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The Effects of Fluoride in the Drinking Water

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The Effects of Fluoride In The Drinking Water[a]

by

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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 throughout life on cognitive and non-cognitive ability, math test scores and labor market outcomes in a large-scale setting. We use a rich Swedish register dataset for the cohorts born 1985–1992 in the main analysis, 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. Taking all together, 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 math test scores for fluoride levels in Swedish drinking water. Third, we find that fluoride improves later labor market outcomes, which indicates that good dental health is a positive factor on the labor market.

Keywords: Fluoride, Cognitive development, Labor market outcomes, Dental health
JEL-codes: 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 a much discussed literature of potential negative side effects of long-term fluoride exposure for lower levels on cognitive development. The hypothesis is that fluoride might function as a neurotoxin.

In contrast to dental products, drinking water containing fluoride is ingested, meaning that everyone drinking water is exposed to fluoride continuously. In this paper we investigate the causal effect of fluoride exposure through the drinking water on cognitive and non-cognitive ability, math test scores 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 also study its effect on other related health outcomes. We use a unique register dataset from Sweden together with drinking water fluoride data, where we exploit intra-municipality variation in fluoride and moving patterns to estimate the effect.

Earlier epidemiological studies have found evidence of negative side effects of fluoride, and the results have sparked a public debate regarding the potential dangers associated with fluoride in the water (e.g. Johnston 2014 in The Telegraph; Mercola 2013 in The Huffington Post).[1] A meta-study by Choi et al. (2012) from Harvard School of Public Health reviewed several earlier 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. The data from the reviewed papers originated from China and Iran (and several of the papers were not written in English). Many of these papers considered very high levels of fluoride which surpasses the recommendation from the World Health Organization (WHO) that fluoride should not exceed 1.5 mg/l in the drinking water (WHO 2011, p.42). However, some of the studies reported negative effects on cognitive development

[1] Lamberg et al. (1997) find evidence that people tend to be concerned with fluoridation. Local authorities in Finland announced to stop water fluoridation at a given date, but, in fact, ceased one month earlier without informing the public. However, people still reported symptoms.

for levels below the recommended level. This is a cause for concern because these levels are present naturally in the drinking water in many parts of the world. Countries that fluoridate the drinking water also have fluoride within this range. Common problems with the studies reviewed by Choi et al. (2012) are that the analyses were based on small samples with less good data quality.[2]

There are, however, other studies that point in the other direction. Broadbent et al. (2015) follows approximately 1,000 individuals in an observational study from New Zeeland, where they measure IQ several times throughout life. The authors find no negative effect on IQ from living in an area in the city of Dunedin with artificial fluoridation. Our objection against this study is that artificial water fluoridation may be an endogenous policy variable, given that certain areas in Dunedin did have artificial water fluoridation and some did not. 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. Water fluoridation is a result of a policy choice, making the identification less clear.[3] Barberio et al. (2017) neither found any association between fluoride exposure and learning disabilities. Their outcome variables were however parental or self-reported in a survey whereas our cognitive and health measures originates from registers with a much larger data sample.

It is possible that fluoride in the drinking water has negative side effects on cognitive ability, but the overall economic effect 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.

This paper is to our knowledge the first to study the effects of fluoride in a large-scale set-up with individual register data and with plausible exogenous variation in fluoride exposure. We also have the possibility to investigate the effect of fluoride on several

[2] See Tang et al. (2008) for an earlier meta-study, which also show a negative relation between fluoride and IQ, and Valdez-Jiménez et al. (2011) for a discussion. Epidemiological papers published after or around Choi et al. (2012) include Ding et al. (2011), Saxena et al. (2012), Seraj et al. (2012), Nagarajappa et al. (2013), Ramesh et al. (2014), Khan et al. (2015), Sebastian and Sunitha (2015), Kundu et al. (2015), Choi et al. (2015), Das and Mondal (2016), Dey and Giri (2016), Aravind et al. (2016), Mondal et al. (2016), Sharma et al. (2016), Jiménez et al. (2017), Razdan et al. (2017) and Bashash et al. (2017) 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.

[3] Näsman 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 et al. (2016) use the same dataset to study the effects on myocardial infarctions and find no effects on this outcome either.

new outcome variables. 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, where the absolute majority of the Swedish water plants has fluoride levels below 1.5 mg/l. Swedish drinking water fluoride levels vary within municipalities which we exploit to estimate the casual effect. In comparison to China and Iran, Sweden has likely a more 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 large problem unless the level exceeds 1.5 mg/l. Since our data include a variation in fluoride in the lower spectra, our results are 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 difference between artificially fluoridated drinking water and water with a natural occurrence of fluoride (John 2002; Harrison 2005), meaning that our results should be valid for countries with comparable artificial fluoride levels.

As economists, we are interested in the connection between fluoride and its long-term effects 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.

