1 million as of 1960 are Allegheny (Pittsburgh), Cook (Chicago), Cuyahoga (Cleveland), Erie (Buffalo), Harris (Houston), Los Angeles, Middlesex (Boston area), Milwaukee, Nassau (Long Island), and Wayne (Detroit).

non-parametric trends, and alternative fluoridation exposure assignment strengthens our claim that we are uncovering a causal effect of fluoridation on earnings.

Exploring Mechanisms

We consider a variety of mechanisms through which childhood fluoridation might affect earnings by adding variables that reflect these mechanisms to the regression specified in equation (7). If these variables mediate how fluoridation affects wages, then including them should lower the estimated effect of fluoridation on earnings relative to baseline estimates. As measures of human capital, we control for job tenure, a self-reported measure of health limitations, a self-esteem score based on the Rosenberg Self-Esteem Scale, and participation in athletics and clubs during high school. To assess consumer discrimination and occupational sorting, we include ONET attributes to reflect the degree to which physical appearance may affect earnings or occupation selection. Assuming we adequately control for these channels, any residual effect of π_1 after controlling for these variables reflects employer discrimination.

Shown in column 1 of Table 5 are the baseline results from our preferred specification in Table 3. Adding the human capital measures in column (2) has no effect on our baseline estimates, suggesting health and human capital do not mediate the relationship between oral health and earnings. Adding occupational information along with its interaction with wf, shown in column (3), however, dramatically reduces the effect: for men and women the residual effect of fluoridation on earnings is now zero. It is remarkable that none of the numerous covariates included in Tables 3 and 4 reduced the effect of fluoridation, and only when we account for occupational sorting and consumer discrimination does the effect disappear. In column (4) we add both types of mechanisms and again find no effect. This suggests all of the effect of oral health on earnings is through occupational sorting and consumer discrimination

Effects by SES

The results in Table 2 suggested that the effects of fluoride exposure on tooth loss might be concentrated among those of lower income. We next examine whether the effects of fluoride exposure on earnings are likewise concentrated among those who would have had less access to alternative tooth loss prevention interventions in childhood. To assess the effects of fluoridation by SES, it is important that we use childhood measures of SES that are not confounded by water fluoridation. Therefore, we explore the effects of fluoridation on earnings separately by race and *parental* occupation. Both of these factors are predetermined and therefore unaffected by fluoridation exposure. It is unfortunately not possible to distinguish whether any difference in effects by SES is due to differential effect of water fluoridation on oral health or differential effects of oral health on earnings.

In Table 6, we divide the sample into subgroups based on parental socioeconomic status and race, and present results from our preferred specification for all individuals and separately for men and women. The first three columns divide the sample into thirds based on respondents whose parents had low, medium, and high occupations status (based on the Duncan Socioeconomic Index) when respondents were 14. The results suggest that, for men, the effects are never large and do not follow any consistent pattern. For women, however, the effects of fluoride exposure on adult earnings decrease monotonically as parental occupational status rises. The final two columns in Table 6 compare black and white samples. The effects of fluoride exposure on subsequent earnings are much larger among black men and women than among whites. These effects are large in magnitude: the effect of 10% from fluoride exposure for black women roughly translates into a return of about $1/hour.[8]

[8] Average hourly earnings in $1998 in the NLSY for women who are black is roughly $11.

In the second panel we explore the extent to which occupational sorting and consumer or employer discrimination vary by SES. In contrast to the results for the entire population, controlling for occupation traits and its interaction with *wf* does little to mediate the overall effect of water fluoridation. This suggests employer discrimination explains most of the effect of oral health on earnings for low SES individuals.

Effect on Marriage Market Outcomes

In addition to affecting labor market outcomes, oral health may have an impact on non-labor market outcomes, such as the marriage market. For example, more attractive individuals may be more likely to marry, or, conditional on marriage, may be more likely to marry a spouse with higher education. To explore this, we estimate (7) using marital status, characteristics of the spouse, and employment status as the dependent variable. Rather than use repeated observations on individuals, we create a summary measure for each individual (and omit age dummies) that better reflect marriage opportunities. For example, although more attractive individuals may be more likely to marry, they may be more likely to divorce if options outside of marriage are also better, so the effect on marital status at any point in time is ambiguous. To define these variables, we use an indicator variable for whether the individual is ever married (and estimate linear probability models) and the highest level of education attained by any spouse (if married) as the dependent variable.

