# The Effects of Fluoride In The Drinking Water*

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**Abstract**

Fluoridation of the drinking water is a public policy whose aim is to improve dental health. Although the evidence is clear that fluoride is good for dental health, concerns have been raised regarding potential negative effects on cognitive development. We study the effects of fluoride exposure through the drinking water in early life on cognitive and non-cognitive ability, education and labor market outcomes in a large-scale setting. We use a rich Swedish register dataset for the cohorts born 1985-1992, together with drinking water fluoride data. To estimate the effect we exploit intra-municipality variation of fluoride, stemming from an exogenous variation in the bedrock. First, we investigate and confirm the long-established positive relationship between fluoride and dental health. Second, we find precisely estimated zero effects on cognitive ability, non-cognitive ability and education. We do not find any evidence that fluoride levels below 1.5 mg/l have negative effects. Third, we find evidence that fluoride improves labor market outcome later in life, which confirms that good dental health is a positive factor on the labor market.

**Keywords:** Fluoride, Cognitive ability, Non-cognitive ability, Income, Education, Employment, Dental health
**JEL Classification:** I10, H42, I18

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# 1 Introduction

It is well-established that fluoride strengthens the tooth enamel and that application of fluoride on the surface of the teeth prevents caries, tooth decay and cavities. The use of fluoride in a wide range of dental products is therefore considered as an important mean to improve dental health. Because there is such a well-defined link between fluoride and healthy teeth, some countries artificially fluoridate the drinking water so that people are continuously exposed to higher levels than the natural level. Australia, Brazil, Canada, Chile, Malaysia, the United Kingdom and the United States are a few examples of countries that apply such a public policy (Mullen, 2005). Other countries, such as Sweden, do not fluoridate the water, but the authorities choose not to reduce the fluoride level in the water cleaning process as long as it is below a certain limit. These public policies are, however, debated. Fluoride is deadly at high levels, and there is an emerging and much discussed epidemiological literature of potential negative side effects of long-term fluoride exposure for lower levels on the central nervous system. The hypothesis is that fluoride might function as a neurotoxin.

In comparison to dental products, drinking water containing fluoride is ingested, meaning that everyone drinking water is exposed to fluoride continuously for a long period of time. In this paper we investigate the causal effect of fluoride exposure in early life through the drinking water on cognitive and non-cognitive development, education and later labor market outcomes. We also study the long-established link between fluoride and dental health. We use a unique register data set from Sweden together with drinking water fluoride data, where we exploit intra-municipality variation in fluoride to estimate the effect.

Earlier epidemiological studies have found evidence of negative side effects of fluoride, and the results have sparked a public debate regarding the potential dangers associated with fluoride in the water (e.g. Johnston, 2014 in The Telegraph; Mercola, 2013 in The Huffington Post).[1] A meta-study by Choi et al. (2012) from Harvard School of Public Health reviewed 27 papers and concluded that exposure to high dosages of fluoride is associated with reduced cognitive ability among children (almost half of a standard deviation in IQ).[2] The studies reviewed originated from China and Iran. Several of these papers considered very high levels of fluoride which surpasses the recommendation from the World Health Organization (WHO) that fluoride should not exceed 1.5 mg/l in the drinking water (WHO, 2011, p.42). However, some of the studies reported negative

[1] One indication that people tend to be very concerned with fluoridation is found in Lamberg et al. (1997). The local authorities in Finland decided that water fluoridation should stop at a given date, and this decision was communicated to the inhabitants. However, water fluoridation ceased one month earlier without notification to the public, but people still reported various symptoms in a survey.

[2] See Tang et al. (2008) for an earlier meta-study, which also show a negative relation between fluoride and IQ. Papers published after or around Choi et al. (2012) include Ding et al. (2011), Saxena et al. (2012), Seraj et al. (2012), Nagarajappa et al. (2013), Ramesh et al. (2014), Khan et al. (2015), Sebastian and Sunitha (2015), Kundu et al. (2015), Choi et al. (2015), Das and Mondal (2016) and Dey and Giri (2016) who all found or discussed negative effects of fluoride on IQ. Additionally, Malin and Till (2015) found a positive association between fluoridated water and the prevalence of ADHD in the U.S.. See also Li et al. (2016) for a study on fluorosis and cognitive impairment.

effects on cognitive development for levels below the recommended level. This is a cause for concern because these levels are present naturally in the drinking water in many parts of the world. Countries that fluoridate the drinking water also have fluoride within this range. Common problems with the studies reviewed by Choi et al. (2012) are that the analyses were based on small samples with poor data quality, and without clear identification strategies.[3]

Our paper is to our knowledge the first to study the effects of fluoride in a large-scale set-up with individual register data. We have access to a rich panel of Swedish register data which enables us to investigate the effect of fluoride in a more credible way and with a much larger sample than earlier studies. Sweden has a natural variation of fluoride in the drinking water which stems mainly from the bedrock under the water sources. The fluoride level in the Swedish drinking water range between 0 and 4 mg/l in our data set, and there is often variation within municipalities which we exploit to estimate the casual effect. In comparison to China and Iran, where the studies reviewed in Choi et al. (2012) originates from, Sweden has a well-supervised water supply system, meaning that other drinking water hazards that can affect cognitive development are not likely to be present. Fluoride in Sweden is generally not considered to be a problem unless the level exceeds 1.5 mg/l.[4] Since our data include a variation in fluoride in the lower spectra, our results are more policy relevant for countries that artificially fluoridate the drinking water, because water authorities seldom add fluoride so that the level exceeds 1.5 mg/l. There are no evidence for any differences between artificially fluoridated drinking water and water with a natural occurrence of fluoride (Harrison, 2005; John, 2002), meaning that our results should be valid for countries with comparable artificial fluoride levels.

As economists, we are interested in the connection between fluoride, cognitive ability, education and labor market outcomes for at least two reasons. First, artificial fluoridation of the drinking water is a common public health program, and it is important that the effectiveness of such a policy is evaluated. Second, economists have in an increasing degree become interested in early determinants of health and human capital, and its long-run effects on labor market outcomes. Our paper is connected to this literature on environmental determinants for cognitive development where we study a treatment that millions of people are affected by all over the world: fluoride in the drinking water.

Our results confirm the positive link between fluoride and dental health. However, in contrast to earlier studies, we find a zero effect of fluoride on cognitive ability, non-cognitive ability and education (measured by test scores on a national math test). Our point estimates with regard to cognitive ability are much more precisely estimated compared with earlier studies and always close to zero. We find evidence that fluoride is a positive factor for later labor market outcomes, which indicates that better dental health is a positive factor on the labor market.

The rest of the paper is organized as follows. In the next section we review related

[3] There are, however, studies that points in the other direction. Broadbent et al. (2015) follows approximately 1,000 individuals in an observational study from New Zeeland. The authors find no negative effect on IQ from living in an area in the city of Dunedin with artificial fluoridation. The main critique against this study is that artificial water fluoridation may be an endogenous policy variable.

[4] The absolute majority of the Swedish water plants have fluoride levels below 1.5 mg/l.

papers, followed by a short medical background for why fluoride might have an effect on the central nervous system. Next, we provide a simple conceptual framework on how we should think about fluoride in the drinking water as a public health policy. Our identification strategy is mainly based upon the variation in fluoride which stems from an exogenous variation in the bedrock, so in section 5, we present the necessary geological background and information on how we have mapped drinking water data to the individuals. In section 6, we describe our data material. Our identification strategy and econometric set-up is discussed in section 7 followed by descriptive statistics in the same section. The empirical results are then presented, next robustness checks and lastly our conclusions. Additional results and figures are presented in the appendix.

## 2 Earlier literature

In this section we review the literature regarding early determinants for health and its effects on labor market outcomes. We explicitly focus on papers that have studied drinking water.

Currie (2011) provides an excellent overview of this research field with a special emphasis on determinants at birth and in utero. Economists acknowledge that health during childhood is an important determinant for success on the labor market (Currie, 2009). Case et al. (2002) and Currie and Stabile (2003) provide evidence for the connection between health and socioeconomic status. Case et al. (2005) present the conclusion that health during one's early years seems to be connected to (among others) socioeconomic status and one's education once becoming an adult. Smith (2009) has also demonstrated this link empirically, and found that poor health before age 16 is negatively associated with future income, wealth and labor supply.

Cognitive development is part of individuals' health, and earlier research have shown that cognitive ability and non-cognitive ability are very adequate explanatory variables for basically everything that we consider as positive individual labor market outcomes (e.g. Heckman et al., 2006, Lindqvist and Vestman, 2011). Cunha and Heckman (2007) create a theoretical model concerning cognitive and non-cognitive ability and Cunha and Heckman (2009) emphasize that there are "critical" and "sensitive" windows when cognitive and non-cognitive abilities are more affected by environmental factors. See also Cunha et al. (2010). According to the authors both cognitive and non-cognitive ability are very important factors for later achievements in life. This view is confirmed in Öhman (2015) and Lindqvist and Vestman (2011), who use the results from the Swedish draft tests for cognitive and non-cognitive ability and show that they are very good predictors for mortality, education and income. If fluoride has negative effects on cognitive development, this adds a piece to the puzzle why some individuals are more successful than others on the labor market.[5]

We are not aware of any other paper that has employed large individual register datasets to estimate the effect of fluoride on cognitive development specifically. In a

[5] A seminal paper by Grossman (1972) presents a framework for individual health investment. Fluoride may affect an individual's health before he or she can make an active investment choice.

recent manuscript, Heck (2016), studies the effects of water fluoridation on health and education with U.S. survey data. He finds that fluoridated water prevents caries in deciduous teeth, but no effects on education and general health. A limitation in this study is that education is measured only at the county level. The main critique is that water fluoridation is a result of a policy choice, making the identification less clear.

Some earlier papers in economics have focused on other potential hazards and their effects on health and cognitive ability. Currie et al. (2013) study the effect of mothers' consumption of polluted drinking water (broadly defined) during pregnancy on birthweight of the offspring with data from New Jersey. They find that the birthweight is negatively affected by contaminated water for mothers with a low education. Zhang (2012) uses Chinese data and study the effect of providing monitored and safe drinking water from a water plant to the population. The author finds a positive effect on the ratio of weight and height for both children and adults and some evidence of less illness among adults.[6] Galiani et al. (2005) study whether privatization of water supply in Argentina improved water quality, and find that children mortality decreased if an area was provided with drinking water from a private provider. Feigenbaum and Muller (2016) study lead and explicitly how people were treated with lead originating from the drinking water pipes. The authors study homicide incidence, where they find a positive effect of lead.

Lead has also been studied with regards to air pollution. Nilsson (2009) study the long-term effects of lead on labor market outcomes. The author uses time variation from the time period when lead in gasoline was reduced together with Swedish geographical data on lead levels in the environment, and concludes that a reduction in lead exposure in early life has positive effects on cognitive ability, education and labor market outcomes. In a similar paper, Grönqvist et al. (2014) conclude that the reduction in lead exposure also reduce criminal behavior. Schlenker and Walker (2016) study pollution from airports in California and find that prevalence of respiratory deceases, heart diseases and asthma increase among the inhabitants, especially among children and older people, if carbon monoxide emission increases. In Jans et al. (2014) the authors study air pollutants' effect on child health. Periods of inversions seems to affects children from high-income families 40 percent less than children from low-income families.

It might be that fluoride in the drinking water has negative side effects on cognitive ability, but the net effect on income still is positive because the effect on dental health is so large. Glied and Neidell (2010) found that women living in areas whose water was fluoridated had higher incomes, where the effect seems to be stronger according to the authors for those with a poor socioeconomic status.

## 3 Medical background

In this section we shortly review the medical discussion about fluoride and its effects on health.

[6]The author briefly discuss fluoride in the Chinese drinking water but do not study this explicitly.

Sodium fluoride (NaF), from now on called fluoride, is a toxic compound which exists naturally in the environment. WHO acknowledge a deadly dose of fluoride to about 5-10 grams depending on the body weight (Liteplo et al., 2002, p. 100). Fluoride intake from the drinking water is absorbed and transmitted throughout the blood system (Fawell et al., 2006, p.29-30). When large amounts of fluoride are ingested it has a number of toxic effects on the body. For example, approximately 100,000 individuals in the Assam region in India have been taken ill with kidney failure stiff joints and anemia and as a result of very high natural levels of fluoride in the water (WHO, 2015). Gessner et al. (1994) discuss a case in Alaska where individuals in a small village accidently were exposed to extremely high levels of fluoride (up to 150 mg/l) due to a malfunctioning water pump. One individual died and many became very ill as a result of fluoride poisoning.

Lower dosages of fluoride have, on the other hand, beneficial effects on dental health (see Griffin et al. (2007) and Twetman et al. (2003) for reviews). For that reason, fluoride is added to toothpaste and in some countries to the drinking water. Fluoride is also present naturally in tea leaves and in low concentration in the food (Liteplo et al., 2002, p. 5).

Water fluoridation is a highly debated issue (Derek, 2002; EBD, 2002; Peckham and Awofeso, 2014). Researchers have called for more research on the subject, where Grandjean and Landrigan (2014) argue for a global initiative for more research on potential neurotoxins, including fluoride. Mullenix et al. (1995) was one of the first papers testing the hypothesis that fluoride exposure has effects on the central nervous system. The researchers exposed randomly selected rats to different fluoride treatments (including fluoridation of the drinking water), and concluded that the rats' brain tissue can store fluoride and that fluoride can pass through the blood-brain barrier. They found that a higher concentration of fluoride in the brain tissue induced behavioral changes meaning that fluoride functions as a neurotoxin in rats. Chioca et al. (2008) also conducted laboratory rat experiments and concluded that high exposure of fluoride through the drinking water induced impaired memory and learning. Whether fluoride can pass the blood-brain barrier in humans is debated. Chioca et al. (2008) state that a one-time high consumption of fluoride does not seem to pass the blood-brain barrier. Hu and Wu (1988) found fluoride present in the cerebrospinal fluid, which surrounds the brain among humans. The question is whether a long-term consumption of fluoride passes the barrier. Consuming water with fluoride is an example of a long-term consumption.

Given that fluoride is both a lethal and dangerous compound at higher dosages, and improves dental health at lower dosages, it is important to find the optimal level. There has been a consensus that fluoride only has adverse effects above the threshold level of 1.5 mg/l (WHO, 2004). In light of recent epidemiological findings reviewed in Choi et al. (2012) this threshold could be questioned.

## 4 Conceptual framework

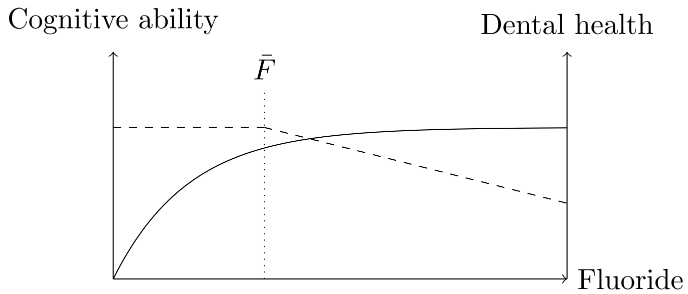
We present a simple and short conceptual framework in this section on how we can think about water fluoridation as a public policy.

Fluoride is a potential neurotoxin that may have a negative effect on cognitive ability, but is known to have a positive effect on dental health. The policy maker must decide on the cost-benefit of fluoridation in comparison to other alternatives. For example, fluoridation of the water can be less expensive than publicly subsidized dental checkups and teeth repairs, thus making it an effective public policy.

It is on the one hand unlikely that the general public would accept fluoridation if it is dangerous for the health in any known way. On the other hand, for economists, the optimal level of fluoride is where the marginal costs equal the marginal benefits. If the positive effect on dental health is very large with only a very small negative effect on cognitive ability, the net effect could still be positive. That would be positive for the individuals given that better dental health is probably a positive factor on the labor market.

Figure 1 illustrates the policy makers problem in a single figure.

Figure 1: The effects of fluoride on dental health (solid line) and cognitive ability (dashed line)




We investigate whether $\bar{F}$ exists in the Swedish drinking water. Based on this, it is possible to do a cost-benefit analysis of the optimal fluoride level.

## 5 Exogenous variation in fluoride: geological background

In this part of the paper we discuss how fluoride varies exogenously in Sweden. We also discuss how we map the drinking water data to individuals' place of residence.

The natural level of fluoride in the drinking water depends on geological characteristics, especially the type of bedrock under a water source (Sveriges Geologiska Undersökning, 2013, p. 81). Fluoride is both tasteless, without odor and without any color for the levels we consider in this paper, implying that individuals cannot know whether they are drinking water with lower or higher levels of fluoride (WHO, 2001).

There are different types of bedrock, providing different levels of fluoride to the water. Soil bedrock is associated with lower levels of fluoride in comparison to granite and greywacke bedrock which yields higher levels. Especially water from drilled bedrock wells usually contains higher levels of fluoride (Sveriges Geologiska Undersökning, 2013, p. 81, 84). Rainfall usually contains low levels of fluoride (Edmunds and Smedley, 2013, p. 313).[7] In Sweden, water sources are situated on different types of bedrock, thus yielding different fluoride levels. For a detailed description about fluoride and its natural geological occurrence, see Edmunds and Smedley (2013) and Sveriges Geologiska Undersökning (2013).

