The Economic Value of Teeth

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ABSTRACT

This paper examines the effect of oral health on labor market outcomes by exploiting variation in fluoridated water exposure during childhood. The politics surrounding the adoption of water fluoridation by local governments suggests exposure to fluoride is exogenous to other factors affecting earnings. Exposure to fluoridated water increases women's earnings by approximately 4 percent, but has no detectable effect for men. Furthermore, the effect is largely concentrated amongst women from families of low socioeconomic status. We find little evidence to support occupational sorting, statistical discrimination, and productivity as potential channels, with some evidence supporting consumer and possibly employer discrimination.

I. Introduction

Healthy teeth are not only a vital component in maintaining general health, but they also make an obvious contribution to physical appearance. In this paper, we examine the effect of teeth on labor market outcomes. While many studies have provided evidence of labor market discrimination related to physical appearance,[1] our focus is unique in that we examine a measure of physical appearance that, unlike race, gender, or height, is highly responsive to interventions. Community

1. See, for example, Hamermesh and Biddle (1994), Persico, Postlewiate, and Silverman (2004), Altonji and Blank (1999), Bertrand and Mullainathan (2004).

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water fluoridation, dental sealants, and fluoride treatments dramatically reduce tooth decay. If tooth decay occurs, caries can be effectively treated through filing decayed teeth. If caries are not treated and tooth loss occurs, restorative care, such as implants and dentures, can compensate for tooth loss.

Estimating the impacts of discrimination is complicated by the fact that researchers observe far less than employers do about potential workers, so any estimated differences in earnings could reflect inadequate controls for prelabor market covariates. Moreover, reverse causality is possible since wages can affect aspects of physical appearance amenable to spending, such as visits to the beauty salon, clothing purchases, and cosmetic surgery. Even more challenging in this research is the ability to identify the mechanisms by which discrimination arise (see, for example, Altonji and Blank 1999). For example, audit studies where fictitious individuals randomly assigned to a racial group apply for jobs largely overcome omitted variable bias and reverse causality issues (Bertrand and Mullainathan 2004), but they are necessarily limited in the duration of followup (since the fictitious job seekers never actually take jobs) and only focus on one possible mechanism (employer discrimination).

To address these concerns, we exploit variation in access to fluoridated water during childhood. Numerous studies have demonstrated that community water fluoridation (CWF) significantly reduces dental caries, by as much as 60 percent, and has a lasting impact on adult oral health. Despite the apparent success of CWF, controversies surrounding the adoption of CWF by local governments suggest exposure to fluoride during childhood is plausibly 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 of 1979 (NLSY79), were children (Crain, Katz, and Rosenthal 1969). The result of this political structure, as empirical evidence below supports, is that CWF adoption is uncorrelated with unobservable factors affecting wages. To the extent that areas that never fluoridate systematically differ from areas that do in unobserved ways, we also focus on areas that eventually fluoridate to exploit the timing of fluoridation adoption.

We find that children who grew up in communities with fluoridated water earn approximately 2 percent 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, to various measures of fluoride exposure, and to focusing exclusively on areas that ultimately fluoridated. These effects are concentrated amongst women, particularly those who grew up in families of lower socioeconomic status. In exploring the mechanisms of labor market discrimination, we find little evidence to support occupational sorting, statistical discrimination, and productivity as potential channels, but find some evidence to support consumer discrimination, and cannot rule out the possibility of employer discrimination.

Our results are also of particular importance to public policy regarding dental care. Low-income individuals, especially children, suffer disproportionately from oral diseases, particularly tooth decay, because of inadequate preventative care and treatment.[2] While the costs of the numerous dental interventions that can effectively

2. For example, the incidence of tooth decay is twice as common for black and Hispanic children than whites (U.S. Department of Health and Human Services 2000).

reduce these disparities are known, the benefits are not. Our estimates of the economic value of teeth in the labor market provide evidence of a largely overlooked benefit of oral health that can be used in assessing the cost-effectiveness of a wide range of dental interventions that may reduce disparities in dental health and thus improve the economic prospects of low-income individuals.

II. Background

A. Fluoride and Teeth

Research in the middle of the 20th century found that communities with higher rates of naturally occurring fluoride had lower rates of dental caries. Public water systems began adding fluoride to drinking water, beginning with Grand Rapids, Michigan in 1945. A wide body of research confirms that fluoride reduces the onset of tooth decay (see U.S. Department of Health and Human Services (2000) for a review). Given the low incidence of side-effects and high cost-effectiveness of fluoridation, the U.S. Centers for Disease Control has labeled this intervention "one of the 10 greatest public health achievements of the 20th century."

Tooth decay occurs when acids in the mouth break down tooth enamel, and dental research suggests fluoride reduces decay in children by altering the composition of enamel prior to tooth eruption (making it more permanently resistant to decay) or protecting enamel after it has formed (Tinanoff 2009). 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 (Singh, Spencer, and Armfield 2003).

For the population we study, born 1957 to 1964, public drinking water was the primary source of fluoride. Alternative delivery mechanisms, such as fluoridated toothpaste and sealants, did not become popular until the late 1960s and early 1970s. Those in our sample exposed to fluoridated water during childhood experience better oral health as adults either because of systemic effects or untreated decay during childhood leading 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 at levels beyond typical CWF adjustments. To the extent that fluorosis exists, any effect we find will be net of this effect. More serious—though more disputed—is the purported link between fluoride intake and other health outcomes, notably bone cancer in children (Bassin et al. 2006). 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.[3]

3. For the purposes of our study, however, a link between fluoride and bone cancer is unlikely to impact our analysis because it is an extremely rare disease—the incidence in children younger than 15 is 5.6 per million—and the magnitude of the estimates documented by Bassin et al. (2006) imply a trivial, if any, impact on our sample of roughly 12,000 individuals.