The estimates for marriage market effects by gender and SES are shown in Table 7. Focusing on whether an individual is ever married, we find women exposed to CWF are 9% more likely to marry but no effect for men. When we focus on the SES breakdown, we again find an SES gradient, but only for women. Turning to education of spouse, we find an effect for men but not women. An SES gradient exists for women, though estimates are imprecise. These results for marriage market outcomes confirm that we are finding an effect of water fluoridation exposure during childhood on adult outcomes.

Falsification Test

As a falsification test, we assess whether water fluoridation affects non-dental related health outcomes: height and AFQT. Water fluoridation does not have a direct effect on height[9] or intelligence, so finding an effect would suggest misspecification.[10] Therefore, if we find that individuals from counties with greater rates of water fluoridation are taller or smarter, for example, this suggests these counties also provided additional unobserved investments that affect adult earnings.

The results by gender and SES are shown in Table 8. As with the marriage market regressions, we use only one measure of height – that obtained in the 1981 interview when respondents were between the ages of 16 and 23 – and one measure of AQFT (and drop the age dummies). In all of our regressions we find no effect of water fluoridation on height. Focusing on females, where we find the largest effect on earnings, our estimates for height are generally smaller than the standard errors. For AFQT we find one statistically significant for low SES individuals, but given the number of regressions presented in this table we expect to find at least one statistically significant effect at 5%. These results support that we are finding a causal effect of water fluoridation on earnings.

7. Conclusion

The most common complaint from individuals who lack health insurance concerns their lack of access to dental care (Sered and Fernandopulle (2005)). The out of pocket expenses

[9] We recognize a limitation of this test is that water fluoridation may affect the ability to consume foods through tooth decay. This is highly unlikely to lead to stunting, though.
[10] Although height in developed countries is often viewed as an exogenous variable largely unaffected by environmental factors, research demonstrates that up to 20% of the variation in height across individuals in developed countries is due to childhood living conditions (Silventoinen (2003)).

prevent many from seeking not only preventative care but also treatment for ongoing conditions. Instead, they often adjust their lifestyles to cope with their deteriorating health, such as altering their diets by consuming more soft, processed foods, consuming alcohol as a salve, or hiding their teeth when they talk or smile. The potential impact from poor oral health extends beyond teeth, but such links have not been systematically investigated.

In this study, we examine the impact of poor oral health on labor market outcomes. We exploit the quasi-random timing of the adoption of community water fluoridation to identify the impact of fluoridation exposure during childhood on earnings as adults. Our results indicate that access to water fluoridation during childhood increases earnings by roughly 4% overall, with a larger effect for women. Furthermore, the effects are largest for individuals from low SES families. All results are remarkably robust to alternative specifications, including controls for various trends and numerous community level variables.

The effects of community water fluoridation for the populations we study may not necessarily generalize to communities fluoridating today for at least two reasons. One, the advent of other products designed to reduce tooth decay, such as fluoridated toothpaste and dietary fluoride drops, has made substitute technologies more affordable. For example, fluoridated toothpaste became widespread in the late 1960s, after most individuals in our data were no longer children. Two, spillover effects from water fluoridation have greatly increased. For example, fluoridated water has worked its way through the food chain – it is now used in most crops grown with irrigated water and in the production of milk and soft drinks – so many individuals are exposed regardless of local water fluoridation status (Leverett (1982)). Consistent with this is evidence that the effectiveness of community water fluoridation has dropped from 50-60% in the 1940s to 15-20% today.