All in all, our results confirm the positive relationship between fluoride and dental health. However, in contrast to many earlier epidemiological studies, we find zero-effects in the main analysis on outcomes connected to cognitive development (cognitive ability, non-cognitive ability and math test scores). Our point estimates with regard to cognitive ability are much more precisely estimated compared to earlier studies and always close to zero. We find 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 subsection we review related papers which have not necessarily studied fluoride but which are connected to the literature of early determinants for health and human capital development. Then follows a short medical background and a discussion on the conceptual framework. Our identification strategy is mainly based upon the variation in fluoride which stems from an exogenous variation in the bedrock, so in section 3, we present the necessary geological background. In section 4, we describe our data material. Our identification strategy and econometric set-up are discussed in section 5 followed by descriptive statistics. The empirical results are then presented, next we discuss our robustness checks, followed by a discussion and a conclusion.

1.1 Related literature on determinants for health and human capital

In this section we review the literature regarding early determinants after birth for health and human capital and their long-run effects. We focus on papers that have studied drinking water.

Health during childhood is an important determinant for success on the labor market (Currie 2009; Currie and Almond 2011).[4] Case et al. (2002) and Currie and Stabile (2003) provide evidence for the connection between health and socioeconomic status. Case et al. (2005) present the conclusion that health during one's early years seems to be connected to (among others) socioeconomic status and one's education once becoming an adult. Smith (2009) has also demonstrated this link empirically, and found that poor health before age 16 is negatively associated with future income, wealth and labor supply. Currie et al. (2010) also finds that health during childhood has long-term consequences on educational attainment among others.

Cognitive development is part of individuals' health, and earlier research have shown that cognitive ability and non-cognitive ability are very adequate explanatory variables for basically everything that we consider as positive individual labor market outcomes (e.g. Heckman et al. 2006, Lindqvist and Vestman 2011). Cunha and Heckman (2007) create a theoretical model concerning cognitive and non-cognitive ability and Cunha and Heckman (2009) emphasize that there are "critical" and "sensitive" windows when cognitive and non-cognitive abilities are more affected by environmental factors (see also Cunha et al. 2010). According to the authors both cognitive and non-cognitive ability are very important factors for later achievements in life. This view is confirmed in 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]

Some earlier papers in economics have particularly focused on potential environmental hazards. Let us turn our attention to those who have focused on drinking water. Currie et al. (2013) study the effect of mothers' consumption of polluted drinking water (broadly

[4] See also Currie (2011) and Zivin and Neidell (2013).

[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.

defined) during pregnancy on birth weight of the offspring. 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 et al. (2005) study whether privatization of water supply in Argentina improved water quality, and find that child 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. Ferrie et al. (2012) is another paper on lead exposure through the drinking water where the authors apply conscription data from World War II. They find that those who have lived in an area with lead water pipes in 1930 had approximately a third of a standard deviation lower test score on the Army General Classification Test when enlisting.

Other than drinking water hazards, earlier researchers have foremost investigated whether air pollution has long terms effects on adult health and cognitive development, where Currie et al. (2014) review the economic literature on the subject. Many of the earlier papers on air pollution have also focused on lead where Grönqvist et al. (2017) uses similar Swedish register data as we do and find that exposure to lead during childhood has negative effects on future adult outcomes.[7]

2 Medical background and conceptual framework

In this section we review the medical discussion about fluoride and its effects on health. We also discuss how we should think about fluoride from a policy perspective.

Sodium fluoride (NaF), from now on called fluoride, is a toxic compound which exists naturally in the environment. WHO acknowledges 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

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

[7] Skerfving et al. (2015) applies Swedish register data and finds that those who had higher lead levels in the blood as children also received lower grades and lower points on the conscription test. Lead levels in the blood for children were only available for a subset of the Swedish population residing in two cities. Jans et al. (2014) study air pollutants' effect on health with Swedish register data. Aizer et al. (2016) study variation in lead in buildings in Rhode Island and find significant positive effects on children's reading test score in third grade for lower lead levels. Rau et al. (2015) finds that the proximity to toxic waste (where lead was one component) reduces test score among children in Chile.

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 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. Pulungan et al. (2016) found on the other hand that rats' memory was not effected by fluoride exposure. 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 (see Twetman et al. (2003) and Griffin et al. (2007) for reviews).[8] For that reason, fluoride is added to dental products 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).[9]

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. WHO believes that fluoride only has adverse effects above the threshold level of 1.5 mg/l (WHO

[8] The review of Sicca et al. (2016) indicate however that water fluoridation might not be an effective measure to reduce dental caries.

[9] In Sweden, some school children were treated with fluoride rinse by the so called *"fluortanten"*. We have no data on this public health measure. Fluoride rinse and other dental products are however not ingested making them not directly equivalent to fluoride in the drinking water.

2004). In light of recent epidemiological findings discussed in the introduction this stipulated threshold could be questioned.

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 large with only a small negative effect on cognitive ability, the net effect could still be positive. The policy maker must thus 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. We investigate whether the potential dangerous threshold level of fluoride exist in the Swedish drinking water. Based on this, it is possible to do a cost-benefit analysis of the optimal fluoride level if it 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 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.

3 Geological background and exogenous variation in fluoride

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 typically contains low levels of fluoride (Edmunds and Smedley 2013, p.313).[10] 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

[10] 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.

