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Smile! The Economic Value of Teeth
(hoping we haven't bit off more than we can chew…)

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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 effect of access to water fluoridation during childhood on labor market earnings as adults. The politics surrounding the adoption of water fluoridation by local water districts suggests exposure to fluoride during childhood is arguably exogenous to other factors that may affect earnings. We find that children who grew up in communities with fluoridated water earn approximately 4% more as adults than children who did not. This effect is considerably greater for women than men, and it is almost exclusively concentrated amongst those from families of low socioeconomic status. We find some evidence of occupational sorting, though results are most consistent with the existence of employer discrimination in favor of more attractive workers.

1. Introduction

Healthy teeth are a vital and visible component of general well-being. Chewing is the first step in digesting food and maintaining nutrition and general health. Good dentition 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, and costs increase further if esthetically more desirable and more comfortable options (such as dental implants) are used.[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] Indeed, the US Centers for Disease Control has labeled water fluoridation "one of the 10 greatest public health achievements of the 20th century." Despite this success, controversies around fluoride continue to exist[4]. Even today, over 1/3 of the US population obtains water from non-flouridated sources (Department of Health and Human Services (2000)).

This variation in fluoridation – which, we argue below, is largely random in occurrence – allows us to examine systematically the nature and magnitude of the effect of dental health in the labor market. An understanding of this relationship is important in understanding the general effects of appearance on labor market success.

The existence of interventions that can readily improve oral health also means that understanding this relationship is of significance to public policy. Low-income children suffer disproportionately from preventable oral diseases, particularly tooth decay, because of inadequate access to dental care (Edelstein (2002); U.S. Department of Health and Human Services (2000)). For example, 80% of children on Medicaid do not have an annual preventive dental visit (U.S. Department of Health and Human Services (1996)) and although most state child health insurance programs (SCHIP) cover preventive dental care, two do not (Edelstein, CDHP Fact Sheet).

In this paper, we examine the effect of access to water fluoridation during childhood on labor market earnings as adults. The politics surrounding the adoption of water fluoridation by local water districts suggests exposure to fluoride during childhood is arguably exogenous to other factors that may affect earnings. We find that children who grew up in communities with fluoridated water earn approximately 4% more as adults than children who did not. This effect is

[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.
[4] http://www.fluoridealert.org/

considerably greater from women than men, and it is almost exclusively concentrated amongst those who grew up in families with low socioeconomic status. We explore several potential channels through which fluoridated water might affect earnings. We find evidence of occupational sorting, though results are most consistent with the existence of employer discrimination in favor of more attractive workers.

2. Background

A. Physical Appearance and the Labor Market

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). Several studies in the social sciences have explored the effect of physical appearance on wages (Hamermesh and Biddle, 1994; Biddle and Hamermesh, 1998). These studies find that individuals rated as more attractive earn higher salaries, after controlling for background characteristics. 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 effect by gender – if anything, males have a higher "return to beauty" – and find that marriage markets and labor force participation do not explain the earnings pattern.

Hamermesh and Biddle (1994) describe several models through which physical appearance might affect labor market outcomes. The beauty premium could arise through overt employer discrimination (employers prefer to work with more attractive co-workers), consumer discrimination (consumers prefer to interact with more attractive employees), and occupational sorting (individuals self-select into certain occupations based on the productivity return to physical appearance). In addition to these mechanisms, physical appearance might also affect individuals' self-confidence. Non-cognitive skills, such as self-confidence, may have a direct effect on productivity ((Mobius and Rosenblatt (2006), Heckman (2000), Persico et al. (2004)). Teeth may also signal to a potential employer the quality of childhood investments, leading to statistical discrimination by employers. Finally, in the case of fluoridation, the physical pain associated with poor oral health might directly interfere with the ability to focus at work or might lead to greater absenteeism. Based on the 1996 National Health Interview Survey (NHIS), there were 3.7 restricted activity days and 1.9 days of work lost per 100 employed persons over age 18 because of dental symptoms or treatment. Below we attempt to isolate some of these channels.

B. Fluoridation and Teeth

While the 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.

By contrast, fluoridation is an intervention in childhood that affects appearance in adulthood. Community water fluoridation protects teeth both topically and systemically. Topical fluoride helps to protect tooth enamel from plaque and sugars, providing continual protection against tooth decay throughout life. The ingestion of fluoride through the first 12 years of life makes tooth enamel stronger and more resistant to decay. Because of the timing of tooth development, ingestion of fluoride during the first 5 to 7 years of life is particularly important for the health of the four front teeth, the most visible components of a smile. Adult fluoride ingestion may be useful for the continued health of molars, but the evidence for such effects is much sparser (Burton Edelstein, personal communication, 2006).