Although the effects of water fluoridation may be different today than for the time period studied, the goal of this paper is to identify the effects of oral health – not CWF – on labor market outcomes. Tooth decay remains widespread today, and other dental interventions, such as dental sealants and fluoride treatments, though more expensive than water fluoridation, are highly effective means for reducing tooth decay. Moreover, not all tooth loss is due to decay and preventable through fluoride; dental care in adulthood reduces tooth loss due to periodontal disease. Furthermore, restorative care, such as implants and dentures, can compensate for tooth loss. The costs of these interventions are known, but the value of the benefits is not. Our estimates of the economic value of teeth in the labor market provide evidence of a largely overlooked benefit of oral health that can be used in assessing further CWF or improved access to preventive and curative dental care for children and adults.[11]

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[11] As our results suggest, for some populations the magnitude of the labor market costs of missing teeth may exceed the costs of remedial intervention, so that individuals appear to not be making privately optimal decisions in this area. If this is the case, public policy intervention might take the form of information or reduction of liquidity constraints.

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Figure 1: Fluoridation Rates in Chicago MSA over Time

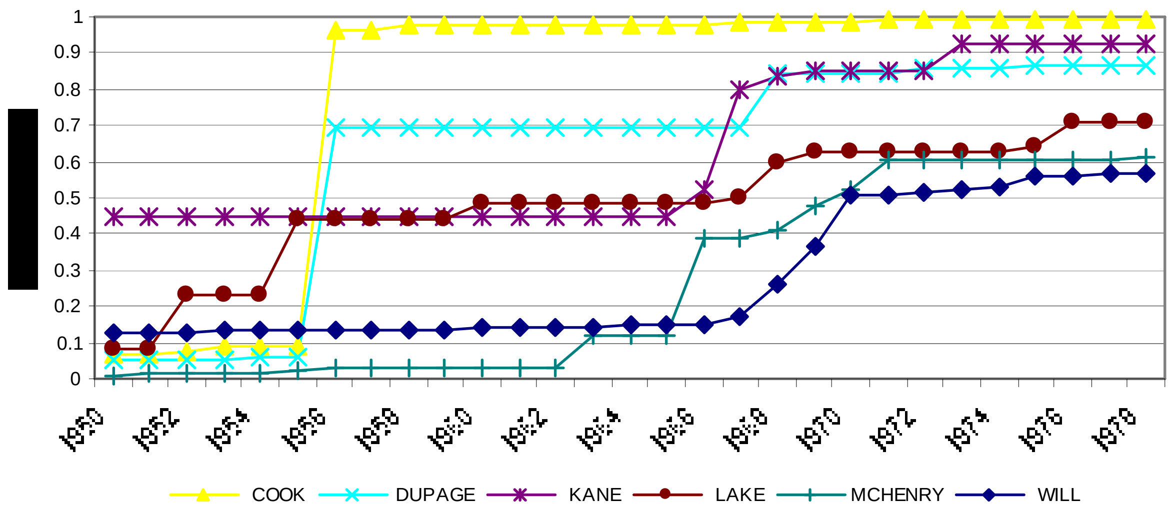

Table 1. Demographic Statistics by Fluoridation Status

fluoridation status:	0	0-.2	.2-.4	.4-.6	.6-.8	.8-1
A. NLSY variables						
urban residence	0.77	0.75	0.71	0.76	0.80	0.95
foreign language	0.21	0.20	0.11	0.15	0.20	0.22
magazine regularly	0.57	0.56	0.61	0.68	0.57	0.57
newspaper regularly	0.74	0.78	0.79	0.87	0.79	0.78
library card	0.68	0.70	0.73	0.76	0.73	0.78
# of siblings	3.81	3.78	3.54	3.57	4.02	3.67
education mother	10.14	10.34	10.89	10.92	10.09	10.81
education father	9.37	9.58	9.88	10.59	9.51	9.86
mom & dad in HH	0.68	0.69	0.70	0.76	0.71	0.66
mom born in US	0.90	0.92	0.95	0.94	0.93	0.90
dad born in US	0.88	0.91	0.95	0.95	0.92	0.90
no religion	0.04	0.05	0.04	0.03	0.03	0.04
Protestant	0.05	0.05	0.06	0.05	0.04	0.05
Baptist	0.30	0.30	0.33	0.19	0.25	0.27
Episcopalian	0.01	0.02	0.01	0.02	0.02	0.01
Lutheran	0.06	0.05	0.06	0.09	0.09	0.04
Methodist	0.07	0.09	0.11	0.09	0.08	0.07
Presbyterian	0.03	0.03	0.03	0.03	0.04	0.02
Roman Catholic	0.33	0.31	0.26	0.38	0.36	0.38
Jewish	0.01	0.01	0.01	0.02	0.01	0.01
other religion	0.11	0.11	0.10	0.11	0.08	0.09
male	0.51	0.50	0.51	0.52	0.48	0.49
black	0.23	0.24	0.26	0.13	0.20	0.32
hispanic	0.17	0.14	0.07	0.07	0.16	0.18
height	67.23	67.08	67.42	67.58	67.10	67.03
AFQT	40.04	40.11	39.46	46.20	41.76	38.44
duncan SEI - mom	17.63	17.40	19.11	18.15	15.26	19.49
duncan SEI - dad	28.75	31.13	29.54	36.09	31.31	30.43
highest grade completed	12.11	12.14	11.99	12.20	11.95	12.11

Table 1. Demographic Statistics by Fluoridation Status (continued)

fluoridation status:	0	0-.2	.2-.4	.4-.6	.6-.8	.8-1
B. 1960 Variables						
pop pct change 1950-60	24.31	32.14	25.46	25.54	33.32	25.16
