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 effects, 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 for fluoride levels below 1.5 mg/l. Third, we find evidence that fluoride improves later labor market outcomes, which indicates 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 through the drinking water on cognitive and non-cognitive ability, education and later labor market outcomes. We also study the long-established link between fluoride and dental health. To further investigate the effect of fluoride, we look at other health outcomes that may be connected to fluoride. We use a unique register dataset 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, Sun, et al. (2012) from Harvard School of Public Health reviewed 27 papers and concluded that exposure to high dosages of fluoride is associated with a reduction of almost half of a standard deviation in IQ among children.[2] The data from the reviewed papers originated from China and Iran. Several of

1. One indication that people tend to be very concerned with fluoridation is found in Lamberg, Hausen, and Vartiainen (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. Epidemiological papers published after or around Choi, Sun, et al. (2012) include Ding et al. (2011), Saxena, Sahay, and Goel (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, Zhang, 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.

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 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, Sun, 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 foremost from the bedrock under the water sources. The fluoride level in our data is hence not endogenous to any policy decision. The fluoride level in the Swedish drinking water ranges between 0 and 4 mg/l in our dataset, and there is often variation within municipalities which we exploit to estimate the casual effect. In comparison to China and Iran, 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 is no evidence of 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 and non-cognitive ability, education and labor market outcomes for at least two reasons. First, 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 human capital 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). We also find a zero-effect on related health outcomes. Our point estimates with regard

3. There are some studies that point 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 majorities of the Swedish water plants has fluoride levels below 1.5 mg/l.

to cognitive ability are much more precisely estimated compared to 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 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 are 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 their long-run effects. 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, Lubotsky, and Paxson (2002) and Currie and Stabile (2003) provide evidence for the connection between health and socioeconomic status. Case, Fertig, and Paxson (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, Stixrud, and Urzua 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, Heckman, and Schennach (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 Lindqvist and Vestman (2011) and Öhman (2015), who use the results from the Swedish draft tests for cognitive and non-cognitive ability and show that they are very good predictors for education, income and mortality. 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 recent unpublished paper, 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.

Earlier papers in economics have focused on other potential hazards and their effects on health and cognitive ability. Currie, Graff Zivin, et al. (2013) study the effect of mothers' consumption of polluted drinking water (broadly defined) during pregnancy on birth weight of the offspring with data from New Jersey. They find that the birth weight is negatively affected by contaminated water for mothers with a low education. Zhang (2012) uses Chinese data to 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, Gertler, and Schargrodsky (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 and find a positive effect of lead, i.e., an increased incidence of homicide.

Aizer et al. 2016 study reductions of lead levels in Rhode Island for cohorts born between 1997 and 2005. They use variation in lead in buildings due to policy implementations as an instrument, and find significant positive effects on children's reading test score in third grade for lower lead levels. Lead has also been studied with regards to air pollution. Nilsson (2009) investigates 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, Nilsson, and Robling (2014) conclude that the reduction in lead exposure also reduce criminal behavior. Other economic papers have studied air pollution in general. Schlenker and Walker (2015) 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, Johansson, and Nilsson (2014) the authors study air pollutants' effect on child health. Periods of inversions seems to affect 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

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.

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

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.[7]

3 Medical background

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

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 be 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.

Water fluoridation is a highly debated issue (Richards 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 also 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), however, found fluoride to be present in the cerebrospinal fluid, which surrounds the brain among humans. Consuming water with fluoride is an example of a long-term consumption and the question is whether this consumption of fluoride can pass the barrier.

Lower dosages of fluoride have, on the other hand, beneficial effects on dental health

7. Näsman, Ekstrand, et al. (2013) also apply Swedish drinking water data, but from an earlier time period. Cohorts born between 1900 and 1919 are included in their study where the authors study the effects on hip fracture incidence. The authors find no indications that fluoride induces hip fractures. Näsman, Granath, et al. (2016) use the same dataset to study the effects on myocardial infarctions and find no effects on this outcome either.

(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).

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, Sun, 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 cost equal the marginal benefit. 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.

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

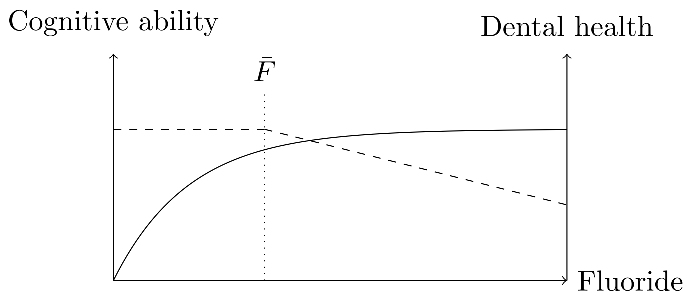


FIGURE 1. The effects of fluoride on dental health (solid line) and cognitive ability (dashed line).

The effects of neurotoxins often take the form of a hockeystick where exposure above a certain level becomes dangerous (Nilsson 2009). The effect of fluoride on dental health on the other hand probably follows a concave function where the marginal benefits on fluoride become smaller for higher levels. 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 if the fluoride level is found to have a negative effect on human capital development. If the fluoride level is not found to have a negative effect on human capital development for the levels of fluoride we consider, the cost-effectiveness of water fluoridation may instead solely be evaluated based on the effects on dental health and the cost of fluoridation. This is possible because countries that fluoridate the water normally do not add more than the WHO recommendation of 1.5 mg/l. To find whether $\bar{F} < 1.5$ mg/l is also important for countries with no artificial fluoridation since they may reduce the fluoride level in the water cleaning process.

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 (SGU 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 stone bedrocks such as granite. Greywacke bedrock also yields higher levels of fluoride. Especially water from drilled bedrock wells usually contains higher levels of fluoride (SGU 2013, p.81,84). Rainfall usually contains low levels of fluoride (Edmunds and Smedley 2013, p.313).[8] 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 SGU (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.[9]

Each municipality in Sweden is responsible for the public drinking water. Because municipalities often have different water sources situated on different types of bedrock, there is a within-municipality variation in fluoride.[10] Each municipality in Sweden is divided into several SAMS (Small Areas for Market Statistics) by Statistics Sweden. We make use of these SAMS when we estimate the effect of fluoride. A SAMS consists of approximately 750 individuals in the year 2011, with median 520. There are almost 9,300 SAMS in Sweden in comparison to 290 municipalities.[11] The large majority in Sweden

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

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

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

11. The reader should note that SAMS are not something that the public in general is aware of. Municipalities, however, are administrative areas that exist in the publics mind.

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).

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 final 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 (our two data sources for the fluoride data, we return to our data sources in the data section below). We also have information about the bedrock for the corresponding water source for the water plants. The variable is categorical where bedrock is classified into three broader categories: Soil bedrock, a mix between soil bedrock and stone bedrock and stone bedrock.

In Table 1 we verify that the fluoride level in the drinking water depends on the bedrock. The benchmark bedrock is soil bedrock and we include dummies for the other two categories. It is clear that the mixed bedrock as well as the stone bedrock yields higher fluoride levels in comparison to soil bedrock, which is exactly what we expect. Note that these three categories include different subtypes of bedrock (granite, greywacke et cetera) meaning that there is variation in fluoride within each category.

Table 1
Bedrock analysis

	F. (0.1 mg/l)
Mix of stone and soil bedrock	2.983***
	(0.526)
Stone bedrock	4.085***
	(0.214)
Constant	3.057***
	(0.129)
R^2	0.1729
Observations	1,788

Notes: The dependent variable is fluoride which is expressed in 0.1 mg/l. Standard errors in parenthesis. *** p < 0.01, ** p < 0.05, * p < 0.1. The benchmark is "soil bedrock". The analysis is based on the entire SGU dataset.

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.[12] Thus, we need a mapping protocol for how to assign fluoride

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

data for each SAMS.[13] 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.

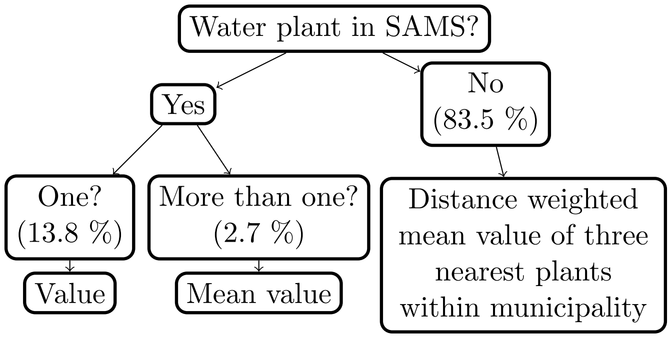
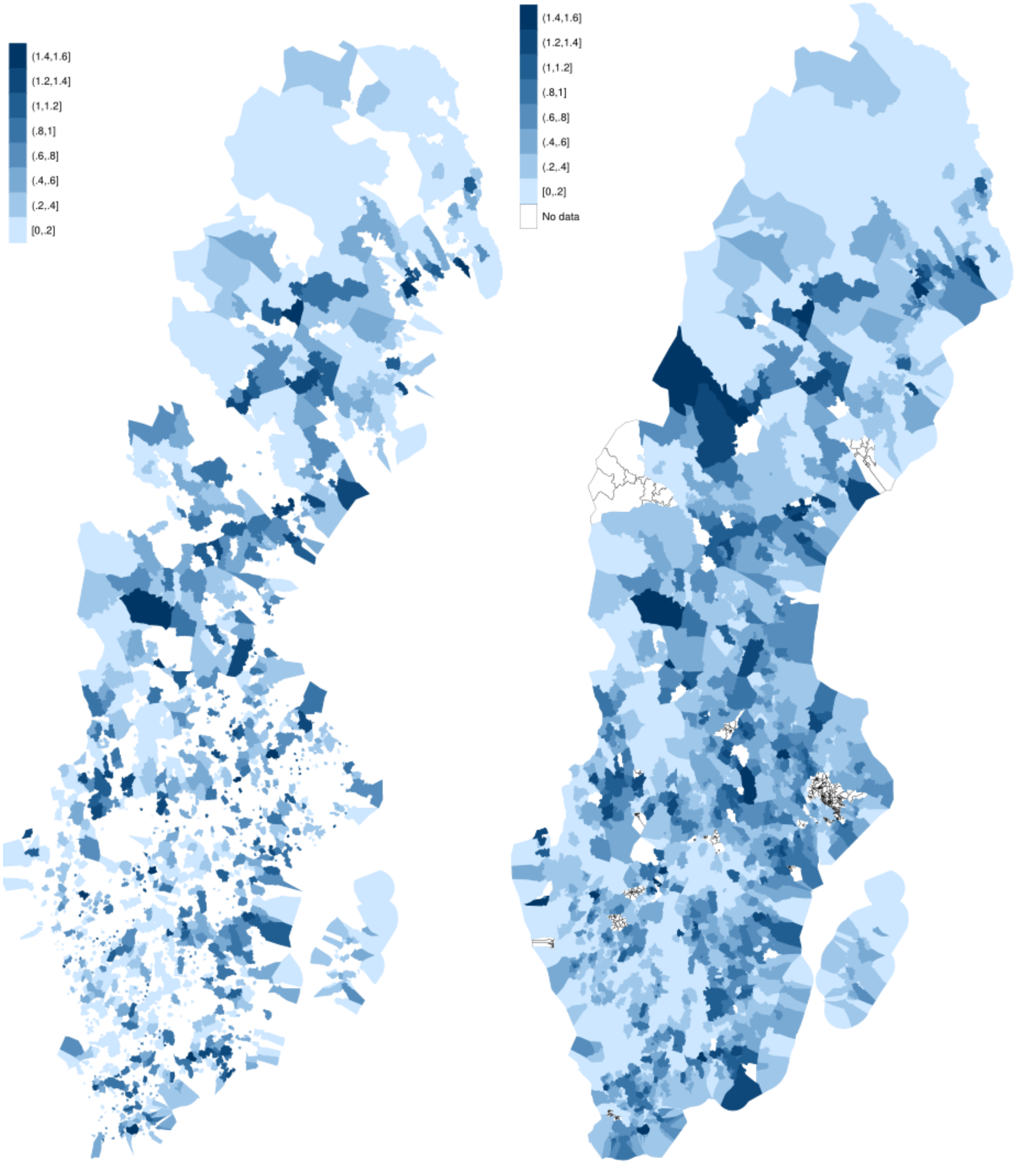


Figure 2. Water plants mapping. Percentage of SAMS in parenthesis.

For SAMS that have a water plant within the borders we assign the fluoride level of that water plant to all 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.

13. 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.



(a) SAMS with at least one water plant (b) Final mapping

FIGURE 3. Mapping of fluoride data.

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 for the years 2008 and 2013, and comes from The National

Board of Health and Welfare. We observe place of residence for all individuals of age 16 and older on the SAMS level.[14] 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 up to the year when we measure the outcome variable.[15] 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.[16] 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.[17]

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

14. 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.