The effects of community water fluoridation for the population we study (those born between 1957 and 1964) may not necessarily generalize to communities fluoridating today because of the advent of other products designed to reduce tooth decay (such as fluoridated toothpaste and dental sealants) and the greater prevalence of spillover effects from water fluoridation. For example, fluoridated water is now used in most crops grown with irrigated water and in the production of milk. Therefore, fluoridated water has worked its way through the food chain so many individuals are exposed regardless of local water fluoridation status (Leverett (1982)). While this limits the generalizability specific to community water fluoridation, the findings are applicable to the impacts of dental interventions in general. That is, any intervention that has a comparable effect on oral health as water fluoridation is likely to have a similar effect on earnings (assuming labor market responses to oral health are constant).

3. Empirical Strategy

Studying the effects of childhood water fluoridation helps avoid the problem of reverse causality between income and appearance. If water fluoridation policy or exposure is a function of parental income and socioeconomic circumstances, or if water fluoridation policy occurs in tandem with other policies that improve life chances, however, the problem will not be entirely avoided. In practice, the political structure of water fluoridation policy reduces the likelihood that decisions about water are related to parental income or to other policies.

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). 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). Only one state (California) requires voter input via referendums in adopting water fluoridation.[5]

The result of this political structure is that the pattern of water fluoridation in the United States follows no discernible pattern. In support of this, we highlight variation in the adoption of community water fluoridation from some of the largest cities in the U.S. Because we will use state fixed effects in our regressions, we include multiple cities within the same state.

City	State	Year Fluoridated
Memphis	TN	1970
Nashville	TN	1953
Columbus	OH	1973
Cleveland	OH	1956
Kansas City	MO	1983
St. Louis	MO	1955
Houston	TX	1982
San Antonio	TX	2000
Dallas	TX	1966
Austin	TX	1973

[5] Results are insensitive to excluding individuals from California from the analysis.

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. Fluoridation exposure appears uncorrelated with most factors that affect adult earnings.

To assess whether fluoridation status is correlated with these characteristics, we also examine the sociodemographic characteristics of the parents of the NLSY sample and the characteristics of fluoridated and non-fluoridated counties (Table 1). Urban residents are more likely to have fluoridated water than rural residents. This is not surprising because of the 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 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. Because wages and occupations are likely to differ by urban residence, we also perform our analyses using only children who resided in an urban residence at age 14.

Other than this difference, however, there are no obvious patterns of difference 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. In a multinomial logit regression of the 6 categories of water fluoridation on these variables (along with state and cohort dummies), we find only 33 of the 255 covariates are statistically significant at the 5% level. In a linear regression of the percent fluoridated in the county on the same variables, only 5 out of 51 are statistically significant. This significance rate is slightly higher than what would arise if fluoridation were randomly assigned. Plus, we will control for these variables in our regressions. Our fundamental identification assumption is that the unobservable factors are uncorrelated with fluoridation status conditional on the included covariates. Although we can never directly test this assumption, these results are encouraging.

Even if policy making is independent of parental preferences and characteristics and water fluoridation is as good as randomly assigned, families can engage in compensatory behavior. Our results would be weakened if parents moved in response to the presence (or absence) of fluoridation. Moving to obtain fluoride is unlikely. Community fluoridation is the most cost-effective way of obtaining fluoride (Griffin et al., 2001), but parents can duplicate the effects of community fluoridation at fairly low cost. Fluoride pills and drops cost about $0.15 per child per day.[6] Although these annualized costs are greater than the costs of water fluoridation, they are likely to be considerably less than the costs associated with moving.

We also examine whether mobility patterns are correlated with fluoridation. Of the individuals who moved during adulthood in our sample, the average change in fluoridation status is 0.002. Although this suggests people are slightly more likely to move to an area that is more fluoridated, this difference is not statistically significant and is very small in magnitude. This suggests that mobility in response to fluoridation rates is not an issue for our analysis.

