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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 their economic value. In this paper, we examine one element of that value, 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 exogenous to other factors affecting earnings. We find that women who resided in communities with fluoridated water during childhood earn approximately 4% more than women who did not, but we find no effect of fluoridation for men. Furthermore, the effect is almost exclusively concentrated amongst women from families of low socioeconomic status. We find little evidence to support occupational sorting, statistical discrimination, and productivity as potential channels of these effects, suggesting consumer and employer discrimination are the likely driving factors whereby oral health affects earnings

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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[2]. If caries are not treated and tooth loss occurs, dentures or implants, though more expensive and of varying quality, can be used to replace lost teeth.[3]

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 60%. As fluoridation rates have increased the rate of edentulism has fallen significantly over

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

time as well.[4] 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 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. Decisions around water fluoridation are typically made with little or no input from local residents, 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 below 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 2% 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 various 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 women who grew up in families of lower socioeconomic status. We find little evidence to support occupational sorting, statistical discrimination, and productivity as potential channels of these effects, suggesting consumer and employer discrimination are the likely driving factors through which oral health affects earnings.

[4] These findings are summarized in U.S. Department of Health and Human Services (2000). The effect of water fluoridation on dental caries has decreased over time because fluoride is more readily available through sources other than local public drinking water.

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 in these studies observe far less than employers do 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 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 examines individuals 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. The number of individuals without dental insurance continues to grow. Low-income individuals, especially 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 black and Hispanic children 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 individuals.

2. Background

2.A. Fluoride and Teeth

A wide body of research confirms that fluoride reduces the onset of tooth decay (see, for example, U.S. Department of Health and Human Services (2000)). Decay occurs when acids in the mouth breakdown, or demineralize, tooth enamel. There are three leading theories of the mechanisms by which fluoride reduces decay in children (Tinanoff (forthcoming)). The first suggests a systemic effect where the ingestion of fluoride mixes with tooth enamel prior to tooth eruption, making tooth enamel more permanently resistant to acids after eruption. The second suggests that fluoride in the bloodstream is contained in saliva, which covers teeth both during and after eruption, to enrich the surface layer of enamel by remineralizing areas attacked by acids. The third is comparable to the second but suggests a topical effect whereby fluoride topically applied to teeth protects tooth enamel.[5] Once adult teeth have formed, topical fluoride continues to protect tooth enamel throughout life, though the impacts are generally believed to be less important at this stage.

[5] In testing these mechanisms, a recent study examined the impact of pre- and post-eruptive fluoride exposure on decay by obtaining complete residential histories linked with fluoridation status and identifying the effects through movers and changes in fluoridation status within a community (Singh et al. (2003)). They found benefits from pre-eruptive exposure regardless of post-eruptive exposure, no benefits from post-eruptive exposure without pre-eruptive exposure, but the largest effect from both pre- and post-eruptive exposure to fluoride.

Although controversy surrounds the mechanisms, distinguishing the relative contribution of each matters little for our study because public drinking water was the primary source of fluoride for the population we study; fluoridated toothpaste and sealants – the most commonly used substitutes – did not become popular until the late 1960s and early 1970s. Therefore, those exposed to fluoridated water during childhood experience better oral health as adults either because of systemic effects or because untreated decay during childhood can lead to tooth loss in adulthood.

Although fluoride reduces tooth decay, several negative side effects from ingestion have been investigated. Excessive intake of fluoride can cause fluorosis, a cosmetic discoloration of the teeth, though this occurs typically at levels beyond which CWF is adjusted. To the extent that fluorosis exists, any effect we find will be net of the effect of fluorosis. More serious – though more disputed – is the purported link between fluoride intake and other health outcomes, notably bone cancer in children (osteosarcoma).[6] 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.[7]

2.B. 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

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[6] Hip fractures in the elderly are also a purported side effect with some empirical support, but this is unlikely to affect our analysis because we focus on a sample of young and middle aged adults.

[7] Resurgence in this debate is largely fueled by recent findings by Bassin et al. (2006). For the purposes of our study, however, a link between fluoride and osteosarcoma is unlikely to impact our analysis because it is an extremely rare disease – the incidence of osteosarcoma in children under age 15 is 5.6 per million – and the magnitude of the effects documented by Bassin et al. (2006) imply a trivial, if any, impact on our sample of roughly 12,000 individuals.

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: ratings of randomly manipulated photographs of teeth reveal that poor oral health is associated with lower esthetic, social, and professional traits (see, e.g. Eli et al. (2001)). Spending on strictly cosmetic oral health products, such as tooth whitening, is a growing business.[8] With respect to employment, the anecdotes described above suggest that people who lack teeth may have trouble finding jobs (Shipler (2004); Eckholm (2006)). Military requirements result in rejecting or not deploying potential soldiers from service because of missing teeth (Britten and Perrott (1941); Klein (1941)) or poor oral health (Chaffin et al. 2003) because dental emergencies interfere with combat readiness (Teweles and King, 1987). But there is no systematic evidence we are aware of that links oral health with labor market outcomes.[9]

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[8] In 2005, Crest sold $300 million worth of White Strips, which is 60% of the market dollar share (Alsever (2006)), and 28% of survey respondents report having tried some form of whitening procedure (American Academy of Cosmetic Dentists (2004)).

[9] In a bivariate regression, Killingsworth (2007) demonstrates a positive association between number of teeth at each age and earnings. Despite obvious limitations in the simplistic regression, the focus of his article was on the accumulation of teeth over the lifecycle, rather than the relationship between teeth and earnings.

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 more physically attractive individuals. The beauty premium could also arise through taste-based employer discrimination where employers prefer to hire more attractive workers. Both of these could lead to occupational sorting whereby more attractive individuals choose professions with more direct customer contact or where they suspect less employer discrimination.

In addition to physical appearance, oral health may affect earnings directly though 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, 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)). Additionally, oral health may 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.

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 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.

Beyond the population served, the decision to fluoridate follows little systematic pattern during the time period we study. Despite public concerns over water fluoridation, roughly two-thirds of decisions around water fluoridation during the early 1960s were made without input from local constituents, with decisions coming from various government administrators (Crain et al. (1969)). Furthermore, since water fluoridation policies are determined at the water district level and water districts boundaries often do not correspond to the municipal boundaries that govern other types of decisions (Foster (1997)), administrators making these decisions are often not held accountable for their actions. Moreover, citizens were often uninformed about whether fluoride has or has not been added to the water; disclosure of fluoride content was not made mandatory until the 1996 amendments to the Safe Drinking Water Act. Although citizens now are more informed and have more input over the process of water fluoridation (for example, referenda are more common), for the time period we investigate 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 several sources of variation in community water fluoridation throughout the U.S. First, we present in the following chart the year major cities within selected states adopted CWF.