pop pct rural 1960	10.28	8.61	10.61	8.60	6.65	1.31
median age 1960	29.45	28.03	28.86	28.89	27.67	30.30
pct pct >65 1960	9.59	8.53	8.97	9.07	8.23	8.83
pop pct <5 1960	11.03	11.87	11.51	11.79	12.38	11.46
death rate 1960	9.43	8.84	8.76	9.07	8.35	9.61
marriage rate 1960	8.84	8.36	9.24	8.26	7.36	7.87
employ rate 1960	95.44	94.69	95.19	94.50	95.40	94.98
pct employ manuf 1960	23.17	25.41	28.67	28.45	31.28	24.03
pct employ constr 1960	6.26	6.37	6.09	6.14	5.85	5.47
pct employ trade 1960	17.83	18.15	17.82	17.79	18.02	19.51
vacancy rate 1960	89.44	89.81	90.67	90.75	92.48	94.00
pct homeowners 1960	61.20	65.78	68.08	67.40	66.67	55.91
pct education exp. 1957	46.78	50.02	46.54	48.48	43.92	37.62
local govt debt ratio 1957	1.22	1.35	1.38	1.28	1.40	1.53
pct vote democ president 1960	0.56	0.41	0.37	0.49	0.60	0.77
pct vote correct president 1960	58.08	57.43	57.53	58.14	59.43	54.13
population 1960	907109	353938	292793	350786	270280	1422716
pop/sq. mile 1960	1577	663	1052	823	753	4627
% pop non-white 1960	12.09	12.81	11.53	8.62	8.44	16.11
% pop with >= HS degree 1960	38.28	40.36	39.71	40.47	40.05	43.28
median schooling 1960	10.16	10.40	10.35	10.56	10.26	10.95
% pop < 5 yrs schooling 1960	10.86	9.91	9.13	7.65	10.69	7.74
household size 1960	4.00	4.09	4.01	4.02	4.07	4.00
% urban 1960	62.43	61.96	58.24	64.16	71.00	91.53
median family income 1960	5106	5352	5313	5548	5662	6136
C. 1970 Variables						
pop pct change 1960-70	12.55	16.59	13.52	16.50	14.39	9.00
pop pct rural 1970	5.95	4.80	6.09	5.09	3.64	0.69
median age 1970	29.31	27.64	28.63	27.55	26.89	29.07
pop pct >65 1970	10.72	9.31	10.01	9.41	8.95	9.86
pop pct <5 1970	8.30	8.59	8.33	8.58	8.84	8.32
death rate 1970	10.23	9.24	9.50	9.16	8.61	10.08
marriage rate 1970	11.03	10.59	13.30	11.97	10.09	9.93
employ rate 1970	95.00	95.52	96.12	95.65	95.70	95.82
pct employ manuf 1970	24.06	25.36	29.21	27.96	28.85	22.83
pct employ constr 1970	6.31	6.43	6.24	5.79	5.87	5.29
pct employ trade 1970	19.52	20.07	19.51	19.85	20.57	21.13
vacancy rate 1970	92.92	92.99	93.79	94.07	94.25	94.69
pct homeowners 1970	62.39	67.02	69.33	68.27	68.24	55.71
pct education exp. 1967	50.85	55.03	55.79	53.86	52.74	44.33
local govt debt ratio 1967	0.92	0.98	0.97	1.00	1.13	1.24
pct vote democ president 1968	0.27	0.37	0.34	0.43	0.41	0.82
pct vote correct president 1968	52.46	51.44	49.60	53.35	55.20	53.30
population 1970	1058852	416545	329058	394542	316673	1516499
pop/sq. mile 1970	1595	729	1054	872	805	4549
% pop non-white 1970	13.06	12.96	12.04	9.06	9.23	20.25
% pop with >= HS degree 1970	48.34	50.95	49.63	52.37	51.30	52.93
median schooling 1970	11.26	11.61	11.50	11.78	11.56	11.89
% pop < 5 yrs schooling 1970	7.49	6.52	5.89	4.79	7.59	5.64
household size 1970	3.97	4.03	3.96	4.02	4.05	4.08
% urban 1970	65.48	65.90	60.01	66.97	74.41	93.96
median family income 1970	8672	9248	9207	9726	9584	9916
median house price 1970	16040	16054	16047	16596	16495	17969
median rent 1970	95.73	101.00	97.58	102.86	103.95	110.44
physicians/1000 pop 1974	2.44	2.43	2.47	2.56	2.63	2.64
dentists/1000 pop 1974	1.02	1.07	1.03	1.02	1.09	1.01
current fluoridation status	0.34	0.47	0.61	0.64	0.69	0.85
N	2,892	3,455	816	542	903	1,313