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, coworkers, or customers have personal preferences about non-job related worker characteristics, such as race or gender. More recently, several studies have documented labor market discrimination related to physical appearance (see, for example, Hamermesh and Biddle 1994 or Biddle and Hamermesh 1998). For example, Hamermesh and Biddle (1994) find that better than average-looking people earn 5–10 percent more than average-looking people, who earn 5–10 percent more than below average-looking people.

There are 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 these employees. Taste-based employer discrimination may cause employers to pay more attractive workers higher wages. Both of these could lead to occupational sorting whereby more attractive individuals choose professions with more direct customer contact or where they suspect more employer discrimination. Appearance may serve as a proxy for human capital, such as the degree of previous labor market success, indicating statistical discrimination by employers. Physical appearance might also affect individuals' noncognitive skills, such as self-confidence, which may have a direct effect on productivity (Mobius and Rosenblatt 2006; Heckman 2000; Persico Postlewaite, and Silverman 2004).

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 (Eli, Bar-Tal, and Kostovetzki 2001). Spending on cosmetic oral health products, such as tooth whitening, is growing rapidly (American Academy of Cosmetic Dentists 2004). Tooth loss is anecdotally associated with difficulty finding employment (Shipler 2004; Eckholm 2006). In a simple prepost design without a control group, Hyde, Satariano, and Weintraub (2006) find that, in a group of welfare recipients in San Francisco, CA, those who completed a dental treatment had better employment outcomes. But there is no systematic empirical evidence we are aware of that causally links oral health with labor market outcomes.[4]

In addition to physical appearance, oral health may affect earnings directly through health. 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 older than 18 and 3.1 days of lost school per 100 youths aged 5–17 because of dental symptoms or treatment. In support of this channel, the military requires rejecting or not deploying potential soldiers because of missing teeth (Britten and Perrott 1941; Klein

4. In a bivariate regression, Killingsworth (1997) 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.

1941) or poor oral health (Chaffin, Marburger, and Fretwell 2003) because dental emergencies interfere with combat readiness (Teweles and King 1987).

III. Empirical Strategy

Most of the costs associated with providing community water fluoridation are fixed, and the marginal cost per person is quite low, so the most important factor in determining fluoridation status is population served by a water district. 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. There may be other notable differences between urban and rural areas, such as differing wages and occupations because of different costs of living and economies of agglomeration. Furthermore, as we describe in more detail below in Section 5A, urban areas are likely to be in larger labor markets with multiple counties of varying fluoridation rates so that an equilibrium with a beauty premium can arise. Therefore, we focus our empirical analysis only on individuals who resided in an urban residence at age 14; this accounts for 78 percent of the NLSY79 sample.[5]

Beyond the population served, the politics behind CWF reduces the likelihood that decisions about water are related to earnings. The political process of community water fluoridation followed different paths in different localities. Smaller communities often held referendums. A substantial political science and sociology literature examining the relationship between community characteristics and fluoridation referendum results found little, if any, correlation between community characteristics and referendum results (see Sapolsky 1968 for a review). Rather, the results of fluoridation referendums tended to reflect the perceived credibility of the expert scientists on each side and the degree of activism by fluoridation opponents, who disputed the dental benefits of fluoride, alleged that fluoride had adverse health consequences, and asserted that community fluoridation infringed on individual liberty.

In larger communities, fluoridation decisions were generally made through administrative action. The decision of New York City provides a typical case of this process, which unfolded over ten years of administrative decisionmaking with little direct public input. In 1952, the New York City Board of Health, an expert panel of appointed physicians and other health leaders, recommended to Mayor Vincent Impellitteri and the City Board of Estimate that fluoridation be implemented. The Board of Estimate, which had budgetary authority, failed to appropriate the funds necessary and the proposal was shelved in 1957 (Illson 1955). Six years later, Mayor Robert F. Wagner, Jr., a strong proponent of fluoridation, and the Board of Estimate revisited the issue (Kihss 1963). At public hearings, opponents demanded a referendum, but the Board of Estimate asserted that no referendum was required and unanimously authorized funds for fluoridation equipment in 1963. In 1964, the Board

5. Consistent with this, when we include all individuals regardless of urban residence, we generally find smaller impacts of CWF.

Chart 1
Year fluoridation adopted in select cities

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)

of Health amended the New York City health code to require fluoridation of the public water supply. Subsequent legal challenges were denied on the grounds that the City's Board of Health had the authority to make amendments to the health code that affected "the security of life and health in the city" (Paduano v. City of New York 1965 and 1966). Finally, in 1965, fluoridation of the water supply commenced.

The case of New York City illustrates the common scenario where the decision to add fluoridation to the water supply for millions of people was ultimately determined by a handful of unelected administrative officials. In fact, 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, Katz, and Rosenthal 1969). The result of this political structure is that the adoption of CWF in communities throughout the United States follows little discernible pattern during the time period we study.