Fluoridation by City and Year within State

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)

As evident in this chart, there are significant time gaps between neighboring cities in when they fluoridated. What prompted St. Louis to fluoridate in 1955 but Kansas City to wait another 28 years before fluoridating is not entirely obvious because both had the same information about CWF. There is no obvious pattern in the timing of fluoridation, at least not one that appears correlated with wages or other predictors of wages.

Similar patterns hold if we examine patterns among less populated areas. Figure 1 plots county level fluoridation rates (described in more detail below) in 1965, with capital cities and cities with over 200,000 people denoted for reference.[10] There are some regional patterns in fluoridation, with rates higher in the near mid-West than in the Mountain region, but no obvious pattern within region (we include state fixed effects to account for these regional differences). For example, there are both high and low fluoridation rates in rural and urban areas alike in numerous states across the country (e.g., Iowa, North Dakota, Kentucky, Georgia, Colorado), with little evidence of clustering.

We also illustrate the apparently exogenous adoption of water fluoridation by focusing on a specific labor market: the Chicago MSA. Figure 2 plots county fluoridation rates for Cook

[10] Fluoridation information from Arkansas is missing in our data.

County and the five counties within Illinois immediately adjacent to it for the time period surrounding when the respondents in the NLSY 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. Importantly, the order of median family income 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. Below we present more formal assessments of exogeneity.

4. Data

4.A. Sources

We combined several secondary data sets in this study in order to capture information on fluoridation status, earnings, and background demographics.[11] 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 served by the water system within the county as of 1990.[12]

For demographic data, we use the geocoded version of the National Longitudinal Study of Youth (NLSY), a nationally representative sample of over 12,000 men and women born

[11] We are unaware of data containing information on earnings, childhood location, and oral health.
[12] If the water system served multiple counties, information for each county served was separately recorded. Multiple water systems within a county were also separately reported.

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 information on earnings, we use the hourly rate of pay from the current or most recent job as our measure of earnings.

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 both child and adult water fluoridation status from the fluoridation census.

We also merge several county level variables to assess the possibility of the endogeneity of CWF. We merge numerous county level variables from the 1960 and 1970 City and County Data Books (CCDB) to account for area demographics, such as housing prices, family income, population, age and education distribution, local government debt, expenditures on education, and voting preferences. We also merge county level data from the 1959 and 1968 Bureau of Economic Analysis (BEA) Regional Economic Information System on income maintenance (SSDI, AFDC, and Food Stamps), medical insurance, and retirement and disability transfers at county level. Last, we merge data from the 1974 County Business Patterns (CBP) to account for the availability of dentists and other health care services during childhood. Appendix Table 1 lists all included county level variables.

4.B. Assigning fluoride exposure

In order to assign fluoride exposure to each individual in the NLSY, we must first compute the percent of each county in the U.S. with access to fluoridated water. To do 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, absent any alternative data source we must 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 by each district as weights. This leaves us with a county-year panel of fluoridation rates.

To compute cumulative exposure for an individual, we compute the mean level of exposure over a period of time that corresponds with the eruption of adult teeth. The four front adult teeth - the most visible components of a smile – erupt between the ages of 5 to 7, while all adult teeth typically erupt by age 12. Based on this, we compute the mean county fluoridation rate over the first 5 and 14 years of life as our measure of fluoride exposure.

To clarify this assignment, consider a county with only one water district that fluoridates, which 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	contemporaneous 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, fluoride exposure is the mean of contemporaneous fluoridation rates for the years 1964-1968, which is .2 (=(.2 + .2 + .2 + .2 + .2)/5). This example also demonstrates why county fixed effects or a regression discontinuity design are not feasible in our analysis: contemporaneous exposure changed abruptly in 1960, but cumulative exposure changed more gradually, so there is considerably less variation in fluoridation exposure within a county.[13]

We do not know an individual's county of residence at each point in time during childhood. In our baseline estimates, we assume the respondent remains in the county of birth for the first 5 years of life. Since we do not have information on location between birth and age 5, this approach may misallocate fluoride exposure in our sample. Moreover, reported county of birth could reflect the county of the hospital of birth rather than of a child's residence (this

[13] We include state fixed effects in all of our analyses and also explore MSA fixed effects to compare geographically close counties.

distinction was not made clear in the NLSY questionnaire). To assess the severity of measurement error, we consider an alternative measure of exposure in sensitivity analyses 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 also has effects in adulthood, we also measure respondent'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 adulthood to exposure during childhood. 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, supporting the plausibility of this assumption.

4.C. Construct validity

It is crucial to our analysis that our method for assigning fluoridation exposure to individuals contains enough signal about actual fluoridation exposure. To assess this, we examine the effect of fluoridation on adult dental health using the Behavioral Risk Factor Surveillance System (BRFSS), 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. We impute exact tooth loss using hot deck imputation with donors coming from the National Survey of Oral Health (NSOH) in U.S. Employed Adults and Seniors (1985–1986), which contains exact number of teeth lost for 14,801 individuals.[14]

The BRFSS only has current county of residence; we have no information on residence during childhood. In our analyses of the BRFSS, we match fluoridation data assuming that respondents live in the same county in adulthood as during childhood. This assumption introduces considerable measurement error, as 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.

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, as we also demonstrate below. Two, other studies look at the effect of childhood fluoridation exposure on tooth decay during childhood, so we are extending this research by looking at oral health during adulthood and using tooth loss as an outcome measure, both of which may make it more difficult to detect an effect.

Nonetheless, our results suggest that assigned fluoridation status has a strong relationship with tooth loss, consistent with the existing dental literature. Table 1 provides estimates from a linear regression of tooth loss against childhood fluoridation exposure against individual level factors, county level factors, age dummies, state dummies, and year dummies for individuals from the BRFSS in the same cohort as the NLSY. The results indicate that water fluoridation significantly reduces tooth loss, which is consistent with previous evidence documenting the

[14] More specifically, for each of the 17,474 individuals in the BRFSS who fell into the two middle categories of tooth loss, we randomly drew an individual from the NSOH with the same tooth loss category, gender, and age, and assigned their exact number of tooth lost to the individual in the BRFSS.

benefits of water fluoridation.[15] Changing from a non-fluoridated to fluoridated community results in roughly one-third of a tooth more in adulthood, and these results are highly insensitive to numerous county level controls, supporting the exogeneity of CWF. These results indicate that the effects of dental health via water fluoridation appear to persist into adulthood, and that our measure of fluoridation exposure is valid.