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.[11]

Each municipality in Sweden is responsible for the public drinking water. Because municipalities often have different water sources, there is often a within-municipality variation in fluoride.[12]

The municipalities are 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 of 520. There are approximately 9,000 SAMS in Sweden in comparison to 290 municipalities.[13] The large majority in Sweden drinks water from the municipal water plants. However, some individuals have private wells for which we do not have data. Approximately 1.2 million people of Sweden's total population of approximately 10 million drink water from private wells (Livsmedelsverket 2015a).

We have information on fluoride levels for the outgoing drinking water from the water plants supervised by the municipalities. There are 1,726 such water plants in our final data where we have manually designated proxy coordinates for the water plants based on the information we have from SGU (The Geological Survey of Sweden) and from the municipalities (our two data sources for the fluoride data; we return to our data sources in the data section below).[14] In total, data from 261 municipalities are included in the empirical analysis.[15]

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 in the table is soil bedrock and we include dummies for the other

[11] 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.

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

[13] 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 public's mind.

[14] We cannot observe the exact location for the water plants, meaning that we have manually placed a coordinate based on the name or information of the water plant in the corresponding city, village or equivalent.

[15] 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. These include several municipalities in the county of Stockholm.

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.

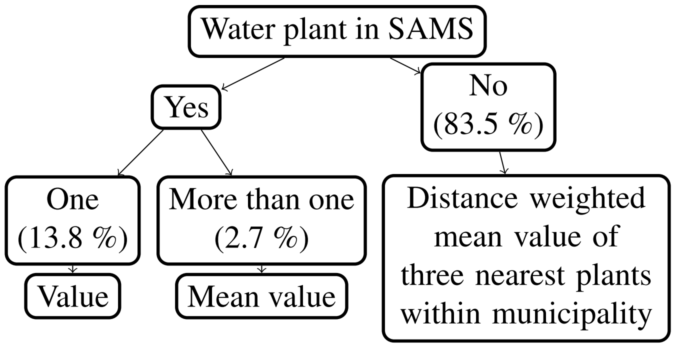


Figure 1: Water plants mapping. Percentage of SAMS in parenthesis.

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.

We know in which SAMS an individual lived for a given year, but we cannot observe the exact geographical coordinate for the location. Thus, we need a mapping protocol for how to assign fluoride data for each SAMS.[16] We map the fluoride level to SAMS using the mapping protocol illustrated in *Figure 1*. We indicate the share of SAMS in each category 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

[16] 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.

assign a mean of the fluoride level for the three closest water plants within that municipality (triangular polygon) using the inverse distance as a weight. This mapping strategy means that we have measurement error in our fluoride variable, where the measurement error likely to be classic. Such a measurement error induces noise to the variable where the estimates including the variable will be biased towards zero. Because of this, it is very important to assess the mapping strategy. This is done by first looking at the effect of fluoride on dental outcomes for which we expect to see an positive effect of fluoride. This analysis also serve the purpose of investigating whether the treatment is strong enough for estimating any effects on human health and other outcome variables.

Figure 2a 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 2b* shows the variation in fluoride between SAMS after our mapping.[17]

4 Data

We have register data at the individual level for all outcomes and covariates except dental health, and observe place of residence for all individuals of age 16 and older on the SAMS level. This means that individuals must exist in Swedish registers at age 16 in order to be included in our analysis.[18] We track the individual's place of residence before age 16 by linking them to their parents, and use the mother's place of residence as a proxy. The treatment period of fluoride consumption spans between birth and up till the year when we measure the outcome.[19] The main analysis include cohorts born between 1985 and 1992. 1985 is the first year we may observe place of residence on the SAMS level. We exclude individuals that have immigrated to Sweden during childhood since we need to track their fluoride level from birth.