To document the seeming randomness of CWF, we highlight several sources of variation in CWF throughout the United States. First, Chart 1 presents the year major cities within selected states adopted CWF. 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 fluoridation rates among less populated areas. Figure 1 plots county level fluoridation rates (described in more detail below) in 1965, with capital cities and cities with more than 200,000 people denoted for reference.[6] 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 (for example, 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 County and the five counties within Illinois immediately

6. Fluoridation information from Arkansas is missing in our data.

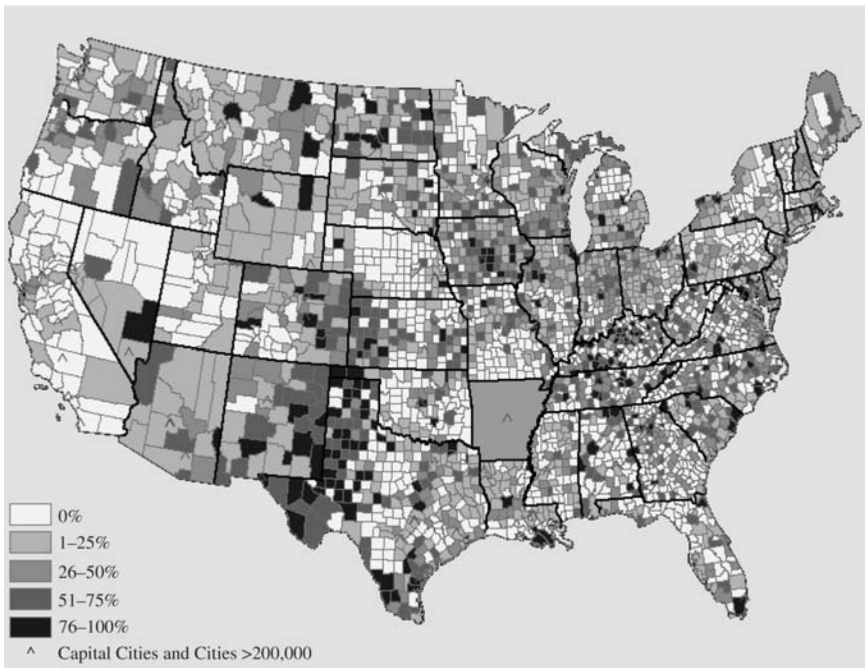

Figure 1
County Fluoridation Rates in 1965

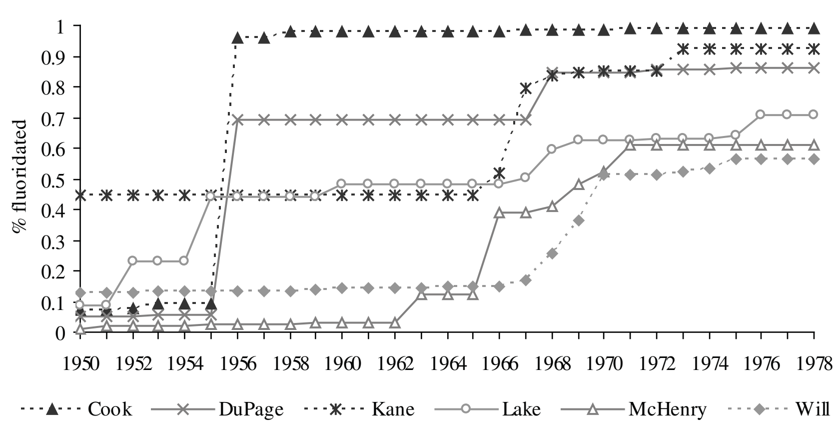

Figure 2
Fluoridation Rates by County in Chicago MSA over Time

adjacent to it for the time period surrounding when the respondents in the NLSY79 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 opposition 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 will identify the causal effect of fluoridation on labor market outcomes. After we explain our data in more detail, we present more formal assessments of the exogeneity of CWF in Section 5D.

IV. Data

A. Sources

We combined several secondary data sets in this study in order to capture information on fluoridation status, earnings, and background demographics. 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.[7]

For demographic data, we use the geocoded version of the National Longitudinal Study of Youth (NLSY79), 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 NLSY79 collects detailed information on economic and social behaviors at each survey wave. 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 NLSY79 is the availability of the county of each respondent's residence at birth, age 14, and 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 in several county level variables to assess the possibility of the endogeneity of CWF. We add 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)

7. 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. Fewer than 5 percent of respondents in our sample live in counties with at least some naturally fluoridated water, so we combine data on naturally and adjusted fluoridated areas.

Regional Economic Information System on income maintenance (SSDI, AFDC, and Food Stamps), medical insurance, and retirement and disability transfers at the 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 A1 lists all included county level variables.

B. Assigning Fluoride Exposure

In order to assign fluoride exposure to each individual in the NLSY79, we first compute county fluoridation rates in 1990 by merging the Fluoridation Census data with total population estimates of each county from the 1990 Census of Population and Housing. 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 five and 14 years of life as our measures 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 1,000 of the 5,000 people within the county, implying a fluoridation rate of 0.2. Table 1 displays how we compute the five-year cumulative fluoride exposure for individuals from the NLSY79 cohort. Since fluoridation began in 1960, the contemporaneous fluoridation rate is 0.2 for 1960 on and 0 for 1959 and earlier. Cumulative fluoride exposure for the first five years of life for an individual born in 1957 is the mean of contemporaneous fluoridation rates for the years 1957–61, which is .08 $(=(0+0+0+0.2+0.2)/5)$. For an individual born in 1964, fluoride exposure is the mean of contemporaneous fluoridation rates for the years 1964–68, which is 0.2 $(=(0.2+0.2+0.2+0.2+0.2)/5)$. 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.

In our baseline estimates, we assume the respondent remains in the county of birth for the first five years of life. Since we do not have information on county of residence between birth and age five, this may misallocate fluoride exposure. Moreover, reported county of birth could reflect the county of the hospital of birth rather than of a child's residence (this distinction was not made clear in the NLSY79 questionnaire). We perform several sensitivity analyses to assess the consequences of measurement error, such as using only respondents who report the same county of residence at both birth and age 14 in the NLSY79, which is roughly 60 percent of our sample.