The fluoride level is, from our perspective, an exogenous variable that is constant for a very long time because the bedrock is constant. Hence, the water authorities have no possibility to manipulate the natural levels of fluoride in raw water. The water authorities may reduce the fluoride levels in the water cleaning process, but this is not done in Sweden unless the level exceeds 1.5 mg/l.[8]

Each municipality in Sweden is divided into several SAMS (Small Areas for Market Statistics) by Statistics Sweden. A SAMS consists of approximately 750 individuals in the year 2011, with median 520, and is a smaller geographical unit than the municipality. There are almost 9,300 SAMS in Sweden in comparison to 290 municipalities.[9] Each municipality in Sweden is responsible for the public drinking water. The large majority in Sweden drinks water from the municipal water plants. However, some individuals have private wells for which we do not have data. Approximately 1.2 million people of Sweden's total population of approximately 10 million drink water from private wells (Livsmedelsverket, 2015). Because municipalities often have different water sources situated on different types of bedrock, there is a within-municipality variation in fluoride on the SAMS level.[10]

We have information on fluoride levels for the outgoing drinking water from the water plants supervised by the municipalities. There are 1,726 water plants in our data where we have manually designated a coordinate for the water plant based on the supplementary information we have from SGU and from the municipalities. Some municipalities do not have a water plant within its borders. These municipalities have been dropped from the analysis together with those municipalities where we do not have any information regarding fluoride. In total, data from 261 municipalities are included. We know in which SAMS an individual lived for a given year, but we cannot observe the exact geographical coordinate for the location where the individual lived within a SAMS.[11] Thus, we need a mapping protocol for how to assign fluoride data for each

[7] One of the main sources of fluoride in rain is volcanic emissions (Edmunds and Smedley, 2013, p. 314), but there are no active volcanos in Sweden.

[8] In our data collecting process from the Swedish municipalities, nothing indicates that water authorities lowered the fluoride if was below 1.5 mg/l.

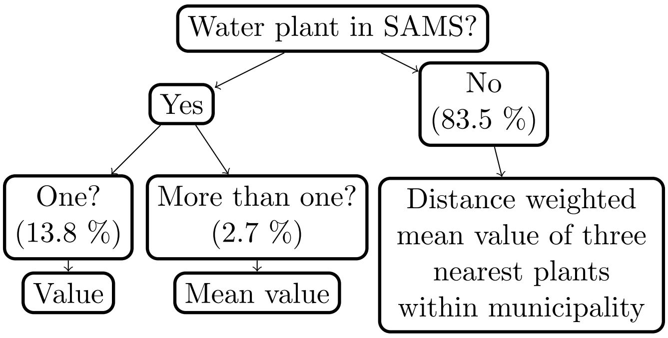
[9] The reader should note that SAMS areas are not something that the public in general is aware of. Municipalities, however, are administrative areas that exist in the public's mind.

[10] Augustsson and Berger (2014) show that there is a variation in the fluoride level in private wells in Kalmar county in Sweden.

[11] Such data would abolish the anonymous structure of the Swedish individual register data, since population address registers are public information in Sweden.

SAMS.[12] We map the fluoride level to SAMS using the mapping protocol illustrated in Figure 2. We indicate the share of SAMS in each category in parenthesis.

Figure 2: Water plants mapping. Percentage of SAMS in parenthesis

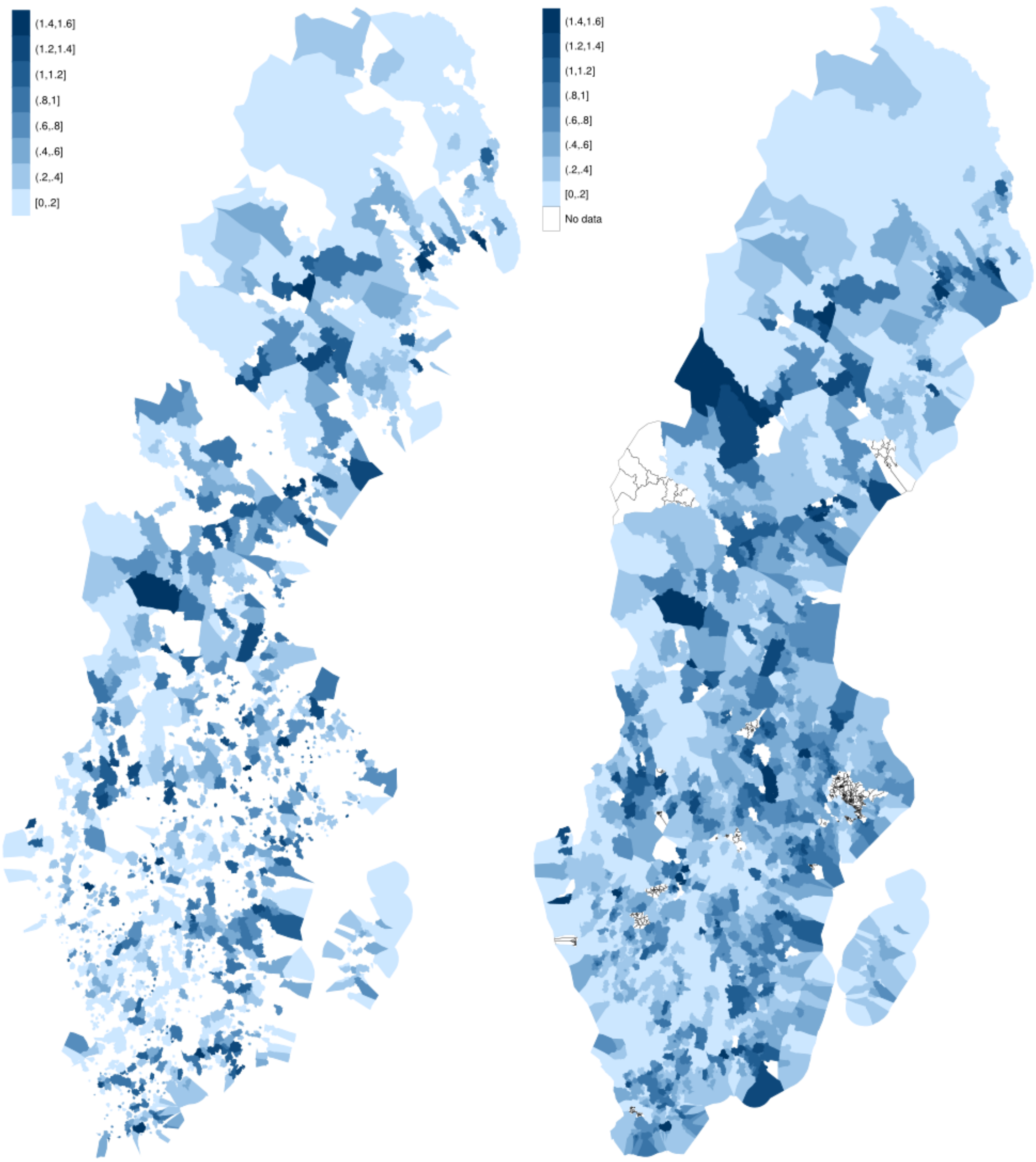



For SAMS that have a water plant within the borders we assign the fluoride level of that water plant to all the individuals that lived in the area. If there is more than one water plant within the SAMS border, we take the mean fluoride level. For SAMS without a water plant within the borders, we calculate the geographical center point of the SAMS, and assign a mean of the fluoride level for the three closest water plants (triangular polygon) using the inverse distance as a weight. We assess this mapping protocol by first looking at the effect of fluoride on dental outcomes for which we expect to see an effect of fluoride. By looking at dental health measures, we also address whether the variation in fluoride in our data is enough to estimate effects.

Figure 3a displays the raw variation in fluoride for those SAMS with a least one water plant. White areas are thus SAMS without a water plant. Figure 3b shows the variation in fluoride between SAMS after our mapping.

[12]Since we cannot observe the exact location within a SAMS, we cannot distinguish on the household level who drinks the water from the municipal water plants and the private wells. We return to this issue in the robustness analysis.

Figure 3: Mapping of fluoride data




(a) SAMS with at least one water plant

(b) Final mapping

# 6 Data

In this section we present the data material.

In short, we have register data at the individual level for all outcomes and covariates except dental health. The dental health data is only available on the SAMS level for each cohort from age 20. We observe place of residence for all individuals of age 16 and older on the SAMS level.[13] In order to track individual's place of residence before age 16 we link them to their parents, and use the mother's place of residence as a proxy. Our treatment period for fluoride consumption spans between birth and age 16. We chose this treatment period because the brain should be more sensitive to potential neurotoxins in early life in comparison to adulthood. The articles reviewed in Choi et al. (2012) never consider individuals older than 16 in their analysis.[14] We include cohorts born between 1985 and 1992 in our data.

## 6.1 Fluoride data

Fluoride data is measured for each water plant, and there are in total 1,726 water plants supervised by the municipalities in our data set. This data comes from two sources: Drinking water data from Swedish Geological Survey (SGU) and drinking water data from the municipalities. We use the SGU data or the municipal data depending on which data set that has the earliest available drinking water data for a given municipality. The SGU data starts in 1998. For some municipalities data is only available for later years.[15] We have contacted each of Sweden 290 municipalities to complement the SGU data set. We asked the municipalities to provide us with additional data from 1985. If data were not available, we asked them whether they have changed any of their water sources since 1985.[16]

It should be noted that the fluoride level is constant back in time because the bedrock has not changed. The fluoride level should only be different if (1) the municipality has changed the water source (which is rare), or, (2) installed any purification for fluoride (which they do not do unless the level exceeds 1.5 mg/l). We collapse the fluoride data into a single measure for each water plant, meaning that we take the average when we have data from several years for a water plant. Variation between the years should be due to variation in the measurement validity for individual data points, meaning that an average measure is more accurate. The reader should note this means that for the very few cases where purification has been installed, we take the average for *all* years

[13] For some individuals and years, SAMS codes are missing. We have imputed SAMS codes from $t-1$ or $t+1$ in these cases if municipal code is the same.

[14] There are some inconsistencies in the register data. For example, we have dropped all individuals with multiple birth years, duplicate observations, individuals not in both the LOUISE database and the multigenerational database. We also drop individuals that have immigrated to Sweden during childhood since we need to track their fluoride level from birth. Their parents may, however, have immigrated before the individual's birth.

[15] We only use the observations from the SGU data regarding drinking water and not the observations for "raw water".

[16] Not all municipalities have kept their statistics from 1985 and some have not been able to answer our questions. In the robustness analysis, we rerun all specifications but only include municipalities where we are sure that they use the same water source since 1985.

available.[17] We drop all individuals who have ever lived in a municipality between birth and age 16 for which we do not have fluoride data.

### 6.2 Individual level data

The data for the individuals originates from several sources which we briefly discuss in this section.

The cognitive and non-cognitive ability measures come from the Swedish military enlistment. For more detailed information about the enlistment, see Öhman (2015). Conscription was obligatory for men between 18-20 years old in Sweden until its abolishment in 2009. Those who declined their call to conscription were punished; however, this practice was not enforced in the end years of the Swedish draft. Conscription involved testing of cognitive and non-cognitive ability and the individual's physical health. Cognitive ability was measured by a test where the purpose was to measure the underlying intelligence, often called the $g$ factor. This was done by using four sub-tests: verbal, spatial, logical and technical knowledge. The overall test score was then standardized into a single measure on a scale between 1 and 9, according to a Stanine scale. The non-cognitive ability was assessed by a psychologist during a half-hour interview with the conscript. The psychologist's goal was to evaluate the person's ability to function in a war scenario. Those who were keen to take initiative and who were well-balanced emotionally ended up with a high score. The psychologist also considered the individual's ability to deal with stressful situations. The overall assessment was a score according to the Stanine scale. Öhman (2015) shows that both these measures are good predictors for individual outcomes later in life. We only include men born before 1988 when estimating these outcomes since we only have access to this data for those years.

In the end years of the Swedish enlistment, there was a theoretical possibility of strategic manipulation of test results. Individuals who scored low on the tests was not always forced to do military service meaning that the incentives to perform well were less clear for later cohorts. However, the Stanine distribution is relative to others enlisting in the same cohort, so we should still be able to capture meaningful differences in cognitive ability and non-cognitive ability within a cohort (see Figure A2 in the appendix). We can also test this by looking at the correlation between this test score and the test score for the same individual on the national math test. In the latter case, the individual has clear incentives to perform well since final grade in math from junior high school depends on this test result. The correlation between these two tests is 0.43. We conclude that strategic manipulation on the military enlistment test does not seem to be a big concern.

As an outcome for education we use results from the national test taken at age 16.

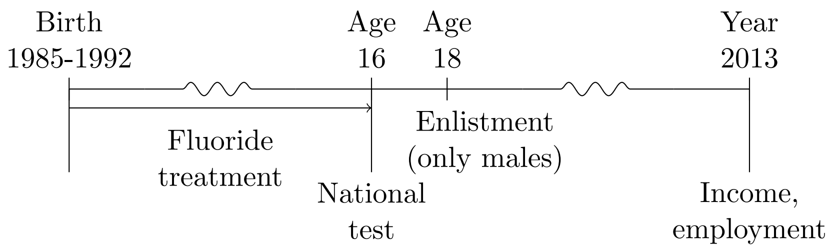
[17] In 2003, the Swedish Food Agency abolished the possibilities to give exceptions for fluoride levels above 1.5 mg/l to 6 mg/l. There were fewer than 100 water plants before 2003 with a median level higher than 1.5 mg/l (Persson and Billqvist, 2004). Those plants provided water to approximately 0.26 % of the Swedish population (Svenskt Vatten, 2016). After 2003, there is a single limit set to 1.5 mg/l (Sveriges Geologiska Undersökning, 2013, p. 82). 1.3 mg/l to 1.5 mg/l yielded a note prior of 2003, but was considered safe and did not result in general purification of the water. Children below half a year old was recommended to drink such water with moderation.

We focus on the basic points result on the math test. This is due to two reasons. First, this is the variable where we have the most detailed statistics, and, second, it should be a fairly good proxy variable for cognitive ability, which our correlation above confirms. The data comes from Statistics Sweden (SCB). We have results for those born in 1987 and later.

Income is measured in 2013 (the last year available), and the data comes from the Swedish tax agency through Statistics Sweden. The variable is defined as gross income for all individuals that have earned any income throughout a year. We exclude all individuals that have earned less than 1,000 Swedish kronor (about $120 in 2016) during a year for this outcome. Employment status is measured in November the year 2013. An individual is coded as employed if he or she has worked at least one hour during a week.

Figure 4 illustrates the timing of the outcome variables and the fluoride treatment.

Figure 4: Timeline for treatment and outcomes




## 7 Empirical strategy

This section contains a presentation of our identification strategy and a discussion about potential threats to identification. The section also includes a presentation of the econometric set-up and descriptive statistics.

We estimate the causal effect of fluoride exposure through the drinking water on cognitive ability, non-cognitive ability, education, employment status and income. The ideal experiment with maximal internal validity would be to randomly assign fluoride to individuals. Due to randomization, the fluoride levels would be independent of individual characteristics, which enable a causal interpretation of the results. Since it is not possible to randomly assign fluoride intake from birth to age 16, we need to rely on a quasiexperimental design.

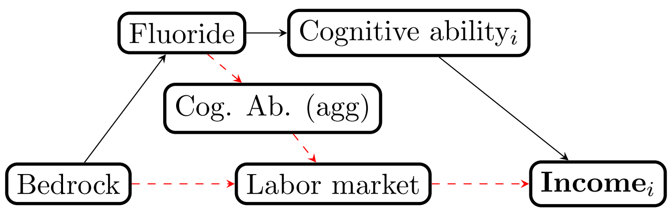
We use exogenous variation in fluoride within municipalities in Sweden to estimate the effect. This enables us to control for unobservable characteristics on the municipal level which could also be determinants for the outcomes we study. We estimate the reduced form effect of fluoride on our outcome variables. Hence, our main identifying variation in fluoride stems from an exogenous geographical variation in the bedrock within municipalities.

In addition to using within-municipality variation in fluoride, we also exploit a second source of variation stemming from individuals' moving patterns. To move or not between birth and 16 is undoubtedly an endogenous outcome, but as long as the choice of moving and the moving location is not dependent on fluoride or other variables correlated with fluoride, this yield an exogenous variation in the intensity of fluoride treatment which depends on the number of years in different SAMS. It is very unlikely that people self-select into SAMS based on the fluoride level. It is difficult to obtain information about the fluoride level since there is no comprehensive open data set in Sweden. People cannot be aware of fluoride in the drinking water because fluoride is tasteless. We confirm that the choice to move is not dependent on the fluoride level in various tests in Table A2 presented in section 11.3 in the appendix.

### 7.1 Threats to identification

The first threat concerns our use of geological variation in fluoride. Because the bedrock is constant, the fluoride level in the drinking water is also constant. Assume that fluoride is negative for cognitive ability. Given that people are living in the same place, fluoride might have an effect on the regional labor market because people on average have a lower cognitive ability. The individual income will depend on the average wage level. Since the labor market has adjusted to a lower cognitive ability pool, the individual wage level will on average be lower. It can also be the case that the bedrock in itself can affect the labor market. For example, specific bedrock might be more suitable for mining, which could affect the structure of the regional labor market and, hence, the labor market outcome for a specific individual. If we would consider large geographical areas and use the variation between these areas, fluoride might not be independent of the outcome variables. Figure 5 illustrates the main identification problem in this setting using the long-run outcome *income* as an example.

Figure 5: Relationships between the bedrock, fluoride level, cognitive ability and income




If our identification strategy relied on between-municipality variation, this would have been a concern. The key to identifying the causal effect of fluoride exposure is to have small geographical units between which there is a variation. We argue that Sweden's approximately 9,000 SAMS are sufficiently small and that fluoride is independent of the outcome between these small areas. A labor market region is larger than a SAMS. Given the use of SAMS level data, the red dashed lines in Figure 5 are blocked.

A second threat to identification would be that municipalities deliberately provide certain SAMS with fluoridated water because municipalities have some inside information about the dangers of fluoride. We demonstrate in Table A3, A4 and A6 in the appendix that this is not the case. There is no evidence that the provided drinking water fluoride level is dependent on predetermined characteristics in any clear way.