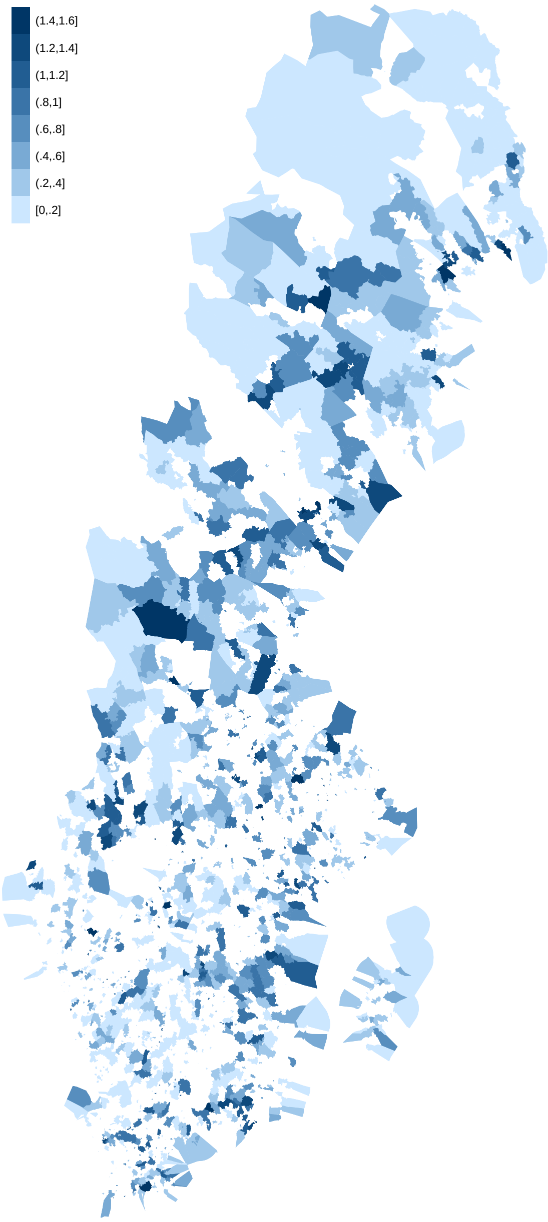
4.1 Fluoride data

Fluoride data is measured for each water plant. 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 dataset that has the earliest available drinking water data for a given municipality. The SGU data

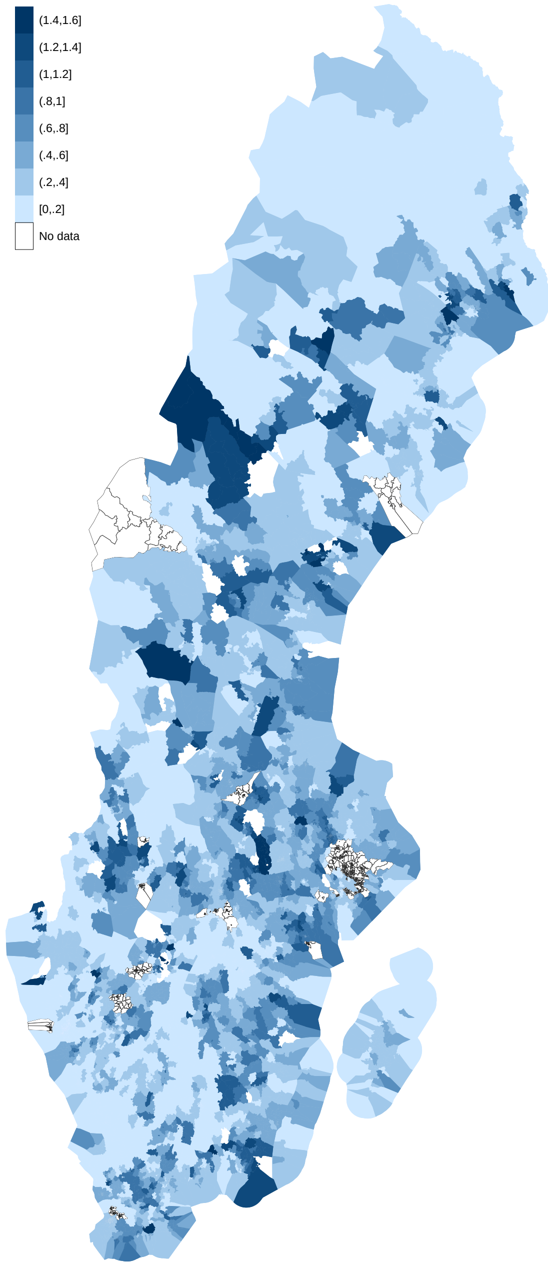
[17] The reader should note that a SAMS area also include some part of the sea. Therefore, the shapes of Öland and Gotland looks a bit odd in the two maps.

[18] Note that this means that many immigrants are are not included in our analysis. 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.

[19] There are some inconsistencies in the register data affecting which individuals are included in the dataset. For example, we have dropped all individuals with multiple birth years, duplicate observations, individuals not in both the LOUISE database and the multigenerational database, and individuals where we cannot identify the mother.



(***a***) SAMS with at least one water plant



(***b***) Final mapping

Figure 2: Mapping of fluoride data.

starts in 1998. For some municipalities data is only available for later years. We have contacted each of Swedens 290 municipalities to complement the SGU dataset. We asked the municipalities to provide us with additional fluoride data from 1985. If data were not available, we asked them whether they have changed any of their water sources since 1985.[20] 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. 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 that this means that we also collapse the data set for the very few cases where purification has been installed.[21] 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.

4.2 Aggregated dental health data

The dental health data is only available on the SAMS level for each cohort for the years 2008 and 2013, and comes from The National Board of Health and Welfare. The fluoride treatment period hence begins at birth and ends in 2008 and 2013 respectively.[22] Our dental health data can be grouped into five main categories: Dental health variables related to visits at a dental clinic, variables related to dental health examinations, variables related to various types of dental repairs, the median of intact teeth and the median of remaining teeth.

[20] In the robustness analysis we run very conservative specifications in which only municipalities that we know have used the same water source since 1985 are included.

[21] 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 were recommended to drink such water with moderation. There is still such a recommendation in place for private wells (Livsmedelsverket 2001, 2015b).

[22] Admittedly, the effect of fluoride exposure through the drinking water in early life should have small effect on adult dental health given that humans have primary teeth. We have however chosen that fluoride treatment begins by birth since we cannot observe in data when a person has received regular teeth and we want to keep the same first time period for fluoride treatment as our other outcome variables.