15. 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.

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

17. 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.[18] We drop all individuals who have ever lived in a municipality between birth and age 16 for which we do not have fluoride data. We choose age 16 because this is the age for which me measure our first outcome variable.

6.2 Individual level data

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

As an outcome for education we use results from the national test taken at age 16. 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 data, and, second, it should be a fairly good proxy variable for cognitive ability. The data comes from Statistics Sweden (SCB). We have results for those born in 1987 and later.

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 were 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

18. 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 (SGU 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.

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.

Income is measured in 2014 (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 2014. An individual is coded as employed if he or she has worked at least one hour during a week.

Our main outcome variables are cognitive and non-cognitive ability, points on the national math test and labor market outcomes. In order to investigate other manifestations of how fluoride affects human capital development, we also look at health outcomes related to the brain. Data on health comes from the prescribed drug register, the inpatient and the outpatient registers. We look at prescription medicines for of ADHD, psychoses and depression which is available for 2005-2009. We also look whether the individual has a diagnosis from either the inpatient register or the outpatient register (both available for 1987-2010) for diagnoses classified within the ICD10-chapter for psychiatric illnesses (chapter F) or neurological diseases (chapter G). There has been a discussion in the earlier medical literature whether fluoride is associated with osteoporosis and hip fracture, see Näsman, Ekstrand, et al. (2013). To connect to this earlier medical literature, we also estimate the effect on skeleton and muscular diseases (chapter M). For all these health outcomes, we create dummy variables for whether an individual received a diagnosis or were prescribed medicines for any of the years available in these health registers.

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

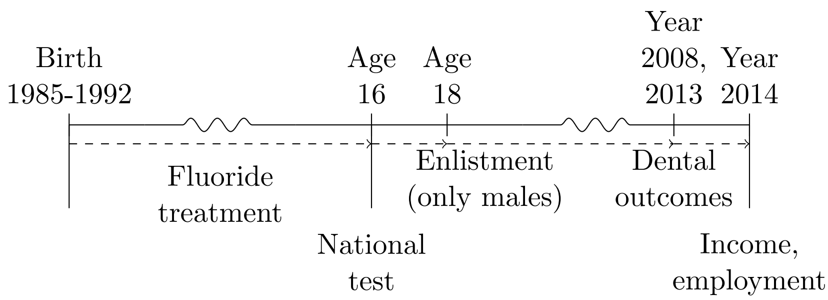


FIGURE 4. Timeline of measurement.

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 dental health cognitive ability, non-cognitive ability, education, employment status and income. We also estimate the effect of fluoride on a set of other health outcomes. 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, 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. 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 is undoubtedly endogenous, 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 dataset 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 A3 presented in section A.4 in the appendix. We also use data from Google Trends in Table A10 and conclude that people overall do not search more for information about fluoride in those regions where the fluoride level is higher.

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 over the years. If we would consider large geographical areas and use the variation between these areas, fluoride might not be independent of the outcome variables. As an illustrating example, assume that fluoride is negative for cognitive ability. If people are living in the same place over the generations, fluoride might have an effect on the regional labor market or the educational system because people on average have a lower cognitive ability. An individual's income would then be a function of individual background characteristics but also the general labor market situation in the area. Since the labor market has adjusted to a lower cognitive ability pool, the individual wage level will on average be lower. It may 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. Figure 5 illustrates the main identification problem in this setting using the long-run outcome income as an example.

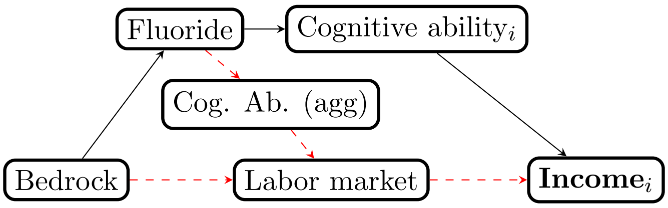


FIGURE 5. Relationships between the bedrock, fluoride level, cognitive ability and income.

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 SAMS are sufficiently small and that fluoride is independent of the outcome between these small areas. 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 A4, A5, A6 and A7 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 to our empirical strategy would be that people do not drink tap water but instead bottled water, meaning that our fluoride data is not accurate for the actual level of fluoride exposure. In general, Swedes drink the tap water and there are no general recommendations not to drink tap water. This is also confirmed by sales data for bottled water. Table A9 in the appendix display the total sales of bottled water per inhabitants in Sweden from 1994 to 2015. The average sales between these years are 20.3 liter per inhabitants and year. The recommended consumption of water for an individual is between 2-4 liters per day in a country with temperate climate (Fagrell 2009). This equals a yearly consumption between 730 and 1460 liters per person. The share of bottled water sales is thus only 1.4-2.8 percent of total yearly consumption of water. It is also likely that individuals during childhood drink less bottled water in comparison to the entire population. We thus conclude that bottled water is not a threat to our empirical strategy.[19]

A fourth 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 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

19. Avoidance behavior due to information in line with the discussion in Neidell (2009) and Zivin, Neidell, and Schlenker (2011) is unlikely since fluoride is not considered to be a hazard for levels below 1.5 mg/l. The sales data for bottled water confirms that people – on the aggregate level – does not seem to substitute tap water to bottled water in Sweden.

have self-selection into who is taking the conscription test and the math test. In Table A8 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 fifth 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 in the present generation. We discuss this in more detail in the robustness analysis.

The sixth 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 up until the year when we measure the outcome variable. 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 2014 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. In the second specification, we analyze only those who move within a municipality but between different SAMS at least once.

We estimate the following regression equation:

$$Y_i = \beta_0 + \beta_1 X_i + \beta_2 W_i + \beta_3 W_s + \beta_4 W_p + \tau_m + \gamma_m + \lambda_c + u_i \quad (1)$$

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. τ_m designates birth municipal fixed effects, γ_m equals municipal fixed effects in 2013 and λ_c designates cohort fixed effects. u_i is the error term. β_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 2014 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. This clustering level is our benchmark and we use it throughout the paper. In the regression tables in the result section, we also add standard errors clustered at other levels. The main variation in fluoride is on the SAMS level so we also cluster the standard errors on the birth SAMS level. In addition, we calculate standard errors clustered at the local labor market region in accordance with the definitions from Statistics Sweden.[20] In a fourth 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 which 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 treatment level taken into account moving patterns between different SAMS and municipalities. The histogram displays treatment up until age 16 which is when our first outcome variable is measured. The WHO recommendation of maximum 1.5 mg/l in the

20. 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 2014 and we only estimate them when we look at personal income and employment status in 2014.

drinking water is marked with a red line.[21]

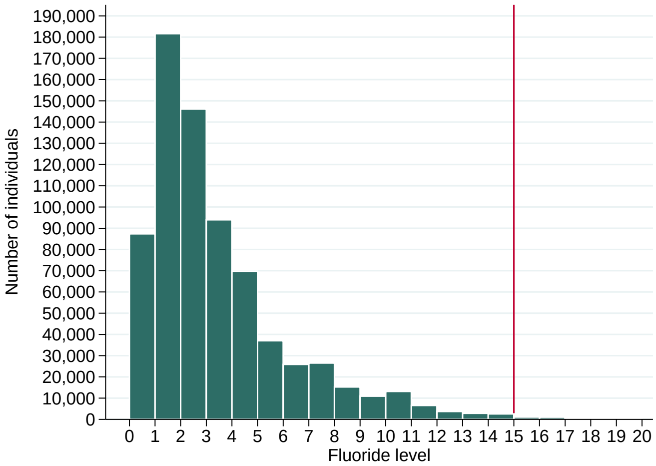


FIGURE 6. Histogram of fluoride levels below 2 mg/l (in 0.1 mg/l).

Our identification is based on an exogenous variation in fluoride stemming from a variation in the bedrock. In Table 2, we present some detailed descriptive statistics of the standard deviation in fluoride levels within and between municipalities. It is clear from the table that there is variation within municipalities, but also between municipalities. The combined variation is used to estimate the effect of fluoride where we consider people's moving patterns within and between municipalities as an additional source of variation.

TABLE 2
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 3 presents the mean and standard deviations for our five main outcomes of interest. The equivalent Table A2 for dental outcomes and the other health outcomes

21. 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.

(Table A1) can be found in the appendix. Cognitive and non-cognitive ability are only measured for men and are centered on 5 with a standard deviation of about 2, which follows the Stanine definition. 73 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 3
Descriptive statistics of main outcome variables

	Mean	SD
Annual income in SEK	183,804	143,198
Employment status	0.73	0.44
Cognitive ability	5.01	1.93
Non-cognitive ability	4.75	1.82
Number of basic points math test	26.18	8.57

Table 4 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 2014. 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 and the last year available) 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 4.[22] 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 2014 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.[23] We have grouped our covariates into two groups: Small set and Large set. Table 4 therefore also indicates which covariate is included in each group.

22. 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.

23. 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 4
Descriptive statistics of covariates

	Mean	SD	Outcomes	Set
Gender	0.49	0.50	All	Small
Individual at least high school	0.92	0.27	Income, employment	Small
Marital status	0.07	0.26	All	Large
Father at least high school	0.82	0.39	All	Large
Father's income	242,878	151,121	All	Large
Father's cognitive ability	5.07	1.90	All but non-cog. ability	Large
Father's non-cognitive ability	5.15	1.75	All but cog. ability	Large
Father immigrant	0.09	0.29	All	Large
Mother at least high school	0.89	0.31	All	Large
Mother's income	158,827	86,940	All	Large
Mother immigrant	0.10	0.30	All	Large
Both parents immigrants	0.04	0.21	All	Large
Cohort education (birth)	12.03	0.58	All	Large
Cohort education (school start)	12.03	0.25	All	Large
Cohort education (16 years age)	12.03	0.25	All	Large
Observations	728,074			

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. Next, we present the results for our additional health outcomes, followed by a section of results for the non-linear specifications. The section is ended with a comparison with earlier studies.

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 Table A11 section A.5 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 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 A2 in the appendix.

We divide our regression results into two separate tables. In Table 5 we run unweighted regressions where we look at the connection between fluoride and the aggregated measure of these six variables on the SAMS level. For this analysis, we focus on the 20 year olds which is the earliest cohort available. We can be more sure that the 20 year olds have not moved from a given SAMS in comparison to later cohorts. In Table 6 we run weighted regressions where we work with our full dataset. For this analysis, individuals from cohorts in the data analysis for the main outcomes are included. In this case, each individual has a unique fluoride treatment depending on moving patterns and the aggregated fluoride level on the SAMS level thus corresponds to those living in a SAMS.[24]

Table 5
Dental outcomes

	Visit	Repair	RiskEvaluation	DiseasePrevention	DiseaseTreatment	RootCanal
2013	-0.6554	-0.3369	-0.6882	-0.8453	-0.3506	-0.0292
	(0.2987)**	(0.1103)***	(0.3015)**	(0.4309)*	(0.1389)**	(0.0172)*
	<0.0879>***	<0.0555>***	<0.0906>***	<0.0835>***	<0.0757>***	<0.0156>*
2008	-0.6356	-0.2290	-0.6765	-0.4337	0.1093	-0.0300
	(0.2935)**	(0.0683)***	(0.3204)**	(0.2238)*	(0.1056)	(0.0197)
	<0.0949>***	<0.0589>***	<0.0974>***	<0.0764>***	<0.0646>*	<0.0168>*

Notes: Standard errors in parenthesis clustered at the municipal level. Standard errors in <> are clustered on the SAMS level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. 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 5 clearly displays a negative effect of fluoride level for these outcomes. The reader may find the results both for the 2008 sample and the 2013 sample in Table 5. The point estimates are large and often statistically significant. If we take the first estimate in Table 5 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 displayed in column 2. If fluoride would increase with 1 mg/l, the share of 20 year olds that had a tooth repaired would be decreased approximately 3.4 percentage points considering the 2013 sample. Again, this effect is large, especially for this cohort. 20 year olds 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 the coefficients are only 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 old. DiseaseTreatment is positive for 2008, but 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.