An additional finding of interest is that low SES individuals are less able to respond to health shocks (such as decayed teeth) than high SES individuals, so water fluoridation should have a greater impact on tooth loss for low SES individuals. For example, the rate of annual, preventive dental care visits is considerably amongst higher SES individuals, so given that dental procedures effectively prevent and treat tooth decay, water fluoridation should have a smaller impact on higher SES individuals. Table 1 supports this: the effect of water fluoridation on tooth loss is greater for blacks, who are, on average, of lower SES. Furthermore, although completed education could be affected by tooth loss, we find a strong gradient in tooth loss by education. These results suggest that any differences in the effect of CWF on earnings by SES could reflect both different labor market responses and different effects of CWF on oral health.

5. Methods

5.A. Behavioral Model

To highlight the mechanisms through which oral health affects wages, we provide a simple behavioral model in which 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

[15] We obtained comparable patterns of estimates from an ordered logit model using the four tooth loss categories.

human capital of the worker. Some of human capital (*hc*) is affected by oral health, 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.[16] 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 ($w_j > w_{-j}$).

If the beauty of a worker is judged as a relative comparison to other workers, then there must be variation in beauty within a labor market in order for the equilibrium wage to have a beauty premium.[17] CWF is a community level treatment, so all individuals within a community are equally treated, making for less variation in relative beauty. However, labor markets often consist of more than one community, and, as Figure 2 also demonstrates, there is considerable spatial variation in fluoridation rates within a small area.[18] This variation is expected to generate varying rates of oral health within a given labor market such that an equilibrium with a beauty premium can arise.

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[16] See Blinder (1974) and Killingsworth (1977) for more detailed models of investing in oral health.
[17] We also recognize that beauty may be absolute or may be relative to individuals outside of the labor market, such as those in print or on television, which would lead to a beauty premium in equilibrium.
[18] We also present analyses where we examine effects only in MSAs.

Three 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 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 address this concern by using an intervention in childhood so that temporal precedence is clearly established.

Three, 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 personal views of their own physical appearance.

5.B. Structural model

We do not observe oral health in our data, so we 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 (1):

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

where y is the log of hourly earnings. Oral health is determined by:

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

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.[19] α_1 represents the direct and indirect effect of childhood exposure to water fluoridation on oral health.

Substituting equation (3) into (2) yields the following reduced form relationship:

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

where π_1 $(=\beta_1 \cdot \alpha_1 = \delta y/\delta oh \cdot \delta oh/\delta wfc)$ represents the reduced form effect of childhood water fluoridation on earnings. Since we excluded wfc from equation (2) on the assumption that water fluoridation does not directly affect labor market outcomes, fluoridation only affects earnings indirectly through its impact on oral health. Since $\alpha_1 > 0$, if we 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

[19] Note that fluoridated toothpaste and dietary fluoride drops were generally unavailable for the time period studied, so formal dental care is the main substitute technology available for our sample respondents during childhood.

behavior our estimate of π_1 instead is $\beta_1 \cdot (\alpha_1 + \delta d/\delta wfc \cdot \alpha_3) = \delta y/\delta oh \cdot (\delta oh/\delta wfc + \delta oh/\delta d \cdot \delta d/\delta wfc)$. 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 1 indicates that the effect of water fluoridation on tooth loss is greater for blacks and the less educated. 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 add potential mechanisms to equation (4) to estimate:

$$(5) \qquad y = \pi_1 wfc + \pi_2 wfa + \pi_3 d + \beta_2 x + \beta_3 occ + \beta_4 hc + \varepsilon.$$

As we successively add *hc* and *occ* to our model, we attribute the degree to which π_1 obtained from equation (4) changes to that channel. For example, if we find that adding *occ* to the regression lowers our estimate of π_1 by 0.25 π_1, this implies occupational sorting explains 25% of the effect of oral health on earnings. In our model, employer (both taste-based and statistical) and consumer discrimination is measured by the residual effect of π_1 after adding all potential mechanisms.

5.C. Empirical model

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

(6) $y_{ijtcs} = \pi_1 wfc_{jcs} + \pi_2 wfa_{tcs} + \pi_3 d_{jcs} + \beta_2 x_{ijcs} + \beta_3 x_{jcs} + \delta_s + \varphi_t + \sigma_j + \upsilon_{ijtcs}$.

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 x_{ijcs} we use numerous individual level variables from the NLSY. For d_{jcs} and x_{jcs}, we include county level demographics from the CCDB, BEA and CBP, and assess the sensitivity of estimates to adding these controls. States with higher overall 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 the 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, which also accounts for clustering at the individual level because it is nested within the county effect.[20]

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.[21] To the extent that individuals consume water from neighboring counties, any spillover effects would dampen our estimate of π_1. If we find that π_1 >

[20] As previously mentioned, we do not estimate model with county fixed effects because there is insufficient variation in cumulative exposure, though we explore model with MSA fixed effects.
[21] Only recently can water filters remove fluoride from drinking water.

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 ($\beta_1 > 0$).

5.D. Assessing exogeneity of water fluoridation

Although we argue above that exposure to CWF is exogenous, there are four potential concerns we must address: 1) selection effects – counties that fluoridate differ from counties that do not; 2) contemporaneous investments – counties that fluoridate expand other programs that may ultimately affect earnings at the same time; 3) compensatory behavior – even if fluoridation is exogenous, individuals respond to whether their water is fluoridation by changing their use of other dental services; and 4) sorting – even if fluoridation is exogenous, families may relocate to an area depending on fluoridation status.

We present several pieces of evidence to more formally assess the exogeneity of water fluoridation. First, we examine several characteristics of the NLSY sample by CWF status in Table 2. Urban residents are more likely to have fluoridated water than rural residents, which is consistent with increasing returns to scale in providing CWF. We also perform analyses using only urban areas because 1) wages and occupations are likely to differ by urban residence and 2) urban areas are likely to be in large labor market areas with multiple counties of varying fluoridation rates so that an equilibrium with a beauty premium can arise, as demonstrated in Figure 2. 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 adult wages – moves up and down across the fluoridation categories. Of the 27 individual level variables other than urban residence, only 3 differences are statistically significant, and 2 of these differences become insignificant when limiting the comparison to urban residences only (not shown). 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.