Table 1
Example of fluoridation exposure assignment based on fluoridation status

year	1990	1968	1967	1966	1965	1964	1963	1962	1961	1960	1959	1958	1957
CFE	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.0	0.0	0.0
WFC	—	—	—	—	—	0.2	0.2	0.2	0.2	0.2	0.16	0.12	0.08

Notes: CFE = contemporaneous fluoride exposure, WFC = five-year cumulative fluoride exposure by birth year

Given that fluoride also has contemporaneous 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 childhood to exposure during adulthood. The fluoridation census ends in 1992, so we assume fluoridation rates are constant after that year. The overall percentage of population receiving fluoridated water has only changed from 56.1 percent in 1992 to 59 percent in 2002, the last year for which data is available in the NLSY79, supporting the plausibility of this assumption.

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 tooth loss 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 four categories to choose from: (1) none; (2) 1–5; (3) six or more but not all; and (4) all teeth missing. We impute exact tooth loss using cold deck imputation with donors coming from the National Survey of Oral Health (NSOH) in U.S. Employed Adults and Seniors (1985–86), which contains exact number of teeth lost for 14,801 individuals.[8]

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 given the high mobility rates in the United States—over half of the respondents in the NLSY79 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.

8. 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.

Our estimates may differ from previous studies of the effect of fluoridation on oral health for at least three reasons. 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, since tooth loss is only one possible consequence of tooth decay (BRFSS does not collect other measures of oral health), any effects we find may understate the full impact of fluoridation on oral health. Three, most studies look at the effect of fluoridation exposure on tooth decay during childhood, so we are extending this research by looking at oral health during adulthood, 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. The first panel of Table 2 provides estimates from a linear regression of tooth loss against childhood fluoridation exposure for individuals from the BRFSS in the same cohort as the NLSY79, with controls for individual and county level covariates and state and year dummy variables. The results indicate that water fluoridation significantly reduces tooth loss: changing from a non-fluoridated to fluoridated community results in roughly one-third of a tooth more in adulthood. These results are highly insensitive to numerous county level controls, supporting the exogeneity of CWF. These results also indicate that the effects of dental health via water fluoridation appear to persist into adulthood and that our measure of fluoridation exposure is valid.

Low SES individuals may be 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 higher amongst higher SES individuals, so water fluoridation should have a smaller impact on higher SES individuals. The second panel of Table 2 supports this: the effect of water fluoridation on tooth loss is greater for blacks, who are, on average, of lower SES. Not only do blacks have a higher incidence of mean tooth loss (2.7 vs. 1.6), but the marginal impact of CWF rises from -0.3 for whites to -1 for blacks. Furthermore, although completed education could potentially be affected by tooth loss, we find a strong gradient in tooth loss by education. High school dropouts have a mean tooth loss of four and a marginal impact of fluoridation of -1, while the respective numbers for college graduates are 0.9 and 0.1.

In the second panel, we examine how fluoride affects whether an individual has lost 6 or more teeth, a more serious indication of tooth deficiency likely to be readily visible in the labor market. On average, 11 percent of blacks have lost six or more teeth, while only 6 percent of whites have. The marginal impact of fluoridation is five percentage points for blacks and one percentage point for whites. Similar patterns arise by education levels.

There results provide three implications for our analysis. (1) Our assignment of fluoride exposure, despite the likely measurement error, supports enough signal for detecting an impact of CWF on earnings. (2) Because the marginal effects of fluoridation are higher for lower SES individuals, 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. (3) Even though our use of tooth loss captures only one aspect of oral health, a considerable degree of poor oral health exists in the population, especially for low SES individuals.

Table 2
Regression Results of Water Fluoridation on Number of Teeth Lost and ≥6 Teeth Lost in BRFSS using NLSY79 Cohort

	1	2	3	4	5
A. All					
y = number of teeth lost	−0.323	−0.33	−0.392	−0.388	−0.397
	[0.106]**	[0.109]**	[0.108]**	[0.109]**	[0.110]**
Observations	44,562	44,562	44,562	44,562	44,562
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
B. By race and education	white	black	HS dropout	HS grad	college grad
y = number of teeth lost	−0.349	−0.977	−0.981	−0.581	0.06
	[0.124]**	[0.284]**	[0.584]	[0.140]**	[0.085]
Mean dependent variable	1.62	2.68	4.05	1.96	0.86
$y = \geq 6$ teeth lost	−0.013	−0.051	−0.034	−0.029	0.005
	[0.007]	[0.018]**	[0.034]	[0.008]**	[0.005]
Mean dependent variable	0.06	0.11	0.20	0.07	0.02
Observations	34,674	4,130	3,176	26,287	15,099
Individual level covariates	Y	Y	Y	Y	Y
1960 demographic variables	Y	Y	Y	Y	Y
1960 investment variables	Y	Y	Y	Y	Y
1970 demographic variables	Y	Y	Y	Y	Y
1970 investment variables	Y	Y	Y	Y	Y
1974 health care variables	Y	Y	Y	Y	Y

Notes: * significant at 5 percent; ** significant at 1 percent. 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 A1.

V. Methods

A. Conceptual Framework

We provide a simple behavioral model where workers sort into occupations and make investments in oral health, and both employers and consumers discriminate in the labor market. Labor market wages (w) in occupation j are determined by productivity (q_j), oral health (oh), and human capital (hc) of the worker. Human capital is affected by oral health, such as absenteeism and self-esteem, and other factors (x). Workers are paid wages according to:

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

Workers invest in oral health, which is affected by CWF and other inputs into dental care (d), such as dentist visits.[9] Their ability to make investments in oral health depends on 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 for 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 increasing human capital, 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 relative to other workers in the same labor market, then there must be variation in beauty within a labor market in order for the equilibrium wage to have a beauty premium. This might attenuate the beauty premium from CWF, which is a community level treatment where all individuals within the community are equally treated. However, labor markets often consist of multiple communities, and, as Figure 2 demonstrates, there is considerable spatial variation in fluoridation rates within a small geographic area, which is expected to generate varying rates of oral health within a given labor market.[10]