A third threat concerns self-selection for the outcome variables. There are missing values for the cognitive and non-cognitive test taken during conscription. There are also some missing values for individuals that have wrote the math test on the national test in ninth grade. Imagine that fluoride is negative for cognitive ability and that some individuals as a result of being exposed to lower levels of fluoride have a possibility to avoid conscription or the math test because they are more intelligent. We would then have self-selection into who is taking the conscription test or the math test. In Table A7 in the appendix, we demonstrate that this is not the case. Whether or not we have a result from the cognitive or non-cognitive ability test or the math test does not depend on the individual fluoride treatment level.

The fourth threat is about biological inheritance of cognitive ability. Assume that fluoride is negative for cognitive ability and that cognitive ability affected by fluoride can be passed on to the offspring. The effect of fluoride on the cognitive ability of the offspring is then an inherited factor, resulting in an overestimation of the effect of fluoride exposure in the present generation. This line of thought requires that environmental cognitive factors can be transmitted. The field of epigenetics concerns environmental factors that can switch genes on and off, and then be transgenerationally transmitted. Fluoride can be stored within the body which may *potentially* switch genes on or off that are related to cognitive ability. We test if such a transmission effect is present by also running all of our specifications for adoptees only. Adoptees have not inherited genes from their adoptive parents, so the effect of fluoride in this case purely stems from variation in fluoride exposure between birth and age 16 in the present generation. We discuss this in the robustness analysis.

The fifth threat to identification is related to nurture. Assume that parents exposed to high levels of fluoride develop lower cognitive ability resulting in bad parenting skills, which in turn affects our measure of cognitive ability in the present generation. Luckily, we have a rich set of generational covariates where we can control for fathers' cognitive and non-cognitive ability measured in the same way during their enlistment. We also have covariates for parents' income and education. We can thus control for nurture effects.

### 7.2 Econometric set-up

The fluoride level for each individual is a weighted average for the number of years a person lived within a specific SAMS. For non-movers, their fluoride level is simply the fluoride level for their SAMS between birth and age 16. People may thus have lived in the same SAMS, moved between SAMS within a municipality, or moved between municipalities. We include municipality fixed effects for where the person was born since there are several differences between municipalities that may also be determinants for our outcomes. To control for age effects we include cohort fixed effects. In addition, we add municipality fixed effects for place of residence in 2013 when we measure income and employment status, since the wage structure and the possibility of employment differs throughout Sweden. We also run two subsample specifications. Those who move could experience multiple treatments; for example, a person moving to a different municipality changes school. In the first sub-sample specification, we analyze the effect of fluoride for the non-movers only, i.e., individuals who have lived in the same SAMS from birth up until age 16. In the second specification, we analyze only those who move within a municipality but between different SAMS at least once between birth to age 16.

We estimate the following regression equation:

$$Y_i = \beta_0 + \beta_1 X_i + \beta_2 W_i + \beta_3 W_s + \beta_4 W_p + \tau_m + \gamma_m + \lambda_c + u_i \tag{1}$$

where $Y_i$ is the outcome variable measured at the individual level (except for dental outcomes where it is measured for each SAMS and cohort). $X_i$ is the amount of individual fluoride exposure, taking into account moving, for each individual. $W_i$ is a vector of covariates on the individual level. We also include aggregated covariates on SAMS level, $W_s$ to control for peer effects. $W_p$ designates parental covariates. $\tau_m$ designates birth municipal fixed effects, $\gamma_m$ equals municipal fixed effects in 2013 and $\lambda_c$ designates cohort fixed effects. $u_i$ is the error term. $\beta_1$ is the treatment effect of interest. The reader should note that we run several specifications where we add covariates and fixed effects sequentially. For cognitive ability, non-cognitive ability and math points, we never include municipal fixed effects in 2013 since these outcomes are measured at an earlier age.

Most SAMS do not have a water plant within the borders, meaning that the fluoride level that we assign to a SAMS is not independent on the fluoride level of the other SAMS within the same municipality. Therefore, we choose to cluster the standard errors on the birth municipal level because municipalities are responsible for the drinking water. In addition, we also calculate standard errors clustered at the local labor market region in accordance with the definitions from Statistics Sweden.[18] In a third standard error specification, we calculate spatial adjusted standard errors in line with Conley (1999) and use 10 kilometers as a spatial cut-off. These standard errors are based upon Euclidian distance, and the clustering structure is specified to last up until 10 kilometers from the center point of each SAMS. It can be argued that geographical distance is a more natural clustering level since individuals living far from each other are less dependent than those who live close, in comparison to municipalities and labor market regions who are administrative constructed entities.

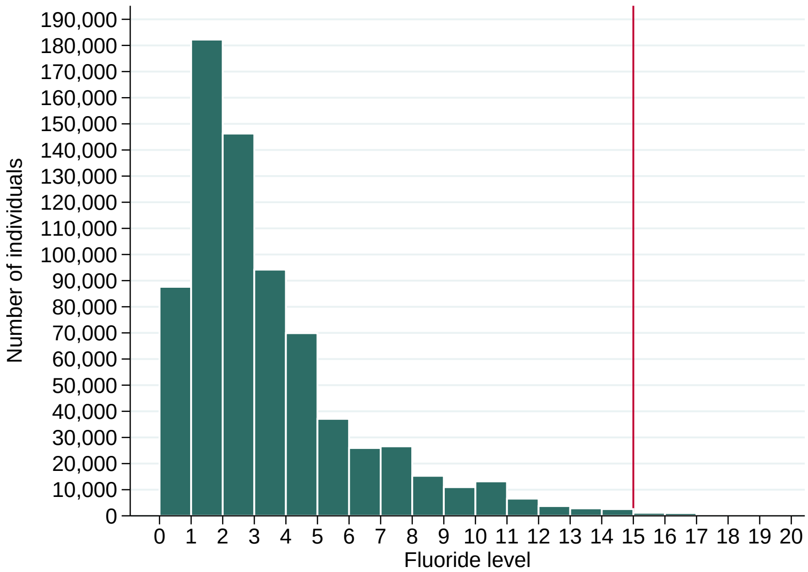
### 7.3 Descriptive statistics

In this subsection we present descriptive statistics. Figure 6 presents a histogram of the frequency of individuals who are treated with the corresponding level of fluoride, expressed in 0.1 mg/l. The level displayed in the histogram is the actual individual

[18]There are 73 local labor market regions in Sweden which are statistical areas for commuting regions. These standard errors are based upon place of residence in 2013 and we only estimate them when we look at personal income and employment status in 2013.

treatment level taken into account moving patterns between different SAMS and municipalities. The WHO recommendation of maximum 1.5 mg/l in the drinking water is marked with a red line.[19]

Figure 6: Histogram of fluoride levels below 2 mg/l (in 0.1 mg/l)




In Table 1, we present some detailed descriptive statistics of the standard deviation in fluoride levels within and between municipalities.

Table 1: Standard deviation decomposition of fluoride

| | Mean | SD |
|---|---|---|
| Fluoride (0.1 mg/l) | 3.53 | |
| *Overall* | | 3.25 |
| *Between* | | 2.95 |
| *Within* | | 1.89 |
| Observations | 8,597 | |

*Notes:* Between and within variation on municipal level.

Table 2 presents the mean and standard deviations for our five main outcomes of interest. The equivalent Table A1 for dental outcomes can be found in the appendix. Cognitive and non-cognitive ability are only measured for men and are centered on 5

[19]Those few cases above 1.5 mg/l originates from the earlier exceptions for higher levels mentioned in the data section. We cut the histogram at 2 mg/l because there are so few observations above 2 mg/l.

with a standard deviation of about 2, which follows the Stanine definition. 70 percent of the individuals in our sample are employed, which is close to the population share of employed. The maximum number of points on the math test is 45, and the mean is about 26 points.

Table 2: Descriptive statistics of main outcome variables

| | Mean | SD |
|---|---|---|
| Annual income in SEK | 164,173 | 134,308 |
| Employment status | 0.70 | 0.46 |
| Cognitive ability | 5.02 | 1.93 |
| Non-cognitive ability | 4.75 | 1.82 |
| Number of basic points math test | 26.19 | 8.57 |

Table 3 presents descriptive statistics of the covariates. The sample is balanced on gender (49 percent women). More than 90 percent have at least high school education in 2013. Only 5 percent is married, which is not surprising given that the individuals in the sample are relatively young. We also include covariates for parents' level of education and income (mean real wage between 1985-2013) for the parents, and whether they are immigrants. Income for the parents are specified as log income in the regressions, but displayed as real income in Table 3.[20] We are also able to include cognitive and non-cognitive ability from the enlistment for the father as covariates. However, the enlistment data starts 1969 so older fathers are not included. To capture peer-effects, we measure the mean education among individuals included in the data for each cohort and SAMS for three time points. We measure the individuals education as grown-ups in 2013 and then aggregate for each cohort and SAMS for where the individuals were born, where they started school (at 7 years of age) and where they lived at age 16. We include a dummy for whether an individual has graduated from high school when we estimate the effect on income and employment, but not when measuring cognitive ability, non-cognitive and the number of math points since these are measured before graduation.[21] We have grouped our covariates into two groups: Small set and Large set. Table 3 therefore also indicates which covariate is included in each group.

[20] Böhlmark and Lindquist (2005) find that current income is not as good measure of lifetime income as the widespread use would imply. See also the discussion in Engström and Hagen (2015). To minimize bias we use all available years of income for the parents.

[21] Whether to graduate or not from high school could be a bad control. However, whether an individual graduates from high school is influenced by several other factors than cognitive ability and at the same time, graduation from high school is important for later labor market status. Therefore, we choose to include it when studying income and employment status.

Table 3: Descriptive statistics of covariates

| | Mean | SD | Outcomes | Set |
|---|---|---|---|---|
| Gender | 0.49 | 0.50 | All | Small |
| Individual at least high school | 0.91 | 0.28 | Income, employment | Small |
| Marital status | 0.05 | 0.22 | All | Large |
| Father at least high school | 0.82 | 0.39 | All | Large |
| Father's income | 240,961 | 149,723 | All | Large |
| Father's cognitive ability | 5.07 | 1.90 | Not non-cog. ability | Large |
| Father's non-cognitive ability | 5.15 | 1.75 | Not cog. ability | Large |
| Father immigrant | 0.09 | 0.29 | All | Large |
| Mother at least high school | 0.89 | 0.32 | All | Large |
| Mother's income | 155,566 | 85,238 | All | Large |
| Mother immigrant | 0.10 | 0.30 | All | Large |
| Both parents immigrants | 0.05 | 0.21 | All | Large |
| Cohort education (birth) | 11.89 | 0.59 | All | Large |
| Cohort education (school start) | 11.89 | 0.60 | All | Large |
| Cohort education (age 16) | 11.89 | 0.60 | All | Large |
| Observations | 729,850 | | | |

*Notes:* Explanatory variables used in the estimations. Small set covariates are also included in the large set covariates. Cohort education variables (last three in the table) are means for cohorts and SAMS.

# 8 Results

In this section we present the results. We start by looking at the effects on dental health, and then present the results for our main outcomes. We have both analyzed linear effects and non-linear effects of fluoride for our main outcomes. This section is ended with a comparison with earlier studies on fluoride.

## 8.1 Effects of fluoride on dental health

If our strategy of mapping statistics from water plants to individual register data on the SAMS level has worked, we expect to see a positive effect of fluoride on dental health. We have dental outcomes for each cohort for each SAMS. The average number of individuals in a SAMS per included cohorts in our dental data set is approximately 16.

We have a set of variables that measure various dental outcomes. We present the results for a subset of these variables below that we judged was closely related to fluoride. The results for all additional outcomes are presented in section 11.4 in the appendix. The variables we focus on here are visits to a dental clinic, tooth repairs, disease evaluation, prevention and treatment and root canal. Given that fluoride is good for dental health, we expect to find negative estimates for these variables. All these variables are expressed as share in percentage points; for example the share of 20 years old in in a given SAMS that had a tooth repaired during a year. For a more detailed description about the variable abbreviations we use for the outcome variables in this section, see Table A1 in the appendix.

We divide our regression results into two separate tables. In Table 4 we run unweightened regressions where we look at the connection between fluoride and the aggregated measure of these six variables on the SAMS level. We have two data years available and the analysis for both years are presented in Table 4. For this analysis, we focus on the 20 years olds which is the earliest cohort available. We can be more sure that the 20 years olds have not moved from a given SAMS in comparison to later cohorts. In Table 5 we run weightened regressions where we work with our full data set. In this case, each individual has a unique fluoride treatment depending on moving patterns (age 0 to age 16) and the aggregated fluoride level on the SAMS level thus corresponds to those living in a SAMS.[22] For this analysis, individuals from cohorts in the data analysis for the main outcomes are included. We present the results for 2013 in Table 5. The reader should consider the results presented in Table 4 as a test whether our strategy mapping water plant statistics to residence data on the SAMS level has worked. The results in Table 5 should be considered as a test whether the combined geographical water-plant-mapping and the variation stemming from individuals' moving patterns captures what we want to measure, namely fluoride treatment.

Table 4: Dental outcomes

| *F.* | Visit | Repair | RiskEvaluation | DiseasePrevention | DiseaseTreatment | RootCanal |
|---|---|---|---|---|---|---|
| 2013 | -0.656** | -0.337*** | -0.689** | -0.845* | -0.350** | -0.0292* |
| | (0.299) | (0.110) | (0.302) | (0.431) | (0.139) | (0.0173) |
| 2008 | -0.637** | -0.229*** | -0.678** | -0.435* | 0.110 | -0.0300 |
| | (0.293) | (0.0684) | (0.320) | (0.224) | (0.106) | (0.0198) |

*Notes:* Standard errors clustered at the municipal level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. First row is for 2013, and the second row for 2008. The number of observations for the year 2013 is 7,622. The number of observations for the year 2008 is 7,606. Fluoride expressed in 0.1 mg/l. The dependent variable is displayed at the top of each column.

Table 4 clearly displays a negative effect of fluoride level for these outcomes except for one point estimate. The point estimates are large and often statistically significant. If we take the first estimate in Table 4 as an example, the share of visits is decreased by approximately 6.6 percentage points if fluoride is increased by 1 mg/l. This should be considered as a large effect. The outcome that should be closest related to fluoride is tooth repair, which is display in column 2. If fluoride would increase with 1 mg/l, the share of 20 years old that had a tooth repaired would be decreased approximately 3.4 percentage points. Again, this effect is large, especially considering this cohort. 20 years old should on average have healthy teeth, but we still find these effects of fluoride. Root canal treatment is generally a treatment for more serious conditions caused by caries. We find a negative point estimate for this outcome (which is expected), but only one coefficient is statistically significant on the 10 percent level. This is again expected given that root canal treatment should be generally rare among those who are 20 years

[22]SAMS is not yet available for 2013 LOUISE data set. We have used SAMS for the individual in 2011 in this case.

old. DiseaseTreatment is non-significant and positive for 2008, but is statistically significant, negative and large for the 2013 sample. It is important to note that comparisons across the years should not be done with this data, since definitions of treatments and diagnostics have somewhat altered across the years.

Table 5: Dental outcomes

| *F.* | (1) | (2) | (3) | (4) | (5) | (6) | (7) |
|---|---|---|---|---|---|---|---|
| Visit | -0.2592* | -0.0639** | -0.0198 | -0.0038 | 0.0059 | -0.0071 | -0.0023 |
| | (0.1472) | (0.0314) | (0.0309) | (0.0299) | (0.0239) | (0.0258) | (0.0264) |
| Repair | -0.0666 | -0.0522*** | -0.0490** | -0.0516** | -0.0575*** | -0.0506** | -0.0562*** |
| | (0.0536) | (0.0188) | (0.0249) | (0.0245) | (0.0207) | (0.0222) | (0.0204) |
| RiskEvaluation | -0.2709* | -0.0645** | -0.0202 | -0.0036 | 0.0068 | -0.0058 | -0.0006 |
| | (0.1546) | (0.0327) | (0.0314) | (0.0304) | (0.0239) | (0.0259) | (0.0267) |
| DiseasePrevention | -0.4409* | -0.0965** | -0.0742* | -0.0651* | -0.0406** | -0.0312 | -0.0305 |
| | (0.2514) | (0.0410) | (0.0380) | (0.0365) | (0.0204) | (0.0242) | (0.0243) |
| DiseaseTreatment | -0.0611 | -0.0196 | -0.0106 | -0.0120 | -0.0200 | -0.0271 | -0.0285 |
| | (0.0886) | (0.0276) | (0.0237) | (0.0237) | (0.0203) | (0.0223) | (0.0224) |
| RootCanal | -0.0031 | -0.0085** | -0.0108* | -0.0139** | -0.0152*** | -0.0108* | -0.0131** |
| | (0.0110) | (0.0041) | (0.0060) | (0.0059) | (0.0054) | (0.0057) | (0.0058) |
| Small set covariates | No | No | No | No | Yes | Yes | Yes |
| Large set covariates | No | No | No | No | No | No | Yes |
| Fe. birth muni. | No | No | Yes | Yes | Yes | Yes | Yes |
| Fe. cohort | No | No | No | Yes | Yes | Yes | Yes |
| Fe. muni. 2013 | No | Yes | No | No | Yes | Yes | Yes |
| Sample | All | All | All | All | All | Col 7 | All |

*Notes:* Standard errors clustered at the municipal level. *** p < 0.01, ** p < 0.05, * p < 0.1. Outcomes on each row. The number of observations ranges between 473,624 (col 6 and 7) and 727,543.