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

Table 6
Dental outcomes

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Visit	-0.2903	-0.0655	-0.0118	-0.0164	0.0067	-0.0052	-0.0011
	(0.1605)*	(0.0458)	(0.0433)	(0.0428)	(0.0343)	(0.0357)	(0.0360)
	<0.0386>***	<0.0178>***	<0.0195>	<0.0194>	<0.0187>	<0.0206>	<0.0206>
Repair	-0.0776	-0.0682	-0.0598	-0.0575	-0.0697	-0.0595	-0.0640
	(0.0600)	(0.0256)***	(0.0317)*	(0.0316)*	(0.0277)**	(0.0294)**	(0.0279)**
	<0.0134>***	<0.0105>***	<0.0138>***	<0.0138>***	<0.0140>***	<0.0152>***	<0.0152>***
RiskEvaluation	-0.3032	-0.0671	-0.0126	-0.0174	0.0062	-0.0042	0.0002
	(0.1685)*	(0.0478)	(0.0444)	(0.0438)	(0.0345)	(0.0360)	(0.0364)
	<0.0400>***	<0.0184>***	<0.0198>	<0.0198>	<0.0190>	<0.0208>	<0.0208>
DiseasePrevention	-0.5169	-0.1318	-0.1154	-0.1186	-0.0748	-0.0613	-0.0607
	(0.2741)*	(0.0619)**	(0.0553)**	(0.0547)**	(0.0348)**	(0.0383)	(0.0384)
	<0.0462>***	<0.0161>***	<0.0174>***	<0.0174>***	<0.0161>***	<0.0185>***	<0.0185>***
DiseaseTreatment	-0.0656	-0.0217	-0.0072	-0.0060	-0.0168	-0.0247	-0.0250
	(0.0996)	(0.0388)	(0.0340)	(0.0340)	(0.0282)	(0.0294)	(0.0296)
	<0.0280>**	<0.0152>	<0.0180>	<0.0180>	<0.0176>	<0.0195>	<0.0195>
RootCanal	-0.0051	-0.0138	-0.0159	-0.0145	-0.0182	-0.0137	-0.0156
	(0.0126)	(0.0058)**	(0.0077)**	(0.0076)*	(0.0070)***	(0.0072)*	(0.0071)**
	<0.0042>	<0.0041>***	<0.0051>***	<0.0051>***	<0.0052>***	<0.0059>**	<0.0059>***
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. 2014	No	Yes	No	No	Yes	Yes	Yes
Sample	All	All	All	All	All	Col 7	All

Notes: Standard errors in parenthesis clustered at the municipal level. Standard errors in <> are clustered on the SAMS level. *** p < 0.01, ** p < 0.05, * p < 0.1. Outcomes on each row. The number of observations ranges between 472,287 (col 6 and 7) and 725,004.

The results presented in Table 6 point in the same direction as the ones in Table 5, but the point estimates are generally smaller in size. The reason for this is probably because we consider the average treatment of fluoride between birth and up until we measure dental outcomes. Fluoride needs to be continuously applied to teeth and fluoride exposure in later years should be more important than the fluoride level that the individual was exposed to several years ago. People tend to move away from their parents after age 20, meaning that the average fluoride level is more representative when measured at age 20 (Table 5) since people probably move more often when they are 21-28 in comparison to when they are 0-20. We focus on the 2013 data sample in Table 6. In the appendix, the reader may find results for additional outcomes and the equivalent results for the 2008 sample in Tables A12, A13 and A14.

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 fluoride increased by 1 mg/l. This effect is smaller than the one found in Table 5, 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 fluoride treatment throughout the entire life has long run positive effects on dental health. Root canal treatment is now often statistically significant, which is expected since we have included older cohorts. Although the point estimates are not always statistically significant for the dental health outcomes, they almost always points in the expected negative direction.[25]

The overall conclusion after considering the results in Table 5-6 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.[26]

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. In this subsection we present the linear specifications. There are, however, reason to believe that the effect may be non-linear, and that fluoride become dangerous above a certain level. 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 and consider a fluoride treatment between birth and age 18. In Table 7 we present the point estimates for fluoride and three types of standard errors. The first standard error in parenthesis is clustered on the birth municipality. The standard errors within <> are clustered on the birth SAMS level. The standard errors in curly brackets are spatial adjusted standard errors in line with Conley (1999). The first column does not include any covariates 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 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 18. In column 6, we run an analysis for those who have lived in the same SAMS in a municipality for the entire period 0-18. 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 0.0045, this means that cognitive

25. We can conclude that the coefficients for the 2008 specification are generally smaller in size and less precisely estimated. A reform was implemented in July 2008 that gave 20-29 years old a special dental care benefits. 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 2008.

26. 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. 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 wisdom teeth incidence. See section A.5 for a discussion and for additional analysis on these two outcomes.

ability is increased by 0.045 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.[27]

Table 7
Cognitive ability

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Fluoride up until age 18 (0.1 mg/l)	-0.0088	-0.0028	-0.0028	-0.0021	0.0045	0.0030	0.0205
	(0.0082)	(0.0051)	(0.0051)	(0.0052)	(0.0038)	(0.0053)	(0.0078)***
	<0.0030>***	<0.0038>	<0.0038>	<0.0045>	<0.0040>	<0.0056>	<0.0084>**
	{0.0086}	{0.0046}	{0.0045}	{0.0052}	{0.0041}	{0.0054}	{0.0088}**
Mean	5.0067	5.0067	5.0067	5.0222	5.0222	5.0897	4.9246
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	0.0216	0.0239	0.0282	0.1718	0.1683	0.1802
Observations	81,776	81,776	81,776	51,203	51,203	20,513	19,178

Notes: Standard errors in parenthesis are clustered at the municipal of birth. Standard errors in <> are clustered on the SAMS 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 0.154 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.

Table 8
Non-cognitive ability

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Fluoride up until age 18 (0.1 mg/l)	0.0026	0.0058	0.0059	0.0109	0.0154	0.0087	0.0353
	(0.0058)	(0.0046)	(0.0046)	(0.0050)**	(0.0050)***	(0.0067)	(0.0148)**
	<0.0026>	<0.0037>	<0.0037>	<0.0046>**	<0.0045>***	<0.0069>	<0.0094>***
	{0.0054}	{0.0043}	{0.0043}	{0.0051}**	{0.0048}***	{0.0066}	{0.0126}***
Mean	4.7340	4.7340	4.7340	4.7754	4.7754	4.9214	4.6953
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	0.0175	0.0176	0.0214	0.0784	0.0791	0.0934
Observations	66,375	66,375	66,375	41,636	41,636	16,731	15,425

Notes: Standard errors in parenthesis are clustered at the municipal of birth. Standard errors in <> are clustered on the SAMS 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. Fluoride treatment now takes place between birth and age 16. 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 almost 500,000 observations so it is not surprising that some of our results are statistically significant. The important part is economic significance. Let us

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

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 less than 0.2 points. This decrease is less than 1 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 9
Math points

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Fluoride up until age 16 (0.1 mg/l)	-0.1031	-0.0296	-0.0269	-0.0269	-0.0435	-0.0163	-0.0184	-0.0191
	(0.0354)***	(0.0126)**	(0.0125)**	(0.0125)**	(0.0144)***	(0.0119)	(0.0133)	(0.0204)
	<0.0099>***	<0.0093>***	<0.0092>***	<0.0092>***	<0.0102>***	<0.0085>*	<0.0118>	<0.0165>
	{0.0355}***	{0.0116}**	{0.0115}**	{0.0115}**	{0.0128}***	{0.0096}*	{0.0120}	{0.0164}
Mean	26.2059	26.2059	26.2059	26.2059	26.4900	26.4900	27.2221	26.0441
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	0.0229	0.0403	0.0403	0.0431	0.1643	0.1472	0.1723
Observations	499,892	499,892	499,892	499,892	336,827	336,827	139,149	127,062

Notes: Standard errors in parenthesis are clustered at the municipal of birth. Standard errors in <> are clustered at the SAMS 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 we cannot reject the null hypothesis that fluoride does *not* have a negative effect on cognitive development.

Table 10 and 11 studies outcomes which are more long-term: Log annual income and employment status in 2014. 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 we add an additional standard error calculation where the standard errors in brackets are clustered at the local labor market area in 2014. We also add an additional set of municipal fixed effects for where the individual lives in 2014. Fluoride is measured between birth and the year 2014.

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 0.0042, meaning that income increases by 4.2 percent if fluoride increases by 1 mg/l. This is not a negligible effect and the estimate should be considered as economically significant.

Table 10
Annual log income in SEK

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Fluoride up until year 2014 (0.1 mg/l)	0.0053	0.0035	0.0040	0.0052	0.0040	0.0042	0.0030	0.0019
	(0.0031)*	(0.0014)**	(0.0014)***	(0.0016)***	(0.0014)***	(0.0014)***	(0.0021)	(0.0040)
	[0.0023]**	[0.0026]	[0.0028]	[0.0016]***	[0.0017]**	[0.0019]**	[0.0021]	[0.0038]
	<0.0007>***	<0.0008>***	<0.0008>***	<0.0008>***	<0.0010>***	<0.0010>***	<0.0010>***	<0.0010>***
	{0.0031}*	{0.0010}***	{0.0011}***	{0.0012}***	{0.0012}***	{0.0012}***	{0.0019}	{0.0025}
Mean	11.9124	11.9124	11.9124	11.9124	11.9229	11.9229	11.8452	11.9544
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 2014	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	0.0002	0.0065	0.0528	0.0967	0.0997	0.1066	0.1289	0.1197
Observations	634,793	634,793	634,793	634,793	419,162	419,162	72,089	150,458

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 <> are clustered at the SAMS 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 continue to the last outcome. Employment status is a dummy variable taking the value 1 if the individual is defined as employed in 2014. In column 6, the point estimate for fluoride is 0.002 and statistically significant. If fluoride is increased by 1 mg/l, then the probability that the person is employed is increased by 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 11
Employment status

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Fluoride up until year 2014 (0.1 mg/l)	0.0021 (0.0013)* [0.0008]*** <0.0003>*** {0.0013}*	0.0016 (0.0006)** [0.0011] <0.0003>*** {0.0004}***	0.0018 (0.0006)*** [0.0012] <0.0004>*** {0.0005}***	0.0023 (0.0007)*** [0.0005]*** <0.0004>*** {0.0005}***	0.0019 (0.0006)*** [0.0006]*** <0.0004>*** {0.0005}***	0.0020 (0.0006)*** [0.0007]*** <0.0004>*** {0.0005}***	0.0016 (0.0010) [0.0010] <0.0007>** {0.0008}**	0.0018 (0.0016) [0.0014] <0.0008>** {0.0010}*
Mean	0.7346	0.7346	0.7346	0.7346	0.7459	0.7459	0.7129	0.7582
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 2014	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	0.0002	0.0069	0.0322	0.0662	0.0661	0.0752	0.0778	0.0789
Observations	728,074	728,074	728,074	728,074	474,556	474,556	81,867	170,142

Notes: Standard errors in parenthesis are clustered at the municipal of birth. Standard errors in <> are clustered at the SAMS 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 the last two tables we looked at income and employment status for all included cohorts born 1985-1992. One objection is that the included cohorts are only 22-29 years old when income and employment status are measured, meaning that the estimates are not representative for the lifetime income and probability of being employed. In the subsample analysis below, we restrict our sample to those who are 27-29 years old in 2014. We also split our sample looking at those who have an academic education and those who do not. The non-college group is defined as those who have at least upper secondary education up until high school education, but not higher. We also split each category for men and women. For the subsample analysis, we have included all fixed effects and all available covariates in all of the specifications expect for the first column.

In following table, we see that the estimates for log income varies between these different samples and the point estimates are not always statistically significant for all standard error specifications. The overall message is however that fluoride seems to have a positive effect. The effect seems overall to be larger for non-academics. The income levels for those who do not have an academic education are probably more representative at age 27-29 than for those who have attended university given that the first mentioned have spent more years on the labor market than the latter. The effect of fluoride is larger for men without academic education in comparison to women without academic education, but we find an opposite relationship for those with an academic education.

Table 12
Annual log income in SEK (subsample)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Fluoride up until year 2014 (0.1 mg/l)	-0.0006	0.0057	0.0062	0.0048	0.0043	0.0042	0.0044
	(0.0012)	(0.0017)***	(0.0018)***	(0.0035)	(0.0025)*	(0.0042)	(0.0033)
	[0.0012]	[0.0025]**	[0.0019]***	[0.0061]	[0.0027]	[0.0033]	[0.0031]
	<0.0008>	<0.0018>***	<0.0019>***	<0.0034>	<0.0024>*	<0.0039>	<0.0031>
	{0.0012}	{0.0017}***	{0.0018}***	{0.0035}	{0.0024}*	{0.0039}	{0.0031}
Mean	12.1639	12.1520	12.3967	11.7976	12.2209	12.3500	12.1347
Birth cohort FE	No	Yes	Yes	Yes	Yes	Yes	Yes
Birth municipal FE	No	Yes	Yes	Yes	Yes	Yes	Yes
Municipal FE, year 2014	No	Yes	Yes	Yes	Yes	Yes	Yes
Small set covariates	No	Yes	Yes	Yes	Yes	Yes	Yes
Large set covariates	No	Yes	Yes	Yes	Yes	Yes	Yes
Sample	All	No. Coll., all	No Coll., men	No Coll., women	Coll., all	Coll., men	Coll., women
R^2	0.0000	0.1195	0.0417	0.0394	0.0562	0.0761	0.0509
Observations	216,779	80,849	47,825	33,024	53,757	21,527	32,230

Notes: Individuals with a yearly income below 1,000 SEK are excluded, and individuals born 1988 or later. Standard errors in parenthesis are clustered at the municipal of birth. Standard errors in <> are clustered at the SAMS 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. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

The same subsample analysis is also conducted for employment status. Again, we find that the effect is stronger for the non-academics.