4.3 Individual level data for all other variables

The first variable we use to measure cognitive development is the results from the national test taken at around age 16 in ninth grade. 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 originates from the Swedish military enlistment. For more detailed information about the enlistment, see Lindqvist and Vestman (2011) and Öhman (2015). Conscription was mandatory 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. 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. 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, 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. The problem is if some individuals do not take the test seriously because this would induce non-classical measurement error. However, the Stanine distribution is relative to others enlisting in the same year (see *Figure A1* in the appendix). Because enlistment was less strict, those who actually enlisted and took all tests were likely those who were more interested in doing military service, meaning that most of them did have incentives to perform well. The remaining problem is whether these individuals are representative for the entire population. We can look at the correlation between this test score and the test score for the same individual on the national math test. For the latter outcome, the individual has clear incentives to perform well since final grade in math from ninth grade depends on this test result. The correlation between these two tests is 0.43.

With regards to labor market outcomes, we have income which is measured in 2014

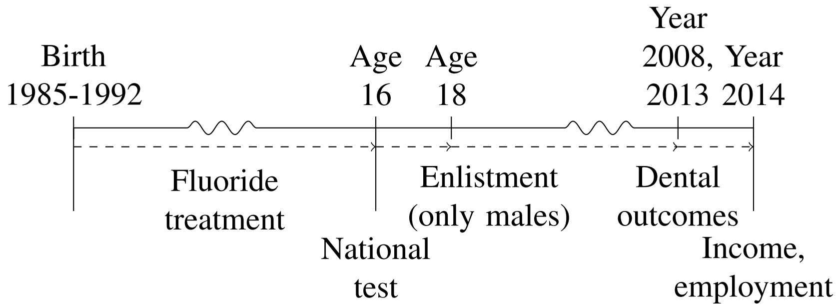


Figure 3: Timeline of measurement.

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 $125 in 2017) during a year for this outcome. The reason for this is that we want to study the effect on non-negligble income levels. 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. *Figure 3* illustrates the timing of measurements.

In the appendix we also run analysis on health outcomes to extend the analysis. For more information on this, see section A6 in the appendix.

5 Empirical framework

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.

Our goal is to estimate the causal effect of fluoride exposure through the drinking water on dental health, cognitive ability, non-cognitive ability, math test scores, income, and employment status. Formally, we would like to estimate $Y_i(X_i)$, where Y_i is the outcome and X_i is the treatment level of one specific unit of fluoride. In terms of the potential outcomes framework, the average partial effect is

$$\frac{1}{N}\sum_{i=1}^{N} Y_i(X_i) - Y_i(X_i - 1).$$

The problem is that we cannot observe $Y_i(X_i - 1)$, i.e., the effect on the outcome for individual i if exposed to 1 unit less fluoride. The ideal empirical strategy to estimate such an effect would be to run a controlled experiment where the fluoride levels are randomized on the individual level. Such an experiment would yield maximal internal validity since the treatment level is independent of the outcomes which eliminates self-selection.

It is however not possible to randomly assign fluoride intake from birth on an individual level in a large scale set-up. Instead, we argue that the geological variation in the bedrock which results in different natural fluoride levels constitute a natural experiment. 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 geological variation in the bedrock.

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 yields an exogenous variation in the intensity of fluoride treatment which depends on the number of years spent 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 and colorless. We confirm that the choice to move is not dependent on the fluoride level in various tests in *Table A2* presented in section A2 in the appendix. We also use data from Google Trends in *Table A9* and conclude that there is no clear evidence that people overall search for more information about fluoride in those regions where the fluoride level is higher.

5.1 Threats to identification

In this subsection we address potential threats to our identification strategy. The discussion is further extended in section A2 in the appendix.

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

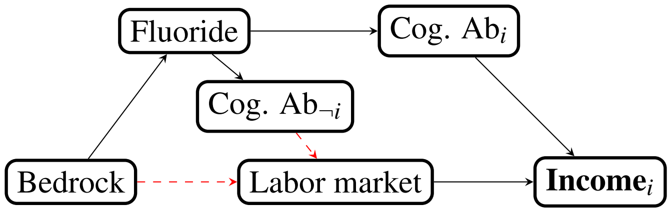


Figure 4: Relationships between the bedrock, fluoride level, cognitive ability and income.

the regional labor market and, hence, the labor market outcome for a specific individual. *Figure 4* illustrates the main identification problem in this setting using the long-run outcome income as an example. 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 4* are blocked.

A second threat to identification would be that municipalities deliberately provide certain SAMS with fluoridated water because municipalities have some inside information about the dangers of fluoride. We demonstrate in *Table A3–Table A6* in the appendix by investigating background variables that this is not the case. There is no evidence that the 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 A8* in the appendix displays 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 1,460 liters per person. The share of bottled water sales is thus only 1.4-2.8 percent of total yearly consumption of water.[23]

A fourth threat would be that individuals exposed to low levels of fluoride in the drinking water compensate by consuming or being treated with other fluoridated products. This is not likely given that individuals in general do not have full information about the

[23] It is also likely that individuals during childhood drink less bottled water in comparison to the entire population. Avoidance behavior due to information in line with the discussion in Neidell (2009) and Zivin et al. (2011) is unlikely since fluoride is not considered to be a hazard for levels below 1.5 mg/l.

fluoride level of the drinking water. We test this by examining the effects of fluoride in the drinking water on dental health where we expect to find positive effects if this threat is not valid.[24]

A fifth threat concerns self-selection for some of 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 have self-selection into who is taking the conscription test and the math test. In *Table A7* in the appendix, we demonstrate that this is not the case. Whether or not we have a result from the cognitive or non-cognitive ability test or the math test does not depend on the individual fluoride treatment level.