The results presented in Table 5 point in the same direction as the ones in Table 4, but the point estimates are generally smaller in size. The reason for this is probably because people have moved between age 16 and 2013 when we measure dental health, meaning that these results are a bit noisier. The fluoride treatment we consider only take place between birth and age 16 since we want to mimic the specifications for dental health with our main results in the next section. The share of repairs is the most well-defined variable where we really expect to find an effect, and the results for this variable are stable across different specifications and points in the expected direction. If we consider column 7 where all covariates and fixed effects are included, the share of individuals that had a tooth repaired would decrease by approximately 0.6 percentage points if their individual fluoride treatment level between birth and age 16 increased by 1 mg/l. This effects is smaller than the one found in Table 4, but still large considering that fluoride needs to be applied continuously to the teeth. What our results indicate – which is interesting in itself – is that early fluoride treatment has long run positive effects on dental health even if we do not consider fluoride treatment after age 16. Root canal treatment is now often statistically significant, which is expected since we have included older cohorts. The reader should note that some of the specifications are very demanding. When we include all fixed effects we compare individuals that are born in the same municipality, in the same cohort and that lives in the same municipality in 2013. Although the point estimates are not always statistically significant, they almost always points in the expected negative direction. In the appendix, the reader may find results for additional outcomes and the equivalent results for the 2008 sample in Tables A9, A10 and A11. Note that for 2008, we cannot include all cohorts since the later cohorts were not above 20 in 2008.

We can conclude that the coefficients for the 2008 specification are generally smaller in size and less precisely estimated, where we have fewer negative (statistically significant) results. We can only speculate why this is the case, but a reform was implemented in July 2008 that gave 20-29 years old a special dental care benefits. In comparison to other health care services in Sweden, the patient pays a much larger share for him/herself for dental care. Given that people in their 20's usually have lower incomes, the benefit probably allowed people between 20 and 29 to visit the dentist regularly, which could potentially explain that the results are less clear for the 2008 sample simply because individuals were refrained in economic terms to seek dental care before the reform. The specifications for 2008 are also based on fewer observations.

The overall conclusion after considering the results in Table 4, 5 and the additional results presented in the appendix is that out mapping strategy seems to have worked. Generally, we find negative and often statistically significant results for fluoride on these outcomes; especially if we consider the 2013 sample.[23]

### 8.2 Main results

In this subsection we present our main results. We begin by looking at cognitive ability, non-cognitive ability and points at the math test taken in ninth grade. Then we move on and investigate the effect of fluoride on more long-term outcomes where we look at income and employment status. We begin by estimating linear effects of fluoride. There are, however, reason to believe that the effect may be non-linear, and that fluoride becomes dangerous above a certain level.[24] We estimate the non-linear effects in the next subsection.

Let us begin with cognitive ability, measured in a Stanine scale. In this case we only include males in our specifications. In the table below we present the point estimates for fluoride and two types of standard errors. The first standard error in parenthesis is clustered on the birth municipality. The standard errors in curly brackets are spatial adjusted standard errors in line with Conley (1999). The first column does not include any covariates and or fixed effects. In the following two columns we add fixed effects. When we include covariates for fathers' cognitive ability our sample is reduced since we

[23] For two of the variables, we find results that point in the opposite directed that we expected for some of the specifications. These variables are median of intact teeth and median of remaining teeth. See the results in the appendix. We expect to find positive point estimates for these variables. After further consideration, we conclude that these outcomes are not suitable for this age group. Wisdom teeth are developed in this age, meaning that the median of remaining and intact teeth are mostly influenced by another factor than fluoride, namely wisdom teeth incidence.

[24] This is why WHO has a recommendation of max 1.5 mg/l fluoride in the drinking water.

only have data on fathers' cognitive ability from 1969. To make the samples comparable with and without the covariates we run column 4 with the same sample as if we had included covariates which we do in column 5. We run two subsample analyses where we only focus on those individuals that have not moved from a municipality between birth and age 16. In column 6, we run an analysis for those who have lived in the same SAMS area in a municipality for the entire period 0-16. In column 7 we restrict our sample to those who have moved, but only within a municipality.

Looking at the point estimates, they are all very small and often not statistically significant different from 0. Sometimes the point estimates are negative and sometimes they are positive, but always very close to 0. Fluoride is expressed in 0.1 mg/l. If we take the point estimate from column 5, which is equal to 0.0073, this means that cognitive ability is increased by 0.073 Stanine points if fluoride is increased by 1 mg/l (a large increase in fluoride). This should be considered as a zero effect on cognitive ability. A Stanine point roughly equals 6-8 IQ points.[25]

Table 6: Cognitive ability

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) |
|---|---|---|---|---|---|---|---|
| Fluoride (0.1 mg/l) | -0.0083 | -0.0024 | -0.0024 | -0.0015 | 0.0073 | 0.0035 | 0.0231 |
| | (0.0081) | (0.0051) | (0.0051) | (0.0052) | (0.0039)* | (0.0050) | (0.0081)*** |
| | {0.0085} | {0.0045} | {0.0045} | {0.0051} | {0.0041}* | {0.0050} | {0.0092}** |
| Mean | 5.0088 | 5.0088 | 5.0088 | 5.0240 | 5.0240 | 5.0851 | 4.9224 |
| Birth cohort FE | No | No | Yes | Yes | Yes | Yes | Yes |
| Birth municipal FE | No | Yes | Yes | Yes | Yes | Yes | Yes |
| Large set covariates | No | No | No | No | Yes | Yes | Yes |
| Sample | All | All | All | Col 5 | All | SAMS stayers | SAMS movers |
| $R^2$ | 0.0002 | 0.0215 | 0.0238 | 0.0281 | 0.1786 | 0.1672 | 0.1906 |
| Observations | 82,010 | 82,010 | 82,010 | 51,322 | 51,322 | 21,348 | 18,848 |

*Notes:* Standard errors in parenthesis are clustered at the municipal of birth. Standard errors in curley brackets are Conley standard errors with a cut-off of 10 km, centered on each SAMS. *** p < 0.01, ** p < 0.05, * p < 0.1.

Let us move on to non-cognitive ability. The point estimates are once again very close to 0 and often not statistically significant. If we do the same calculation as before with an increase in fluoride by 1 mg/l, the non-cognitive score would increase by 0.171 Stanine points according to column number 5. In this column, the point estimate is actually statistically significant, but the result should be interpreted as a negligible effect because of the very small estimated coefficient. In economic terms, the effect is zero.

[25] IQ measure with population mean of 100 and a standard deviation of 15. See Öhman (2015)

Table 7: Non-cognitive ability

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) |
|---|---|---|---|---|---|---|---|
| Fluoride (0.1 mg/l) | 0.0026 | 0.0059 | 0.0059 | 0.0110 | 0.0171 | 0.0087 | 0.0347 |
| | (0.0057) | (0.0047) | (0.0047) | (0.0052)** | (0.0054)*** | (0.0067) | (0.0150)** |
| | {0.0053} | {0.0044} | {0.0044} | {0.0052}** | {0.0050}*** | {0.0064} | {0.0129}*** |
| Mean | 4.7341 | 4.7341 | 4.7341 | 4.7751 | 4.7751 | 4.9133 | 4.6873 |
| Birth cohort FE | No | No | Yes | Yes | Yes | Yes | Yes |
| Birth municipal FE | No | Yes | Yes | Yes | Yes | Yes | Yes |
| Large set covariates | No | No | No | No | Yes | Yes | Yes |
| Sample | All | All | All | Col 5 | All | SAMS stayers | SAMS movers |
| $R^2$ | 0.0000 | 0.0173 | 0.0175 | 0.0211 | 0.0791 | 0.0761 | 0.0998 |
| Observations | 66,561 | 66,561 | 66,561 | 41,730 | 41,730 | 17,408 | 15,159 |

*Notes:* Standard errors in parenthesis are clustered at the municipal of birth. Standard errors in curley brackets are Conley standard errors with a cut-off of 10 km, centered on each SAMS. *** p < 0.01, ** p < 0.05, * p < 0.1.

For the next outcome variable – the number of points at the math test taken in the ninth grade – we have data for both males and females. In this case we also have data for additional cohorts in comparison to the first two outcomes. The average score was approximately 26. All of the point estimates are negative in this case and some of the estimated coefficients are statistically different from zero. The size of the point estimates are, however, very small. In the first four columns we have more than 500,000 observations so it is not surprising that some of our results are statistically significant. The important part is economic significance. Let us focus on column 6 where we have included all covariates and all fixed effects. If fluoride is increased by 1 mg/l (again, this is a large increase), the number of points on the math test should decrease by approximately 0.1 points. This decrease is less than 0.5 percent of the average number of points on the test which was 26 points. In economic terms, this effect should be considered as a zero effect.

Table 8: Math points

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
|---|---|---|---|---|---|---|---|---|
| Fluoride (0.1 mg/l) | -0.1029 | -0.0295 | -0.0268 | -0.0268 | -0.0437 | -0.0110 | -0.0208 | -0.0180 |
| | (0.0354)*** | (0.0126)** | (0.0125)** | (0.0125)** | (0.0144)*** | (0.0136) | (0.0132) | (0.0237) |
| | {0.0355}*** | {0.0116}** | {0.0115}** | {0.0115}** | {0.0128}*** | {0.0102} | {0.0118}* | {0.0189} |
| Mean | 26.2100 | 26.2100 | 26.2100 | 26.2100 | 26.4943 | 26.4943 | 27.2265 | 26.0476 |
| Birth cohort FE | No | No | Yes | Yes | Yes | Yes | Yes | Yes |
| Birth municipal FE | No | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Small set covariates | No | No | No | Yes | Yes | Yes | Yes | Yes |
| Large set covariates | No | No | No | No | No | Yes | Yes | Yes |
| Sample | All | All | All | All | Col 6 | All | SAMS stayers | SAMS movers |
| $R^2$ | 0.0013 | 0.0230 | 0.0404 | 0.0404 | 0.0431 | 0.1709 | 0.1487 | 0.1826 |
| Observations | 500,995 | 500,995 | 500,995 | 500,995 | 337,404 | 337,404 | 139,276 | 127,334 |

*Notes:* Standard errors in parenthesis are clustered at the municipal of birth. Standard errors in curley brackets are Conley standard errors with a cut-off of 10 km, centered on each SAMS. *** p < 0.01, ** p < 0.05, * p < 0.1.

We may thus conclude that fluoride does not have a negative effect on cognitive development. The last two tables include outcomes which are more long-term: Log annual income and employment status in 2013. These are the outcome variables for which we have the largest number of observations. Given the zero results for the three variables above, we do not expect to find a negative effect on these long-term outcomes. It is, however, possible that fluoride has a positive effect, because of better dental health for the individuals. In the two tables below we add an additional standard error calculation where the standard errors in brackets are clustered at the local labor market area in 2013. We also add an additional set of municipal fixed effects for where the individual lives in 2013.

Looking at log income, we have often statistically significant point estimates and the coefficients are always positive. If we look at column 6, the point estimate equals 0.004, meaning that income increases by 4 percent if fluoride increases by 1 mg/l. This is not a negligible effect and the estimate should be considered as economically significant. This indicates that fluoride improves labor market outcomes through better dental health. One interpretation could be that better looking teeth is a positive factor on the labor market. Our estimate is in line with Glied and Neidell (2010), who find that women who drinks fluoridated water on average earn 4 percent more.

Table 9: Annual log income in SEK

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
|---|---|---|---|---|---|---|---|---|
| Fluoride (0.1 mg/l) | 0.0068 | 0.0064 | 0.0051 | 0.0052 | 0.0042 | 0.0040 | 0.0026 | 0.0029 |
| | (0.0032)** | (0.0015)*** | (0.0014)*** | (0.0013)*** | (0.0012)*** | (0.0010)*** | (0.0016) | (0.0031) |
| | [0.0018]*** | [0.0017]*** | [0.0016]*** | [0.0009]*** | [0.0010]*** | [0.0010]*** | [0.0016] | [0.0029] |
| | {0.0031}** | {0.0010}*** | {0.0010}*** | {0.0010}*** | {0.0010}*** | {0.0009}*** | {0.0014}* | {0.0024} |
| Mean | 11.7798 | 11.7798 | 11.7798 | 11.7798 | 11.7942 | 11.7942 | 11.8449 | 11.7835 |
| Birth cohort FE | No | No | Yes | Yes | Yes | Yes | Yes | Yes |
| Birth municipal FE | No | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Municipal FE, year 2013 | No | No | No | Yes | Yes | Yes | Yes | Yes |
| Small set covariates | No | No | No | Yes | Yes | Yes | Yes | Yes |
| Large set covariates | No | No | No | No | No | Yes | Yes | Yes |
| Sample | All | All | All | All | Col 6 | All | SAMS stayers | SAMS movers |
| $R^2$ | 0.0004 | 0.0078 | 0.0594 | 0.1004 | 0.1028 | 0.1121 | 0.1277 | 0.1096 |
| Observations | 628,732 | 628,732 | 628,732 | 628,732 | 415,341 | 415,341 | 172,669 | 155,980 |

*Notes:* Individuals with a yearly income below 1,000 SEK are excluded. Standard errors in parenthesis are clustered at the municipal of birth. Standard errors in brackets are clustered at the local labor market area defined by Statistics Sweden (SCB). Standard errors in curley brackets are Conley standard errors with a cut-off of 10 km, centered on each SAMS. *** p < 0.01, ** p < 0.05, * p < 0.1.

Let us continue to the last outcome. Employment status is a dummy variable taking the value 1 if the individual is defined as employed in 2013. In column 6, the point estimate for fluoride is 0.0012 and statistically significant. If fluoride is increased by 1 mg/l, then the probability that the person is employed is increased by 1.2 percentage points. This result thus point in the same direction as the results for log income where both these results are significant in economic terms.

Table 10: Employment status

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
|---|---|---|---|---|---|---|---|---|
| Fluoride (0.1 mg/l) | 0.0026 | 0.0025 | 0.0022 | 0.0022 | 0.0013 | 0.0012 | 0.0005 | 0.0000 |
| | (0.0012)** | (0.0007)*** | (0.0007)*** | (0.0006)*** | (0.0006)** | (0.0005)** | (0.0007) | (0.0013) |
| | [0.0007]*** | [0.0007]*** | [0.0007]*** | [0.0004]*** | [0.0004]*** | [0.0005]*** | [0.0005] | [0.0011] |
| | {0.0012}** | {0.0005}*** | {0.0005}*** | {0.0004}*** | {0.0005}*** | {0.0004}*** | {0.0006} | {0.0010} |
| Mean | 0.7019 | 0.7019 | 0.7019 | 0.7019 | 0.7147 | 0.7147 | 0.7420 | 0.7109 |
| Birth cohort FE | No | No | Yes | Yes | Yes | Yes | Yes | Yes |
| Birth municipal FE | No | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Municipal FE, year 2013 | No | No | No | Yes | Yes | Yes | Yes | Yes |
| Small set covariates | No | No | No | Yes | Yes | Yes | Yes | Yes |
| Large set covariates | No | No | No | No | No | Yes | Yes | Yes |
| Sample | All | All | All | All | Col 6 | All | SAMS stayers | SAMS movers |
| $R^2$ | 0.0003 | 0.0073 | 0.0326 | 0.0688 | 0.0689 | 0.0794 | 0.0830 | 0.0789 |
| Observations | 729,850 | 729,850 | 729,850 | 729,850 | 475,414 | 475,414 | 192,740 | 179,374 |

*Notes:* Standard errors in parenthesis are clustered at the municipal of birth. Standard errors in brackets are clustered at the local labor market area defined by Statistics Sweden (SCB). Standard errors in curley brackets are Conley standard errors with a cut-off of 10 km, centered on each SAMS. *** p < 0.01, ** p < 0.05, * p < 0.1.

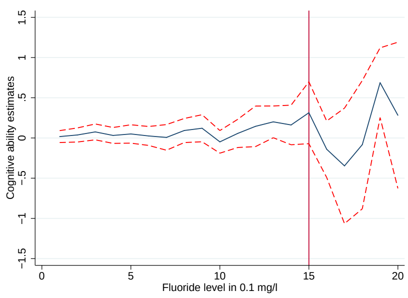
In conclusion, we find zero effects on cognitive and non-cognitive ability. We also find zero effects for the number of math points. These results indicate that fluoride does not have adverse negative effect on cognitive development for the fluoride levels we consider. We discuss our zero results in a separate subsection below. We also find that fluoride has positive effects on log income and employment status which could indicate that better dental health is a positive factor on the labor market. These results are in line with our previous results for dental health where we found that fluoride seems to results in better dental health in this age group.

### 8.3 Non-linear effects

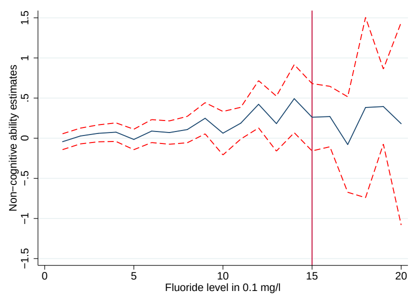
There are reasons to believe that a potential neurotoxic effect of fluoride on the central nervous system is not linear. As with many toxic compounds, small amounts do not yield any dramatic damage, but the effects manifest itself above a certain threshold. We therefore continue our analysis and look for non-linear effects.

In Figures 7-9 the effect for each fluoride level is displayed. We have created dummy variables taking the value 1 for each 0.1 fluoride level and then included these in a regression. When we run the regressions, all fixed effects and all covariates are included just as in column 6 in the tables above. We then plot the effect for each 0.1 mg/l in a figure. Fluoride in our data is between 0 and 4 mg/l, but we have very few observations above the threshold level of 1.5 mg/l, meaning that the estimated effect is very noisy. In the figures below, we have therefore cut the individual fluoride treatment level at 2 mg/l. The blue lines in the figures are the plotted point estimates and the red dashed lines are 95 % confidence intervals. The conclusion is that the effect up until 1.5 mg/l is always close to zero. In line with the earlier results for log income and employment status, the line in the figures below seems to increase when closing on 1.5 mg/l, which indicate a positive effect of fluoride through dental health for higher levels. In line with the main analysis, the point estimates for the number of math points are sometimes statistically significant. The size of the point estimates are small, and the effect does not seem to be significant when considering fluoride levels close to 1.5 mg/l, which we would expect if fluoride had a negative effect on cognitive development.