We believe that labor market actors observe only the presence and appearance of teeth, not the underlying caries experience. There have been numerous technological innovations in dental care over the time period studied, such as fluoridated toothpaste, fluoride tablets, dental sealants, and fluoride treatments. Parents can use this dental care to correct for caries or tooth loss. Higher income families are more likely to purchase these services than are lower income families. Moreover, prior research finds much lower rates of dental service utilization among black than among white children, even controlling for insurance and parental income. In 1989, for example, only 57% of black children had visited the dentist, compared to 72% of white

[6] This price was obtained from https://www.rxsolutions.com/a/discountrx/PricingDetail.asp as of 7/14/2006.

children (Gift and Newman, 1992). This pattern suggests that we should expect effects to be stronger among blacks than among whites. Therefore, we hypothesize that the effects of lack of fluoridation on tooth loss will be greatest for children in lower income families who have less access to this substitute care.

Adults can correct for the effects on appearance of tooth loss by purchasing implants or dentures. Therefore, we expect the effects of childhood fluoride exposure in the labor market will be strongest among those with low earnings capacity. Both childhood and adult patterns suggest the effects of fluoridation on wages are likely to be greatest for individuals who were low SES as children.

4. Data

The data used in this study combines several secondary data sets in order to capture information on fluoridation status, earnings, and background demographics. The 1992 Water Fluoridation Census compiled by the CDC contains detailed information of 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, the county served, and the population within the county served as of 1990. Merging this data with total population estimates of each county from the 1990 Census of Population and Housing, we compute the percent of the county exposed to water fluoridation for each year since 1945 assuming county populations are constant over time. To compute cumulative exposure over a period of years, we compute the mean level of relevant exposure over time. For example, if the percent of a county with access to fluoridated water is 50% in 1960, 52% in 1961, and 60% in 1962, we compute the 3-year cumulative fluoridation exposure as 54%. Based on the timing of the effects of water fluoridation, we compute the mean over the first 5 years of life and the first 14 years of life.

We use the geocoded version of the National Longitudinal Study of Youth (NLSY) for information on earnings and to assign childhood exposure to water fluoridation. 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.

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. We also merge numerous county level variables from the 1960 City and County Data Books (CCDB) to account for factors that may be contemporaneously related to water fluoridation status.

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 several analyses using only respondents who report the same county of residence at both birth and age 14 in the NLSY. More than half of the respondents in the NLSY meet this criteria. Additionally, given that mobility and fluoridation appear uncorrelated, this suggests the measurement error that results by using the available county measures is likely to be random, so it attenuates our estimates of the effect of water fluoridation.

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 our assignment of childhood exposure and available measures of oral health from 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.[7] 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. In the BRFSS, however, we only have current county of residence. We assume that the current location is the same as the location during childhood to merge the fluoridation census. 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 – as we discussed above, there is no evidence of systematic mobility toward (or away from) fluoridated areas in adulthood.

It is important to note several reasons why our estimates may differ from previous studies of the effect of fluoridation on oral health document. One, the measurement error by assuming zero mobility throughout life is likely to further exacerbate our already attenuated estimates. 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 serious outcome, so that it may be more difficult to detect an effect.

[7] The question was asked in the core module in several years and in numerous state modules in other years.

Nonetheless, our results suggest that assigned fluoridation status has a strong effect on reducing tooth loss that is consistent with the existing dental literature. Shown in Table 2 are 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. We perform these linear regressions to obtain marginal effects that can be easily compared with our main regressions. Because the dependent variable is a categorical variable, we assign individuals the mean tooth loss within the category.[8] 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.

5. Methods

To estimate the effect of water fluoridation on wages, we estimate the following earnings equation:

$$(1) \qquad y_{ijcst} = \pi_1 pf_{cs} + \pi_2 x_{icst} + \delta_s + \varphi_t + c_j + \theta_i + \upsilon_{ijcst}.$$

y_{ijct} is a measure of the (log) hourly wage of individual i in cohort j at time t, who resided in county c of state s during childhood. pf is the percent of county with access to fluoridated water during childhood, averaged over either the first 5 or 14 years. Because fluoridation is assigned at the county level, we cluster standard errors appropriately. x are other productivity enhancing factors that affect wages, described in more detail below. δ_s are state fixed effects. States with higher rates of fluoridation may have other generous programs that affect health and wages, so

[8] Results from an ordered logit reveal the same patterns.

by including state-specific constants we limit our comparisons to counties within the same state. φ_t is a non-parametric time trend that controls for patterns in lifecycle earnings, dental care, and other time-varying factors. c_j are cohort fixed effects. We also control for state, time, and cohort variables in a flexible manner, such as allowing for state-specific time trends, to assess the robustness of our model. Since we observe individuals in multiple time periods, θ_i is an individual specific effect. Because there is no variation in *pf* over time for an individual, we estimate random effects models. υ is an idiosyncratic error term.