The sixth 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. 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 the robustness analysis.

The seventh 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.[25]

[24] Note that this also address the potential threat of the fluoride rinse treatment in some schools by "fluortanten".

[25] An additional objection may be that fluoride affects fertility. If fluoride has a negative effect on cognitive development and if cognitive ability affects fertility, we will estimate the effect on a selective subset of individuals whose parents, ceteris paribus, were exposed to lower levels of fluoride. Our results will however still be policy relevant given that our aim is to estimate the effect of fluoride in the present generation.

5.2 Econometric set-up

The fluoride level for each individual is a weighted average for the number of years they lived within a specific SAMS. For non-movers, the fluoride level is simply the level for their SAMS between birth and up until the year when we measure the outcome variable. 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:

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

where Y_i is the outcome variable measured at the individual level, i (except for dental outcomes which are 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 2014 and λ_c designates cohort fixed effects. u_i is the error term. β_1 is the treatment effect of interest.

With regards to dental health, we have aggregated data on SAMS level for each cohort. We run two types of specifications. First, we run unweighted regressions and study the relation between aggregated fluoride and the aggregated measure of dental health (on the SAMS level). For this analysis, we only focus on the youngest cohort available. It is more likely that they have not moved from a given SAMS in comparison to earlier cohorts. Furthermore, 20 years old may visit the dentist for free, meaning that the monetary constraint is not an issue for this cohort. Second, we run weighted regressions with our full dataset that we use in the main analysis. In this case, each individual has a unique fluoride treatment. The outcome variable is however only available on the aggregated SAMS cohort level.[26]

[26] We use SAMS for the individual in 2011 for the later years, since it is not available for the last years.

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 of 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 regions (commuting areas) in accordance with the definitions from Statistics Sweden. In a fourth standard error specification, we calculate spatial adjusted standard errors based on place of residence at birth in line with Conley (1999), Conley (2008) and Hsiang (2010) and use 10 kilometers from the center point of each SAMS as a spatial cut-off.[27]

5.3 Descriptive statistics

Figure 5 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 drinking water is marked with a red line. Although the distribution is skewed, the number of observation on the right tail is still numerous in comparison to earlier studies.[28]

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 both within and between municipalities. The combined variation is used to estimate the effect of fluoride.

Table 3 presents the summary statistics for our five main outcomes of interest. The equivalent tables for dental outcomes and the other health outcomes can be found in the appendix, *Table A1* and *Table A26* respectively.

Table 4 presents descriptive statistics of the covariates. Income for the parents are

[27] We only calculate these standard errors for our outcomes in the main analysis since it takes very long time to estimate them. In order to facilitate computation of the Conley standard errors, we have demeaned the data given that we have many fixed effects. Since we do not have a panel data set we are not correcting for temporal correlation.

[28] 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.

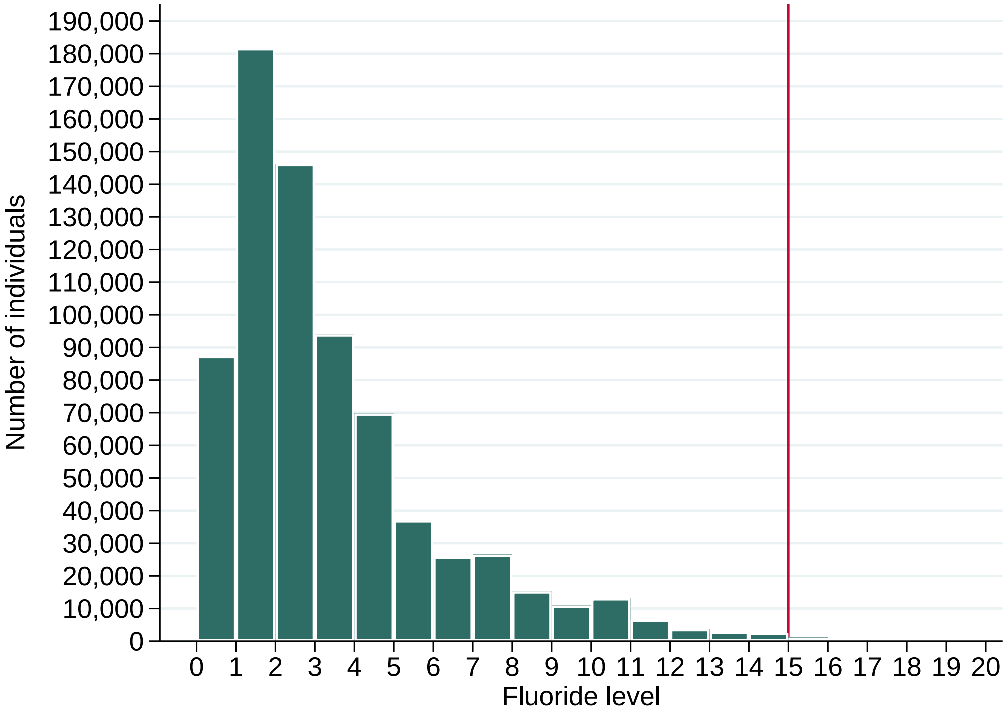


Figure 5: Histogram of fluoride levels below 2 mg/l (in 0.1 mg/l).