Figure 7: Non-linear effects for ability measures




(a) Cognitive ability estimates




(b) Non-Cognitive ability estimates

Figure 8: Non-linear math points estimates

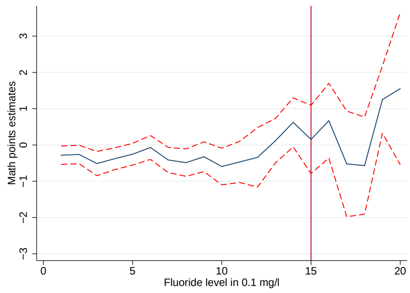
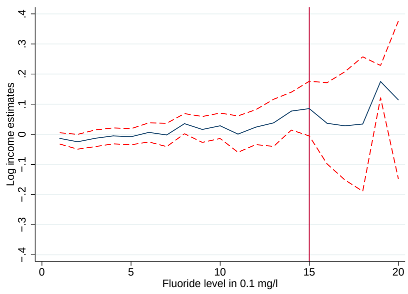
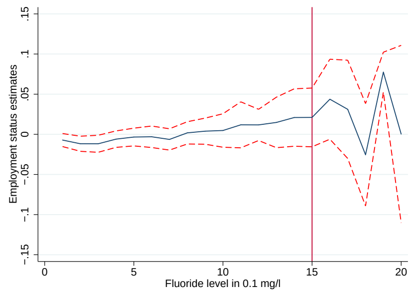



Figure 9: Non-linear effects labor market outcomes




(a) Log income estimates




(b) Employment estimates

In section 11.5 in the appendix, we also present regression tables where we run the regressions with dummy variables for each quartile value in the fluoride distribution. In the tables, we run the exact same specifications for each outcome variable as in the tables in the last section when we looked at linear effects. The conclusion is, again, that there are no indications that fluoride has an effect other than zero for cognitive ability, non-cognitive ability and math points. For cognitive ability and math points, we have some statistically significant, negative point estimates for the third quartile dummy. For the fourth quartile however, the point estimates are insignificant for all specifications which we expect if fluoride does not have a negative effect on these outcomes. With regard to log income and employment status, we find positive and statistically significant results for the fourth quartile, which again points towards the explanation that fluoride has a positive effect thorough dental health – especially for higher levels of fluoride.

## 8.4 Comparison with earlier studies

Are our estimated results for cognitive ability really zero? One way to evaluate a zero-result is to look at earlier studies which have found statistically significant results and compare the precision of the estimates. In the table below, we have summarized the results for the reviewed papers in Choi et al. (2012). We have only included the papers which study fluoride levels that are roughly equal to the levels we consider. Because earlier papers only have considered cognitive ability, we can only compare this outcome variable. To make our results comparable to the other papers, we have normalized cognitive ability around 0. The reader should note that we have not read the original articles since most of them are printed in Chinese or Persian. Instead, the comparison below is based on Choi et al. (2012).[26]

Table 11: Comparison with earlier studies

| Study | Obs. | *F.* | CI 95 % |
|---|---|---|---|
| **Our study:** No cov. or f.e. | 82,010 | 0.05-4.10 | -0.1262, 0.0399 |
| **Our study:** Cov. and f.e. | 51,322 | 0.05-4.10 | -0.0023, 0.0781 |
| Chen et al. (1991) | 640 | 0.89-4.55 | -0.41, -0.10 |
| Lin et al. (1991) | 119 | 0.34-0.88 | -1.01, -0.28 |
| Xu et al. (1994) | 129 | 0.80-1.80 | -1.35, -0.52 |
| Yang et al. (1994) | 60 | 0.50-2.97 | -1.01, 0.02 |
| Li et al. (1995) | 907 | 1.02-2.69 | -0.70, -0.39 |
| Zhao et al. (1996) | 320 | 0.91-4.12 | -0.76, -0.31 |
| Yao et al. (1997) | 502 | 0.40-2.00 | -0.61, -0.25 |
| Lu et al. (2000) | 118 | 0.37-3.15 | -0.98, -0.25 |
| Hong et al. (2001) | 117 | 0.75-2.90 | -0.85, -0.03 |
| Wang et al. (2001) | 60 | 0.50-2.97 | -1.01, 0.02 |
| Xiang et al. (2003) | 512 | 0.18-4.50 | -0.82, -0.46 |
| Seraj et al. (2006) | 126 | 0.40-2.50 | -1.28, -0.50 |
| Li et al. (2009) | 80 | 0.96-2.34 | -0.94, 0.08 |
| Poureslami et al. (2011) | 119 | 0.41-2.38 | -0.77, -0.04 |

*Notes:* $F$ is fluoride level in mg/l. This table consists of the results of comparable studies presented in Table 1 and Figure 2 on page 1364-1366 in Choi et al. (2012). Note that these studies have not considered a continuous measure of fluoride.

In contrast to earlier papers, our study is based on a much larger data sample and our point estimates are much more precise. Earlier papers have found negative and statistically significant effects in many cases, but our results are always very close to 0. Our 95 % confidence intervals includes the zero both with or without fixed effects and covariates.

Broadbent et al. (2015) also claim to find a zero-result. Their confidence intervals are, however, much broader than ours. They estimate a 95 % confidence interval for the effect of living in a high fluoride (0.7-1 mg/l) area in comparison to those living in a low fluoride area (0-0.3 mg/l) on cognitive ability (with covariates) to be (-3.49, 3.20) for those between 7 and 13 years old and between (0.02, 5.98) for those at age

[26]Since we have not read the original research articles, we do not cite them in the reference list. See Choi et al. (2012) for details about these papers.

38. In this case, cognitive ability is measured in IQ points with a mean of 100. If we translate our estimates to IQ points, roughly by replacing the Stanine scores with the corresponding IQ[27], our confidence intervals are (-1.8084, 0.5735) for the specifications without covariates or fixed effects and (-0.0362, 1.1131) for the specifications with all covariates and fixed effects.

Based on the assessment of the earlier literature, we are confident to claim that we have estimated a zero effect on cognitive ability.

# 9 Robustness analysis

In this section we discuss the results from various robustness checks.

First we address the potential threat to our identification strategy that fluoride as an environmental factor can switch certain genes on and off in accordance with the idea in epigenetics. To test if this is a problem, we rerun all our specifications only including individuals that were adopted in section 11.6. Their place of residence and fluoride treatment between birth and age 16 is thus that of their adoptive parents who they do not share an inherited factor with. The regression tables are presented in the appendix. The estimates point somewhat in the same direction as the ones in the main analysis, but the point estimates are not statistically significant. The reader should note that we have a much smaller sample for this robustness check.

We use a mapping protocol to assign water plant data on fluoride in the drinking water to SAMS. Since we cannot observe the exact coordinate where an individual lives, we will have some measurement error with regard to those who drink water from a private well. All we know is if an individual live in a specific SAMS for a given year.[28] The probability that an individual consume the drinking water provided by the municipality should increase when the SAMS is small and/or when the distance from the water plant to the center of the SAMS is small. Smaller SAMS equals more densely populated areas. We have run all of our specifications in section 11.7 and 11.8 in the appendix where we look at subsamples in our data for various sizes of SAMS and various distances between the nearest water plant and the center point of the SAMS. We have plotted these estimates in graphs presented in the appendix. In conclusion, the point estimates does not seem to differ in a systematic way when just considering smaller SAMS and shorter distances.

We do not have water statistics for each year from 1985 for all municipalities. We have therefore contacted all municipalities and asked them if they have changed their water sources after 1985. Because the bedrock is constant, they level of fluoride should also be constant from 1985 if the water source is the same. All municipalities do not have exact information regarding their water sources and we have not received confirmation from all of them. In section 11.9 in the appendix, we also run a specification including only those municipalities where we have data from 1985 or where we have received a

[27] See Table 1 in Öhman (2015).

[28] In a theoretical scenario where we have severe measurement error, we would have bias in our estimates towards 0. This is not likely given our results for dental health.

clear confirmation that the municipality has not changed their water sources after 1985. The results for cognitive and non-cognitive ability are in economic terms still zero. The estimated coefficients for math points are negative and sometimes statistically significant (as in the main analysis), but very small in size. For log income and employment status, we find positive and sometimes statistically significant results as in the main analysis, but the estimated coefficients are generally smaller in magnitude in this specification.

We include cohorts born between 1985 and 1992 in our main analysis. This could be problematic when we estimate the effect of fluoride on employment status and income, because those who are born in 1992 are only 21 years old in 2013 (the year we measure these two outcomes). Younger cohorts have not established themselves on the labor market to that high extent. We therefore also run specific analysis only for those born in 1985 in section 11.10. The results point in the same direction as in the main analysis, but the point estimates are not always statistically significant anymore. The size of the point estimates for log income is sometimes larger. This is what we expect given that there is a positive effect of fluoride on log income. The results for employment status are similar to the ones discussed in the main analysis.

We also run a specification where we only look at those SAMS which had one and only one water plant and where we have full information from 1985 from the municipalities in section 11.11. In this specification we only include those who have not moved between birth and age 16. In this case we are left with much fewer observations. For cognitive ability, non-cognitive ability and math points, there is still no evidence of any negative effects. For log income and employment status, the point estimates varies between different specifications and we no longer have statistically significant results. This is probably a result of having fewer observations and thus lower statistical power.

We have also run an analysis for an alternative income measure in section 11.12 in the appendix. In the main analysis we look at a measure for income from employment. In the alternative specification, we run the same analysis for a measure for income from employment and business income (förvärvsinkomst). These results point in the same direction as the ones in the main analysis.

# 10 Conclusions

We have investigated the effects of fluoride on outcomes related to the central nervous system and more long-term labor market outcomes. We find a zero effect of fluoride on cognitive ability, non-cognitive ability and points on the national test in math. For income and employment status we found evidence of a positive effect of fluoride, which would be in line with the explanation that better dental health is a positive factor on the labor market. We began our analysis by first investigating the dental health effects of fluoride, and could confirm the long well-established positive relationship.

Our paper is to our knowledge the first large scale empirical study with individual register data to assess the effects of drinking water fluoride. Earlier studies, which have found a negative effect of fluoride on cognitive ability, rely on much smaller samples originating from countries with poorer data quality. In addition, these papers have usually not applied credible identification strategies. That said, earlier studies have sometimes focused on higher levels of fluoride than the levels we consider in this paper. It may be that higher levels of fluoride in the drinking water have negative effects on cognitive ability. However, in comparison our paper is more policy relevant for developed countries, because water authorities seldom consider fluoridating the drinking water above 1.5 mg/l. Based on the results we find, the policy implications are that fluoride exposure through the drinking water either in the form of natural levels or artificial fluoridation is a good mean of improving dental health without risking negative side effects on cognitive development.

Future studies should try to establish where the dangerous level of fluoride begins. Since we know that fluoride is lethal and dangerous in very high dosages, it is crucial to find the safe limit for fluoride in the drinking water. Our results indicate that the dangerous level is not below 1.5 mg/l.

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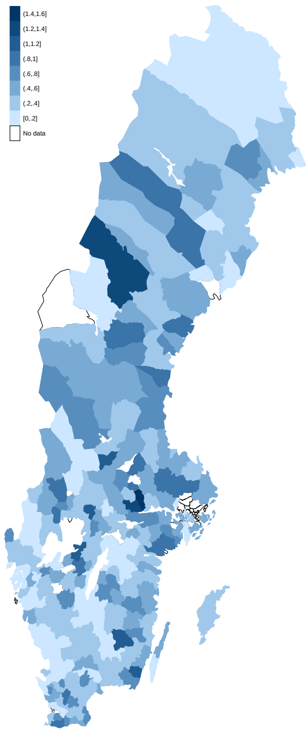
# 11 Appendix

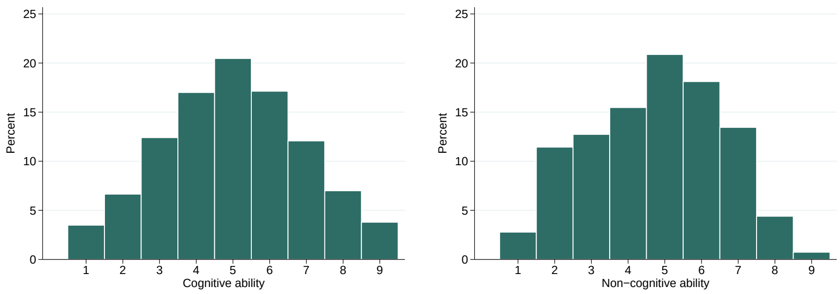
## 11.1 Exogenous variation in fluoride: geological background

Figure A1: Fluoride levels in Sweden: Variation between municipalities after mapping




## 11.2 Data: Individual level data

Figure A2: Distribution of cognitive and non-cognitive ability




(a) .

(b) .

## Data: Descriptive statistics

Table A1: Descriptive statistics of dental outcomes

| | Mean | SD | Max | Min |
|---|---|---|---|---|
| Visits dental clinic | 66.31 | 24.31 | 100.00 | 0.00 |
| Basic check-ups | 59.42 | 25.92 | 100.00 | 0.00 |
| Risk evaluation, health improvement measures | 64.78 | 24.64 | 100.00 | 0.00 |
| Disease prevention | 12.82 | 18.97 | 100.00 | 0.00 |
| Disease treatment | 31.31 | 23.21 | 100.00 | 0.00 |
| Dental surgical measures | 6.33 | 11.66 | 100.00 | 0.00 |
| Root canal treatment | 2.75 | 7.67 | 100.00 | 0.00 |
| Orthognathic treatment | 1.37 | 5.50 | 100.00 | 0.00 |
| Dental repair | 18.85 | 19.22 | 100.00 | 0.00 |
| Prosthesis treatment | 0.72 | 4.04 | 100.00 | 0.00 |
| Orthodontics and replacement measures | 0.18 | 2.06 | 100.00 | 0.00 |
| Diagnosis: Check-ups and evalutions | 64.77 | 24.64 | 100.00 | 0.00 |
| Diagnosis: Dental health improvement measures | 9.44 | 15.31 | 100.00 | 0.00 |
| Diagnosis: Treatment of illness and pain | 34.93 | 24.00 | 100.00 | 0.00 |
| Diagnosis: Dental repair | 22.86 | 20.67 | 100.00 | 0.00 |
| Diagnosis: Habilitation and rehabilitation | 0.76 | 4.05 | 100.00 | 0.00 |
| Median remaining teeth | 29.52 | 1.36 | 32.00 | 1.00 |
| Median intact teeth | 25.87 | 2.89 | 32.00 | 0.00 |

### 11.3 Empirical framework: Balance tests

Our identifying variation stems from a geological variation in fluoride and from individuals' moving patterns between birth and age 16. It is important that we verify that people are not moving from and to different SAMS because of the fluoride level. If people were, we would have self-selection into the intensity of treatment meaning that we cannot separate treatment from the outcomes.

Table A2 displays balance tests for moving patterns where each row is a separate regression. Overall, the moving pattern is on average not depending on the individual fluoride treatment level. We run specific balance test for dummy variables taking the value 1 if an individual has moved within a municipality but between SAMS, if the individual has moved between municipalities and if the individual has moved between counties. We also run balance test for the number of moves between SAMS, municipalities and counties and the average number of years within a SAMS, municipality or county. The point estimates are always small and statistically insignificant. If the individual fluoride treatment increases by 0.1 mg/l, the probability that the individual has moved between SAMS within a municipality is 0.49 percentage points lower according to row 1 in Table A2. We have also conducted a comparison in difference in means for first time movers. The mean fluoride level prior of moving was approximately 0.33 mg/l and after moving the mean was 0.34 mg/l. Hence, there is no evidence that people move from high fluoride areas.

Table A2: Balance test. Moving pattern, individual fluoride treatment level.

| | *F.* (0.1 mg/l) |
|---|---|
| Move within municipality | -0.00487<br>(0.00408) |
| Municipal Move | 0.0000963<br>(0.00263) |
| County Move | 0.00138<br>(0.00158) |
| # moves within municipality | -0.00373<br>(0.00809) |
| # moves between municipalities | 0.00135<br>(0.00429) |
| # moves between counties | 0.00239<br>(0.00224) |
| Average years SAMS | 0.0279<br>(0.0273) |
| Average years municipality | -0.000902<br>(0.0158) |
| Average year county | -0.00792<br>(0.00880) |
| Observations | 733,683 |

*Notes:* Standard errors clustered at the birth municipal level. *** p < 0.01, ** p < 0.05, * p < 0.1. Each row is a separate regression, where the dependent variable is displayed on the row. The number of observations refers to the maximum number of observation. For row 1 and 4, we restrict the sample to those who have moved within a municipality, but between SAMS. The number of observations are thus smaller for these two specification.

In Table A3 we investigate whether the municipality provided water is endogenously rerouted to specific groups. We investigate this by running balance test for predetermined characteristics on the SAMS level for where the individual was born.[29] Municipalities may potentially know that fluoride is dangerous, and therefore give such water to groups with lower socioeconomic status. We also investigate whether other characteristics are dependent on the fluoride level, such as the size of SAMS or the distance to the water

[29]We cannot run this for income and education since these are outcomes that we are interested in.

plant. These balance tests address the question whether fluoride is correlated with population density, since less populated areas have larger SAMS. We have also run a test for those municipalities for which we do not have full information about their drinking water from 1985. Table A4 and A5 displays a similar analysis for the years of immigration for the parents. This variable is also predetermined, where we run the balance test for various dummy variables for mothers and fathers respectively. We focus on where the individual was born and calculate the share of immigrants that arrived for each year. All shares are then included into a single regression.