Table 13
Employment status (subsample)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Fluoride up until year 2014 (0.1 mg/l)	0.0010	0.0034	0.0032	0.0038	0.0001	0.0016	-0.0009
	(0.0008)	(0.0007)***	(0.0009)***	(0.0011)***	(0.0010)	(0.0016)	(0.0011)
	[0.0004]***	[0.0009]***	[0.0008]***	[0.0018]**	[0.0010]	[0.0014]	[0.0011]
	<0.0003>***	<0.0007>***	<0.0009>***	<0.0012>***	<0.0009>	<0.0015>	<0.0011>
	{0.0008}	{0.0007}***	{0.0008}***	{0.0011}***	{0.0010}	{0.0017}	{0.0011}
Mean	0.8156	0.8178	0.8413	0.7852	0.8544	0.8319	0.8698
Birth cohort FE	No	Yes	Yes	Yes	Yes	Yes	Yes
Birth municipal FE	No	Yes	Yes	Yes	Yes	Yes	Yes
Municipal FE, year 2014	No	Yes	Yes	Yes	Yes	Yes	Yes
Small set covariates	No	Yes	Yes	Yes	Yes	Yes	Yes
Large set covariates	No	Yes	Yes	Yes	Yes	Yes	Yes
Sample	All	No Coll., all	No Coll., men	No Coll., women	College, all	College, men	College, women
R^2	0.0001	0.0606	0.0629	0.0658	0.0406	0.0667	0.0374
Observations	245,116	92,275	53,659	38,616	57,664	23,456	34,208

Notes: Individuals born 1988 or later are excluded. Standard errors in parenthesis are clustered at the municipal of birth. Standard errors in <> are clustered at the SAMS 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 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. We investigate the reduced form results for income and employment status further below.

8.2.1 Interpreting the reduced form effect for labor market outcomes

The initial hypothesis that we wanted to test was whether fluoride has negative effects on human capital development. Log income and employment status was considered as alternative outcomes also measuring human capital development later in life. We could however not reject the null hypothesis that the effect was zero for cognitive and non-cognitive ability or math points on the national test. What we do in this subsection is that we run an IV analysis for dental health on labor market outcomes using fluoride as an instrument for dental health. This is however not an IV in the strict sense where we argue that the effect of the instrument only goes through the instrumented variable. We have already presented a potential second pathway that goes through human capital development where the hypothesis was that fluoride may be a neurotoxin. We merely use the IV as a method to interpret the size of the reduced form where we estimate the effect of dental health on labor market outcomes. Dental health status is only available to us on the aggregate level for each SAMS and cohort. We therefore collapse out data on later labor market status and fluoride to the same level to make the estimates interpretable. Given that the data is collapsed, we cannot include individual covariates or any fixed effects anymore. We choose to focus on dental repairs in the IV analyses since dental repairs have such clear connection to fluoride.

In Table 14 the IV for log income is presented. The reader may both find the OLS, the first stage, the reduced form and the 2SLS for this collapsed data set. The F-values for the first stage is presented at the bottom of the table. Two different analyses are presented. In the first part of the table, we run the analysis for all available cohorts. In the second part, we restrict the analysis to those who are 27-29 years old. The average share of repairs is about 18 percent (with a median of 17 percent).

TABLE 14
Annual log income in SEK

	OLS Log income	FS Repair	RF Log income	2SLS Log income
Repair	0.0005			-0.0208
	(0.0002)***			(0.0282)
	<0.0002>***			<0.0071>***
Fluoride		-0.1625	0.0034	
		(0.0830)*	(0.0033)	
		<0.0325>***	<0.0009>***	
F stat. Municipality		3.83		
F stat. SAMS		25.07		
Sample	All			
Repair	0.0000			0.2420
	(0.0002)			(2.4793)
	<0.0003>			<1.1406>
Fluoride		-.0122	-0.0030	
		(0.1225)	(0.0019)	
		<0.0572>	<0.0015>*	
F stat. Municipality		0.01		
F stat. SAMS		0.05		
Sample	1985-1987			

Notes: Individuals with a yearly income below 1,000 SEK are excluded. Standard errors in parenthesis are clustered at the municipal level. Standard errors in <> are clustered at the SAMS level. *** $p < 0.01$, ** $p < 0.05$, * < 0.1.

Table 15
Employment status

	OLS Employment	FS Repair	RF Employment	2SLS Employment
Repair	0.0005			-0.0151
	(0.0001)***			(0.0175)
	<0.0001>***			<0.0040>***
Fluoride		-0.1673	0.0025	
		(0.0844)**	(0.0019)	
		<0.0326>***	<0.0004>***	
F stat. Municipality		3.93		
F stat. SAMS		26.33		
Sample	All			
Repair	0.0004			-0.0610
	(0.0001)***			(0.3942)
	<0.0001>***			<0.1661>
Fluoride		-0.0218	0.0013	
		(0.1247)	(0.0013)	
		<0.0577>	<0.0007>*	
F stat. Municipality		0.03		
F stat. SAMS		0.14		
Sample	1985-1987			

Notes: Standard errors in parenthesis are clustered at the municipal level. Standard errors in <> are clustered at the SAMS level. *** p < 0.01, ** p < 0.05, * < 0.1.

Considering the full sample in Table 14, we find that when dental repairs increases by 1 percentage point, income decreases by 2 percent on the same aggregate level. This effect is clearly economically significant. This indicates that fluoride improves labor market outcomes through better dental health. The reduced form estimate in Table 14 equals 0.0034, meaning that when fluoride increases by 1 mg/l, income increases by 3.4 percent. This estimate may be compared to Glied and Neidell (2010), who find that women who drinks fluoridated water on average earn 4 percent more. The effect on income may also be compared to estimated education premiums. Card (1999) conducts a meta-study reviewing several papers that have used different techniques to estimate the causal effect of education. The return of one additional year of education seems to be associated with an increase in income by approximately 6-10 percent, considering the IV estimates in the review study. If the share of dental repairs increases by 1 percentage point, the income is reduced be 2 percent according to our results. This corresponds to a quarter of a year longer education. For employment status, we find estimates going in a similar direction. If dental repairs increase by one percentage point, the probability of being employed on the same aggregated level is decreased by 1.5 percentage point considering the full sample. When we restrict the analysis to only those who are 27-29 years old, the F-values for the first stage is extremely small, making the IV uninterpretable. We have the same problem when we cluster the standard errors on the muncipal level.[28]

The question is what the causal channel looks like. The estimated effect could be interpreted as a beauty-effect. Given that we found larger effects for non-academics in the earlier reduced form analyses, one explanation might be that people working in the

28. One explanation for why we no longer find the same effect in the reduced form or in the first stage is probably because our data is now collapsed where each cohort and SAMS have an equal weight in the regressions. For some SAMS and cohorts, many individuals are included, and in others, far fewer individuals are included.

service sector – which is not uncommon for this age-group – are more sensitive to bad looking teeth. This is probably not the entire explanation however. Having bad dental health is probably associated with pain, and individuals with dental problems should on average be more sick and more absent from work. This could explain why they earn less and are less likely to be employed.

8.3 Additional outcomes: Health status

The purpose of this paper is primarily to study human capital development where we have focused on cognitive and non-cognitive abilities, education and labor market status. Given that we did not find any negative effects of fluoride on these outcomes, it is not likely that a negative effect of fluoride would manifest itself on more serious health outcomes. It is however interesting to see if this really is the case. In Table 16 and 17 we run the analysis on the prescription of medicines for ADHD, depression and psychoses. We also run the analysis for diagnoses from the outpatient and the inpatient registers. We look at psychiatric diagnoses and neurological diagnoses. We also estimate the effect on diagnoses for muscular and skeleton diseases to connect to the discussion whether fluoride has an effect on osteoporosis. All outcome variables are defined as dummy variables for whether the individual was prescribed or diagnosed sometimes during the measurement period. The ATC and ICD codes that we use can be found in appendix A.17.

It is clear from the first table that there is a zero-effect of fluoride on the probability of being prescribed any of these medicines. The point estimates are not always statistically significant and always small in size. Taking the estimate in the sixth column as an example, the probability of receiving ADHD medicines is decreased by 0.2 percentage points if fluoride is increased by 1 mg/l. In economic terms, this effect is a zero-effect.

Table 16
Prescription of medicine

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
ADHD medicine	0.0000	-0.0001	-0.0001	-0.0002	-0.0001	-0.0002	-0.0001	0.0001
	(0.0001)	(0.0001)	(0.0001)	(0.0001)*	(0.0001)*	(0.0001)**	(0.0001)*	(0.0002)
	<0.0001>	<0.0001>*	<0.0001>	<0.0001>**	<0.0001>**	<0.0001>***	<0.0001>*	<0.0002>
Antidepressants	0.0003	0.0000	-0.0001	-0.0002	-0.0002	-0.0003	-0.0005	-0.0002
	(0.0003)	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)**	(0.0005)
	<0.0001>**	<0.0002>	<0.0002>	<0.0002>	<0.0002>	<0.0002>**	<0.0002>**	<0.0004>
Antipsychotics	0.0000	-0.0000	-0.0001	-0.0001	-0.0001	-0.0001	-0.0000	0.0000
	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0002)
	<0.0000>	<0.0001>	<0.0001>	<0.0001>	<0.0001>	<0.0001>	<0.0001>	<0.0001>
Small set covariates	No	No	No	Yes	Yes	Yes	Yes	Yes
Large set covariates	No	No	No	No	No	Yes	Yes	Yes
Fe. birth muni.	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fe. cohort	No	No	Yes	Yes	Yes	Yes	Yes	Yes
Fe. muni. 2013	No	No	No	Yes	Yes	Yes	Yes	Yes
Sample	All	All	All	All	Col 7	All	SAMS stayers	SAMS movers

Notes: Standard errors in parenthesis clustered at the municipal of birth. Standard errors in <> clustered on the SAMS of birth. *** p < 0.01, ** p < 0.05, * p < 0.1. Outcomes on each row. The number of observations ranges between 292,307 and 724,945.

The same picture emerges with diagnosis. The estimated effects are small and often statistically insignificant.

Table 17
Diagnosis

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Mental retardation in childhood	0.0006 (0.0006) <0.0002>***	-0.0001 (0.0004) <0.0002>	-0.0001 (0.0004) <0.0002>	-0.0003 (0.0004) <0.0002>	-0.0003 (0.0003) <0.0002>	-0.0005 (0.0004) <0.0002>**	-0.0004 (0.0003) <0.0002>	-0.0002 (0.0008) <0.0005>
Neurological diseases	0.0001 (0.0001) <0.0001>	0.0001 (0.0001) <0.0001>	0.0001 (0.0001) <0.0001>	-0.0000 (0.0001) <0.0001>	-0.0000 (0.0001) <0.0001>	-0.0000 (0.0001) <0.0001>	0.0001 (0.0002) <0.0002>	-0.0001 (0.0002) <0.0003>
Musculoskeletal diseases	-0.0006 (0.0004) <0.0002>***	-0.0005 (0.0002)** <0.0002>**	-0.0005 (0.0002)** <0.0002>**	-0.0006 (0.0003)** <0.0002>***	-0.0006 (0.0002)** <0.0002>***	-0.0006 (0.0002)** <0.0002>**	-0.0003 (0.0003) <0.0003>	-0.0005 (0.0006) <0.0005>
Small set covariates	No	No	No	Yes	Yes	Yes	Yes	Yes
Large set covariates	No	No	No	No	No	Yes	Yes	Yes
Fe. birth muni.	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fe. cohort	No	No	Yes	Yes	Yes	Yes	Yes	Yes
Fe. muni. 2013	No	No	No	Yes	Yes	Yes	Yes	Yes
Sample	All	All	All	All	Col 7	All	SAMS stayers	SAMS movers

Notes: Standard errors in parenthesis clustered at the municipal of birth. Standard errors in <> clustered on the SAMS of birth. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Outcomes on each row. The number of observations ranges between 292,307 and 724,945

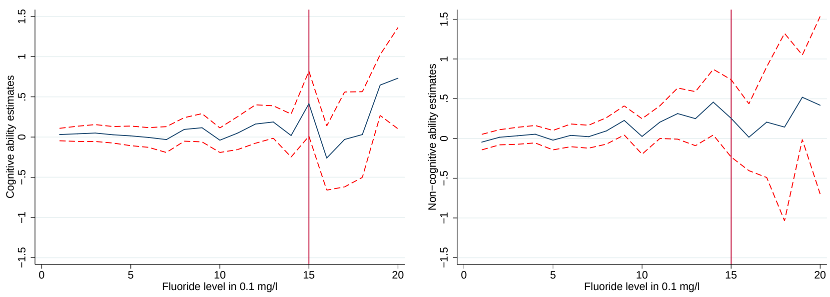
In conclusion, we do not find that fluoride has any effects on these health outcomes. This further strengthens our argument that fluoride does not have any negative effects for levels below 1.5 mg/l on human capital development or health outcomes related to human capital development. It is also interesting that we do not find any effects on diagnoses for muscular and skeleton diseases, which has been a question also discussed in connection to fluoride.