As a falsification test for the endogeneity of CWF, we assess whether water fluoridation affects two non-dental related health outcomes: height and AFQT scores. Water fluoridation is not believed to have a direct impact on height[22] or intelligence[23], so finding an effect would suggest misspecification.[24] 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 overall and by gender are shown in Table 3. We use only one measure of height and AFQT – that obtained in the 1981 interview when respondents were between the ages of 16 and 23 – and drop the age dummies. In all of our regressions we find no statistically significant effect of water fluoridation on height or AFQT. Our estimates are generally smaller than the standard errors, are small in magnitude, and follow no consistent pattern in sign.

As a second falsification test, we assess whether families sort into neighborhoods with (or without) CWF. Parents who move to neighborhoods with CWF may be high human capital investing parents, and we may not observe all of these investments. In the second panel of Table 3, we present results from separate regressions of occupation and education of the parents of the NLSY respondents on fluoridation status. In no instance do we find evidence that parents with

[22] 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 be severe enough to lead to stunting, though.

[23] Two concerns with using AFQT as a falsification test are that 1) AFQT could be affected by water fluoridation if better oral health improves human capital through reduced absenteeism or better ability to focus in the classroom and 2) some evidence suggests a relationship with IQ and excessive intake of fluoride (Xiang et al. (2003)), though this study was an event study using two villages in China, so valid statistical inference is compromised.

[24] 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)).

more education or in higher ranked occupations are more likely to reside in a fluoridated area. These results support that any measurement error in fluoridation exposure is likely to be classical, and also support our assumption of the exogeneity of water fluoridation.

6. Results

6.A. Main results

Table 4 shows our main results in which we assign fluoride status based on county of residence at birth and measure fluoride exposure as the average over the first 5 years, the point at which the front 4 teeth develop. In a model that includes only variables from 1960 CCDB as measures of county level influences, we find a positive but statistically insignificant effect of CWF on earnings of 1.4% for all individuals. In the second column we add county level variables designed to capture contemporaneous investments, and our estimates fall minimally to 1.3%. In the third column, we add 1970 CCDB variables, and estimates are again comparable. When we add 1970 investment variables in column (4), our estimates are also unchanged. In the last column, when we add county level data on dental and medical care availability, our estimates are again unaffected. The robustness of these estimates to the numerous county level controls underscores the strength of our empirical strategy, though we can not reject the null hypothesis that CWF has no effect on earnings.

Urban residence is an important predictor of both fluoridation status and earnings, so we repeat this same set of specifications for individuals residing in an urban residence at age 14, shown in the second panel. Our estimates remain statistically insignificant, but are slightly larger (around 2.4%) and also extremely insensitive to the inclusion of controls. Since those in urban residence during childhood are also likely to be in an MSA as an adult[25], this supports the notion of variation on CWF within a labor market in order for a beauty premium to arise.

To assess whether gender differences exist, we also estimate effects separately by gender. For males, shown in Panel B, we find smaller effects indistinguishable from zero in all specifications, regardless of urban residence. For women, however, we find larger effects that are also insensitive to controls. Furthermore, we now find statistically significant effects when focusing on urban residents. In our full specification, exposure to fluoridation during childhood increases earnings by 4.5%. This provocative pattern by gender points to potentially important labor market differences in how men and women are treated, and below we further probe explanations for this.

The fact that we document an effect of CWF for women and not for men further strengthens our claim that CWF is exogenous. If, for example, communities that fluoridate their drinking water contemporaneously provide additional public investments in children, then in order to invalidate our research design these investments must only have had an effect on women's earnings and not men's earnings, which we find highly implausible.

Table 5 shows further sensitivity analyses for the urban sample.[26] Column (1) repeats results from our preferred specification. The next column allows earnings profiles within states to vary over time by interacting cohort, age, and state dummies, but this has virtually no effect on the estimates, though it decreases precision.

As another specification test, we limit our analysis to only counties that eventually fluoridated as of 1970, the last year the youngest respondents in the NLSY were age 5, to eliminate the concern that counties that never fluoridate systematically differ from counties that

[25] This is true for 73% of our sample.
[26] Estimates for the entire sample were also robust to the sensitivity analyses.

do. In a sense, this specification check presents a model that exploits the timing of CWF adoption by comparing only counties that fluoridate, but do so at different times. The results, shown in column (3), are also virtually unchanged.

In column 4, we eliminate all individuals born in the 10 counties with greater than 1 million people as of 1960 to assess the influence of outliers.[27] It is possible that results are driven by, say, New York, Los Angeles, Houston, and Chicago, where labor markets may differ from the rest of the county. Results, however, are again unaffected.

In column 5, we estimate models with MSA fixed effects to exploit the variation in fluoridation exposure within geographically close areas and limit our comparisons to individuals residing in a large labor market. The results for all individuals are now slightly larger, though the effect for females is unaffected. This raises the possibility of an effect for males, though it is still considerably smaller than the effect for women.

In the final two columns of Table 5, we examine the sensitivity of our results to alternate measures of fluoride exposure. We reports results using CWF exposure through age 14 and for the sample that did not move between birth and age 14. Results are again comparable to the baseline results, supporting our assignment of fluoridation exposure.

The results thus far examined the impact on labor market earnings, but it is possible that oral health affects one's ability to secure employment.[28] Table 6 presents results with employment status as the dependent variable. Although results are imprecise, they generally support an impact of oral health on labor market outcomes: CWF has a larger effect on

[27] 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).

[28] Although the focus of this paper is on labor markets, we also explored the effect of CWF on marriage markets, but found little evidence of an effect. One complication in such an analysis is that although better oral health may increase the opportunity for marriage, it may also increase options outside of marriage.

employment status for women than men, and the effect of CWF is larger in urban areas. Furthermore, when we add employment status to our earnings regression (not shown), the effects of CWF are slightly smaller, which is consistent with oral health affecting the probability of being employed.[29]

In sum, the results from Tables 4, 5, and 6 suggest that fluoride exposure in childhood has a robust, statistically significant effect on hourly earnings of women. The effect for men is much smaller and 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 non-parametric trends, and alternative fluoridation exposure assignment strengthens our claim that we uncover a causal effect of fluoridation on earnings.

6.B. Effects by SES

The results in Table 3 suggest that the effects of fluoride exposure on tooth loss might be concentrated among those of lower SES, so we next examine whether the effects of fluoride exposure on earnings are likewise concentrated among low SES. We assess the effects of childhood SES on the effects of fluoridation by exploring effects of fluoridation on earnings separately by *parental* occupation, a predetermined factors unaffected by fluoridation exposure. Note that it is 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.

[29] Since recorded earnings reflect wages from current or most recent job, a currently unemployed person may have a lower wage because of the wage from their previous job does not account for inflation.