Our main test regards the parameter π_1. This parameter represents the direct effect from a dental intervention (community water fluoridation) on earnings. If we find that $\pi_1 > 0$, this suggests that individuals with greater fluoride exposure earn higher wages. Although we cannot determine whether individuals residing in communities with fluoridated water are necessarily consuming that water, there were few alternatives to public drinking water during the period studied. If people were successful in avoiding fluoridation, however, we can interpret π_1 as reflecting intent to treat.

This model is not structural in nature; it represents the reduced form effect of water fluoridation on earnings. To interpret our results as the effect of better oral health, we assume the only channel by which water fluoridation affects wages is through its effect on oral health. Confounding issues aside, there is no other plausible explanation for water fluoridation to affect labor market outcomes. Therefore, if we find that $\pi_1 > 0$, then given the knowledge that water fluoridation improves oral health, this necessarily implies that better oral health leads to higher wages.

We begin our analyses by including in *x* only covariates measured through age 14. We restrict the set of covariates through age 14 because it is possible that later covariates may reflect an effect of the intervention. For example, it seems natural to control for education in *x*. However, education is an endogenous choice variable that may be affected by fluoridation. Better oral health via fluoridation may affect completed education by reducing school absenteeism. Therefore, education would be a potential mechanism through which fluoridation affects earnings, and controlling for it would dampen the effect of water fluoridation. Omitting these covariates is consistent with approaches taken elsewhere (Persico et al., (2004); Neal and Johnson (1996); Heckman (1998)).

Included in *x* from the NLSY are several standard demographics (race, ethnicity, gender, and urban/rural residence) and some in depth information on family background, including parental education and occupation, family size and structure, religion, language spoken at home, whether the family received newspapers or magazines on a regular basis, and a measure of intelligence (AFQT[9]). Because we are concerned with community level confounding, we also include in *x* various county level data from the CCDB, including age distribution, local government expenditures on education (per capita), and political preferences. We assess the sensitivity of our estimates to including these variables in the regressions, and find they make very little difference. While it is likely there are unmeasured covariates through age 14 that may affect earnings in adulthood, it is unlikely they are correlated with fluoridation status during childhood.

The effect of fluoridation 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

[9] Although AFQT is acquired past age 14 for all respondents, we include this as a measure of ability rather than achievement. Given the controversy assuming this (Cascio and Lewis (2006)), however, we also omit this variable, but find no effect on our estimates.

attractive women. Different effects by gender may also arise because of selection into occupations where the importance of physical appearance varies. For example, men are more likely to work in construction and manufacturing industries, where workers are "behind the scenes" and do not interact with consumers. On the other hand, women may be 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. To assess if gender differences exist, in all analyses we also examine the effects separately by gender.

Any differences in the effect of fluoridation on earnings by gender should, however, not reflect differential effects of fluoridation on oral health by gender. Fluoridation affects the oral health of both groups similarly. As Table 2 confirms, our estimates of the effect of fluoridation on tooth loss are virtually identical for men and women. Any differences in the effects of fluoridation on earnings by gender must represent differential effects of similar oral health on earnings.

Another important way in which the effects of fluoridation on earnings may vary is through SES. Individuals from wealthier families may have several means for caring for their teeth in addition to community water fluoridation, so fluoridation may have little marginal effect on their oral health. On the other hand, children from poorer families may have limited access to alternative dental services, so that water fluoridation has greater marginal effects. Table 2 supports this argument: the effect of water fluoridation on adult tooth loss is greater for blacks than whites. Even if they suffer tooth loss, wealthier individuals may be better able to "cover-up" esthetic blemishes resulting from poor oral health, through implants or dentures, while low SES individuals may not. In the BRFSS, the use of dentures is uniform by SES despite the greater prevalence of tooth loss for low SES individuals. Therefore, we expect water fluoridation to have a larger effect on the earnings of low SES individuals.

To assess this possibility, 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. Our hypothesis is that π_1 for low SES is greater than π_1 for high SES.