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: Descriptive statistics of main outcome variables

	Mean	SD
Annual income in SEK	183,818	143,206
Employment status	0.73	0.44
Cognitive ability	5.02	1.93
Non-cognitive ability	4.75	1.82
Number of basic points math test	26.18	8.57

Table 4: Descriptive statistics of covariates

	Mean	SD	Group
Sex	0.49	0.50	1
Marital status	0.07	0.26	1
Father at least upper secondary school	0.82	0.39	2
Father's income	201,618	112,587	2
Father's cognitive ability	5.07	1.90	2
Father's non-cognitive ability	5.15	1.75	2
Father immigrant	0.09	0.29	2
Mother at least upper secondary school	0.89	0.31	2
Mother's income	108,001	70,949	2
Mother immigrant	0.10	0.30	2
Both parents immigrants	0.04	0.21	2
Cohort mean education in SAMS at birth	12.03	0.60	2
Cohort mean education in SAMS at school start	12.03	0.25	2
Cohort mean education in SAMS at 16 years age	12.03	0.25	2
Observations	728,356		

Notes: Explanatory variables used in the estimations. Cohort education are means for cohorts per SAMS measured in 2014.

specified as log real income in the regressions, but displayed as real income in *Table 4*.[29] 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 fathers from earlier cohorts are not included. To capture peer-effects, we take the leave-out mean years of education at the cohort and SAMS level at 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. The covariates are grouped into two groups, indicated in *Table 4*.

6 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. Throughout this entire section we are going to analyze the effect on the outcome if fluoride would increase by 1 mg/l. The reason is that an increase to 1 mg/l is the policy-relevant increase for a country considering fluoridation of the water.

6.1 Dental health

If our strategy of mapping data on fluoride from water plants to individual register data on the SAMS level has worked, we expect to see that higher fluoride levels improves dental health.

We have variables that measure various dental outcomes. We present the results for

[29] 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). We use parents income at the age 31–35.

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.

a subset of these variables below that we judged was closest related to fluoride. The results for all additional outcomes are presented in the appendix. The variables we focus on here are visits to a dental clinic, tooth repairs and root canal (where the latter is a type of repair for more serious conditions) and three variables regarding dental health examination: disease evaluation, disease prevention and disease treatment. 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 repair during a year.

Table 5 presents the results for the unweighted regressions (both 2008 and 2013 sample) where we use aggregated data for fluoride and dental outcomes for the youngest cohort. The results clearly displays a negative effect of fluoride level for these outcomes. The point estimates are large and often statistically significant. If we take the first estimate as an example, the share of visits is decreased by approximately 6.6 percentage points if fluoride is increased by 1 mg/l. The outcome that should be closest related to fluoride is tooth repairs, 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 by 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. 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.

The results presented in *Table 6* where we run weightened regressions point in the same direction as the ones in *Table 5*, but the point estimates are generally smaller in size. In this table we include our data set used in the main analysis as explained in section 5.2. 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 *Table A11–Table A13*.

Table 6: Dental outcomes

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Visit	-0.2903	-0.0655	-0.0118	-0.0164	0.0090	-0.0078	-0.0044
	(0.1605)*	(0.0458)	(0.0433)	(0.0428)	(0.0344)	(0.0368)	(0.0372)
	<0.0386>***	<0.0178>***	<0.0195>	<0.0194>	<0.0187>	<0.0212>	<0.0212>
Repair	-0.0776	-0.0682	-0.0598	-0.0575	-0.0702	-0.0548	-0.0583
	(0.0600)	(0.0256)***	(0.0317)*	(0.0316)*	(0.0278)**	(0.0286)*	(0.0272)**
	<0.0134>***	<0.0105>***	<0.0138>***	<0.0138>***	<0.0140>***	<0.0155>***	<0.0155>***
RiskEvaluation	-0.3032	-0.0671	-0.0126	-0.0174	0.0086	-0.0063	-0.0026
	(0.1685)*	(0.0478)	(0.0444)	(0.0438)	(0.0346)	(0.0370)	(0.0375)
	<0.0400>***	<0.0184>***	<0.0198>	<0.0198>	<0.0190>	<0.0214>	<0.0214>
DiseasePrevention	-0.5169	-0.1318	-0.1154	-0.1186	-0.0742	-0.0621	-0.0617
	(0.2741)*	(0.0619)**	(0.0553)**	(0.0547)**	(0.0347)**	(0.0401)	(0.0402)
	<0.0462>***	<0.0161>***	<0.0174>***	<0.0174>***	<0.0161>***	<0.0190>***	<0.0190>***
DiseaseTreatment	-0.0656	-0.0217	-0.0072	-0.0060	-0.0164	-0.0323	-0.0324
	(0.0996)	(0.0388)	(0.0340)	(0.0340)	(0.0282)	(0.0304)	(0.0305)
	<0.0280>**	<0.0152>	<0.0180>	<0.0180>	<0.0176>	<0.0199>	<0.0199>
RootCanal	-0.0051	-0.0138	-0.0159	-0.0145	-0.0188	-0.0107	-0.0122
	(0.0126)	(0.0058)**	(0.0077)**	(0.0076)*	(0.0070)***	(0.0074)	(0.0073)*
	<0.0042>	<0.0041>***	<0.0051>***	<0.0051>***	<0.0052>***	<0.0061>*	<0.0060>**
Covariate group 1	No	No	No	No	Yes	Yes	Yes
Covariate group 2	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 437,987 (col 6 and 7) and 725,286.