Table 2. Tooth Loss in BRFSS by Gender & Race using NLSY Cohort

A. Number of teeth missing

	all	male	female	white	black
0	26,741	11,496	15,245	22,085	1,563
1-5	15,189	6,470	8,719	10,701	2,154
>5	2,441	890	1,551	1,742	395
all	479	172	307	391	48

B. Linear Regression Results

	1	2	3	4	5
	all	male	female	white	black
fluoridation s	-0.599	-0.623	-0.580	-0.575	-0.852
	[0.124]**	[0.154]**	[0.153]**	[0.149]**	[0.300]**
Observations	44850	19028	25822	34919	4160

Notes: * significant at 5%; ** significant at 1%. Standard errors that adjust for clustering at the county level in brackets. All specifications include state and year dummies, and controls for age, race, and gender.

Table 3. Regression Results of Fluoridation Status on Log Hourly Earnings by Gender

	1	2	3	4	5	6
1. All						
Fluoridation status	0.037	0.022	0.027	0.029	0.029	0.038
	[0.018]*	[0.015]	[0.014]	[0.021]	[0.017]	[0.018]*
	n=94938, i=9629, c=977			*n=74216, i=7478, c=509*		
2. Male						
Fluoridation status	0.035	0.023	0.028	0.027	0.025	0.032
	[0.021]	[0.021]	[0.021]	[0.022]	[0.024]	[0.025]
	n=49135, i=4816, c=701			*n=38217, i=3735, c=417*		
3, Female						
Fluoridation status	0.041	0.024	0.023	0.039	0.039	0.044
	[0.023]	[0.019]	[0.019]	[0.027]	[0.020]*	[0.020]*
	n=45803, i=4813, c=676			*n=35999, i=3743, c=382*		
County in MSA	*N*	N	N	*Y*	Y	Y
State dummies	Y	Y	Y	Y	Y	Y
Cohort dummies	Y	Y	Y	Y	Y	Y
Age dummies	Y	Y	Y	Y	Y	Y
Current fluoridation status	Y	Y	Y	Y	Y	Y
Age 14 NLSY covariates	Y	Y	Y	Y	Y	Y
1960 County level covariates	N	Y	Y	N	Y	Y
1970 County level covariates	N	N	Y	N	N	Y