6. Results

A. Impact of Fluoridation on Earnings

Our first set of results focuses on the effects of fluoride on earnings for all individuals, and separately for men and women. As Table 1 suggested, fluoridation exposure is correlated with urban residence, so we also repeat our analyses limiting the sample only to urban residents at age 14. These analyses are reported in the second row of each panel in Table 3. In these analyses we assign fluoride status based on county at age 14. We measure fluoride exposure as the average over the first 5 years, the point at which the front 4 teeth develop. Given that this variables lies in the range of 0 to 1, we can interpret the coefficient on *pf* as the effect of living in a fluoridated community relative to living in a non-fluoridated community.

The first column in Table 3 presents results without any controls except year, state, and cohort dummies. We find a positive but statistically insignificant 2.9% increase in hourly earnings from fluoridation exposure. The effects are much stronger among women, with a 6% effect that is statistically significant. For men, the effect is very small, with a standard error that are roughly three times larger than the point estimate. The effects also tend to be stronger in the comparison among urban residents than in the full sample, though this difference is not substantial.

In the second column, we add controls for family characteristics at age 14 using variable from the NLSY. In this specification, the magnitude of the coefficients increases to about 4% overall and stays at 6% for women, and is statistically significant at the 5% level for both groups. The effect for men slightly increases to 2%, but it does not approach statistical significance at a conventional level. Again, the effects are generally larger for urban residents.

In the third column, our preferred specification, we add controls for characteristics of the county of residence from the CCDB in addition to the NLSY controls. The coefficients decrease slightly in magnitude but mostly remain statistically significant. Although our estimates are not entirely insensitive to these controls, as previously mentioned people can respond to their treatment even if random assignment occurs. As we discuss below, the sensitivity of our estimates is being driven solely by high SES individuals, which supports the hypothesis that people from high SES families are able to compensate for not having access to fluoridated water.

In the next 3 columns, we explore the sensitivity of our estimates to various trends. For example, although we are including state and year fixed effects, it is possible that unique trends within states are having differential effects on earnings. Adding cohort-year dummies (column 4), year-state dummies (column 5), and cohort-state dummies (column 6) have virtually no effect on the estimates. The estimates are highly robust to these controls.

In sum, these results suggest that fluoride exposure in childhood has substantial and statistically significant effects on hourly earnings of women, and small, statistically insignificant effects on the earnings of men. 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.

In Table 4, we examine the sensitivity of our results to the choice of measure of fluoride status. 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 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. Overall, this table suggests that our results are generally insensitive to our assignment and measurement of fluoridation exposure.

B. Effects by Childhood Socioeconomic Status

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.

In Table 5, 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. We omit results for urban residents at age 14, which are similar to the presented results. 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. However, for women the effects of fluoride exposure on adult earnings increase monotonically as parental occupational status falls. In fact, the effect for women from low SES families is 9% while for high SES families it is essentially zero. The final two columns in Table 5 compare black and white samples. The effects of fluoride exposure on subsequent earnings are much larger among black women than among white women. Furthermore, the results for low SES individuals are largely insensitive to the inclusion of NLSY and CCDB covariates, but the estimates for high SES are sensitive (not shown).

The effects of fluoride exposure on later earnings are concentrated among women from low SES families. Women from high SES backgrounds are able to fully offset the effects of not living in a fluoridated community. These patterns are consistent with lower use of dental care in lower SES populations. The effects for low SES women are large in magnitude, with fluoridation having as high as an 11% effect for blacks. Given average hourly earnings in 1998 in the NLSY for women who are black or from low-occupation families of roughly $11 and $12, respectively, this effect translates into a return of about $1/hour.

C. Mechanisms

Our findings suggest that fluoridation – and the reduction in tooth loss that results – improves the earnings of women, particularly black women and those from low income families. We consider a variety of mechanisms through which childhood fluoridation might affect earnings for these groups. In Table 6, we examine the effect of different controls on the magnitude of the relationship between fluoridation and earnings. We only examine this effect for women (overall and low SES) because this is the only group where we find an effect of fluoridation. Column 1 repeats the baseline results from our preferred specification in Table 3 and the low SES groups in Table 5. In each subsequent column, we separately add specific variables that may be potential mechanisms to the regression. If these variables mediate how fluoridation affects wages, then including them should alter the estimated effect of fluoridation on earnings relative to the baseline estimate.

One way that fluoridation could affect earnings is through changes in the acquisition of human capital. The 1996 NHIS also indicates there were 3.1 days of lost school per 100 youths aged 5-17 because of dental symptoms or treatment. Therefore, water fluoridation can help to reduce tooth-related pain that leads to absenteeism or reduces the ability to focus at school, and increase human capital. Controlling for educational attainment, labor market experience, and tenure, however, generates coefficients that are surprisingly larger in magnitude. This might reflect that less attractive individuals compensate for their lack of physical appearance by investing more in their human capital.