8.4 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 earlier tables. 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 for high levels. In the figures, 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 seem to increase when closing on 1.5 mg/l, which indicate a positive effect of fluoride through dental health for higher levels. Also 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.

The corresponding figures for dental health and other health outcomes may be found in the appendix (Figure A3 and A4). For the other health outcomes, the results are stable around zero. If we look at dental repairs and disease prevention, we can see an improvement of the dental health for fluoride levels up till 1 mg/l (fewer repairs, less preventions). However, for the other results, there are no evidence of an increasing effect higher fluoride levels. In section A.8 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 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 and positive 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 through dental health – especially for higher levels of fluoride.[29]



(a) Cognitive ability estimates (b) Non-cognitive ability estimates

FIGURE 7. Non-linear effects for ability measures.

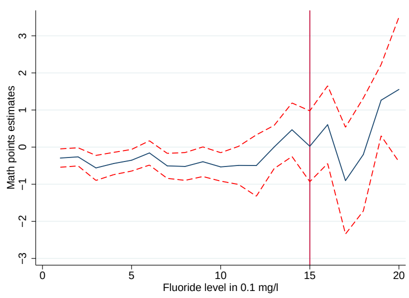
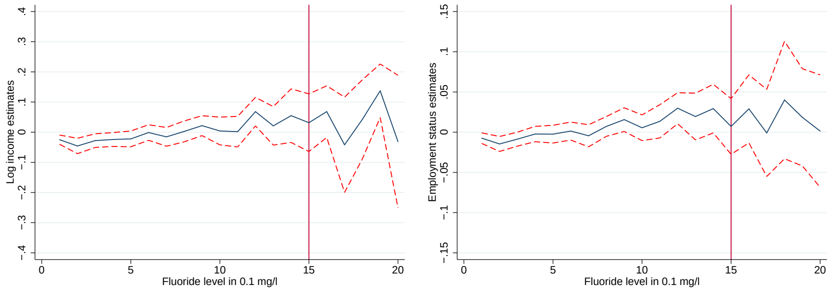


FIGURE 8. Non-linear math points estimates.

29. We have also created corresponding non-linear effects tables for dental outcomes. These tables are available from the authors upon request.



(a) Log income estimates (b) Employment estimates

FIGURE 9. Non-linear effects labor market outcomes.

8.5 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 Table 18, we have summarized the results for the reviewed papers in Choi, Sun, 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, Sun, et al. (2012).[30]

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

TABLE 18
Comparison with earlier studies

Study	Obs.	*F.*	CI 95 %
Our study: No cov. or f.e.	81,776	0.05-4.10	-0.1296, 0.0386
Our study: Cov. and f.e.	51,203	0.05-4.10	-0.0156, 0.0626
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, Sun, et al. (2012). Note that these studies have not considered a continuous measure of fluoride.

In comparison to earlier papers, our study is based on a much larger 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 include the zero both with and 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 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[31], our confidence intervals are (-1.8560, 0.5546) for the specifications without covariates or fixed effects and (-0.2267, 0.8919) for the specifications with all covariates and fixed effects, when fluoride is increased by 1 mg/l.

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

31. See Table 1 in Öhman (2015).

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 A.9 in the appendix. The estimates are more noisy in this case since we are left with fewer observations. We find mixed results on income and employment, but no statistically significant negative results. There are no indications of any negative effect human capital development.

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.[32] 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 A.10 and A.11 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, which is reassuring.

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 A.12 in the appendix, we also run a specification including only those municipalities where we have data from 1985 or where we have received a clear confirmation (conservative judgement) 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 estimate positive coefficients as in the main analysis, but the estimated point estimates are generally smaller in magnitude in this specification.

We also run specific analysis only for those only born in 1985 in section A.13 for labor market outcomes. The results point in the same direction as in the main analysis for employment, but is more mixed for income. The specifications with all covariates and fixed effects point in the same direction as in the main analysis.

We also run a specification where we only look at those SAMS which had one and only

32. 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, however.

one water plant and where we have full information from 1985 from the municipalities in section A.14. In this specification we only include those who have not moved. 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 again 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 A.15 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.

Finally, we have run specifications where we have included mother fixed effects. The variation in fluoride now stems from different moving patterns of a family where siblings have been exposed to different fluoride levels throughout life because they have resided in different areas for different amount of time. The reader should note that this specification is very demanding and forces the comparisons in the regressions to be very selective. If we take cognitive ability for instance, the variation in fluoride now stems from brothers born between 1985-1987 where the family has moved between their respective births and age 18. The empirical results points in different directions depending on the outcome variable. For math points, we find no evidence of any negative effects. For cognitive ability and non-cognitive ability, the estimates are not statistically significant, but the point estimates are negative and large. For income and employment status, we have some negative, very large and statistically significant effects, but the point estimates moves towards zero when other fixed effects and covariates are included and becomes statistically insignificant.

Overall, while the results are mixed in our robustness checks, we are confident to conclude that we find support for our main analysis. The reader should bare in mind that when testing many different specifications for different subsamples, one can expect to find some that show different results.

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. We also find a zero-effect of the probability of being prescribed medicines for ADHD, depression or psychiatric conditions as well as the probability of being diagnosed for psychiatric illnesses, neurological illnesses or muscular or musculoskeletal diseases. 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 fluoride in the drinking water. 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. Given our results, it is possible to do a cost-benefit analysis whether artificial fluoridation is cost-effective, without worrying about negative side effects.

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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A Appendix

A.1 Exogenous variation in fluoride: Geological background

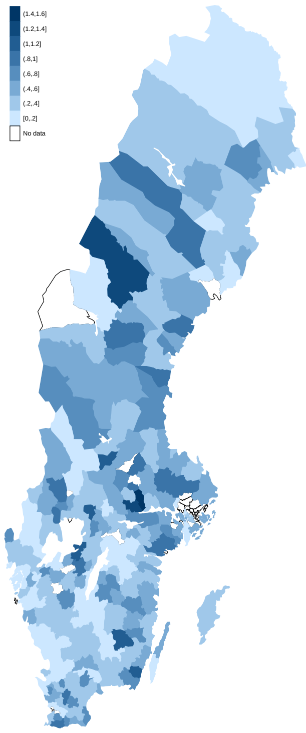


Figure A1. Fluoride levels in Sweden: Variation between municipalities after mapping.

A.2 Data: Individual level

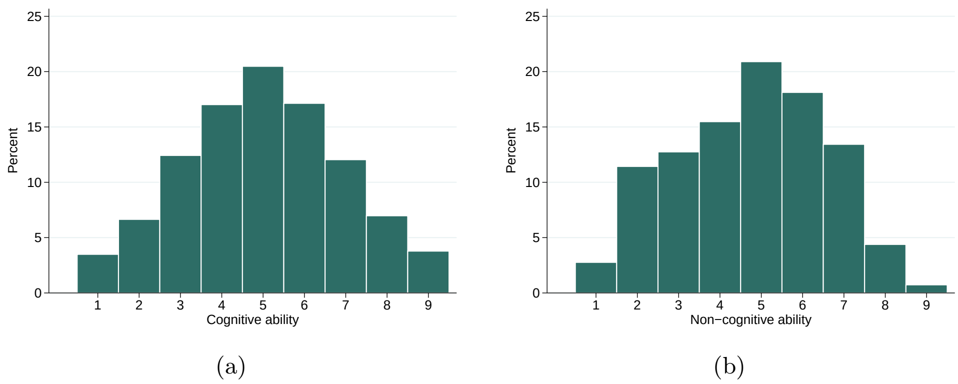


Figure A2. Distribution of cognitive and non-cognitive abilities.

Table A1
Descriptive statistics of dental outcomes

	Mean	SD
ADHD medicine	0.01	0.11
Antidepressants	0.06	0.24
Antipsychotics	0.01	0.10
Mental retardation in childhood	0.12	0.32
Neurological diseases	0.04	0.19
Musculoskeletal diseases	0.13	0.34

A.3 Data: SAMS and cohort level

Table A2
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

A.4 Empirical framework: Balance tests

Our identifying variation stems from a geological variation in fluoride and from individuals' moving patterns. 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. In the following balance test we investigate if the moving patterns are related to the fluoride level between birth and age 16 (the first year for our outcome variables).

Table A3 display 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 tests using dummy variables taking the value 1 if an individual has moved between SAMS within a municipality, if the individual has moved between municipalities, and if the individual has moved between counties. We also run balance tests 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 A3. 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 A3
Balance test. Moving pattern, individual fluoride treatment level

	F. (0.1 mg/l)
Move within municipality	-0.00487 (0.00408)
Municipal Move	0.0000883 (0.00263)
County Move	0.00139 (0.00158)
# moves within municipality	-0.00371 (0.00807)
# moves between municipalities	0.00133 (0.00428)
# moves between counties	0.00240 (0.00223)
Average years SAMS	0.0184 (0.0354)
Average years municipality	-0.0329 (0.0365)
Average year county	-0.0367 (0.0229)
Observations	731,888

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 observations. 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 (566,631 observations).

In Table A4 we investigate whether the municipality provided water is endogenously rerouted to specific groups. We investigate this by running balance tests on predetermined characteristics on the SAMS level for where the individual was born. 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 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 A5 and A6 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 for 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. We have one statistically significant result for the number of water plants within a SAMS. Those SAMS without a water plant 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 A5 and Table A6, 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 A6 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 0.08 mg/l lower. The reader should note 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 A4
Balance test. Predetermined characteristics. Fluoride for each SAMS

	F. (0.1 mg/l)
SAMS area	3.550 (2.523)
Distance WP	0.0803 (0.182)
Not full info	0.000580 (0.0115)
Number WP, SAMS	0.0203*** (0.00710)
Father immigrant	-0.00159 (0.00171)
Mother immigrant	-0.00215 (0.00169)
Both parents immigrants	-0.00119 (0.000971)
Father immigrant outside Nordic	-0.00238* (0.00143)
Mother immigrant outside Nordic	-0.00237* (0.00129)
Both parents immigrant outside Nordic	-0.00136* (0.000807)
Father immigrant outside Europe	-0.00130 (0.000892)
Mother immigrant outside Europe	-0.00120 (0.000823)
Both parent immigrant outside Europe	-0.000762 (0.000541)
Mother's age at birth	-0.0320 (0.0317)
Father's age at birth	-0.0260 (0.0245)
Gender	0.000304 (0.000303)
Adopted	0.000101 (0.000109)

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 observations ranges between 8,023 and 8,597.

Table A5
Fathers

	Fluoride (0.1 mg/l)
1945	-0.8420***
1946	-0.3145***
1947	-0.6139*
1948	0.2294
1949	0.0332
1950	0.5998*
1951	0.5872***
1952	0.0959
1953	-0.4260***
1954	0.0065
1955	0.3217**
1956	0.1253
1957	0.1388*
1958	-0.0244
1959	0.0870
1960	0.0484
1961	0.0525
1962	-0.0331
1963	0.0387
1964	0.0231
1965	0.1123
1966	0.0762
1967	-0.0096
1968	-0.0192
1969	0.0018
1970	0.0057
1971	-0.1015**
1972	-0.0200**
1973	-0.0412**
1974	-0.0116
1975	-0.0167
1976	-0.0326
1977	-0.0390
1978	-0.0127
1979	-0.0267
1980	-0.0143
1981	-0.0285
1982	-0.0304
1983	-0.0273
1984	-0.0451*
1985	-0.0379
1986	-0.0803**
1987	-0.0303*
1988	-0.0204
1989	0.0130
1990	-0.0747*
1991	-0.0365***
1992	0.0721

Notes: Standard errors clustered at the municipal level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. The number of observations are 8,017. Fluoride is dependent variable.