Three empirical issues arise in estimating Equation 1. 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, particularly by gender. Although Hamermesh and Biddle (1994) do not find statistically significant evidence of differential effects of beauty by gender, several studies find considerably larger impacts of obesity on earnings for women (see, for example, Averett and Korenman 1996 and Cawley 2004). Although the reasons for this difference are largely unknown, one hypothesis suggests 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 at-

9. See Blinder (1974) and Killingsworth (1977) for more detailed models of investing in oral health.
10. With varying rates of fluoridation, a beauty premium can arise in equilibrium under various market scenarios, such as imperfect competition, asymmetric information, job search costs, or portable preferences (Altonji and Blank 1999; Charles and Guryan 2008).

tractive 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 may be more likely to work in manufacturing industries with limited consumer interactions, while women may be more likely to enter service occupations where consumer interaction is the norm. If consumer discrimination is important, women may choose particular occupations depending on their subjective views of their own physical appearance.

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 relate oral health to earnings by removing the potential mechanisms from Equation 1:

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

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

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

where *wf* indicates fluoride exposure during adulthood (a) and childhood (c) and d are substitutes for water fluoridation, namely the use of formal dental care through dentists. α_1 represents the effect of childhood exposure to water fluoridation on oral health.

Substituting Equation 3 into Equation 2 yields the following reduced form relationship:

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

where $\pi_1 (= \beta_1 \cdot \alpha_1 = \delta y / \delta oh \cdot \delta oh / \delta wfc)$ represents the reduced form effect of childhood water fluoridation on earnings. Since we exclude *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 NLSY79 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. For example, unfluoridated areas may have more dentists, which lowers the price of dental care and increases the use of CWF substitutes. To the extent that we do not adequately capture this, our estimate of π_1 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, our estimates understate the effect of water fluoridation on wages.

We expect compensatory behavior to vary by SES if wealthier families are more likely to use substitute care. Data from the 1986–87 National Survey of Oral Health in U.S. School Children indicate that 68 percent of white children residing in unfluoridated communities supplement their diets with fluoride tabs or drops, while fewer than 46 percent of blacks and Hispanics do. The percent of decayed teeth that are filled is also considerably higher for white children. Furthermore, Table 2 indicates that the effect of water fluoridation on tooth loss is greater for blacks 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.

Since we find that $\pi_1 > 0$, we then explore the mechanisms by which oral health affects wages. To do this, we add potential mechanisms to Equation 4 to estimate:

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

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 adding *occ* to the regression lowers our estimate of π_1 by 0.25 π_1, this implies occupational sorting explains 25 percent of the effect of oral health on earnings.[11] In our model, employer (both taste-based and statistical) and consumer discrimination is the residual effect of π_1 after adding all potential mechanisms.

C. Empirical Model

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

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

y_{ijcts} 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 NLSY79. 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 nonparametrically controls for the lifecycle earnings profile. σ_j are birth 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

11. Since $\pi_1 = \beta_1 \cdot \alpha_1$, we must assume that α_1 does not vary as we include the potential mechanisms. Although we are unable to test this directly, CWF circumvents this issue because of its temporal precedence. For example, we do not expect the impact of childhood CWF to differentially affect oral health because of one's occupation.

and serial correlation within a county, which also accounts for clustering at the individual level because it is nested within the county effect.[12]

Our main test regards the parameter π_1. Given that *wfc* ranges from 0 to 1, we can interpret π_1 as the effect on earnings from living in a fluoridated area relative to a non-fluoridated area. Although we cannot determine whether individuals residing in an area with fluoridated water necessarily consume that water, there were few alternatives to public drinking water during the period studied.[13] If, however, individuals consume water from neighboring counties, any spillover effects would dampen our estimate of π_1. If we find that $\pi_1 > 0$, this suggests that individuals with greater fluoride exposure earn higher wages. Given that water fluoridation improves oral health ($\alpha_1 > 0$), this implies that better oral health leads to higher wages ($\beta_1 > 0$).

D. Assessing Exogeneity of Water Fluoridation

Although we argue above that exposure to CWF is exogenous, there are two potential sources of endogeneity we must address: (1) selection effects—counties that fluoridate differ from counties that do not; and (2) contemporaneous investments—counties that fluoridate simultaneously expand other programs that may ultimately affect earnings.[14]

We present several pieces of evidence to more formally assess the exogeneity of water fluoridation. First, we examine several characteristics of the NLSY79 sample by CWF status by computing the mean of each covariate in five categories of percent fluoridated, shown in Appendix Table A2. There are no obvious differences between people with high and low fluoride exposure. For example, parental education moves up and down across the fluoridation categories. Of the 28 individual level variables, only two differences are statistically significant at conventional levels. 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[15] or cognitive skills,[16] so finding an effect would suggest misspecification. If we find that individuals with higher CWF are taller or smarter, for example, this suggests these counties

12. We do not estimate model with county fixed effects because there is insufficient variation in cumulative exposure, though we explore models with MSA fixed effects.
13. Only recently can water filters remove fluoride from drinking water.
14. Compensatory behavior may impact our estimates but will not bias them, since it does not affect the exogeneity of fluoridation.
15. Water fluoridation may affect the ability to consume foods through tooth decay, but is unlikely to lead to stunting.
16. 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 cognition 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.

also provided additional unobserved investments that affect adult earnings. The results overall and by gender are shown in Table 3. Unlike our wage regressions, 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—so we estimate Equation 6 but exclude the time fixed effects (φ_t). In all of our regressions we do not find statistically significant estimates of CWF 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 based on CWF status. Parents who move to neighborhoods with CWF may be higher 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 NLSY79 respondents on fluoridation status. We do not find evidence that parents with 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.