To assess whether women select into occupations based on their physical appearance, in column 3 we control for 3-digit occupation codes. Rather than rate occupations based on appearance, we include separate dummy variables for each of the 565 occupation codes. We can no longer obtain valid standard errors for inference, but we can still assess the effect on the magnitude of our estimate.[10] Controls for occupation explain roughly 10-25% of the fluoridation effect for women overall and the separate groups. This suggests that physical appearance affects

[10] Invalid standard errors arise because the number of observations minus the number of regressors relative to the number of clusters must go to infinity, and this is not the case when we include separate occupation dummies.

the occupation selection of women, and this mediates a considerable portion of the effect of fluoridation on earnings.

We also examine whether fluoridation may affect earnings through the marriage market. More attractive individuals may be more likely to marry and, conditional on marriage, may be more likely to find a higher earning spouse. If both of these factors reduce one's attachment to the labor force, including them would increase the effect of fluoridation on earnings. Controls for marriage (column 4) have little impact on the coefficients for women, with only a modest 5% effect for women with low occupation parents.

We next consider whether fluoridation status affects earnings by changing people's self-esteem. As previously mentioned, physical appearance may improve self-confidence, and confidence has been found to improve productivity. In 1980, the NLSY asked several questions regarding self-esteem based on the Rosenberg Self-Esteem Scale.[11] Including this measure (column 6) has modest effects on the estimates, implying self-esteem is not a mediator.

If the discomfort from poor oral health persists in adulthood, individuals may have less energy or miss more time from work as the NHIS indicates, thus resulting in lost productivity. Unfortunately, the NLSY does not contain detailed information on tooth problems. To test this channel, we use a self-reported measure of general health: whether health affects the amount or kind of work the respondent can perform.[12] Although this crude measure may not capture the relevant health problems, it does have a statistically significant effect on earnings. However, including it has no impact on our estimated effect of fluoridation (column 6).

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[11] This response was missing for numerous respondents. To prevent the loss in sample size, we imputed this variable using best subset regression with the self-esteem score form the 1987 wave and the 1992 and 2002 CESD depression scores as controls.
[12] This variable combines the response from two separate questions: one for the amount of work, the other for kind of work.

Individuals with better teeth may be more likely to move to urban areas where there are more opportunities for social interactions. Since urban locations typically have higher wages, this could explain part of the effect of fluoridation. In addition to controlling for urban residence at age 14, we also include whether the current residence is urban or an SMSA. Current residence explains roughly 10% of the overall effect for women, with the effect concentrated amongst individuals from middle occupation families. This finding suggests that although current residence is a mediator, this channel does not help the lowest SES group, perhaps due to greater mobility costs.

In the last specification, we include all controls together (column 8) to determine the total impact of these mediators. All controls together explain 27% of the estimated baseline effect for women overall. For adults from middle-occupation families, the controls explain over 30% of the variation, while for low occupation families and blacks they explain less than 10% of the variation. This large residual effect is consistent with employer discrimination.

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 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 nearly all of the effect coming for women (5-6%). Furthermore, the effects are largest for individuals of low SES during childhood. We find that black females earn as much as 11% more as a result of access to fluoridated water. All results are remarkably robust to alternative specifications, including controls for state-year trends and numerous community level variables.

This research informs program decisions and policy debates concerning dental care by examining a largely overlooked benefit of oral health. By establishing that the benefits from existing dental programs are greater than currently believed, particularly for low SES individuals, this strengthens the justification for greater public interventions in oral health, such as greater insurance coverage, improved access to safety-net clinics, and increased dental screening in preschools and schools. Such changes have the potential to increase care and reduce disparities in dental health, improving the economic prospects of low-income children.