Table A6
Mothers

	Fluoride (0.1 mg/l)
1944	-1.1273***
1945	-2.3393
1946	-0.1197
1947	-0.9070**
1948	-0.1104
1949	1.1819*
1950	-0.0141
1951	0.3395
1952	-0.0574
1953	0.1247
1954	0.2745*
1955	0.0103
1956	-0.0077
1957	0.0382*
1958	-0.1383
1959	-0.0401
1960	0.0325
1961	0.0068
1962	-0.0398
1963	0.0547
1964	0.0487
1965	0.0940
1966	0.0017
1967	-0.0463
1968	-0.0189
1969	0.0537
1970	-0.0108
1971	0.0334
1972	-0.0424
1973	-0.0388
1974	0.0173
1975	-0.0745***
1976	-0.0401*
1977	-0.0323**
1978	-0.0561***
1979	-0.0673
1980	-0.0070
1981	-0.0142
1982	-0.0123
1983	-0.0607**
1984	0.0030
1985	-0.0296*
1986	-0.0271
1987	-0.0267
1988	-0.0110
1989	-0.0186*
1990	-0.0692**
1991	-0.0735**
1992	-0.0375

Notes: Standard errors clustered at the municipal level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. The number of observations are 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 A7, 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 A7
Balance test. Cohorts and sibling order

	F. (0.1 mg/l)
Cohort 1986	0.00691
	(0.0119)
Cohort 1987	-0.00783
	(0.0146)
Cohort 1988	0.00542
	(0.0161)
Cohort 1989	-0.00657
	(0.0154)
Cohort 1990	-0.0360**
	(0.0165)
Cohort 1991	-0.0208
	(0.0180)
Cohort 1992	-0.0744***
	(0.0201)
Sibling order	0.0415*
	(0.0215)

Notes: Standard errors clustered at the municipal level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. The number of observation is 731,888 for the cohorts and 419,558 for the sibling order regression. Fluoride is dependent variable.

Another 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 A8
Balance test. Missing test scores

	F. (0.1 mg/l)
No Cog. ab.	0.000742 (0.000797)
No Non-Cog. ab.	-0.000155 (0.000307)
No math test	-0.000168 (0.000911)

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 376,402 and for the last outcome 569,648.

In Table A10, we have regressed the search intensity (data from Google Trends) on the fluoride level on the county level. The reader should note that Google does not provide data if the number of searches has been too low in an area. We have downloaded data for various search words in Swedish between 2004 and August 2016. More specifically we have run the analysis for *Fluor, Fluor - kemiskt ämne, Dricksvatten* and *Fluorid*. *Fluor* is the Swedish everyday word used for the chemical compound fluoride. *Dricksvatten* is Swedish for Drinking Water.

We only find one statistically significant result. People living in areas with higher fluoride seems use the word for drinking water more in their searches. We do not however find any evidence that they search more for fluoride, which is reassuring. The reader should note that we have no information about the number of searches, meaning that relative search intensity may still be based on very few actual searches.

Table A9 of the sales of bottled water discussed in the empirical framework section is also presented here.

Table A9
Bottled water sales

	Bott. wat. l./inh.
1994	12.13
1995	13.16
1996	13.00
1997	14.31
1998	14.25
1999	16.18
2000	16.95
2001	18.06
2002	19.52
2003	20.76
2004	22.03
2005	25.02
2006	29.34
2007	27.95
2008	23.90
2009	21.91
2010	22.01
2011	22.27
2012	22.43
2013	23.35
2014	24.38
2015	23.50

Notes: This data comes from the Swedish Brewers Association, *Sveriges Bryggerier*.

Table A10
Google searches

	F. (0.1 mg/l)
Drinking water	0.814**
	(0.338)
Fluor, chemical	0.719
	(0.699)
Fluor, search	0.720
	(0.468)
Fluoride	1.329
	(0.805)

Notes: Data from Google trends. Number of observations depends on whether Google Trends display searches for each county. The number of observations ranges between 752 and 8,370. Each outcome has a maximum of 100 and displays the relative search intensity on the county level in Sweden. 50 means that the word was half as popular and 1 means that the search word was 1 percent as popular in comparison to where it was the most popular.

A.5 Results: Effects of fluoride on dental health

Table A11
Unweighted regressions dental outcomes

	CheckUps	DentalSurgery	Orthognathic	Prosthesis	OrthodontReplace	DiCheckUpsEval	DiDentHealth	DiDiseasePain	DiRepairs	DiRehabHab	MedianRemaining	MedianIntact
2013	-0.745**	0.0215	-0.0509*	-0.00810	-0.00641	-0.688**	-0.371*	-0.614**	-0.531***	-0.0208	-0.0127	0.0135
	(0.330)	(0.0451)	(0.0292)	(0.00902)	(0.0280)	(0.302)	(0.205)	(0.262)	(0.193)	(0.0290)	(0.0101)	(0.0194)
2008	-0.714**	-0.0856***	-0.0323*	0.0141	-0.00386	-0.677**	-0.229	-0.120	-0.279***	-0.0116	-0.0718**	-0.0186
	(0.345)	(0.0308)	(0.0169)	(0.0167)	(0.00312)	(0.320)	(0.194)	(0.117)	(0.0722)	(0.0154)	(0.0329)	(0.0449)

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

Table A12
Dental outcomes 2013. Additional specifications. Weighted regressions

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
CheckUps	-0.3635*	-0.0626	-0.0101	-0.0159	0.0227	0.0139	0.0202
	(0.2016)	(0.0550)	(0.0512)	(0.0503)	(0.0388)	(0.0397)	(0.0403)
DentalSurgery	0.0093	-0.0160	-0.0046	-0.0039	-0.0206	-0.0202	-0.0230
	(0.0307)	(0.0125)	(0.0163)	(0.0161)	(0.0151)	(0.0158)	(0.0149)
Orthognathic	-0.0250**	-0.0069*	-0.0075	-0.0076*	-0.0028	-0.0012	-0.0012
	(0.0098)	(0.0038)	(0.0047)	(0.0046)	(0.0043)	(0.0055)	(0.0055)
Prosthesis	-0.0176***	-0.0108***	-0.0161***	-0.0156***	-0.0114***	-0.0094***	-0.0096***
	(0.0043)	(0.0022)	(0.0030)	(0.0030)	(0.0028)	(0.0030)	(0.0030)
OrthodontReplace	-0.0051**	-0.0021*	-0.0031**	-0.0031**	-0.0018	-0.0012	-0.0011
	(0.0024)	(0.0011)	(0.0015)	(0.0015)	(0.0015)	(0.0017)	(0.0017)
DiCheckUpsEval	-0.3032*	-0.0671	-0.0126	-0.0174	0.0062	-0.0042	0.0002
	(0.1685)	(0.0478)	(0.0444)	(0.0438)	(0.0345)	(0.0360)	(0.0364)
DiDentHealth	-0.1990	-0.0252	0.0026	0.0005	0.0017	0.0095	0.0100
	(0.1325)	(0.0305)	(0.0294)	(0.0295)	(0.0232)	(0.0260)	(0.0261)
DiDiseasePain	-0.2500*	-0.0829*	-0.0642	-0.0633	-0.0557*	-0.0605*	-0.0614*
	(0.1396)	(0.0439)	(0.0394)	(0.0396)	(0.0337)	(0.0347)	(0.0348)
DiRepairs	-0.1770*	-0.1034***	-0.1049**	-0.1028**	-0.0973***	-0.0831**	-0.0884**
	(0.0929)	(0.0375)	(0.0449)	(0.0450)	(0.0370)	(0.0391)	(0.0374)
DiRehabHab	-0.0121**	-0.0095***	-0.0114***	-0.0114***	-0.0095***	-0.0082**	-0.0084**
	(0.0050)	(0.0026)	(0.0035)	(0.0035)	(0.0033)	(0.0034)	(0.0034)
MedianRemaining	-0.0172**	-0.0085***	-0.0133***	-0.0128***	-0.0078***	-0.0066***	-0.0065***
	(0.0069)	(0.0021)	(0.0023)	(0.0026)	(0.0018)	(0.0018)	(0.0018)
MedianIntact	-0.0165	-0.0038	-0.0125*	-0.0131*	-0.0049	-0.0058	-0.0045
	(0.0196)	(0.0066)	(0.0076)	(0.0075)	(0.0056)	(0.0055)	(0.0050)
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. 2014	No	Yes	No	No	Yes	Yes	Yes
Sample	All	All	All	All	All	Col 7	All
Observations	720,401	720,401	720,401	720,401	720,401	469,207	469,207

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 469,207 and 725,004.

Table A13

Dental outcomes 2008. Main outcomes. Weighted regressions

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Visit	-2.3819**	-0.0094	-0.0544	-0.1228	0.3412	0.2654	0.3253
	(0.9978)	(0.2545)	(0.3992)	(0.3900)	(0.3377)	(0.3446)	(0.3417)
Repair	-0.4461	-0.3960*	-0.3079	-0.2778	-0.3676	-0.4719	-0.4972
	(0.4539)	(0.2015)	(0.3277)	(0.3278)	(0.2970)	(0.3178)	(0.3098)
RiskEvaluation	-2.5889**	-0.0158	-0.0938	-0.1646	0.3230	0.2402	0.3040
	(1.0831)	(0.2649)	(0.4114)	(0.4011)	(0.3465)	(0.3556)	(0.3562)
DiseasePrevention	-2.7806*	0.2148	0.2625	0.2434	0.1689	0.1820	0.2176
	(1.5433)	(0.2577)	(0.5424)	(0.5425)	(0.3500)	(0.3721)	(0.3665)
DiseaseTreatment	0.7981	0.0019	-0.2339	-0.1992	-0.3082	-0.4745*	-0.4807*
	(0.6791)	(0.1626)	(0.2517)	(0.2506)	(0.2360)	(0.2761)	(0.2755)
RootCanal	-0.1575	-0.0721	-0.1270	-0.1114	-0.0525	-0.0334	-0.0432
	(0.1006)	(0.0481)	(0.0796)	(0.0803)	(0.0720)	(0.0808)	(0.0804)
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. 2014	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 209,468 and 335,687.

Table A14
Dental outcomes 2008. Additional specifications. Weighted regressions

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
CheckUps	-2.8652**	0.1945	0.0302	-0.0574	0.5416	0.4332	0.5130
	(1.2202)	(0.2930)	(0.4519)	(0.4403)	(0.3832)	(0.3935)	(0.3935)
DentalSurgery	-0.2571	-0.2090***	-0.3171***	-0.2915***	-0.3022***	-0.3260***	-0.3415***
	(0.1753)	(0.0784)	(0.1079)	(0.1080)	(0.1062)	(0.1226)	(0.1216)
Orthognathic	-0.1309**	0.0207	-0.0661	-0.0649	0.0040	-0.0086	-0.0060
	(0.0548)	(0.0311)	(0.0403)	(0.0405)	(0.0420)	(0.0503)	(0.0501)
Prosthesis	-0.0251	0.0066	-0.0278	-0.0237	0.0011	0.0232	0.0227
	(0.0379)	(0.0253)	(0.0348)	(0.0349)	(0.0339)	(0.0414)	(0.0413)
OrthodontReplace	-0.0294*	-0.0308***	-0.0392***	-0.0396***	-0.0375***	-0.0388***	-0.0385***
	(0.0162)	(0.0081)	(0.0112)	(0.0112)	(0.0121)	(0.0147)	(0.0147)
DiCheckUpsEval	-2.5889**	-0.0158	-0.0938	-0.1646	0.3230	0.2402	0.3040
	(1.0831)	(0.2649)	(0.4114)	(0.4011)	(0.3465)	(0.3556)	(0.3562)
DiDentHealth	-1.3861	0.3730	0.5994	0.5900	0.2934	0.3275	0.3626
	(1.2635)	(0.2265)	(0.4893)	(0.4889)	(0.2995)	(0.3302)	(0.3269)
DiDiseasePain	-0.7863	-0.1631	-0.5904**	-0.5555*	-0.3587	-0.5330**	-0.5378**
	(0.5878)	(0.1776)	(0.2912)	(0.2902)	(0.2449)	(0.2692)	(0.2688)
DiRepairs	-0.5358	-0.4949**	-0.4261	-0.3908	-0.5116	-0.6089*	-0.6391*
	(0.4692)	(0.2129)	(0.3458)	(0.3460)	(0.3164)	(0.3412)	(0.3311)
DiRehabHab	-0.0636	-0.0266	-0.0427	-0.0426	-0.0289	-0.0059	-0.0067
	(0.0479)	(0.0273)	(0.0386)	(0.0386)	(0.0377)	(0.0466)	(0.0468)
MedianRemaining	-0.4245***	-0.0497***	-0.2175***	-0.2136***	-0.0365**	-0.0283	-0.0295
	(0.1457)	(0.0149)	(0.0590)	(0.0596)	(0.0183)	(0.0209)	(0.0209)
MedianIntact	-0.0759	0.1321***	0.0627	0.0551	0.0901*	0.1057*	0.1168**
	(0.2200)	(0.0369)	(0.0684)	(0.0688)	(0.0517)	(0.0550)	(0.0539)
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. 2014	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 208,245 and 335,687.