Notes: * significant at 5%; ** significant at 1%. Heteroskedasticity-consistent standard errors that adjust for clustering at the county level in brackets. Variables included in 'Age 14 NLSY covariates' and '1960/70 County level variables' are listed in table 1.

Table 4. Sensitivity Analysis

A. Alternative specifications

	1	2	3	4	5	6	7
1. All							
Fluoridation status	0.038	0.039	0.041	0.028	0.030	0.029	0.017
	[0.018]*	-	-	-	-	[0.019]	[0.021]
n	74216	74216	74216	74216	74216	66804	62398
2. Male							
Fluoridation status	0.032	0.032	0.032	0.014	0.020	0.014	-0.002
	[0.025]	-	-	-	-	[0.027]	[0.031]
n	38217	38217	38217	38217	38217	34279	32010
3, Female							
Fluoridation status	0.044	0.044	0.047	0.040	0.038	0.040	0.038
	[0.020]*	-	-	-	-	[0.022]	[0.023]
n	35999	35999	35999	35999	35999	32525	30388
Cohort-age dummies	N	Y	N	N	N	N	N
Age-state dummies	N	N	Y	N	N	N	N
Cohort-state dummies	N	N	N	Y	N	N	N
Cohort-age-state dummies	N	N	N	N	Y	N	N
CWF 92 > 0	N	N	N	N	N	Y	N
1960 population < 1m	N	N	N	N	N	N	Y

B. Alternative measures of fluoride exposure

	1	2	3	4
1. All				
Fluoridation status	0.038	0.021	0.028	0.030
	[0.018]*	[0.014]	[0.023]	[0.021]
n	74216	66584	43413	74216
2. Male				
Fluoridation status	0.032	0.018	-0.006	0.039
	[0.025]	[0.020]	[0.038]	[0.028]
n	38217	34370	22669	38217
3, Female				
Fluoridation status	0.044	0.028	0.054	0.024
	[0.020]*	[0.019]	[0.025]*	[0.022]
n	35999	32214	20744	35999
Exposure years:	5	5	5	14
Age at residence:	14	birth	14=birth	14

Table 5. Mechanisms

	1	2	3	4
1. All				
Fluoridation status	0.038	0.028	-0.009	-0.023
	[0.018]*	[0.015]	[0.035]	[0.032]
n	74204	74204	74204	74204
2. Male				
Fluoridation status	0.032	0.021	-0.009	-0.03
	[0.025]	[0.024]	[0.043]	[0.041]
n	38213	38213	38213	38213
3, Female				
Fluoridation status	0.044	0.039	0.008	0.014
	[0.020]*	[0.018]*	[0.051]	[0.047]
n	35991	35991	35991	35991
Productivity variables	N	Y	N	Y
Occupation variables	N	N	Y	Y

Table 6. Regression Results of Fluoridation Status on Log Hourly Earnings by SES

	Low occupation 1	Middle occupation 2	High occupation 3	Black 4	White 5
A. Baseline					
1. All					
Fluoridation status	0.088	0.078	-0.018	0.115	0.037
	[0.030]**	[0.026]**	[0.029]	[0.034]**	[0.024]
n	21717	24641	27846	18335	42701
2. Male					
Fluoridation status	0.042	0.053	0.038	0.152	0.038
	[0.041]	[0.048]	[0.038]	[0.059]*	[0.034]
n	11037	13278	13898	9360	21974
3, Female					
Fluoridation status	0.138	0.105	-0.033	0.101	0.046
	[0.042]**	[0.032]**	[0.037]	[0.055]	[0.026]
n	10680	11363	13948	8975	20727
B. Mechanisms					
1. All					
Fluoridation status	-0.005	0.029	-0.048	0.131	-0.028
	[0.049]	[0.055]	[0.053]	[0.066]*	[0.045]
n	21717	24641	27846	18335	42701
2. Male					
Fluoridation status	-0.062	0.008	0.052	0.211	-0.03
	[0.066]	[0.083]	[0.062]	[0.080]**	[0.057]
n	11037	13278	13898	9360	21974
3, Female					
Fluoridation status	0.102	0.165	-0.178	0.136	0.004
	[0.080]	[0.095]	[0.092]	[0.091]	[0.081]
n	10680	11363	13948	8975	20727