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Table 1. Demographic Statistics by Fluoridation Status

fluoridation status:	0	0-.2	.2-.4	.4-.6	.6-.8	.8-1
urban residence	0.758	0.746	0.706	0.750	0.806	0.945
foreign language	0.162	0.173	0.096	0.122	0.163	0.173
magazine regularly	0.579	0.569	0.616	0.683	0.573	0.580
newspaper regularly	0.757	0.790	0.784	0.871	0.814	0.795
library card	0.691	0.706	0.729	0.764	0.727	0.792
# of siblings	3.807	3.772	3.517	3.568	4.018	3.676
education mother	11.077	11.036	11.361	11.570	10.732	11.438
education father	11.063	11.065	11.258	11.880	10.878	11.491
mom & dad in HH	0.678	0.683	0.699	0.759	0.711	0.657
mom born in US	0.951	0.947	0.970	0.959	0.954	0.939
dad born in US	0.931	0.932	0.965	0.964	0.939	0.929
No Religion	0.041	0.046	0.043	0.040	0.027	0.047
Protestant	0.048	0.052	0.063	0.049	0.042	0.053
Baptist	0.320	0.302	0.332	0.182	0.260	0.285
Episcopalian	0.014	0.019	0.014	0.022	0.017	0.016
Lutheran	0.059	0.051	0.057	0.081	0.100	0.041
Methodist	0.078	0.086	0.111	0.088	0.085	0.076
Presbyterian	0.028	0.025	0.026	0.031	0.042	0.025
Roman Catholic	0.296	0.298	0.247	0.371	0.345	0.357
Jewish	0.009	0.007	0.006	0.023	0.006	0.008
Other Religion	0.108	0.115	0.099	0.115	0.077	0.092
male	0.507	0.497	0.521	0.531	0.479	0.488
black	0.242	0.240	0.263	0.129	0.209	0.340
hispanic	0.122	0.118	0.059	0.059	0.131	0.142
height	67.232	67.014	67.378	67.523	67.114	67.013
AFQT	42.418	41.699	41.024	47.795	43.283	40.863
duncan SEI - mom	16.703	15.895	17.596	17.322	13.925	18.406
duncan SEI - dad	20.804	21.112	21.443	26.804	22.462	20.543
pop pct change 1950-60	22.879	31.561	25.762	25.189	33.289	23.581
pop pct rural 1960	10.754	8.631	10.707	8.463	6.658	1.326
median age 1960	29.348	28.081	28.799	28.919	27.750	30.280
pct pct >65 1960	0.096	0.086	0.090	0.091	0.083	0.088
pop pct <5 1960	0.110	0.119	0.115	0.118	0.123	0.115
death rate 1960	9.471	8.884	8.765	9.102	8.400	9.661
marriage rate 1960	8.994	8.181	9.322	8.540	7.406	7.881
employ rate 1960	0.943	0.947	0.952	0.945	0.954	0.950
pct employ manuf 1960	0.230	0.256	0.287	0.284	0.316	0.244
pct employ constr 1960	0.063	0.063	0.061	0.061	0.059	0.054
pct employ trade 1960	0.178	0.181	0.178	0.177	0.180	0.194
vacancy rate 1960	0.893	0.899	0.906	0.907	0.926	0.941
pct homeowners 1960	0.617	0.659	0.682	0.673	0.668	0.558
pct education exp. 1957	0.475	0.501	0.467	0.485	0.438	0.376
local govt debt ratio 1957	1.223	1.314	1.393	1.268	1.392	1.529
pct vote democ president 1960	0.537	0.405	0.370	0.496	0.586	0.765
pct vote correct president 1960	0.582	0.575	0.576	0.581	0.594	0.541
N	2,832	3,495	837	556	904	1,290

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 status	-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	0.029	0.039	0.031	0.032	0.030	0.027
N=90218, I=10162	[0.022]	[0.016]*	[0.017]	[0.017]	[0.017]	[0.017]
Fluoridation status if urban	0.034	0.044	0.041	0.042	0.040	0.034
N=79268, I=7959	[0.023]	[0.018]*	[0.018]*	[0.018]*	[0.018]*	[0.018]*
2. Male						
Fluoridation status	0.009	0.020	0.017	0.017	0.015	0.017
N=46952, I=5107	[0.025]	[0.019]	[0.022]	[0.022]	[0.021]	[0.022]
Fluoridation status if urban	0.006	0.020	0.029	0.030	0.027	0.027
N=36511, I=3980	[0.026]	[0.020]	[0.024]	[0.024]	[0.023]	[0.024]
3. Female						
Fluoridation status	0.060	0.059	0.049	0.050	0.049	0.049
N=43266, I=5055	[0.024]*	[0.021]**	[0.021]*	[0.021]*	[0.022]*	[0.022]*
Fluoridation status if urban	0.071	0.069	0.056	0.057	0.056	0.053
N=33757, I=3979	[0.027]**	[0.023]**	[0.022]*	[0.022]*	[0.023]*	[0.025]*
Year dummies	Y	Y	Y	Y	Y	Y
Age 14 NLSY covariates	N	Y	Y	Y	Y	Y
County level variables	N	N	Y	Y	Y	Y
Cohort-year dummies	N	N	N	Y	N	N
Year-state dummies	N	N	N	N	Y	N
Cohort-state dummies	N	N	N	N	N	Y