In Table A15, we run the dental regressions for older cohorts to investigate further the effect on the median of remaining teeth and the median of intact teeth.[33] In our main analysis, we found effects that sometimes pointed in the opposite direction that we expected. In the analysis below, we use data for older cohorts. This data is only available to us on the municipal level because it is not part of our main dental dataset which only includes cohorts born 1985-1992. The analysis is based on the assumption that those people living in a municipality in 2013 have also lived there for a longer period of time. The results from the analysis should thus be interpreted with caution. We find that the median of intact teeth now points in the expected direction, namely that increased fluoride increases the median of intact teeth in a municipality. This is reassuring given that intact teeth should be more closely related to dental health status that could be affected by fluoride. For remaining teeth we still have results that points in an opposite

33. The data originates from the open data published at the website of The National Board Board of Health and Welfare.

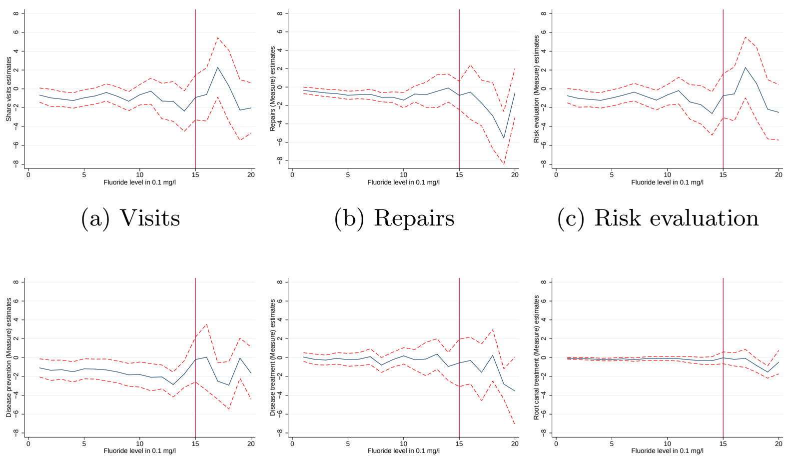
direction than expected. However, no point estimates are statistically significant with the exception of one that is significant at the 10 percent level.

Table A15
Dental outcomes. Older cohorts. Aggregated data

	Remaning teeth	Intact teeth
F. (0.1 mg/l)	-0.0450*	0.0304
	(0.0269)	(0.0247)
F. (0.1 mg/l)	-0.0609	0.0319
	(0.0397)	(0.0234)

Notes: Standard errors clustered at the municipal level. *** p < 0.01, ** p < 0.05, * p < 0.1. First row is for people age 40-90 years old. The second row is for individuals aged 60-90 years old. The dependent variable is displayed at the top of each column. The number of observations are 8,597. The outcome is aggregated and measured at the municipal level.

A.6 Results: Non-linear effects. Dental health

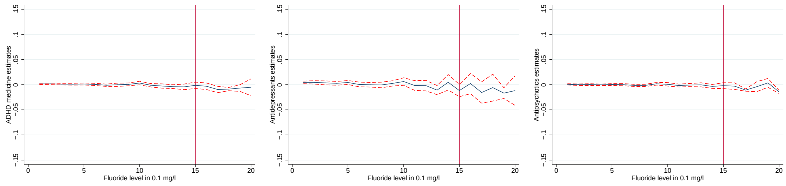


(a) Visits (b) Repairs (c) Risk evaluation

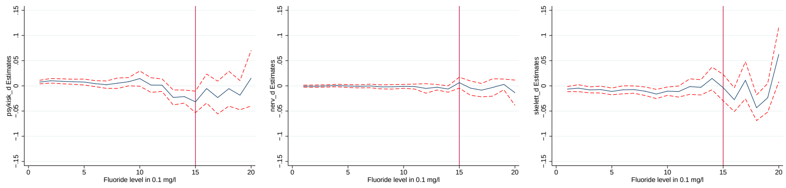
(d) Disease prevention (e) Disease treatment (f) Root canal

Figure A3. Non-linear effects: Dental health estimates.

A.7 Results: Non-linear effects. Additional health outcomes



(a) ADHD medicine (b) Depression medicine (c) Psychiatric medicine



(d) Psychiatric diagnosis (e) Neurological diagnosis (f) Skeletal and muscular diagnosis

FIGURE A4. Non-linear effects: Additional health outcomes estimates.

A.8 Results: Non-linear effects, regression tables. Main outcomes

TABLE A16
Cognitive ability

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Fluoride 2nd quartile	0.1360**	0.0532	0.0505	0.0084	0.0528*	0.0161	0.0402
	(0.0662)	(0.0416)	(0.0421)	(0.0437)	(0.0282)	(0.0510)	(0.0470)
Fluoride 3nd quartile	-0.1649**	-0.0542	-0.0526	-0.0465	-0.0184	-0.0091	-0.0385
	(0.0712)	(0.0341)	(0.0339)	(0.0350)	(0.0256)	(0.0466)	(0.0553)
Fluoride 4nd quartile	0.0099	0.0197	0.0194	-0.0069	0.0042	0.0547	0.1086
	(0.0516)	(0.0262)	(0.0261)	(0.0335)	(0.0263)	(0.0433)	(0.0677)
Mean	5.006726	5.006726	5.006726	5.022206	5.022206	5.089748	4.924601
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	81,776	81,776	81,776	51,203	51,203	20,513	19,178

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

Table A17
Non-cognitive ability

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Fluoride 2nd quartile	-0.0188	-0.0542	-0.0546	-0.0749*	-0.0422	-0.0376	-0.0127
	(0.0656)	(0.0341)	(0.0340)	(0.0388)	(0.0344)	(0.0619)	(0.0623)
Fluoride 3nd quartile	-0.0687	0.0182	0.0186	0.0313	0.0539*	0.0913*	0.0866
	(0.0663)	(0.0313)	(0.0311)	(0.0354)	(0.0304)	(0.0522)	(0.0777)
Fluoride 4nd quartile	0.0608	0.0267	0.0270	0.0273	0.0367	0.0419	0.1574**
	(0.0428)	(0.0255)	(0.0255)	(0.0357)	(0.0331)	(0.0559)	(0.0634)
Mean	4.733996	4.733996	4.733996	4.775411	4.775411	4.921403	4.6953
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	66,375	66,375	66,375	41,636	41,636	16,731	15,425

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

Table A18
Math points

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Fluoride 2nd quartile	-0.0314	-0.2692**	-0.2558*	-0.2558*	-0.3340**	-0.1886*	-0.0878	-0.2538*
	(0.2729)	(0.1348)	(0.1374)	(0.1374)	(0.1328)	(0.0989)	(0.1487)	(0.1513)
Fluoride 3nd quartile	-0.9200***	-0.3043**	-0.3031**	-0.3029**	-0.2915**	-0.1373	0.0764	-0.1384
	(0.3260)	(0.1202)	(0.1187)	(0.1186)	(0.1311)	(0.1045)	(0.1347)	(0.1261)
Fluoride 4nd quartile	0.0789	0.1104	0.1186	0.1186	0.0015	0.0967	-0.0059	0.1525
	(0.2537)	(0.0949)	(0.0965)	(0.0965)	(0.0934)	(0.0929)	(0.1060)	(0.1246)
Mean	26.20586	26.20586	26.20586	26.20586	26.48997	26.48997	27.22212	26.04409
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	499,892	499,892	499,892	499,892	336,827	336,827	139,149	127,062

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

Table A19
Annual log income in SEK

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Fluoride 2nd quartile	-0.0224	0.0074	-0.0210**	-0.0138	-0.0162	-0.0128	0.0073	0.0268
	(0.0290)	(0.0107)	(0.0106)	(0.0100)	(0.0104)	(0.0099)	(0.0196)	(0.0166)
Fluoride 3nd quartile	0.0394	0.0112	0.0065	0.0130	0.0098	0.0122	0.0194	0.0247*
	(0.0255)	(0.0081)	(0.0064)	(0.0119)	(0.0123)	(0.0125)	(0.0197)	(0.0133)
Fluoride 4nd quartile	0.0194	0.0127**	0.0207***	0.0214***	0.0195***	0.0184***	0.0167	0.0022
	(0.0150)	(0.0059)	(0.0057)	(0.0055)	(0.0060)	(0.0059)	(0.0168)	(0.0119)
Mean	11.91243	11.91243	11.91243	11.91243	11.92288	11.92288	11.84519	11.9544
Birth cohort FE	No	No	Yes	Yes	Yes	Yes	Yes	Yes
Birth municipal FE	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Municipal FE, 2014	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	634,793	634,793	634,793	634,793	419,162	419,162	72,089	150,458

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

Table A20
Employment status

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Fluoride 2nd quartile	-0.0052	0.0038	-0.0047	-0.0024	-0.0032	-0.0016	0.0004	0.0104
	(0.0121)	(0.0045)	(0.0044)	(0.0040)	(0.0043)	(0.0040)	(0.0077)	(0.0074)
Fluoride 3nd quartile	0.0107	0.0020	0.0005	0.0027	0.0023	0.0034	-0.0006	0.0119**
	(0.0109)	(0.0034)	(0.0030)	(0.0046)	(0.0045)	(0.0045)	(0.0080)	(0.0056)
Fluoride 4nd quartile	0.0107	0.0074***	0.0098***	0.0113***	0.0104***	0.0098***	0.0121*	0.0072
	(0.0074)	(0.0027)	(0.0028)	(0.0027)	(0.0028)	(0.0027)	(0.0073)	(0.0057)
Mean	.7346382	.7346382	.7346382	.7346382	.7458825	.7458825	.7129002	.7582255
Birth cohort FE	No	No	Yes	Yes	Yes	Yes	Yes	Yes
Birth municipal FE	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Municipal FE, 2014	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	728,074	728,074	728,074	728,074	474,556	474,556	81,867	170,142

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

A.9 Robustness analysis: Analysis with adoptees only

Table A21
Cognitive ability, adopted

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Fluoride up until age 18 (0.1 mg/l)	-0.0207	-0.0451	-0.0472	0.0317	0.0436	-0.1027	-0.2074
	(0.0218)	(0.0645)	(0.0651)	(0.0692)	(0.0782)	(0.3207)	(0.2184)
Mean	4.294677	4.294677	4.294677	4.328671	4.328671	4.160714	4.456522
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	526	526	526	286	286	112	92

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

Table A22
Non-cognitive ability, adopted

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Fluoride up until age 18 (0.1 mg/l)	-0.0271	0.0302	0.0236	-0.0359	-0.0405	-0.1255	-0.0914
	(0.0206)	(0.0648)	(0.0645)	(0.0890)	(0.0878)	(0.2728)	(0.1546)
Mean	4.4914	4.4914	4.4914	4.671233	4.671233	4.592593	4.685714
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	407	407	407	219	219	81	70

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

Table A23
Math points, adopted

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Fluoride up until age 16 (0.1 mg/l)	-0.0387	-0.1384	-0.1467	-0.1488	-0.0992	-0.0913	-0.1310	0.0019
	(0.0934)	(0.1325)	(0.1308)	(0.1310)	(0.1614)	(0.1550)	(0.2505)	(0.3810)
Mean	23.74629	23.74629	23.74629	23.74629	24.07754	24.07754	24.70705	23.52427
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	2,089	2,089	2,089	2,089	1,251	1,251	553	412

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

Table A24
Annual log income, adopted

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Fluoride up until year 2014 (0.1 mg/l)	0.0138**	0.0045	0.0043	-0.0027	0.0008	-0.0008	0.0720	-0.0115
	(0.0070)	(0.0092)	(0.0090)	(0.0104)	(0.0136)	(0.0139)	(0.0554)	(0.0411)
Mean	11.86561	11.86561	11.86561	11.86561	11.85763	11.85763	11.69303	11.8584
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 2014	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	3,176	3,176	3,176	3,176	1,714	1,714	306	565

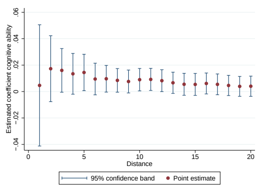
Notes: Standard errors clustered at the municipal level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table A25
Employment status, adopted

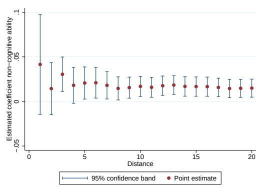
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Fluoride up until year 2014 (0.1 mg/l)	0.0013	-0.0005	-0.0008	-0.0004	0.0059	0.0061	0.0110	0.0116
	(0.0026)	(0.0045)	(0.0044)	(0.0046)	(0.0062)	(0.0064)	(0.0206)	(0.0087)
Mean	.7005768	.7005768	.7005768	.7005768	.696837	.696837	.6005435	.7016248
Birth cohort FE	No	No	Yes	Yes	Yes	Yes	Yes	Yes
Birth municipal FE	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Municipal FE, year 2014	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	3,814	3,814	3,814	3,814	2,055	2,055	368	677

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

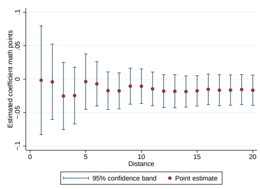
A.10 Robustness analysis: Distance of SAMS



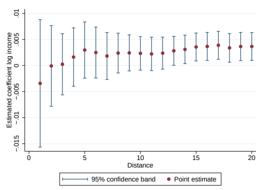
(a) Cognitive ability



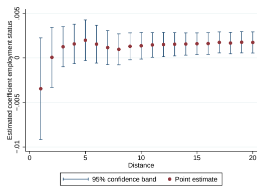
(b) Non-Cognitive ability



(c) Math points



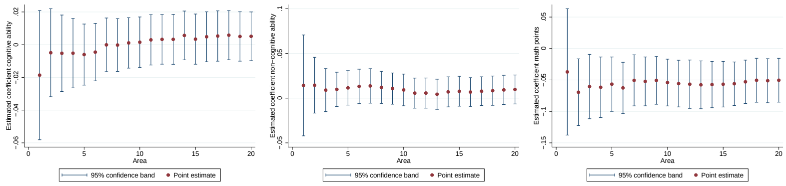
(d) Annual log income



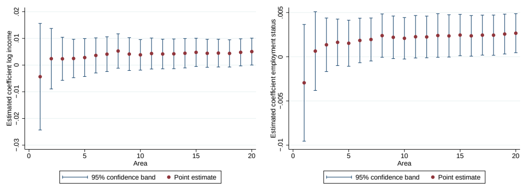
(e) Employment status

Figure A5. 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.11 Robustness analysis: Area of SAMS



(a) Cognitive ability (b) Non-Cognitive ability (c) Math points



(d) Annual log income (e) Employment status

FIGURE A6. Estimates for different geographical areas SAMS. The X-axis corresponds to areas in square kilometers.