Table 7. Regression Results of Fluoridation Status on Marriage Market Outcomes by Gender and SES

	All 1	Low occupation 2	Middle occupation 3	High occupation 4	Black 5	White 6
A. Ever Married						
1. All						
Fluoridation status	0.028	0.031	0.044	0.002	0.018	0.014
	[0.018]	[0.037]	[0.036]	[0.030]	[0.057]	[0.023]
n	7988	2429	2653	2906	1962	4730
2. Male						
Fluoridation status	-0.024	-0.043	0.044	-0.036	-0.016	0.005
	[0.027]	[0.058]	[0.054]	[0.045]	[0.093]	[0.038]
n	4003	1195	1375	1433	984	2384
3, Female						
Fluoridation status	0.091	0.151	0.076	0.067	0.069	0.027
	[0.025]**	[0.049]**	[0.045]	[0.037]	[0.080]	[0.026]
n	3985	1234	1278	1473	978	2346
B. Education of spouse (if married)						
1. All						
Fluoridation status	0.145	0.440	-0.167	0.197	0.063	0.060
	[0.102]	[0.209]*	[0.168]	[0.185]	[0.302]	[0.130]
n	5833	1613	1956	2264	1137	3706
2. Male						
Fluoridation status	0.271	0.378	0.115	0.251	0.255	0.244
	[0.132]*	[0.342]	[0.245]	[0.232]	[0.744]	[0.170]
n	2709	726	938	1045	547	1720
3, Female						
Fluoridation status	0.001	0.264	-0.240	-0.021	0.660	-0.173
	[0.151]	[0.305]	[0.259]	[0.272]	[0.484]	[0.192]
n	3124	887	1018	1219	590	1986

Table 8. Regression Results of Fluoridation Status on Teenage Height and AFQT by Gender and SES

	All	Low occupation	Middle occupation	High occupation	Black	White
	1	**2**	**3**	**4**	**5**	**6**
A. Height						
1. All						
Fluoridation status	0.132	0.403	-0.249	0.214	-0.342	0.116
	[0.130]	[0.274]	[0.275]	[0.200]	[0.303]	[0.154]
n	7988	2429	2653	2906	1962	4730
2. Male						
Fluoridation status	0.082	0.416	-0.364	0.266	-0.824	0.225
	[0.186]	[0.375]	[0.389]	[0.288]	[0.620]	[0.225]
n	4003	1195	1375	1433	984	2384
3, Female						
Fluoridation status	0.195	0.666	0.047	0.367	0.116	0.049
	[0.157]	[0.384]	[0.343]	[0.248]	[0.455]	[0.182]
n	3985	1234	1278	1473	978	2346
B. AFQT						
1. All						
Fluoridation status	0.13	3.626	-1.081	-0.61	-0.323	0.243
	[0.969]	[1.689]*	[1.701]	[1.550]	[1.742]	[1.156]
n	6938	2336	2530	2793	1910	4511
2. Male						
Fluoridation status	1.476	1.791	-0.659	0.454	-5.249	1.45
	[1.297]	[2.544]	[2.430]	[2.183]	[3.567]	[1.698]
n	3449	1142	1312	1367	956	2265
3, Female						
Fluoridation status	-1.302	3.239	-1.174	-0.736	0.611	-0.543
	[1.424]	[2.242]	[2.626]	[2.065]	[2.953]	[1.582]
n	3489	1194	1218	1426	954	2246