We do not find support of the concerns discussed above. We have statistically significant results on the 10 percent level for the share (expressed between 0 and 1) of immigrants outside the Nordic countries (although not outside Europe), but the estimates are negatively related to the fluoride level. This means that our concern that municipalities give high fluoride water does not have any support. We have one statistically significant result for the number of water plants within a SAMS. Those SAMS without a water plants have on average lower fluoride. This is because the three largest cities in Sweden has few and large water plants and generally low fluoride levels. These areas also consist of many SAMS because of large populations. The point estimate is however very small. If the fluoride level within a SAMS increased by 0.1 mg/l, the number of water plants would increase by 0.02 water plants. In practice, this is a zero effect. With regards to Table A4 and Table A5, there is no evidence that municipalities reroute fluoride to certain immigration cohorts. The share in this case is expressed between 0 and 100. Some results are statistically significant, but all point estimates are small in magnitude (below 0.1 mg/l), with the exception of one coefficient. Let us take the first row in Table A5 as an example. If the share of immigrant fathers that arrived to Sweden in 1945 increases by 1 percentage point of the SAMS population (a large increase), the fluoride level to that SAMS would be 0.09 mg/l lower. The reader should not when interpreting statistically significant results that the precision of fluoride measurement is 0.1 mg/l. The reader should also note that some of these immigration cohorts consist of very few people.

Table A3: Balance test. Predetermined characteristics. Fluoride for each SAMS

| | *F.* (0.1 mg/l) |
|---|---|
| SAMS area | 3.552<br>(2.525) |
| Distance WP | 0.0804<br>(0.182) |
| Not full info | 0.000563<br>(0.0115) |
| Number WP, SAMS | 0.0203***<br>(0.00711) |
| Father immigrant | -0.00163<br>(0.00176) |
| Mother immigrant | -0.00218<br>(0.00171) |
| Both parents immigrants | -0.00122<br>(0.000999) |
| Father immigrant outside Nordic | -0.00244*<br>(0.00146) |
| Mother immigrant outside Nordic | -0.00239*<br>(0.00131) |
| Both parents immigrant outside Nordic | -0.00139*<br>(0.000829) |
| Father immigrant outside Europe | -0.00132<br>(0.000914) |
| Mother immigrant outside Europe | -0.00120<br>(0.000833) |
| Both parent immigrant outside Europe | -0.000771<br>(0.000556) |
| Mother's age at birth | -0.0317<br>(0.0317) |
| Father's age at birth | -0.0270<br>(0.0250) |
| Gender | 0.000275<br>(0.000303) |
| Adopted | 0.000102<br>(0.000108) |

*Notes:* Standard errors clustered at the municipal level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Each row is a separate regression, where the dependent variable is displayed on the row. The number of observation ranges between 8,023 and 8,597

Table A4: Fathers

| | Fluoride (0.1 mg/l) |
|---|---|
| 1945 | -0.8690*** |
| 1946 | -0.3151*** |
| 1947 | -0.7601** |
| 1948 | 0.2093 |
| 1949 | 0.0096 |
| 1950 | 0.4872 |
| 1951 | 0.5415*** |
| 1952 | 0.1027 |
| 1953 | -0.4337*** |
| 1954 | 0.0103 |
| 1955 | 0.3470** |
| 1956 | 0.1211 |
| 1957 | 0.1381* |
| 1958 | -0.0201 |
| 1959 | 0.0946 |
| 1960 | 0.0463 |
| 1961 | 0.0505 |
| 1962 | -0.0319 |
| 1963 | 0.0374 |
| 1964 | 0.0246 |
| 1965 | 0.1001 |
| 1966 | 0.0659 |
| 1967 | -0.0097 |
| 1968 | -0.0238 |
| 1969 | 0.0024 |
| 1970 | 0.0054 |
| 1971 | -0.1031** |
| 1972 | -0.0198** |
| 1973 | -0.0445** |
| 1974 | -0.0096 |
| 1975 | -0.0136 |
| 1976 | -0.0296 |
| 1977 | -0.0480 |
| 1978 | -0.0129 |
| 1979 | -0.0254 |
| 1980 | -0.0154 |
| 1981 | -0.0282 |
| 1982 | -0.0231 |
| 1983 | -0.0292 |
| 1984 | -0.0453* |
| 1985 | -0.0374 |
| 1986 | -0.0745** |
| 1987 | -0.0352** |
| 1988 | -0.0154 |
| 1989 | 0.0154 |
| 1990 | -0.0704* |
| 1991 | -0.0368*** |
| 1992 | 0.0612 |

*Notes:* Standard errors clustered at the municipal level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. The number of observation is 8,018. Fluoride is dependent variable.

Table A5: Mothers

| | Fluoride (0.1 mg/l) |
|---|---|
| 1944 | -1.1401*** |
| 1945 | -2.3599 |
| 1946 | -0.0863 |
| 1947 | -0.9317*** |
| 1948 | -0.1115 |
| 1949 | 0.6072 |
| 1950 | -0.0143 |
| 1951 | 0.2971 |
| 1952 | -0.0561 |
| 1953 | 0.1288 |
| 1954 | 0.2730* |
| 1955 | 0.0028 |
| 1956 | -0.0081 |
| 1957 | 0.0390* |
| 1958 | -0.1378* |
| 1959 | -0.0430 |
| 1960 | 0.0187 |
| 1961 | 0.0077 |
| 1962 | -0.0360 |
| 1963 | 0.0567 |
| 1964 | 0.0438 |
| 1965 | 0.0940 |
| 1966 | 0.0057 |
| 1967 | -0.0408 |
| 1968 | -0.0195 |
| 1969 | 0.0546 |
| 1970 | -0.0096 |
| 1971 | 0.0341 |
| 1972 | -0.0556 |
| 1973 | -0.0390 |
| 1974 | 0.0178 |
| 1975 | -0.0722*** |
| 1976 | -0.0400* |
| 1977 | -0.0338*** |
| 1978 | -0.0570*** |
| 1979 | -0.0716* |
| 1980 | -0.0112 |
| 1981 | -0.0140 |
| 1982 | -0.0136 |
| 1983 | -0.0585** |
| 1984 | 0.0033 |
| 1985 | -0.0293* |
| 1986 | -0.0250 |
| 1987 | -0.0256 |
| 1988 | -0.0114 |
| 1989 | -0.0176 |
| 1990 | -0.0679** |
| 1991 | -0.0770** |
| 1992 | -0.0365 |

*Notes:* Standard errors clustered at the municipal level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. The number of observation is 8,029. Fluoride is dependent variable.

A third category of predetermined characteristics concerns cohorts. Assume that people suddenly become very concerned about fluoride, and moves from high fluoride areas. If that is the case, later cohorts would have a lower fluoride level than older cohorts. We test this in Table A6, with cohort 1985 as benchmark. We also include sibling order for those with at least one sibling (twins removed). We have three statistically significant results, but the point estimates are very small. Those born in 1992 received on average 0.007 mg/l lower fluoride than those born in 1985. In terms of economic significance, this is a zero effect and below the measurable precision level of fluoride.

Table A6: Balance test. Cohorts and sibling order

| | *F.* (0.1 mg/l) |
|---|---|
| Cohort 1986 | 0.00665 |
| | (0.0118) |
| Cohort 1987 | -0.00843 |
| | (0.0147) |
| Cohort 1988 | 0.00451 |
| | (0.0163) |
| Cohort 1989 | -0.00623 |
| | (0.0156) |
| Cohort 1990 | -0.0357** |
| | (0.0164) |
| Cohort 1991 | -0.0195 |
| | (0.0182) |
| Cohort 1992 | -0.0743*** |
| | (0.0203) |
| Sibling order | 0.0423* |
| | (0.0215) |

*Notes:* Standard errors clustered at the municipal level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. The number of observation is 733, 683 for the cohorts and 421,241 for the sibling order regression. Fluoride is dependent variable.

A third concern would be that high cognitive ability individuals, who were exposed to lower dosages of fluoride, were able to avoid enlistment, meaning that when we run the analysis we only estimate the effect for a biased sample. Therefore we run balance tests to see if the fluoride treatment level for men without cognitive and non-cognitive ability scores differs from those who enlisted. We also run the test for taking the math test in ninth grade (for both males and females). In conclusion, there is no evidence of such sorting.

Table A7: Balance test. Missing test scores

| | *F.* (0.1 mg/l) |
|---|---|
| No Cog. ab. | 0.000758<br>(0.000799) |
| No Non-Cog. ab. | -0.000149<br>(0.000301) |
| No math test | -0.000149<br>(0.000301) |

*Notes:* Standard errors clustered at the municipal level. *** p < 0.01, ** p < 0.05, * p < 0.1. Each row is a separate regression, where the dependent variable is displayed at the row. The number of observations for the two first outcomes are 377,360 and for the last outcome 570,954.

## 11.4 Result: Effects of fluoride on dental health

Table A8: Unweightened regressions dental outcomes

| *F.* | CheckUps | DentalSurgery | Orthognathic | Prosthesis | OrthodontReplace | DiCheckUpsEval | DiDentHealth | DiDiseasePain | DiRepairs | DiRehabHab | MedianRemaining | MedianIntact |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2013 | -0.745** | 0.0216 | -0.0508* | -0.00807 | -0.00639 | -0.688** | -0.371* | -0.614** | -0.531*** | -0.0208 | -0.0127 | 0.0135 |
| | (0.330) | (0.0452) | (0.0293) | (0.00902) | (0.0280) | (0.302) | (0.205) | (0.262) | (0.193) | (0.0290) | (0.0101) | (0.0194) |
| 2008 | -0.715** | -0.0863*** | -0.0322* | 0.0141 | -0.00386 | -0.678** | -0.230 | -0.119 | -0.278*** | -0.0119 | -0.0718** | -0.0187 |
| | (0.345) | (0.0307) | (0.0169) | (0.0167) | (0.00313) | (0.320) | (0.195) | (0.118) | (0.0723) | (0.0154) | (0.0329) | (0.0450) |

*Notes:* Standard errors clustered at the municipal level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. The number of observation ranges between 7,386 and 7,622 for 2013 and between 7,352 and 7,606 for 2008.

Table A9: Dental outcomes 2013. Additional specifications

| *F.* | (1) | (2) | (3) | (4) | (5) | (6) | (7) |
|---|---|---|---|---|---|---|---|
| CheckUps | -0.3242* | -0.0614* | -0.0158 | 0.0032 | 0.0221 | 0.0111 | 0.0189 |
| | (0.1847) | (0.0368) | (0.0360) | (0.0346) | (0.0265) | (0.0282) | (0.0296) |
| DentalSurgery | 0.0095 | -0.0127 | -0.0053 | -0.0073 | -0.0178 | -0.0184 | -0.0220* |
| | (0.0270) | (0.0088) | (0.0130) | (0.0130) | (0.0115) | (0.0124) | (0.0113) |
| Orthognathic | -0.0218** | -0.0052* | -0.0046 | -0.0040 | -0.0011 | -0.0007 | -0.0007 |
| | (0.0089) | (0.0028) | (0.0038) | (0.0037) | (0.0035) | (0.0045) | (0.0046) |
| Prosthesis | -0.0143*** | -0.0061*** | -0.0092*** | -0.0098*** | -0.0063*** | -0.0047** | -0.0048** |
| | (0.0038) | (0.0017) | (0.0023) | (0.0023) | (0.0021) | (0.0023) | (0.0023) |
| OrthodontReplace | -0.0043* | -0.0011 | -0.0017 | -0.0015 | -0.0004 | 0.0003 | 0.0003 |
| | (0.0022) | (0.0008) | (0.0012) | (0.0012) | (0.0012) | (0.0014) | (0.0014) |
| DiCheckUpsEval | -0.2709* | -0.0644** | -0.0202 | -0.0036 | 0.0068 | -0.0058 | -0.0006 |
| | (0.1546) | (0.0327) | (0.0314) | (0.0304) | (0.0239) | (0.0259) | (0.0267) |
| DiDentHealth | -0.1734 | -0.0266 | -0.0039 | 0.0026 | -0.0013 | 0.0034 | 0.0040 |
| | (0.1216) | (0.0202) | (0.0206) | (0.0206) | (0.0159) | (0.0182) | (0.0182) |
| DiDiseasePain | -0.2159* | -0.0598* | -0.0435 | -0.0445 | -0.0407* | -0.0449* | -0.0470* |
| | (0.1270) | (0.0309) | (0.0284) | (0.0280) | (0.0240) | (0.0260) | (0.0262) |
| DiRepairs | -0.1508* | -0.0757*** | -0.0772** | -0.0792** | -0.0730*** | -0.0634** | -0.0700*** |
| | (0.0840) | (0.0268) | (0.0345) | (0.0339) | (0.0262) | (0.0286) | (0.0265) |
| DiRehabHab | -0.0097** | -0.0059*** | -0.0074*** | -0.0072*** | -0.0052** | -0.0042 | -0.0043 |
| | (0.0044) | (0.0020) | (0.0028) | (0.0027) | (0.0025) | (0.0027) | (0.0027) |
| MedianRemaining | -0.0138** | -0.0040*** | -0.0065*** | -0.0080*** | -0.0044*** | -0.0036*** | -0.0036*** |
| | (0.0063) | (0.0014) | (0.0018) | (0.0020) | (0.0012) | (0.0013) | (0.0013) |
| MedianIntact | -0.0143 | -0.0009 | -0.0066 | -0.0058 | 0.0003 | -0.0004 | 0.0010 |
| | (0.0174) | (0.0046) | (0.0056) | (0.0055) | (0.0039) | (0.0040) | (0.0035) |
| Small set covariates | No | No | No | No | Yes | Yes | Yes |
| Large set covariates | No | No | No | No | No | No | Yes |
| Fe. birth muni. | No | No | Yes | Yes | Yes | Yes | Yes |
| Fe. cohort | No | No | No | Yes | Yes | Yes | Yes |
| Fe. muni. 2013 | No | Yes | No | No | Yes | Yes | Yes |
| Sample | All | All | All | All | All | Col 7 | All |

*Notes:* Standard errors clustered at the municipal level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Outcomes on each row. The number of observations ranges between 470,528 and 727,543.

Table A10: Dental outcomes 2008

| *F.* | (1) | (2) | (3) | (4) | (5) | (6) | (7) |
|---|---|---|---|---|---|---|---|
| Visit | -0.2242** | -0.0130 | -0.0096 | -0.0095 | 0.0195 | 0.0095 | 0.0229 |
| | (0.0949) | (0.0210) | (0.0346) | (0.0338) | (0.0286) | (0.0299) | (0.0304) |
| Repair | -0.0409 | -0.0334* | -0.0277 | -0.0269 | -0.0316 | -0.0416 | -0.0458* |
| | (0.0424) | (0.0170) | (0.0291) | (0.0291) | (0.0259) | (0.0280) | (0.0266) |
| RiskEvaluation | -0.2430** | -0.0139 | -0.0123 | -0.0121 | 0.0176 | 0.0072 | 0.0214 |
| | (0.1030) | (0.0218) | (0.0356) | (0.0348) | (0.0293) | (0.0309) | (0.0321) |
| DiseasePrevention | -0.2651* | 0.0147 | 0.0093 | 0.0094 | 0.0092 | 0.0103 | 0.0181 |
| | (0.1458) | (0.0222) | (0.0470) | (0.0469) | (0.0309) | (0.0329) | (0.0320) |
| DiseaseTreatment | 0.0730 | 0.0050 | -0.0223 | -0.0215 | -0.0241 | -0.0389 | -0.0403* |
| | (0.0632) | (0.0139) | (0.0213) | (0.0212) | (0.0204) | (0.0242) | (0.0241) |
| RootCanal | -0.0140 | -0.0065 | -0.0094 | -0.0092 | -0.0054 | -0.0031 | -0.0051 |
| | (0.0093) | (0.0040) | (0.0069) | (0.0069) | (0.0062) | (0.0071) | (0.0071) |
| Small set covariates | No | No | No | No | Yes | Yes | Yes |
| Large set covariates | No | No | No | No | No | No | Yes |
| Fe. birth muni. | No | No | Yes | Yes | Yes | Yes | Yes |
| Fe. cohort | No | No | No | Yes | Yes | Yes | Yes |
| Fe. muni. 2013 | No | Yes | No | No | Yes | Yes | Yes |
| Sample | All | All | All | All | All | Col 7 | All |

*Notes:* Standard errors clustered at the municipal level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Outcomes on each row. The number of observations ranges between 209,914 and 336,637