In Table 7, we 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 are concentrated amongst those with parents of low status occupations. These effects are large in magnitude: the effect from fluoride exposure roughly translates into a return of nearly $1/hour.[30]

6.C. 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 (6). If these factors mediate how fluoridation affects wages, then including them should lower the estimated effect of fluoridation on earnings relative to baseline estimates, with the degree to which π_1 changes reflecting the extent of mediation from that factor. We explore the role of occupation sorting and productivity via health and non-cognitive skills. Assuming we adequately control for these channels, any residual effect of π_1 after controlling for these variables reflects employer (both taste-based and statistical) and consumer discrimination, which we unfortunately cannot explicitly test for with the data.[31]

Table 7 presents our baseline results first, followed by results that include mechanisms. In column 2, we control for a self-reported measure of health limitations in the amount or kind of

[30] Average hourly earnings in $1998 in the NLSY for women from the low SES category is roughly $11.
[31] Hamermesh and Biddle (1994) provide a test of consumer discrimination that we do not pursue here. The test would involve assessing whether the effect of CWF differs across occupations. For example, does CWF have a bigger effect in, say, sales than in construction, where there is more consumer interaction? The first issue with this test involves locating a suitable source that rates professions based on consumer interactions. The second, and perhaps more substantive issue, is that individuals who choose professions with consumer interactions despite poor oral health are likely to have other characteristics that make them particularly suitable for interacting with consumers, such as persuasiveness or friendliness, if poor oral health lowers productivity.

work, which is updated in every survey wave, as a measure of health. Although this does not directly relate to limitations associated with oral health, it has a statistically significant association with earnings. The effect of CWF is, however, unaffected by this variable, suggesting health may not be a mechanism.

In column 3, as measures of non-cognitive skills we include scores on the Rosenberg Self-Esteem (RSE) Scale, obtained in 1980 and 1987, and Center for Epidemiological Studies Depression (CESD) Scale, obtained in 1992 and 1994.[32] After imputing each score to preserve sample size, we separately average RSE and CESD scores for each individual to create one measure per individual. Our results suggest that although measures of self-esteem and depression are significantly associated with earnings, they do not impact our CWF estimate, suggesting non-cognitive skills are unlikely to be a channel whereby oral health affects earnings.

To assess the role of occupational sorting, we include a full set of 3-digit occupation dummies (based on the 1980 census of occupations) to reflect the degree to which physical appearance may affect earnings through occupation selection. Adding occupational dummies, shown in the next column, reduces the effect minimally, by about 6%, suggesting the possibility that occupational sorting explains some of the effect of oral health on earnings, but the effect is not substantial. In the final set of columns, we add all potential mechanisms simultaneously, and this makes little difference to our estimates.

The differences by gender that persist after accounting for occupational sorting furthers our ability to rule out certain mechanisms. Although our included measures of health and non-cognitive skills are incomplete, it seems unlikely that they explain different wage effects of oral health on earnings by gender. We can also rule out the possibility of statistical discrimination; if

[32] The CESD was also collected in 2002 in the over 40 health module, so is only available for a subset of the population.

employers use teeth as a signal of past investments, it seems implausible that within the same occupation these signals are used differentially depending on the gender of the employee. Based on these results, we conclude that oral health affects earnings primarily through consumer and taste-based employer discrimination.

6.D. The Labor Market Returns to Teeth

Although our primary goal in exploring the effect of CWF on tooth loss using the BRFSS was to assess the construct validity of our water fluoridation variable, we can also combine our estimates from the BRFSS and the NLSY to estimate the labor market returns to teeth for women. This is akin to split-sample instrumental variables, where the results from Table 3 are the first stage estimates of α_1 from equation (3) and the results from Table 4 are the reduced form estimates of π_1 from equation (4), so $\pi_1/\alpha_1=\beta_1$, the labor market returns to teeth. We note that this estimate overstates the impact of tooth loss because water fluoridation affects oral health in more ways than through tooth loss, so our estimates of the first stage are underestimates of the full effect of fluoridation on oral health.

To do this, we also adjust the BRFSS estimates to reflect the measurement error that occurs because we measure only county of residence in adulthood. We assess the magnitude of this measurement error by re-estimating our NLSY models but treating current county of residence as county of residence in childhood. The ratio of our baseline estimates to this estimate from the NLSY (3.46) gives a measurement error adjustment factor that we assign to α_1, making the effect of CWF on tooth loss -1.374 (instead of -0.397).[33]

[33] More formally, under classical measurement error, $\pi_1=\lambda\cdot\pi_1^*$, where π_1 is the estimated effect of CWF on earnings using county of birth to assign childhood CWF (the true measure of CWF), π_1^* is the estimated effect of CWF on earnings using current county to assign childhood CWF, and λ is the ratio of the variance of the true measure of CWF to the variance of the true measure of CWF plus the variance of any measurement error. Therefore, $\lambda=\pi_1/\pi_1^*=$ 3.46. We only have an estimate of α_1^*, so we assume measurement error from assuming current county is county of birth is the same in the NLSY and BRFSS (of which we have no reason to believe otherwise), and use λ to scale our estimate of α_1^* to obtain an estimate of α_1 ($=\lambda\cdot\alpha_1^*$).

The results indicate the labor market value of the marginal tooth for a women is 3.3% of hourly earnings. For an urban-residing woman earning $11/hour and working full time, this amounts to nearly $720 per year. To put this in context, the cost of a commercial dental implant ranges from $1250 to $3000.[34] As these results suggest, for some populations the magnitude of the labor market costs of missing teeth may exceed the costs of remedial intervention after a short period of time. The introductory anecdotes suggest these individuals appear to be making (privately) sub-optimal decisions, so public policy intervention might take the form of improving information or reducing liquidity constraints.

7. Conclusion

The most common complaint from individuals who lack health insurance concerns their lack of access to dental care (Sered and Fernandopulle (2005)). High 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 2% 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. Our evidence generally supports

[34] See http://www.aboutcosmeticdentistry.com/procedures/dental_implants/cost.html.

employer and consumer discrimination as the main channels whereby oral health effects earnings, which supports the “Beauty Myth” argument that women are held to different standards regarding physical appearance than men.

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. 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 community water fluoridation – on labor market outcomes. Tooth decay remains widespread today, and other highly effective dental interventions can decrease the onset and consequences of poor oral health. Knowing the full benefits from these interventions is crucial for assessing the cost-effectiveness of these dental interventions, and our estimates of the economic value of teeth in the labor market help to fill this gap.