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

Table 4. Regression Results of Fluoridation Status on Log Hourly Earnings by Gender for Various Measures of Fluoridation Status

	1	**2**	**3**	**4**
Exposure years:	5	5	5	14
Age at residence:	14	birth	14=birth	14
<u>All</u>				
Fluoridation status	0.031	0.021	0.023	0.030
	[0.017]	[0.015]	[0.020]	[0.019]
N	90218	83298	52402	90218
# of individuals	10162	9373	5761	10162
<u>Male</u>				
Fluoridation status	0.017	0.003	-0.010	0.020
	[0.022]	[0.018]	[0.027]	[0.024]
N	46952	43181	27396	46952
# of individuals	5107	4709	2910	5107
<u>Female</u>				
Fluoridation status	0.049	0.040	0.060	0.045
	[0.021]*	[0.019]*	[0.025]*	[0.023]*
N	43266	40117	25006	43266
# of individuals	5055	4664	2851	5055

Notes: * significant at 5%; ** significant at 1%. Heteroskedasticity-consistent standard errors that adjust for clustering at the county level in brackets. All specifications are the same specification as column 3 in table 3.

Table 5. Regression Results of Fluoridation Status on Log Hourly Earnings by Gender and Socioeconomic Status

	Low occupation	Middle occupation	High occupation	Black	White
	1	**2**	**3**	**4**	**5**
All					
Fluoridation status	0.048	0.057	-0.006	0.087	0.026
	[0.026]	[0.027]*	[0.024]	[0.028]**	[0.020]
N	27831	30356	32031	21934	54194
# of individuals	3251	3379	3532	2405	6301
Male					
Fluoridation status	-0.003	0.045	-0.001	0.066	0.015
	[0.036]	[0.036]	[0.036]	[0.042]	[0.028]
N	14541	16337	16074	11431	28037
# of individuals	1614	1750	1743	1226	3163
Female					
Fluoridation status	0.093	0.065	0.007	0.114	0.034
	[0.036]**	[0.034]	[0.028]	[0.036]**	[0.024]
N	13290	14019	15957	10503	26157
# of individuals	1637	1629	1789	1179	3138

For parental occupation codes, 'low' is defined as occupation missing or <= 17 on the Duncan Socioeconomic Index; 'mid' is 17-48; and 'high' is >= 48. All results use fluoridation status through age 5 using county of residence at age 14. All specifications are the same specification as column 3 in table 3.

Table 6. Mechanisms by SES for Females

	1	2	3	4	5	6	7	8
	base	human capital	occupatn	marriage	self-esteem	health	residence	all
All								
Fluoridation status	0.049	0.054	0.037	0.049	0.047	0.05	0.044	0.036
N=43266	[0.021]*	[0.021]**	-	[0.021]*	[0.022]	[0.020]*	[0.020]*	-
Low-parental occupation								
Fluoridation status	0.093	0.096	0.081	0.088	0.095	0.093	0.091	0.083
N=13290	[0.039]*	[0.038]**	-	[0.039]*	[0.039]*	[0.039]*	[0.039]*	-
Mid-parental occupation								
Fluoridation status	0.065	0.069	0.046	0.066	0.056	0.064	0.059	0.042
N=14019	[0.038]	[0.037]*	-	[0.037]	[0.037]	[0.037]	[0.038]	-
Black								
Fluoridation status	0.114	0.123	0.104	0.112	0.112	0.112	0.114	0.108
N=10503	[0.045]*	[0.044]**	-	[0.045]*	[0.044]*	[0.044]*	[0.045]*	-

Notes: * significant at 5%; ** significant at 1%. Heteroskedasticity-consistent standard errors that adjust for clustering at the county level in brackets. All specifications are the same specification as corresponding columns in tables 3 & 5.
'human capital' includes schooling, tenure, and a quadratic in experience
'occupation' includes dummies for census 80 3-digit occupation codes
'marriage' includes marital status, schooling and earnings of spouse
'self-esteem' includes a measure of self-esteem
'health' include responses to any health conditions that limits amount or kind of work
'residence' includes current county unemployment rate, urban residence, and smsa residence.
'all' include all of the above variables