Table A11: Dental outcomes 2008. Additional specifications

| *F.* | (1) | (2) | (3) | (4) | (5) | (6) | (7) |
|---|---|---|---|---|---|---|---|
| CheckUps | -0.2692** | 0.0022 | -0.0010 | -0.0010 | 0.0346 | 0.0224 | 0.0400 |
| | (0.1161) | (0.0241) | (0.0395) | (0.0385) | (0.0324) | (0.0341) | (0.0358) |
| DentalSurgery | -0.0223 | -0.0168** | -0.0272*** | -0.0268*** | -0.0276*** | -0.0319*** | -0.0345*** |
| | (0.0164) | (0.0068) | (0.0097) | (0.0097) | (0.0093) | (0.0107) | (0.0106) |
| Orthognathic | -0.0121** | 0.0017 | -0.0051 | -0.0051 | -0.0001 | -0.0016 | -0.0012 |
| | (0.0052) | (0.0027) | (0.0038) | (0.0038) | (0.0038) | (0.0045) | (0.0045) |
| Prosthesis | -0.0019 | 0.0008 | -0.0017 | -0.0016 | 0.0001 | 0.0027 | 0.0026 |
| | (0.0036) | (0.0022) | (0.0032) | (0.0032) | (0.0030) | (0.0037) | (0.0037) |
| OrthodontReplace | -0.0027* | -0.0025*** | -0.0034*** | -0.0034*** | -0.0031*** | -0.0033** | -0.0033** |
| | (0.0015) | (0.0007) | (0.0010) | (0.0010) | (0.0010) | (0.0013) | (0.0013) |
| DiCheckUpsEval | -0.2430** | -0.0139 | -0.0123 | -0.0121 | 0.0176 | 0.0072 | 0.0214 |
| | (0.1030) | (0.0218) | (0.0356) | (0.0348) | (0.0293) | (0.0309) | (0.0321) |
| DiDentHealth | -0.1369 | 0.0288 | 0.0354 | 0.0356 | 0.0195 | 0.0225 | 0.0301 |
| | (0.1185) | (0.0197) | (0.0418) | (0.0417) | (0.0265) | (0.0293) | (0.0286) |
| DiDiseasePain | -0.0726 | -0.0119 | -0.0500** | -0.0491** | -0.0311 | -0.0474** | -0.0485** |
| | (0.0542) | (0.0152) | (0.0247) | (0.0247) | (0.0214) | (0.0239) | (0.0239) |
| DiRepairs | -0.0491 | -0.0414** | -0.0386 | -0.0377 | -0.0440 | -0.0534* | -0.0586** |
| | (0.0440) | (0.0179) | (0.0309) | (0.0309) | (0.0275) | (0.0300) | (0.0284) |
| DiRehabHab | -0.0058 | -0.0022 | -0.0036 | -0.0035 | -0.0024 | -0.0007 | -0.0008 |
| | (0.0045) | (0.0023) | (0.0034) | (0.0034) | (0.0033) | (0.0042) | (0.0042) |
| MedianRemaining | -0.0381*** | -0.0043*** | -0.0153*** | -0.0152*** | -0.0032** | -0.0023 | -0.0024 |
| | (0.0138) | (0.0013) | (0.0049) | (0.0049) | (0.0016) | (0.0018) | (0.0018) |
| MedianIntact | -0.0075 | 0.0124*** | 0.0062 | 0.0060 | 0.0093** | 0.0104** | 0.0122** |
| | (0.0204) | (0.0031) | (0.0057) | (0.0057) | (0.0045) | (0.0048) | (0.0047) |
| Small set covariates | No | No | No | No | Yes | Yes | Yes |
| Large set covariates | No | No | No | No | No | No | Yes |
| Fe. birth muni. | No | No | Yes | Yes | Yes | Yes | Yes |
| Fe. cohort | No | No | No | Yes | Yes | Yes | Yes |
| Fe. muni. 2013 | No | Yes | No | No | Yes | Yes | Yes |
| Sample | All | All | All | All | All | Col 7 | All |

*Notes:* Standard errors clustered at the municipal level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Outcomes on each row. The number of observations ranges between 208,691 and 336,637

## 11.5 Results: Non-linear effects, regression tables

Table A12: Cognitive ability

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) |
|---|---|---|---|---|---|---|---|
| Fluoride 2nd quartile | 0.1444** | 0.0654 | 0.0633 | 0.0184 | 0.0628** | 0.0323 | 0.0776* |
| | (0.0656) | (0.0412) | (0.0416) | (0.0436) | (0.0261) | (0.0508) | (0.0468) |
| Fluoride 3nd quartile | -0.1729** | -0.0669** | -0.0654** | -0.0524 | -0.0033 | -0.0230 | -0.0598 |
| | (0.0696) | (0.0325) | (0.0324) | (0.0336) | (0.0253) | (0.0453) | (0.0575) |
| Fluoride 4nd quartile | 0.0136 | 0.0263 | 0.0257 | 0.0006 | 0.0117 | 0.0549 | 0.1395** |
| | (0.0518) | (0.0258) | (0.0258) | (0.0326) | (0.0262) | (0.0417) | (0.0628) |
| Mean | 5.008816 | 5.008816 | 5.008816 | 5.024005 | 5.024005 | 5.085113 | 4.922379 |
| Birth cohort FE | No | No | Yes | Yes | Yes | Yes | Yes |
| Birth municipal FE | No | Yes | Yes | Yes | Yes | Yes | Yes |
| Large set covariates | No | No | No | No | Yes | Yes | Yes |
| Sample | All | All | All | Col 5 | All | SAMS stayers | SAMS movers |
| Observations | 82,010 | 82,010 | 82,010 | 51,322 | 51,322 | 21,348 | 18,848 |

*Notes:* Standard errors clustered at the municipal level. *** p < 0.01, ** p < 0.05, * p < 0.1.

Table A13: Non-cognitive ability

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) |
|---|---|---|---|---|---|---|---|
| Fluoride 2nd quartile | -0.0196 | -0.0559 | -0.0561 | -0.0679* | -0.0324 | -0.0342 | -0.0082 |
| | (0.0655) | (0.0347) | (0.0346) | (0.0409) | (0.0358) | (0.0636) | (0.0638) |
| Fluoride 3nd quartile | -0.0652 | 0.0260 | 0.0262 | 0.0312 | 0.0651** | 0.1049** | 0.1144 |
| | (0.0665) | (0.0311) | (0.0310) | (0.0346) | (0.0305) | (0.0531) | (0.0782) |
| Fluoride 4nd quartile | 0.0528 | 0.0131 | 0.0135 | 0.0180 | 0.0283 | 0.0273 | 0.1293* |
| | (0.0430) | (0.0261) | (0.0260) | (0.0355) | (0.0343) | (0.0557) | (0.0701) |
| Mean | 4.734139 | 4.734139 | 4.734139 | 4.775078 | 4.775078 | 4.913258 | 4.687314 |
| Birth cohort FE | No | No | Yes | Yes | Yes | Yes | Yes |
| Birth municipal FE | No | Yes | Yes | Yes | Yes | Yes | Yes |
| Large set covariates | No | No | No | No | Yes | Yes | Yes |
| Sample | All | All | All | Col 5 | All | SAMS stayers | SAMS movers |
| Observations | 66,561 | 66,561 | 66,561 | 41,730 | 41,730 | 17,408 | 15,159 |

*Notes:* Standard errors clustered at the municipal level. *** p < 0.01, ** p < 0.05, * p < 0.1.

Table A14: Math points

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
|---|---|---|---|---|---|---|---|---|
| Fluoride 2nd quartile | -0.0316 | -0.2773** | -0.2649* | -0.2649* | -0.3439*** | -0.1956** | -0.1076 | -0.1887 |
| | (0.2741) | (0.1341) | (0.1367) | (0.1367) | (0.1322) | (0.0970) | (0.1450) | (0.1469) |
| Fluoride 3nd quartile | -0.9186*** | -0.3013** | -0.2990** | -0.2989** | -0.2884** | -0.0797 | 0.0919 | -0.1268 |
| | (0.3272) | (0.1205) | (0.1190) | (0.1189) | (0.1313) | (0.1026) | (0.1319) | (0.1174) |
| Fluoride 4nd quartile | 0.0765 | 0.1050 | 0.1123 | 0.1122 | -0.0045 | 0.1096 | -0.0415 | 0.1695 |
| | (0.2538) | (0.0941) | (0.0959) | (0.0959) | (0.0924) | (0.0988) | (0.1036) | (0.1293) |
| Mean | 26.20998 | 26.20998 | 26.20998 | 26.20998 | 26.4943 | 26.4943 | 27.22649 | 26.04757 |
| Birth cohort FE | No | No | Yes | Yes | Yes | Yes | Yes | Yes |
| Birth municipal FE | No | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Small set covariates | No | No | No | Yes | Yes | Yes | Yes | Yes |
| Large set covariates | No | No | No | No | No | Yes | Yes | Yes |
| Sample | All | All | All | All | Col 6 | All | SAMS stayers | SAMS movers |
| Observations | 500,995 | 500,995 | 500,995 | 500,995 | 337,404 | 337,404 | 139,276 | 127,334 |

*Notes:* Standard errors clustered at the municipal level. *** p < 0.01, ** p < 0.05, * p < 0.1.

Table A15: Annual log income in SEK

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
|---|---|---|---|---|---|---|---|---|
| Fluoride 2nd quartile | -0.0407 | -0.0009 | -0.0023 | -0.0040 | -0.0045 | -0.0050 | 0.0086 | 0.0216 |
| | (0.0319) | (0.0109) | (0.0111) | (0.0104) | (0.0111) | (0.0094) | (0.0132) | (0.0190) |
| Fluoride 3nd quartile | 0.0466* | 0.0149* | 0.0128* | 0.0133 | 0.0067 | 0.0076 | 0.0131 | 0.0093 |
| | (0.0265) | (0.0078) | (0.0073) | (0.0105) | (0.0104) | (0.0098) | (0.0109) | (0.0133) |
| Fluoride 4nd quartile | 0.0301* | 0.0264*** | 0.0209*** | 0.0199*** | 0.0196*** | 0.0183*** | 0.0140 | -0.0002 |
| | (0.0172) | (0.0068) | (0.0066) | (0.0057) | (0.0060) | (0.0057) | (0.0095) | (0.0119) |
| Mean | 11.77979 | 11.77979 | 11.77979 | 11.77979 | 11.79419 | 11.79419 | 11.84486 | 11.78348 |
| Birth cohort FE | No | No | Yes | Yes | Yes | Yes | Yes | Yes |
| Birth municipal FE | No | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Municipal FE, year 2013 | No | No | No | Yes | Yes | Yes | Yes | Yes |
| Small set covariates | No | No | No | Yes | Yes | Yes | Yes | Yes |
| Large set covariates | No | No | No | No | No | Yes | Yes | Yes |
| Sample | All | All | All | All | Col 6 | All | SAMS stayers | SAMS movers |
| Observations | 628,732 | 628,732 | 628,732 | 628,732 | 415,341 | 415,341 | 172,669 | 155,980 |

*Notes:* Standard errors clustered at the municipal level. *** p < 0.01, ** p < 0.05, * p < 0.1.

Table A16: Employment status

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
|---|---|---|---|---|---|---|---|---|
| Fluoride 2nd quartile | -0.0150 | -0.0047 | -0.0050 | -0.0043 | -0.0049 | -0.0044 | 0.0028 | 0.0081 |
| | (0.0114) | (0.0047) | (0.0048) | (0.0045) | (0.0045) | (0.0038) | (0.0058) | (0.0072) |
| Fluoride 3nd quartile | 0.0115 | 0.0002 | -0.0005 | 0.0003 | -0.0006 | 0.0005 | 0.0014 | 0.0007 |
| | (0.0098) | (0.0032) | (0.0031) | (0.0042) | (0.0041) | (0.0039) | (0.0046) | (0.0055) |
| Fluoride 4nd quartile | 0.0173** | 0.0152*** | 0.0136*** | 0.0125*** | 0.0088*** | 0.0079*** | 0.0020 | 0.0062 |
| | (0.0078) | (0.0031) | (0.0030) | (0.0027) | (0.0028) | (0.0025) | (0.0043) | (0.0052) |
| Mean | .7018826 | .7018826 | .7018826 | .7018826 | .7147307 | .7147307 | .7419529 | .7108723 |
| Birth cohort FE | No | No | Yes | Yes | Yes | Yes | Yes | Yes |
| Birth municipal FE | No | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Municipal FE, year 2013 | No | No | No | Yes | Yes | Yes | Yes | Yes |
| Small set covariates | No | No | No | Yes | Yes | Yes | Yes | Yes |
| Large set covariates | No | No | No | No | No | Yes | Yes | Yes |
| Sample | All | All | All | All | Col 6 | All | SAMS stayers | SAMS movers |
| Observations | 729,850 | 729,850 | 729,850 | 729,850 | 475,414 | 475,414 | 192,740 | 179,374 |

*Notes:* Standard errors clustered at the municipal level. *** p < 0.01, ** p < 0.05, * p < 0.1.

## 11.6 Robustness analysis: Analysis with adoptees only

Table A17: Cognitive ability, adopted

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) |
|---|---|---|---|---|---|---|---|
| Fluoride (0.1 mg/l) | -0.0220 | -0.0478 | -0.0498 | 0.0286 | 0.0369 | -0.1619 | -0.1423 |
| | (0.0222) | (0.0650) | (0.0654) | (0.0700) | (0.0782) | (0.3014) | (0.2493) |
| Mean | 4.30303 | 4.30303 | 4.30303 | 4.34375 | 4.34375 | 4.163793 | 4.533333 |
| Birth cohort FE | No | No | Yes | Yes | Yes | Yes | Yes |
| Birth municipal FE | No | Yes | Yes | Yes | Yes | Yes | Yes |
| Large set covariates | No | No | No | No | Yes | Yes | Yes |
| Sample | All | All | All | Col 5 | All | SAMS stayers | SAMS movers |
| Observations | 528 | 528 | 528 | 288 | 288 | 116 | 90 |

*Notes:* Standard errors clustered at the municipal level. *** p < 0.01, ** p < 0.05, * p < 0.1.

## Table A18: Non-cognitive ability, adopted

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) |
|---|---|---|---|---|---|---|---|
| Fluoride (0.1 mg/l) | -0.0276 | 0.0254 | 0.0182 | -0.0416 | -0.0421 | 0.0665 | -0.1832 |
| | (0.0209) | (0.0658) | (0.0654) | (0.0874) | (0.0864) | (0.2175) | (0.1958) |
| Mean | 4.491443 | 4.491443 | 4.491443 | 4.669683 | 4.669683 | 4.635294 | 4.617647 |
| Birth cohort FE | No | No | Yes | Yes | Yes | Yes | Yes |
| Birth municipal FE | No | Yes | Yes | Yes | Yes | Yes | Yes |
| Large set covariates | No | No | No | No | Yes | Yes | Yes |
| Sample | All | All | All | Col 5 | All | SAMS stayers | SAMS movers |
| Observations | 409 | 409 | 409 | 221 | 221 | 85 | 68 |

*Notes:* Standard errors clustered at the municipal level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

## Table A19: Math points, adopted

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
|---|---|---|---|---|---|---|---|---|
| Fluoride (0.1 mg/l) | -0.0386 | -0.1278 | -0.1354 | -0.1379 | -0.0833 | -0.0816 | -0.1532 | -0.0036 |
| | (0.0933) | (0.1305) | (0.1288) | (0.1290) | (0.1603) | (0.1523) | (0.2526) | (0.3897) |
| Mean | 23.73546 | 23.73546 | 23.73546 | 23.73546 | 24.06825 | 24.06825 | 24.69838 | 23.54964 |
| Birth cohort FE | No | No | Yes | Yes | Yes | Yes | Yes | Yes |
| Birth municipal FE | No | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Small set covariates | No | No | No | Yes | Yes | Yes | Yes | Yes |
| Large set covariates | No | No | No | No | No | Yes | Yes | Yes |
| Sample | All | All | All | All | Col 6 | All | SAMS stayers | SAMS movers |
| Observations | 2,098 | 2,098 | 2,098 | 2,098 | 1,260 | 1,260 | 557 | 413 |

*Notes:* Standard errors clustered at the municipal level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

## Table A20: Annual log income, adopted

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
|---|---|---|---|---|---|---|---|---|
| Fluoride (0.1 mg/l) | 0.0105* | 0.0153 | 0.0120 | 0.0132 | 0.0206 | 0.0189 | 0.0024 | 0.0088 |
| | (0.0059) | (0.0105) | (0.0107) | (0.0123) | (0.0195) | (0.0197) | (0.0306) | (0.0474) |
| Mean | 11.75914 | 11.75914 | 11.75914 | 11.75914 | 11.7436 | 11.7436 | 11.72156 | 11.783 |
| Birth cohort FE | No | No | Yes | Yes | Yes | Yes | Yes | Yes |
| Birth municipal FE | No | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Municipal FE, year 2013 | No | No | No | Yes | Yes | Yes | Yes | Yes |
| Small set covariates | No | No | No | Yes | Yes | Yes | Yes | Yes |
| Large set covariates | No | No | No | No | No | Yes | Yes | Yes |
| Sample | All | All | All | All | Col 6 | All | SAMS stayers | SAMS movers |
| Observations | 3,167 | 3,167 | 3,167 | 3,167 | 1,712 | 1,712 | 735 | 551 |

*Notes:* Standard errors clustered at the municipal level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

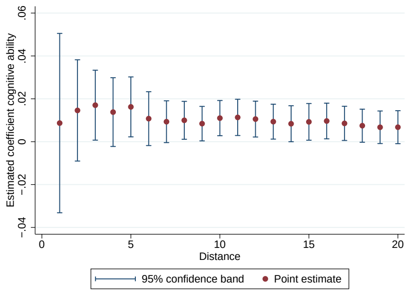
## Table A21: Employment status, adopted

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
|---|---|---|---|---|---|---|---|---|
| Fluoride (0.1 mg/l) | 0.0030 | 0.0022 | 0.0008 | 0.0033 | 0.0036 | 0.0033 | 0.0031 | 0.0322 |
| | (0.0024) | (0.0038) | (0.0038) | (0.0040) | (0.0066) | (0.0067) | (0.0113) | (0.0326) |
| Mean | .6738847 | .6738847 | .6738847 | .6738847 | .6661836 | .6661836 | .6575964 | .6910198 |
| Birth cohort FE | No | No | Yes | Yes | Yes | Yes | Yes | Yes |
| Birth municipal FE | No | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Municipal FE, year 2013 | No | No | No | Yes | Yes | Yes | Yes | Yes |
| Small set covariates | No | No | No | Yes | Yes | Yes | Yes | Yes |
| Large set covariates | No | No | No | No | No | Yes | Yes | Yes |
| Sample | All | All | All | All | Col 6 | All | SAMS stayers | SAMS movers |
| Observations | 3,833 | 3,833 | 3,833 | 3,833 | 2,070 | 2,070 | 882 | 657 |

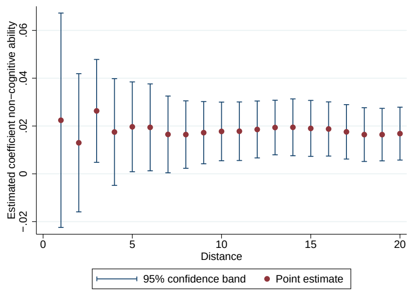
*Notes:* Standard errors clustered at the municipal level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

## 11.7 Robustness analysis: Distance of SAMS

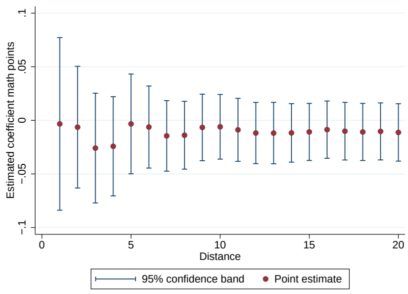
Figure A3: Estimates for different geographical distances from water plant. The X-axis corresponds to distances in kilometers between water plant and the center point of the SAMS.