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Figure 1. County Fluoridation Rates in 1965

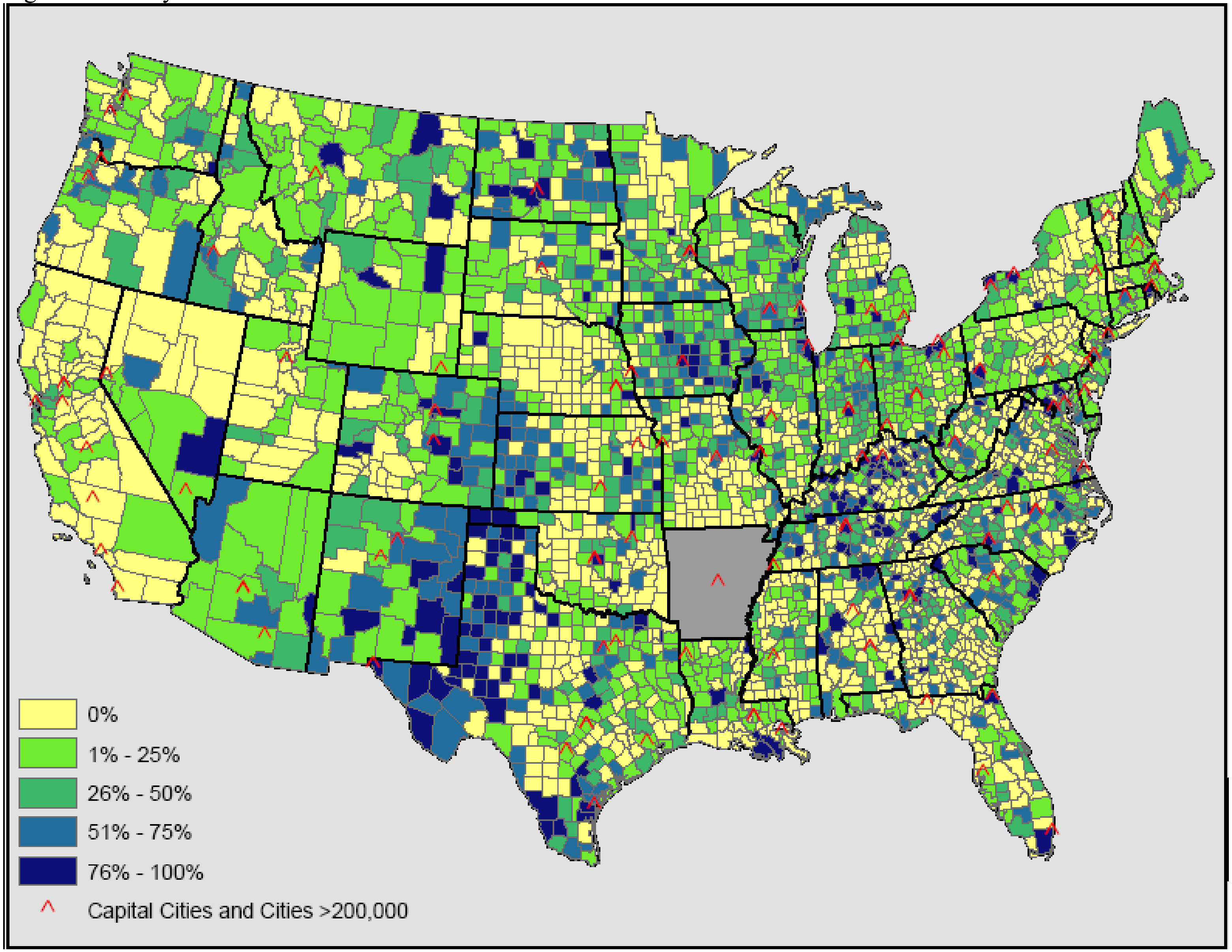

Figure 2: Fluoridation Rates in Chicago MSA over Time

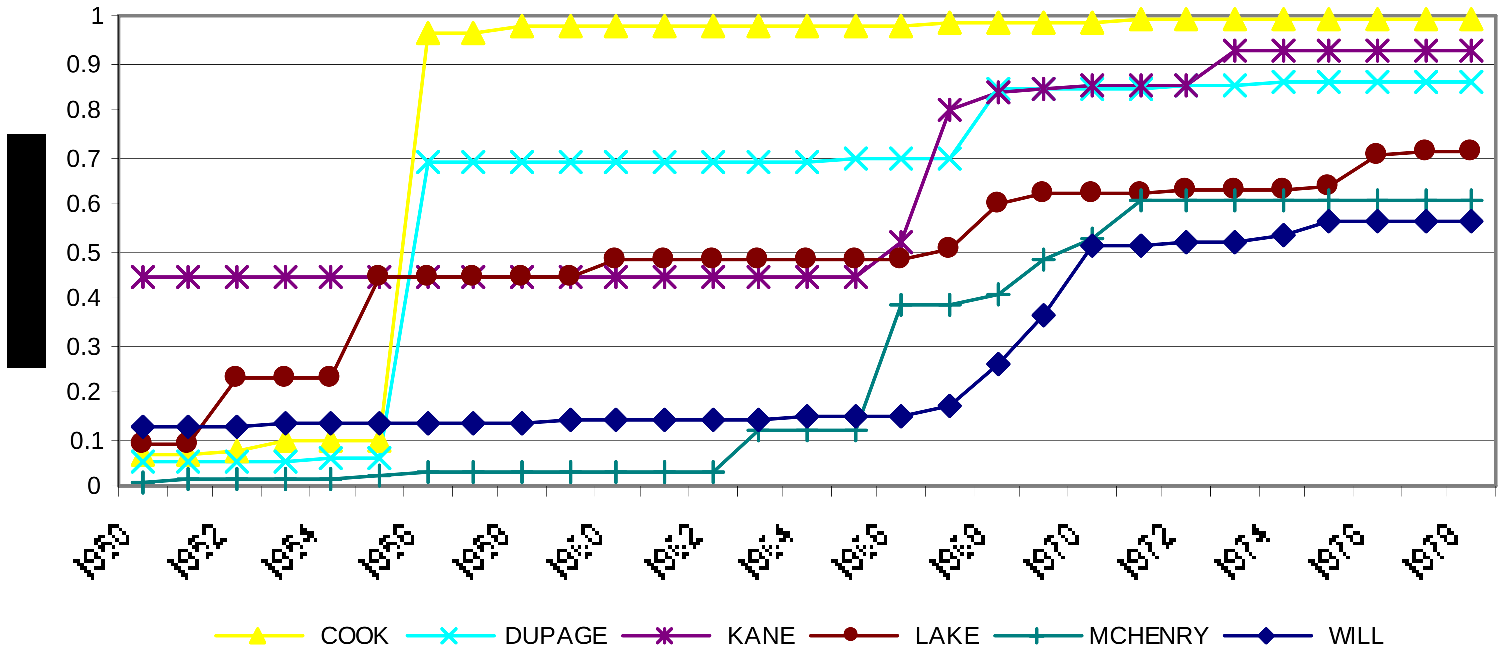

Table 1. Regression Results of Water Fluoridation on Number of Teeth Lost in BRFSS using NLSY Cohort