A.12 Robustness analysis: Confirmed water source

TABLE A26
Cognitive ability, confirmed water source since 1985

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Fluoride up until age 18 (0.1 mg/l)	-0.0187*	0.0091	0.0087	0.0122	0.0176**	0.0025	0.0375**
	(0.0109)	(0.0081)	(0.0080)	(0.0077)	(0.0084)	(0.0087)	(0.0187)
Mean	4.974421	4.974421	4.974421	4.972386	4.972386	5.078782	4.862705
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	18,922	18,922	18,922	12,204	12,204	6,042	5,317

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

TABLE A27
Non-cognitive ability, confirmed water source since 1985

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Fluoride up until age 18 (0.1 mg/l)	-0.0038	0.0086	0.0086	0.0165	0.0248	0.0234*	0.0192
	(0.0096)	(0.0121)	(0.0121)	(0.0147)	(0.0154)	(0.0123)	(0.0276)
Mean	4.77522	4.77522	4.77522	4.817776	4.817776	4.951318	4.670572
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	15,246	15,246	15,246	9,856	9,856	4,930	4,268

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

Table A28
Math points, confirmed water source since 1985

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Fluoride up until age 16 (0.1 mg/l)	-0.2401***	-0.0423	-0.0436	-0.0437	-0.0629**	-0.0182	0.0027	-0.0480
	(0.0558)	(0.0288)	(0.0270)	(0.0270)	(0.0282)	(0.0261)	(0.0249)	(0.0366)
Mean	26.35896	26.35896	26.35896	26.35896	26.53781	26.53781	27.26578	25.83514
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	113,378	113,378	113,378	113,378	79,497	79,497	40,402	34,618

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

Table A29
Annual log income, confirmed water source since 1985

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Fluoride up until year 2014 (0.1 mg/l)	0.0057	0.0012	0.0028*	0.0027*	0.0011	0.0010	0.0047	0.0037
	(0.0042)	(0.0018)	(0.0015)	(0.0017)	(0.0020)	(0.0020)	(0.0036)	(0.0029)
Mean	11.94695	11.94695	11.94695	11.94695	11.95188	11.95188	11.84664	11.97675
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 2014	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	145,385	145,385	145,385	145,385	99,557	99,557	20,511	40,975

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

Table A30
Employment status, confirmed water source since 1985

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Fluoride up until year 2014 (0.1 mg/l)	0.0020	0.0008	0.0012*	0.0013	0.0007	0.0007	0.0013	0.0029*
	(0.0019)	(0.0007)	(0.0007)	(0.0009)	(0.0011)	(0.0011)	(0.0012)	(0.0016)
Mean	.7524632	.7524632	.7524632	.7524632	.7609301	.7609301	.712957	.7686438
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 2014	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	164,626	164,626	164,626	164,626	111,641	111,641	23,223	46,262

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

A.13 Robustness analysis: Only those born in 1985

Table A31
Annual log income, cohort 1985

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Fluoride up until year 2014 (0.1 mg/l)	-0.0014	-0.0027	-0.0027	0.0027	0.0020	0.0029	-0.0030	-0.0018
	(0.0015)	(0.0019)	(0.0019)	(0.0021)	(0.0025)	(0.0025)	(0.0150)	(0.0078)
Mean	12.22359	12.22359	12.22359	12.22359	12.23666	12.23666	12.25366	12.24548
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 2014	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	70,114	70,114	70,114	70,114	41,544	41,544	1,977	13,083

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

Table A32
Employment status, cohort 1985

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Fluoride up until year 2014 (0.1 mg/l)	0.0007	0.0001	0.0001	0.0018**	0.0013	0.0016	-0.0007	0.0047**
	(0.0009)	(0.0008)	(0.0008)	(0.0009)	(0.0010)	(0.0010)	(0.0041)	(0.0021)
Mean	.8374533	.8374533	.8374533	.8374533	.8529284	.8529284	.8105082	.8553713
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 2014	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	79,005	79,005	79,005	79,005	46,168	46,168	2,322	14,596

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

A.14 Robustness analysis: Confirmed water source and only one water plant within SAMS, non-movers

Table A33
Cognitive ability

	(1)	(2)	(3)	(4)	(5)
Fluoride up until age 18 (0.1 mg/l)	-0.0188	0.0123	0.0120	0.0091	0.0091
	(0.0111)*	(0.0168)	(0.0165)	(0.0180)	(0.0180)
Mean	4.9905	4.9905	4.9905	4.9144	4.9144
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	1992	1992	1992	1285	1285

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

Table A34
Non-cognitive ability

	(1)	(2)	(3)	(4)	(5)
Fluoride up until age 18 (0.1 mg/l)	-0.0134	0.0071	0.0073	0.0137	0.0137
	(0.0136)	(0.0134)	(0.0134)	(0.0182)	(0.0182)
Mean	4.8369	4.8369	4.8369	4.8711	4.8711
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	1,625	1,625	1,625	1,055	1,055

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

Table A35
Math points

	(1)	(2)	(3)	(4)	(5)	(6)
Fluoride up until age 16 (0.1 mg/l)	-0.0457	0.0463	0.0412	0.0408	0.0104	0.0036
	(0.0192)**	(0.0273)*	(0.0270)	(0.0270)	(0.0298)	(0.0247)
Mean	26.6661	26.6661	26.6661	26.6661	26.8053	26.8053
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	12,661	12,661	12,661	12,661	9,164	9,164

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

Table A36
Annual log income

	(1)	(2)	(3)	(4)	(5)	(6)
Fluoride up until year 2014 (0.1 mg/l)	-0.0042	0.0022	0.0026	0.0024	0.0020	0.0029
	(0.0048)	(0.0045)	(0.0044)	(0.0039)	(0.0060)	(0.0060)
Mean	11.9282	11.9282	11.9282	11.9282	11.9345	11.9345
Birth cohort FE	No	No	Yes	Yes	Yes	Yes
Birth municipal FE	No	Yes	Yes	Yes	Yes	Yes
Municipal FE, year 2014	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	6,955	6,955	6,955	6,955	5,035	5,035

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

Table A37
Employment status

	(1)	(2)	(3)	(4)	(5)	(6)
Fluoride up until year 2014 (0.1 mg/l)	-0.0013	-0.0009	-0.0009	-0.0010	-0.0008	-0.0007
	(0.0012)	(0.0018)	(0.0019)	(0.0018)	(0.0019)	(0.0018)
Mean	0.7474	0.7474	0.7474	0.7474	0.7502	0.7502
Birth cohort FE	No	No	Yes	Yes	Yes	Yes
Birth municipal FE	No	Yes	Yes	Yes	Yes	Yes
Municipal FE, year 2014	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	7,802	7,802	7,802	7,802	5,616	5,616

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

A.15 Robustness analysis: Alternative income measure

Table A38
Log income, "förvärvsinkomst"

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Fluoride up until year 2014 (0.1 mg/l)	0.0063*	0.0040**	0.0046***	0.0045***	0.0034**	0.0034**	0.0034*	0.0013
	(0.0035)	(0.0017)	(0.0016)	(0.0017)	(0.0015)	(0.0013)	(0.0021)	(0.0042)
Mean	11.99991	11.99991	11.99991	11.99991	12.01073	12.01073	11.88782	12.04571
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 2014	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	641,629	641,629	641,629	641,629	423,411	423,411	72,861	151,885

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

A.16 Robustness analysis: Analysis with sibling fixed effects

Table A39
Cognitive ability

	(1)	(2)	(3)	(4)	(5)
Fluoride up until age 18 (0.1 mg/l)	-0.2302	-0.2354	-0.2074	-0.3170	-0.2894
	(0.6207)	(0.7068)	(0.6598)	(0.8508)	(0.8524)
Mean	5.049126	5.049126	5.049126	5.096304	5.096304
Birth cohort FE	No	No	Yes	Yes	Yes
Birth municipal FE	No	Yes	Yes	Yes	Yes
Large set covariates	No	No	No	No	Yes
Sample	All	All	All	Col 5	All
Observations	46,208	46,208	46,208	32,439	32,439

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

Table A40
Non-cognitive ability

	(1)	(2)	(3)	(4)	(5)
Fluoride up until age 18 (0.1 mg/l)	-0.3620	-0.2547	-0.2314	-0.2583	-0.2316
	(0.9665)	(1.0682)	(1.0435)	(1.4663)	(1.3804)
Mean	4.775179	4.775179	4.775179	4.826302	4.826302
Birth cohort FE	No	No	Yes	Yes	Yes
Birth municipal FE	No	Yes	Yes	Yes	Yes
Large set covariates	No	No	No	No	Yes
Sample	All	All	All	Col 5	All
Observations	37,492	37,492	37,492	26,454	26,454

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

Table A41
Math points

	(1)	(2)	(3)	(4)	(5)	(6)
Fluoride up until age 16 (0.1 mg/l)	0.1369	0.0802	0.0554	0.0553	0.0912	0.1062
	(0.1527)	(0.1656)	(0.1688)	(0.1689)	(0.2073)	(0.2019)
Mean	26.23297	26.23297	26.23297	26.23297	26.50438	26.50438
Birth cohort FE	No	No	Yes	Yes	Yes	Yes
Municipal FE, age 0-16	No	Yes	Yes	Yes	Yes	Yes
Small set covariates	No	No	No	Yes	Yes	Yes
Large set covariates	No	No	No	No	No	Yes
Sample	All	All	All	All	Col 6	All
Observations	306,834	306,834	306,834	306,834	216,311	216,311

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

Table A42
Annual log income

	(1)	(2)	(3)	(4)	(5)	(6)
Fluoride up until year 2014 (0.1 mg/l)	-0.0421***	-0.0393***	-0.0130**	-0.0088	-0.0098	-0.0100
	(0.0075)	(0.0071)	(0.0065)	(0.0093)	(0.0088)	(0.0088)
Mean	11.92662	11.92662	11.92662	11.92662	11.94066	11.94066
Birth cohort FE	No	No	Yes	Yes	Yes	Yes
Birth municipal FE	No	Yes	Yes	Yes	Yes	Yes
Municipal FE, year 2014	No	No	No	Yes	Yes	Yes
Small set covariates	No	No	No	Yes	Yes	Yes
Large set covariates	No	No	No	No	No	Yes
Sample	All	All	All	All	Col 6	All
Observations	380,077	380,077	380,077	380,077	267,436	267,436

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

Table A43
Employment status

	(1)	(2)	(3)	(4)	(5)	(6)
Fluoride up until year 2014 (0.1 mg/l)	-0.0171***	-0.0161***	-0.0081***	-0.0039	-0.0029	-0.0029
	(0.0029)	(0.0029)	(0.0026)	(0.0033)	(0.0033)	(0.0033)
Mean	.7415351	.7415351	.7415351	.7415351	.7523387	.7523387
Birth cohort FE	No	No	Yes	Yes	Yes	Yes
Birth municipal FE	No	Yes	Yes	Yes	Yes	Yes
Municipal FE, year 2014	No	No	No	Yes	Yes	Yes
Small set covariates	No	No	No	Yes	Yes	Yes
Large set covariates	No	No	No	No	No	Yes
Sample	All	All	All	All	Col 6	All
Observations	433,587	433,587	433,587	433,587	301,666	301,666

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

A.17 ATC-codes and diagnostic codes

Table A44 and A45 This is a list for the ATC-codes and the diagnostic codes (on the chapter level) we have used for our health outcomes.

Table A44
ATC codes for medicines

Medicine	ATC
ADHD	N06B
Antidepressants	N06A
Neuroleptics	N05A

Table A45
ICD codes for diagnoses

Diagnosis	ICD10
Psychiatric	F
Neurological	G
Skeleton and muscular	M