VI. Results

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 five years, the point at which the front four 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 2.3 percent for all individuals. In the second column we add county level variables designed to capture contemporaneous investments, and our estimates rise minimally to 2.4 percent. In the third column, we add 1970 CCDB variables, and estimates are again comparable at 2.5 percent. When we add 1970 investment variables in Column 4, our estimates are also similar at 2.2 percent. 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 cannot reject the null hypothesis that CWF has no effect on earnings for the full population.

We next assess whether gender differences exist by estimating regressions stratified by gender. For males, shown in Panel B, we find smaller effects indistinguishable from zero in all specifications. For women, however, we find larger, statistically significant effects, suggesting exposure to fluoridation during childhood increases earnings by 4.5 percent. This pattern points to potentially important labor market differences by gender, which we explore below.

The fact that we document an effect of CWF for women and not for men is consistent with 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

Table 3
Falsification Tests for Exogeneity of Water Fluoridation

	1 All	2 Male	3 Female
A. Omitted variable test			
y = AFQT	−0.494	0.024	−1.187
	[0.797]	[1.203]	[1.146]
Observations	7,011	3,475	3,536
y = height	−0.053	0.037	−0.157
	[0.122]	[0.178]	[0.163]
Observations	7,303	3,649	3,654
B. Sorting test			
y = parent's education	0.046	0.107	0.014
	[0.114]	[0.153]	[0.152]
Observations	7,099	3,537	3,562
y = Duncan SEI	1.231	0.676	1.477
	[1.035]	[1.474]	[1.385]
Observations	6,504	3,257	3,247

Notes: * significant at 5 percent; ** significant at 1 percent. See notes to Table 2. Results are based on specification with individual and county level covariates. The unit of observation is the individual.

must only have had an effect on women's earnings and not men's earnings, which we find largely implausible.

Table 5 shows further sensitivity analyses. Column 1 repeats results from our preferred specification. The next column allows earnings profiles within states to vary over time by interacting birth cohort, year, 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 NLSY79 were age five, to eliminate the concern that counties that never fluoridate systematically differ from counties that do. This model 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.[17] It is possible that results are driven by, say, New York, Los Angeles, Houston, and Chicago,

17. Counties with more than one million people in 1960 are Allegheny, Penn.; Cook, Ill.; Cuyahoga, Oh; Erie, N.Y.; Harris, Tex; Los Angeles, Calif; Middlesex, Mass.; Milwaukee, Wis.; Nassau, N.Y.; and Wayne, Mich.

Table 4
Regression Results of Water Fluoridation on Log Hourly Earnings

	1	2	3	4	5
A. All					
Fluoridation rate	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	−0.004	−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	0.046	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 percent; ** significant at 1 percent. 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 listed in Appendix Table A2. Demographic, investment, and health care variables listed in Appendix Table A1.

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.

In Columns 6 and 7 of Table 5, we examine the sensitivity of our results to alternate measures of fluoride exposure. First, we use CWF exposure through age 14. The front four adult teeth are in place by the time an individual reaches age five, and all adult teeth are in by age 12. If the front four teeth are most important for physical appearance, then additional exposure to fluoride after age five will have a minimal impact. Our estimates confirm this, as the coefficient on exposure during the first 14 years is relatively unchanged from the coefficient on exposure during the first five years. Second, we estimate models for the sample that did not move between birth and age 14. These estimates are also quite comparable to the baseline results, suggesting measurement error is not a major empirical concern in our analysis, although we recognize that the lack of a change in coefficients could be due to important changes in the sample.

Table 5
Sensitivity Analysis of Regression Results of Water Fluoridation

	1	2	3	4	5	6	7	8
	Base	Time-Cohort-State Dummies	WF 1970 > 0	Population < 1 Million	MSA Fixed Effect	WF Through Age 14	County of Birth = County At Age 14	Employment Status
A. All								
Fluoridation rate	0.023	0.012	0.03	0.021	0.035	0.013	0.026	0.010
	[0.015]	[0.025]	[0.018]	[0.017]	[0.016]*	[0.017]	[0.021]	[0.006]
Observations	72,395	72,395	55,839	60,593	57,482	72,395	46,649	75,490
B. Male								
Fluoridation rate	−0.004	−0.02	0.01	−0.012	0.023	−0.018	−0.001	0.004
	[0.020]	[0.027]	[0.025]	[0.023]	[0.024]	[0.022]	[0.030]	[0.008]
Observations	37,098	37,098	28,337	31,058	29,417	37,098	24,024	38,816
C. Female								
Fluoridation rate	0.045	0.044	0.041	0.046	0.047	0.048	0.035	0.012
	[0.020]*	[0.030]	[0.026]	[0.023]*	[0.021]*	[0.023]*	[0.032]	[0.009]
Observations	35,297	35,297	27,502	29,535	28,065	35,297	22,625	36,674

Notes: * significant at 5 percent; ** significant at 1 percent. Results are based on specification in Column 5 of Table 4, which includes all covariates listed in Appendix Table A1.

The results thus far examined the impact on labor market earnings, but oral health may affect one's ability to secure employment.[18] Column 8 presents results with employment status as the dependent variable. Although results are imprecise, they generally support our results thus far: CWF has a larger effect on employment status for women than men. Furthermore, when we add employment status to our earnings regression (not shown), the effect of CWF is slightly smaller, which is consistent with oral health affecting the probability of being employed.[19]

In sum, the results from Tables 4 and 5 suggest that fluoride exposure in childhood has a robust, statistically significant effect on hourly earnings of women, while the effect for men is much smaller and statistically insignificant. This pattern by gender is consistent with previous evidence on obesity and earnings. 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.