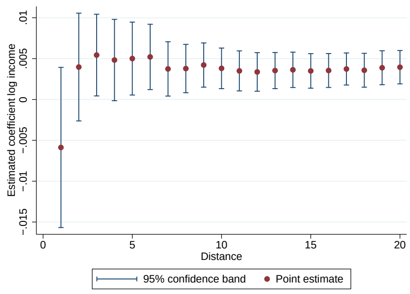

(a) Cognitive ability



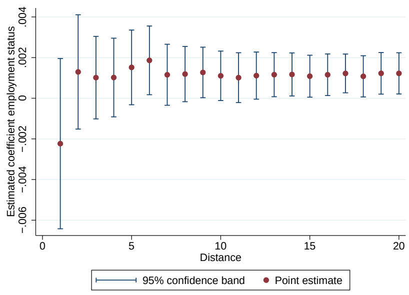

(b) Non-Cognitive ability




(c) Math points



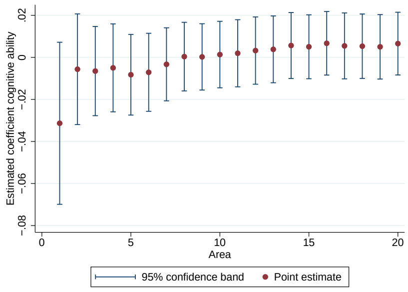

(d) Annual log income



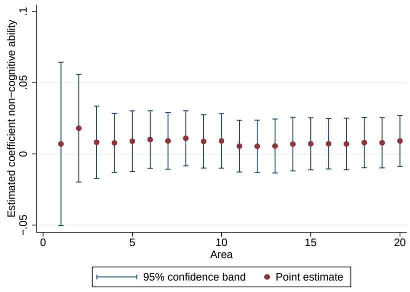

(e) Employment status

## 11.8 Robustness analysis: Area of SAMS

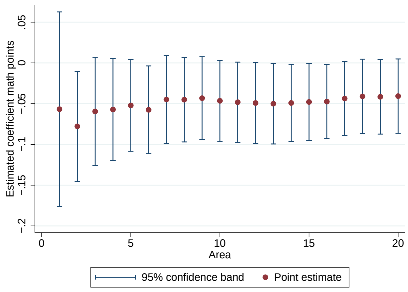
Figure A4: Estimates for different geographical areas SAMS. The X-axis corresponds to areas in square kilometers.



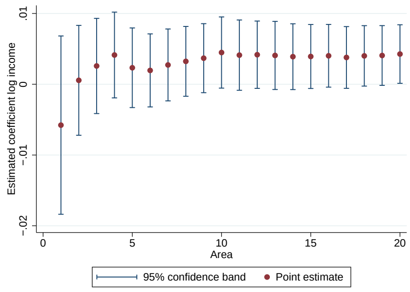

(a) Cognitive ability



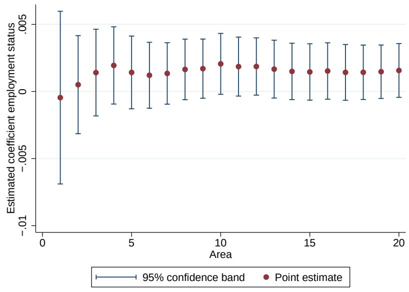

(b) Non-Cognitive ability




(c) Math points




(d) Annual log income




(e) Employment status

## 11.9 Robustness analysis: Confirmed water source

Table A22: Cognitive ability, confirmed water source since 1985

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) |
|---|---|---|---|---|---|---|---|
| Fluoride (0.1 mg/l) | -0.0185* | 0.0079 | 0.0076 | 0.0113 | 0.0190** | 0.0044 | 0.0430** |
| | (0.0105) | (0.0078) | (0.0077) | (0.0075) | (0.0083) | (0.0088) | (0.0181) |
| Mean | 4.976069 | 4.976069 | 4.976069 | 4.975969 | 4.975969 | 5.072222 | 4.869272 |
| Birth cohort FE | No | No | Yes | Yes | Yes | Yes | Yes |
| Birth municipal FE | No | Yes | Yes | Yes | Yes | Yes | Yes |
| Large set covariates | No | No | No | No | Yes | Yes | Yes |
| Sample | All | All | All | Col 5 | All | SAMS stayers | SAMS movers |
| Observations | 18,971 | 18,971 | 18,971 | 12,234 | 12,234 | 6,300 | 5,194 |

*Notes:* Standard errors clustered at the municipal level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table A23: Non-cognitive ability, confirmed water source since 1985

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) |
|---|---|---|---|---|---|---|---|
| Fluoride (0.1 mg/l) | -0.0028 | 0.0075 | 0.0076 | 0.0158 | 0.0251 | 0.0256* | 0.0181 |
| | (0.0095) | (0.0122) | (0.0123) | (0.0147) | (0.0154) | (0.0132) | (0.0265) |
| Mean | 4.776578 | 4.776578 | 4.776578 | 4.819875 | 4.819875 | 4.939883 | 4.674413 |
| Birth cohort FE | No | No | Yes | Yes | Yes | Yes | Yes |
| Birth municipal FE | No | Yes | Yes | Yes | Yes | Yes | Yes |
| Large set covariates | No | No | No | No | Yes | Yes | Yes |
| Sample | All | All | All | Col 5 | All | SAMS stayers | SAMS movers |
| Observations | 15,285 | 15,285 | 15,285 | 9,882 | 9,882 | 5,140 | 4,174 |

*Notes:* Standard errors clustered at the municipal level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table A24: Math points, confirmed water source since 1985

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
|---|---|---|---|---|---|---|---|---|
| Fluoride (0.1 mg/l) | -0.2399*** | -0.0404 | -0.0416 | -0.0417 | -0.0614** | -0.0119 | 0.0022 | -0.0386 |
| | (0.0560) | (0.0290) | (0.0273) | (0.0273) | (0.0284) | (0.0274) | (0.0248) | (0.0391) |
| Mean | 26.36135 | 26.36135 | 26.36135 | 26.36135 | 26.54011 | 26.54011 | 27.26725 | 25.83771 |
| Birth cohort FE | No | No | Yes | Yes | Yes | Yes | Yes | Yes |
| Birth municipal FE | No | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Small set covariates | No | No | No | Yes | Yes | Yes | Yes | Yes |
| Large set covariates | No | No | No | No | No | Yes | Yes | Yes |
| Sample | All | All | All | All | Col 6 | All | SAMS stayers | SAMS movers |
| Observations | 113,568 | 113,568 | 113,568 | 113,568 | 79,597 | 79,597 | 40,430 | 34,685 |

*Notes:* Standard errors clustered at the municipal level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table A25: Annual log income, confirmed water source since 1985

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
|---|---|---|---|---|---|---|---|---|
| Fluoride (0.1 mg/l) | 0.0081** | 0.0064*** | 0.0056*** | 0.0039*** | 0.0023 | 0.0016 | 0.0013 | 0.0058* |
| | (0.0039) | (0.0014) | (0.0013) | (0.0013) | (0.0016) | (0.0015) | (0.0021) | (0.0032) |
| Mean | 11.81459 | 11.81459 | 11.81459 | 11.81459 | 11.82211 | 11.82211 | 11.85328 | 11.79489 |
| Birth cohort FE | No | No | Yes | Yes | Yes | Yes | Yes | Yes |
| Birth municipal FE | No | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Municipal FE, year 2013 | No | No | No | Yes | Yes | Yes | Yes | Yes |
| Small set covariates | No | No | No | Yes | Yes | Yes | Yes | Yes |
| Large set covariates | No | No | No | No | No | Yes | Yes | Yes |
| Sample | All | All | All | All | Col 6 | All | SAMS stayers | SAMS movers |
| Observations | 144,066 | 144,066 | 144,066 | 144,066 | 98,690 | 98,690 | 50,298 | 42,853 |

*Notes:* Standard errors clustered at the municipal level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table A26: Employment status, confirmed water source since 1985

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
|---|---|---|---|---|---|---|---|---|
| Fluoride (0.1 mg/l) | 0.0030* | 0.0025*** | 0.0023** | 0.0017* | 0.0006 | 0.0003 | 0.0002 | 0.0010 |
| | (0.0018) | (0.0009) | (0.0009) | (0.0009) | (0.0011) | (0.0011) | (0.0011) | (0.0017) |
| Mean | .7197483 | .7197483 | .7197483 | .7197483 | .7289151 | .7289151 | .7457007 | .7160464 |
| Birth cohort FE | No | No | Yes | Yes | Yes | Yes | Yes | Yes |
| Birth municipal FE | No | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Municipal FE, year 2013 | No | No | No | Yes | Yes | Yes | Yes | Yes |
| Small set covariates | No | No | No | Yes | Yes | Yes | Yes | Yes |
| Large set covariates | No | No | No | No | No | Yes | Yes | Yes |
| Sample | All | All | All | All | Col 6 | All | SAMS stayers | SAMS movers |
| Observations | 164,966 | 164,966 | 164,966 | 164,966 | 111,810 | 111,810 | 56,056 | 49,170 |

*Notes:* Standard errors clustered at the municipal level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

## 11.10 Robustness analysis: Only those born in 1985

Table A27: Annual log income, cohort 1985

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
|---|---|---|---|---|---|---|---|---|
| Fluoride (0.1 mg/l) | 0.0004 | 0.0018 | 0.0018 | 0.0034** | 0.0042** | 0.0051** | -0.0020 | 0.0154*** |
| | (0.0014) | (0.0016) | (0.0016) | (0.0017) | (0.0020) | (0.0021) | (0.0038) | (0.0049) |
| Mean | 12.14913 | 12.14913 | 12.14913 | 12.14913 | 12.16456 | 12.16456 | 12.22664 | 12.14301 |
| Birth cohort FE | No | No | Yes | Yes | Yes | Yes | Yes | Yes |
| Birth municipal FE | No | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Municipal FE, year 2013 | No | No | No | Yes | Yes | Yes | Yes | Yes |
| Small set covariates | No | No | No | Yes | Yes | Yes | Yes | Yes |
| Large set covariates | No | No | No | No | No | Yes | Yes | Yes |
| Sample | All | All | All | All | Col 6 | All | SAMS stayers | SAMS movers |
| Observations | 69,909 | 69,909 | 69,909 | 69,909 | 41,393 | 41,393 | 16,978 | 15,271 |

*Notes:* Standard errors clustered at the municipal level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table A28: Employment status, cohort 1985

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
|---|---|---|---|---|---|---|---|---|
| Fluoride (0.1 mg/l) | 0.0014* | 0.0009 | 0.0009 | 0.0012 | 0.0007 | 0.0011 | 0.0001 | 0.0029* |
| | (0.0008) | (0.0007) | (0.0007) | (0.0008) | (0.0008) | (0.0008) | (0.0010) | (0.0017) |
| Mean | .8132965 | .8132965 | .8132965 | .8132965 | .8294167 | .8294167 | .8648925 | .820007 |
| Birth cohort FE | No | No | Yes | Yes | Yes | Yes | Yes | Yes |
| Birth municipal FE | No | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Municipal FE, year 2013 | No | No | No | Yes | Yes | Yes | Yes | Yes |
| Small set covariates | No | No | No | Yes | Yes | Yes | Yes | Yes |
| Large set covariates | No | No | No | No | No | Yes | Yes | Yes |
| Sample | All | All | All | All | Col 6 | All | SAMS stayers | SAMS movers |
| Observations | 79,329 | 79,329 | 79,329 | 79,329 | 46,341 | 46,341 | 18,563 | 17,234 |

*Notes:* Standard errors clustered at the municipal level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

## 11.11 Robustness analysis: Confirmed water source and only one water plant within SAMS, non-movers

Table A29: Cognitive ability

| | (1) | (2) | (3) | (4) | (5) |
|---|---|---|---|---|---|
| Fluoride (0.1 mg/l) | -0.0208 | 0.0119 | 0.0112 | 0.0065 | 0.0065 |
| | (0.0098)** | (0.0143) | (0.0141) | (0.0150) | (0.0150) |
| Mean | 4.9742 | 4.9742 | 4.9742 | 4.9064 | 4.9064 |
| Birth cohort FE | No | No | Yes | Yes | Yes |
| Birth municipal FE | No | Yes | Yes | Yes | Yes |
| Large set covariates | No | No | No | Yes | Yes |
| Sample | All | All | All | Col 5 | All |
| Observations | 2,051 | 2,051 | 2,051 | 1,325 | 1,325 |

*Notes:* Standard errors clustered at the municipal level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table A30: Non-cognitive ability

| | (1) | (2) | (3) | (4) | (5) |
|---|---|---|---|---|---|
| Fluoride (0.1 mg/l) | -0.0153 | 0.0035 | 0.0037 | 0.0145 | 0.0145 |
| | (0.0136) | (0.0131) | (0.0131) | (0.0182) | (0.0182) |
| Mean | 4.8273 | 4.8273 | 4.8273 | 4.8612 | 4.8612 |
| Birth cohort FE | No | No | Yes | Yes | Yes |
| Birth municipal FE | No | Yes | Yes | Yes | Yes |
| Large set covariates | No | No | No | Yes | Yes |
| Sample | All | All | All | Col 5 | All |
| Observations | 1,668 | 1,668 | 1,668 | 1,081 | 1,081 |

*Notes:* Standard errors clustered at the municipal level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table A31: Math points

| | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| Fluoride (0.1 mg/l) | -0.0457 | 0.0470 | 0.0420 | 0.0416 | 0.0107 | 0.0032 |
| | (0.0192)** | (0.0270)* | (0.0268) | (0.0268) | (0.0297) | (0.0242) |
| Mean | 26.6662 | 26.6662 | 26.6662 | 26.6662 | 26.8046 | 26.8046 |
| Birth cohort FE | No | No | Yes | Yes | Yes | Yes |
| Birth municipal FE | No | Yes | Yes | Yes | Yes | Yes |
| Large set covariates | No | No | No | No | Yes | Yes |
| Sample | All | All | All | All | Col 6 | All |
| Observations | 12,671 | 12,671 | 12,671 | 12,671 | 9,174 | 9,174 |

*Notes:* Standard errors clustered at the municipal level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table A32: Annual log income

| | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| Fluoride (0.1 mg/l) | 0.0019 | 0.0010 | 0.0007 | -0.0001 | -0.0033 | -0.0031 |
| | (0.0022) | (0.0030) | (0.0030) | (0.0028) | (0.0038) | (0.0035) |
| Mean | 11.9054 | 11.9054 | 11.9054 | 11.9054 | 11.9060 | 11.9060 |
| Birth cohort FE | No | No | Yes | Yes | Yes | Yes |
| Birth municipal FE | No | Yes | Yes | Yes | Yes | Yes |
| Municipal FE, year 2013 | No | No | No | Yes | Yes | Yes |
| Small set covariates | No | No | No | Yes | Yes | Yes |
| Large set covariates | No | No | No | No | Yes | Yes |
| Sample | All | All | All | All | Col 6 | All |
| Observations | 16,401 | 16,401 | 16,401 | 16,401 | 11,439 | 11,439 |

*Notes:* Standard errors clustered at the municipal level. *** p < 0.01, ** p < 0.05, * p < 0.1.

Table A33: Employment status

| | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| Fluoride (0.1 mg/l) | 0.0006 | 0.0010 | 0.0009 | 0.0005 | -0.0015 | -0.0014 |
| | (0.0011) | (0.0012) | (0.0013) | (0.0013) | (0.0017) | (0.0016) |
| Mean | 0.7685 | 0.7685 | 0.7685 | 0.7685 | 0.7724 | 0.7724 |
| Birth cohort FE | No | No | Yes | Yes | Yes | Yes |
| Birth municipal FE | No | Yes | Yes | Yes | Yes | Yes |
| Municipal FE, year 2013 | No | No | No | Yes | Yes | Yes |
| Small set covariates | No | No | No | Yes | Yes | Yes |
| Large set covariates | No | No | No | No | Yes | Yes |
| Sample | All | All | All | All | Col 6 | All |
| Observations | 18,185 | 18,185 | 18,185 | 18,185 | 12,651 | 12,651 |

*Notes:* Standard errors clustered at the municipal level. *** p < 0.01, ** p < 0.05, * p < 0.1.

## 11.12 Robustness analysis: Alternative income measure

Table A34: Log income, "förvärvsinkomst"

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
|---|---|---|---|---|---|---|---|---|
| Fluoride (0.1 mg/l) | 0.0078** | 0.0069*** | 0.0054*** | 0.0047*** | 0.0035*** | 0.0031*** | 0.0027 | 0.0013 |
| | (0.0035) | (0.0017) | (0.0016) | (0.0014) | (0.0013) | (0.0011) | (0.0017) | (0.0033) |
| Mean | 11.8526 | 11.8526 | 11.8526 | 11.8526 | 11.86668 | 11.86668 | 11.9128 | 11.85671 |
| Birth cohort FE | No | No | Yes | Yes | Yes | Yes | Yes | Yes |
| Birth municipal FE | No | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Municipal FE, year 2013 | No | No | No | Yes | Yes | Yes | Yes | Yes |
| Small set covariates | No | No | No | Yes | Yes | Yes | Yes | Yes |
| Large set covariates | No | No | No | No | No | Yes | Yes | Yes |
| Sample | All | All | All | All | Col 6 | All | SAMS stayers | SAMS movers |
| Observations | 634,842 | 634,842 | 634,842 | 634,842 | 419,164 | 419,164 | 174,362 | 157,356 |

*Notes:* Standard errors clustered at the municipal level. *** p < 0.01, ** p < 0.05, * p < 0.1.