	1	2	3	4	5	6	7	8	9	10
			all			white	black	HS dropout	HS grad	college grad
Fluoridation rate	-0.323	-0.33	-0.392	-0.388	-0.397	-0.349	-0.977	-0.981	-0.581	0.06
	[0.106]**	[0.109]**	[0.108]**	[0.109]**	[0.110]**	[0.124]**	[0.284]**	[0.584]	[0.140]**	[0.085]
Observations	44562	44562	44562	44562	44562	34674	4130	3176	26287	15099
Individual level covariates	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
1960 demographic variables	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
1960 investment variables	N	Y	Y	Y	Y	Y	Y	Y	Y	Y
1970 demographic variables	N	N	Y	Y	Y	Y	Y	Y	Y	Y
1970 investment variables	N	N	N	Y	Y	Y	Y	Y	Y	Y
1974 health care variables	N	N	N	N	Y	Y	Y	Y	Y	Y

Notes: * significant at 5%; ** significant at 1%. Heteroskedasticity-consistent standard errors that adjust for clustering at the county level in brackets. Number of teeth lost imputed for those with 1 or more but not all lost, described in more detail in text. The unit of observation is individual. All regressions include state, cohort, and age dummies and fluoridation rate in current county of residence. Individual level controls include age, gender, race, and education. Demographic, investment, and health care variables listed in Appendix Table 1.

Table 2. Demographic Statistics by Fluoridation Status

percent fluoridated	0%	1-25%	26-50%	51-75%	76-100%	Prob > F
Urban residence	0.77	0.75	0.72	0.77	0.87	0.00
Foreign language	0.16	0.15	0.12	0.18	0.17	0.44
Magazine regularly	0.58	0.58	0.61	0.60	0.59	0.82
Newspaper regularly	0.76	0.80	0.81	0.78	0.80	0.34
library card	0.71	0.72	0.70	0.71	0.77	0.11
# of siblings	3.77	3.72	3.71	4.04	3.64	0.62
Education mother	10.41	10.51	10.82	10.32	10.85	0.17
Education father	9.61	9.81	9.87	9.69	9.92	0.86
Mom & dad in HH	0.68	0.69	0.73	0.69	0.67	0.13
Mom born in US	0.95	0.95	0.97	0.93	0.94	0.09
Dad born in US	0.93	0.94	0.96	0.93	0.93	0.20
No religion	0.04	0.04	0.04	0.03	0.04	0.47
Protestant	0.05	0.05	0.05	0.04	0.05	0.72
Baptist	0.30	0.31	0.30	0.27	0.28	0.92
Episcopalian	0.02	0.02	0.01	0.02	0.02	0.90
Lutheran	0.07	0.05	0.07	0.11	0.05	0.09
Methodist	0.08	0.10	0.09	0.09	0.08	0.61
Presbyterian	0.03	0.03	0.02	0.03	0.03	0.51
Roman Catholic	0.31	0.28	0.30	0.33	0.37	0.52
Jewish	0.01	0.01	0.01	0.00	0.01	0.56
other religion	0.10	0.12	0.12	0.10	0.08	0.03
Male	0.51	0.50	0.53	0.50	0.49	0.29
Black	0.24	0.24	0.23	0.22	0.29	0.86
Hispanic	0.12	0.11	0.07	0.13	0.15	0.16
Height	67.35	67.20	67.42	67.32	67.10	0.34
AFQT	41.03	40.56	40.43	40.18	40.41	1.00
Duncan SEI - mom	17.95	17.73	18.63	15.24	19.28	0.05
Duncan SEI - dad	29.74	31.34	28.85	31.49	31.34	0.44
Highest grade comple	12.18	12.15	11.96	12.01	12.11	0.29
Observations	2,557	3,260	921	896	1,718	

Note: 'Prob > F' is p-value from F-test that means are equal across fluoridation categories

Table 3. Falsification Tests for Exogeneity of Water Fluoridation

	1	2	3	4	5	6
		all			urban	
	all	male	female	all	male	female
ommited variable bias test						
y=AFQT	0.333	0.944	-0.6	-0.494	0.024	-1.187
	[0.762]	[1.160]	[1.019]	[0.797]	[1.203]	[1.146]
Observations	9017	4498	4519	7011	3475	3536
y=height	-0.049	-0.017	-0.042	-0.053	0.037	-0.157
	[0.111]	[0.160]	[0.154]	[0.122]	[0.178]	[0.163]
Observations	9389	4720	4669	7303	3649	3654
sorting test						
y=parent's education	0.043	0.085	0.04	0.046	0.107	0.014
	[0.102]	[0.135]	[0.129]	[0.114]	[0.153]	[0.152]
Observations	9129	4571	4558	7099	3537	3562
y=Duncan SEI	0.373	-0.474	1.031	1.231	0.676	1.477
	[0.921]	[1.287]	[1.209]	[1.035]	[1.474]	[1.385]
Observations	8390	4218	4172	6504	3257	3247

Notes: * significant at 5%; ** significant at 1%. See notes to Table 3. Results are based on specification with individual and county level covariates. The unit of observation is the individual.

Table 4. Regression Results of Water Fluoridation on Log Hourly Earnings

	1	2	3	4	5
A. All					
Fluoridation rate	0.014	0.013	0.016	0.014	0.015
N=93,171	[0.014]	[0.014]	[0.014]	[0.013]	[0.014]
Fluoridation rate (if urban)	0.023	0.024	0.025	0.022	0.023
N=72,395	[0.015]	[0.015]	[0.015]	[0.015]	[0.015]
B. Male					
Fluoridation rate	-0.006	-0.007	-0.001	-0.005	-0.003
N=47,965	[0.020]	[0.020]	[0.019]	[0.020]	[0.019]
Fluoridation rate (if urban)	-0.004	-0.005	0.000	-0.006	-0.004
N=37,098	[0.021]	[0.021]	[0.020]	[0.020]	[0.020]
C. Female					
Fluoridation rate	0.032	0.031	0.029	0.029	0.030
N=45,206	[0.018]	[0.018]	[0.018]	[0.018]	[0.018]
Fluoridation rate (if urban)	0.046	0.048	0.044	0.044	0.045
N=35,297	[0.020]*	[0.020]*	[0.020]*	[0.020]*	[0.020]*
Individual level covariates	Y	Y	Y	Y	Y
1960 demographic variables	Y	Y	Y	Y	Y
1960 investment variables	N	Y	Y	Y	Y
1970 demographic variables	N	N	Y	Y	Y
1970 investment variables	N	N	N	Y	Y
1974 health care variables	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. The unit of observation is individual-year. All regressions include state, cohort, age dummies, and fluoridation rate in current county of residence. Individual level controls given in Table 1. Demographic, investment, and health care variables listed in Appendix Table 1.