B. Effects by SES

The results in Table 2 suggest that the effects of fluoride exposure on tooth loss might be concentrated among those of lower SES, which is consistent with less compensatory behavior for lower income individuals. We next examine whether the effects of fluoride exposure vary by SES, recognizing we cannot distinguish whether any difference by SES is due to differential effects of water fluoridation on oral health or differential effects of oral health on earnings. In assessing differences by SES, we must use a measure of childhood SES not confounded by fluoridation exposure, so we use the child's *parent's* occupation as a measure of childhood SES.

In Table 6, we divide the sample into thirds based on respondents whose parents had low, medium, and high occupational 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 largely concentrated among those with parents of low status occupations. We find a statistically significant estimate of 12 percent for the lowest SES group, and statistically insignificant estimates of around 4 percent for the two higher SES groups. The effects for the lowest SES group are large in magnitude: the effect from fluoride exposure roughly translates into a return of nearly \$1/hour.[20]

C. Exploring Mechanisms

Table 7 presents our baseline results first, followed by results that include potential mechanisms associated with occupational sorting and productivity. Assuming we adequately control for these channels, any residual effect of π_1 after controlling for

18. 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.
19. Since recorded earnings reflect wages from current or most recent job, a currently unemployed person may have a lower wage because of inflation.
20. Average hourly earnings in \$1998 in the NLSY79 for women from the low SES category is roughly \$11.

Table 6
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	0.053	−0.001	0.023
	[0.027]*	[0.024]	[0.027]
Observations	20,828	24,144	27,423
B. Male			
Fluoridation rate	−0.042	−0.041	0.007
	[0.037]	[0.038]	[0.034]
Observations	10,735	12,843	13,520
C. Female			
Fluoridation rate	0.121	0.031	0.037
	[0.041]**	[0.030]	[0.033]
Observations	10,093	11,301	13,903

Notes: * significant at 5 percent; ** significant at 1 percent. Results are based on specification in Column 5 of Table 4, which includes all covariates listed in Appendix Table A1.

these variables reflects employer and consumer discrimination. We then provide a crude test for exploring consumer and employer discrimination, described below.

First, we assess the role of occupational sorting by including a full set of three-digit occupation dummies (based on the 1980 census of occupations). If physical appearance affects occupational choice, then controlling for occupation will dampen the estimate of CWF. Adding occupational dummies, shown in Column 2, reduces the coefficient on CWF by only 6 percent, suggesting occupational sorting does not appear to be an important channel.

Second, we explore productivity as a possible channel. In Column 3 we include a self-reported measure of health limitations in the amount or kind of work, which is updated in every survey wave, as a measure of health.[21] Although this measure of health does not specifically identify oral health limitations, it has a statistically significant association with earnings. The effect of CWF is, however, unaffected by this variable. In Column 4 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, as measures of non-cognitive performance. 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

21. This is the most detailed question about general health available for all respondents in the NLSY79.

Table 7
Exploring Channels of Relationship between Water Fluoridation and Earnings

	1	2	3	4	5
A. All					
Fluoridation rate	0.023	0.022	0.022	0.023	0.022
	[0.015]	[0.017]	[0.015]	[0.015]	[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	72,395	72,395	72,395	72,395	72,395
B. Male					
Fluoridation rate	−0.004	0.000	−0.006	−0.006	0.003
	[0.020]	[0.021]	[0.020]	[0.020]	[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	37,098	37,098	37,098	37,098	37,098
C. Female					
Fluoridation rate	0.045	0.042	0.045	0.046	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	35,297	35,297	35,297	35,297	35,297
Occupation dummies	N	Y	N	N	Y

Notes: * significant at 5 percent; ** significant at 1 percent. Results are based on specification in Column 5 of Table 4, which includes all covariates listed in Appendix Table A1.

results suggest that although measures of self-esteem and depression are significantly associated with earnings, they do not impact our CWF estimate. Although the health and non-cognitive variables are imperfect measures, the differential wage premium by gender that persists after accounting for occupation furthers our ability to rule out productivity as a potential channel; it seems unlikely that health or non-cognitive skills can explain differential effects of oral health on earnings by gender. Thus, productivity does not appear to be a channel whereby oral health affects earnings.

The difference by gender also enables us to rule out statistical discrimination; if 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 employee's gender.

In the final column, we show that adding all mechanisms simultaneously has little impact on our estimates. Based on these results, we conclude that oral health affects earnings primarily through consumer and taste-based employer discrimination. Our estimates are consistent with the hypothesis that women are more greatly affected by consumer or employer discrimination, rather than differentially selecting into occupations based on their physical appearance.

We perform a crude test to separate consumer from employer discrimination by estimating the wage premium separately for those employed in the manufacturing sector (occupation codes 100–392) and service sector (occupation codes 761–892). Our hypothesis is that if consumer discrimination exists, then employees in the service industry, where there are frequent interactions with customers, should see a higher wage premium than those in the manufacturing industry.[22] Our results, while imprecise because of the small sample of workers in the service industry (2,311), lend support to consumer discrimination as a potential mechanism. The coefficient on CWF of 0.081 (with a standard error of 0.055) for women is larger than the overall impact of 0.045 and the impact in the manufacturing sector of 0.027. While these results are far from conclusive, they point towards consumer discrimination as a potentially important channel through which oral health impacts earnings.

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 NLSY79 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. Since water fluoridation affects tooth decay, of which tooth loss is one possible outcome, our estimate of α_1 understates the true first stage, so the estimate of β_1 overstates the impact of tooth loss on wages.

We also adjust the BRFSS estimate to reflect the measurement error that occurs from using county of residence in adulthood rather than childhood. We assess the magnitude of this measurement error by reestimating our NLSY79 models but treating current county of residence as county of residence in childhood. The ratio of our baseline estimates to this estimate from the NLSY79 (3.46) gives a measurement

22. Individuals in professions with consumer interactions despite poor oral health may have other highly valued characteristics by consumers, such as persuasiveness or friendliness.

error adjustment factor that we assign to α_1, making the effect of CWF on tooth loss -1.374 (instead of -0.397).[23]

The results indicate the labor market value of the marginal tooth for women is 3.3 percent 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 $1,250 to $3,000.[24] 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. This suggests some individuals with missing teeth may be making (privately) suboptimal decisions, so public policy interventions might take the form of improving information or reducing liquidity constraints.

VII. Conclusion

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 percent overall, with a larger effect for women supporting the "Beauty Myth" argument that women are held to different standards regarding physical appearance than men. 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 consumer and possibly employer discrimination as the main channels through which oral health affects earnings.

The effects of community water fluoridation for the populations we study may not necessarily generalize to communities fluoridating today for at least two reasons. First, the advent of other products designed to reduce tooth decay, such as fluoridated toothpaste and dietary fluoride drops, has made substitute technologies more affordable. Second, spillover effects from water fluoridation have greatly increased. For example, fluoridated water 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 percent in the 1940s to 15–20 percent today.

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23. 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), $\pi_1{}^*$ 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 $\alpha_1{}^*$, so we assume measurement error from assuming current county is county of birth is the same in the NLSY79 and BRFSS (of which we have no reason to believe otherwise), and use λ to scale our estimate of $\alpha_1{}^*$ to obtain an estimate of $\alpha_1 (= \lambda \cdot \alpha_1{}^*)$.

24. See http://www.aboutcosmeticdentistry.com/procedures/dental_implants/cost.html.

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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Appendix Table A1
County Level Variables Included in Analysis

1960 demographic variables (from 1960 CCDB)	1970 demographic variables (from 1970 CCDB)
Population percent change 10 years	Population percent change 10 years
Population percent rural farm	Population percent rural farm
Median age	Median age
Percent > 65 years old	Percent > 65 years old
Population percent < five years old	Population percent < five years old
Death rate	Death rate
Marriage rate	Marriage rate
Employ rate	Employ rate
Percent employed manufacturing	Percent employed manufacturing
Percent employed construction	Percent employed construction
Percent employed wholesale/retail trade	Percent employed wholesale/retail trade
Vacancy rate	Vacancy rate
Percent homeowners	Percent homeowners
Percent vote democratic president	Percent vote democratic president (68)
Percent vote correct president	Percent vote correct president (68)
Population	Population
Population per square mile	Population per square mile
Percent population nonwhite	Percent population nonwhite
Percent population with ≥ high school degree	Percent population with ≥ high school degree
Median schooling	Median schooling
Percent population < five years of schooling	Percent population < five years of schooling
Household size	Household size
Percent urban	Percent urban
Median family income	Median family income
	Median house price
1960 investment variables (from 1959 BEA, except (*) from CCDB)	Median rent
Local government percent spending on education (57)*	1970 investment variables (from 1968 BEA, except (*) from CCDB)
Local government debt ratio (57)*	Local government percent spending on education (67)*
Income maintenance transfers (59)	Local government debt ratio (67)*
Retirement & disability transfers (59)	Income maintenance transfers (68)
	Retirement & disability transfers (68)
1974 health care variables (from 1974 CBP)	Medical insurance transfers (68)
Physicians per capita	
Dentists per capita	

Notes: CCDB = City and County Data Books, BEA = Bureau of Economic Analysis, CBP = County Business Patterns

Appendix Table A2
Demographic Statistics by Fluoridation Status

Percent fluoridated	1 0 percent	2 1–25 percent	3 26–50 percent	4 51–75 percent	5 76–100 percent	6 Prob > *F*
Foreign language	0.18	0.17	0.13	0.18	0.18	0.30
Magazine regularly	0.57	0.57	0.59	0.59	0.59	0.93
Newspaper regularly	0.77	0.83	0.82	0.79	0.81	0.08
Library card	0.76	0.77	0.76	0.77	0.80	0.53
Number of siblings	3.77	3.61	3.72	4.04	3.64	0.27
Education mother	10.49	10.69	10.86	10.39	10.87	0.29
Education father	9.74	10.08	10.00	9.68	9.96	0.72
Mom & dad in HH	0.65	0.67	0.72	0.68	0.66	0.08
Mom born in U.S.	0.94	0.95	0.97	0.94	0.94	0.26
Dad born in U.S.	0.92	0.94	0.95	0.93	0.93	0.30
No religion	0.04	0.04	0.04	0.03	0.04	0.84
Protestant	0.05	0.05	0.05	0.04	0.05	0.89
Baptist	0.28	0.30	0.29	0.28	0.27	0.96
Episcopalian	0.01	0.02	0.01	0.02	0.02	0.57
Lutheran	0.06	0.04	0.06	0.10	0.05	0.15
Methodist	0.07	0.09	0.07	0.09	0.07	0.59
Presbyterian	0.03	0.02	0.02	0.03	0.03	0.82
Roman Catholic	0.34	0.32	0.34	0.34	0.39	0.77
Jewish	0.01	0.01	0.01	0.00	0.01	0.41
Other religion	0.10	0.11	0.11	0.08	0.08	0.03
Male	0.51	0.49	0.54	0.50	0.49	0.30
Black	0.27	0.24	0.25	0.24	0.30	0.86
Hispanic	0.14	0.13	0.07	0.13	0.16	0.09
Height	67.26	67.17	67.52	67.16	67.13	0.38
AFQT	40.87	40.89	39.49	39.37	39.98	0.94
Duncan SEI - mom	18.76	18.34	18.59	16.01	19.62	0.12
Duncan SEI - dad	30.41	32.47	29.74	32.10	31.55	0.53
Highest grade completed	12.22	12.20	11.97	11.99	12.11	0.20
Observations	1,986	2,457	673	697	1,507	

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