Table 5. Sensitivity Analysis of Regression Results of Water Fluoridation on Log Hourly Earnings

	1	2	3	4	5	6	7
	base	age-cohort-state dummies	WF 1970 > 0	pop < 1 million	MSA fixed effect	WF through age 14	county of birth = county at 14
A. All							
Fluoridation rate (if urban)	0.023	0.012	0.03	0.021	0.035	0.013	0.026
	[0.015]	[0.025]	[0.018]	[0.017]	[0.016]*	[0.017]	[0.021]
Observations	72395	72395	55839	60593	57482	72395	46649
B. Male							
Fluoridation rate (if urban)	-0.004	-0.02	0.01	-0.012	0.023	-0.018	-0.001
	[0.020]	[0.027]	[0.025]	[0.023]	[0.024]	[0.022]	[0.030]
Observations	37098	37098	28337	31058	29417	37098	24024
C. Female							
Fluoridation rate (if urban)	0.045	0.044	0.041	0.046	0.047	0.048	0.035
	[0.020]*	[0.030]	[0.026]	[0.023]*	[0.021]*	[0.023]*	[0.032]
Observations	35297	35297	27502	29535	28065	35297	22625

Notes: * significant at 5%; ** significant at 1%. Results are based on specification in column (5) of Table 4.

Table 6. Regression Results of Water Fluoridation on Employment Status

	1 all	2 male	3 female
Fluoridation rate	0.005	0.000	0.008
	[0.006]	[0.007]	[0.008]
Observations	97204	50195	47009
Fluoridation rate (if urban)	0.010	0.004	0.012
	[0.006]	[0.008]	[0.009]
Observations	75490	38816	36674

Notes: * significant at 5%; ** significant at 1%. Results are based on specification in column (5) of Table 4.

Table 7. Regression Results of Water Fluoridation on Log Hourly Earnings by Socioeconomic Status

	1 Low occupation	2 Middle occupation	3 High occupation
A. All			
Fluoridation rate (if urban)	0.053	-0.001	0.023
	[0.027]*	[0.024]	[0.027]
Observations	20828	24144	27423
B. Male			
Fluoridation rate (if urban)	-0.042	-0.041	0.007
	[0.037]	[0.038]	[0.034]
Observations	10735	12843	13520
C. Female			
Fluoridation rate (if urban)	0.121	0.031	0.037
	[0.041]**	[0.030]	[0.033]
Observations	10093	11301	13903

Notes: * significant at 5%; ** significant at 1%. Results are based on specification in column (5) of Table 4.

Table 8. Exploring Channels of Relationship between Water Fluoridation and Earnings

	1	2	3	4	5
A. All					
Fluoridation rate (if urban)	0.023	0.022	0.023	0.022	0.022
	[0.015]	[0.015]	[0.015]	[0.017]	[0.016]
health limitation		-0.157			-0.123
		[0.016]**			[0.016]**
Rosenberg self-esteem scale			0.013		0.01
			[0.001]**		[0.001]**
CESD scale			-0.004		-0.003
			[0.001]**		[0.000]**
Observations	72395	72395	72395	72395	72395
B. Male					
Fluoridation rate (if urban)	-0.004	-0.006	-0.006	0.000	0.003
	[0.020]	[0.020]	[0.020]	[0.021]	[0.019]
health limitation		-0.185			-0.137
		[0.024]**			[0.019]**
Rosenberg self-esteem scale			0.013		0.01
			[0.002]**		[0.001]**
CESD scale			-0.006		-0.004
			[0.001]**		[0.001]**
Observations	37098	37098	37098	37098	37098
C. Female					
Fluoridation rate (if urban)	0.045	0.045	0.046	0.042	0.042
	[0.020]*	[0.020]*	[0.020]*	[0.020]*	[0.019]*
health limitation		-0.132			-0.108
		[0.021]**			[0.017]**
Rosenberg self-esteem scale			0.015		0.01
			[0.002]**		[0.001]**
CESD scale			-0.003		-0.003
			[0.001]**		[0.000]**
Observations	35297	35297	35297	35297	35297
Occupation dummies	N	N	N	Y	Y

Notes: * significant at 5%; ** significant at 1%. Results are based on specification in column (5) of Table 4.

Appendix Table 1. County Level Variables Included in Analysis

1960 demographic variables from 1960 City & County Data Books (CCDB)
population % change 10 years
population % rural farm
median age
% >65 years old
population % <5 years old
death rate
marriage rate
employ rate
% employed manufacturing
% employed construction
% employed wholesale/retail trade
vacancy rate
% homeowners
% vote democratic president
% vote correct president
population
population per square mile
% population non-white
% population with >= HS degree
median schooling
% population < 5 yrs schooling
household size
% urban
median family income

1960 investment variables from 1959 Bureau of Economics Analsysis (BEA) and 1960 CCDB
local government % spending on education (1957)
local government debt ratio (1957)
income maintenance transfers (1959)
retirement & disability transfers (1959)

1970 demographic variables from 1970 CCDB
population % change 10 years
population % rural farm
median age
% >65 years old
population % <5 years old
death rate
marriage rate
employ rate
% employed manufacturing
% employed construction
% employed wholesale/retail trade
vacancy rate
% homeowners
% vote democratic president (1968)
% vote correct president (1968)
population
population per square mile
% population non-white
% population with >= HS degree
median schooling
% population < 5 yrs schooling
household size
% urban
median family income
median house price
median rent

1970 investment variables from 1968 BEA and 1970 CCDB
local government % spending on education (1967)
local government debt ratio (1967)
income maintenance transfers (1968)
retirement & disability transfers (1968)
medical insurance transfers (1968)

1974 health care variables from 1974 County Business Patterns
physicians per capita
dentists per capita