Dental repair 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 in *Table 6* where all covariates and fixed effects are included, the share of individuals that had a tooth filled 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. Neidell et al. (2010) also finds results in line with the hypothesis that fluoride treatment through the drinking water in early life has a long-term effect on dental health. Our point estimates are not always statistically significant for all dental health outcomes, they almost always point in the expected direction.[30]

The overall conclusion after considering the results in *Table 5–Table 6* and the additional results presented in the appendix is that our mapping strategy seems to work.

[30] The coefficients for the 2008 specification are less precisely estimated. A reform was implemented in July 2008 that gave 20–29 years old special dental care benefits. The benefit probably allowed people between 20 and 29 to visit the dentist regularly, which could explain that the results are less clear for 2008.

Generally, we find negative and often statistically significant results for fluoride on these outcomes; especially if we consider the 2013 sample.[31] Non-linear effects for dental outcomes are presented in section A5 in the appendix.

6.2 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. The effect could, however, be non-linear. We estimate the non-linear effects in the appendix.

Let us begin with cognitive ability for men in *Table 7*, measured on a Stanine scale. 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 0.0058, this means that cognitive ability is increased by 0.058 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.[32] We can also interpret the lowest point of the 95 percent confidence interval. For example, if we consider the fifth specification and the first standard error, a 1 mg/l increase of fluoride would then translate to a decrease of 0.02 Stanine points, which is a negligible effect. We return to the question whether this is to be considered a zero-effect in section 8.

Let us move on to non-cognitive ability in *Table 8*. The point estimates are once again

[31] For median of intact and remaining teeth, we find results that point in the opposite direction that we expected for some of the specifications. See the results and discussion 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 and not fluoride.

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

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	-0.0003	0.0058	0.0068	0.0183
	(0.0082)	(0.0051)	(0.0051)	(0.0056)	(0.0041)	(0.0058)	(0.0082)**
	<0.0030>***	<0.0038>	<0.0038>	<0.0047>	<0.0041>	<0.0059>	<0.0089>**
	{0.0086}	{0.0046}	{0.0045}	{0.0054}	{0.0043}	{0.0057}	{0.0091}**
Mean	5.0067	5.0067	5.0067	5.0447	5.0447	5.1000	4.9517
Birth cohort FE	No	No	Yes	Yes	Yes	Yes	Yes
Birth municipal FE	No	Yes	Yes	Yes	Yes	Yes	Yes
Covariate group 2	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	0.0286	0.1624	0.1643	0.1685
Observations	81,776	81,776	81,776	47,241	47,241	18,894	17,864

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. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

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	0.0129	0.0165	0.0102	0.0331
	(0.0058)	(0.0046)	(0.0046)	(0.0050)**	(0.0049)***	(0.0065)	(0.0151)**
	<0.0026>	<0.0037>	<0.0037>	<0.0047>***	<0.0046>***	<0.0072>	<0.0098>***
	{0.0054}	{0.0043}	{0.0043}	{0.0052}**	{0.0049}***	{0.0068}	{0.0132}**
Mean	4.7340	4.7340	4.7340	4.7957	4.7957	4.9343	4.7161
Birth cohort FE	No	No	Yes	Yes	Yes	Yes	Yes
Birth municipal FE	No	Yes	Yes	Yes	Yes	Yes	Yes
Covariate group 2	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	0.0701	0.0765	0.0811
Observations	66,375	66,375	66,375	38,527	38,527	15,431	14,408

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. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

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 0.165 Stanine points according to column 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.

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. All of the point estimates in *Table 9* 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 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 27 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 (0.0354)*** <0.0099>*** {0.0355}***	-0.0296 (0.0126)** <0.0093>*** {0.0116}**	-0.0269 (0.0125)** <0.0092>*** {0.0115}**	-0.0267 (0.0124)** <0.0092>*** {0.0115}**	-0.0429 (0.0146)*** <0.0104>*** {0.0130}***	-0.0205 (0.0113)* <0.0088>** {0.0098}**	-0.0144 (0.0129) <0.0123> {0.0122}	-0.0258 (0.0197) <0.0174> {0.0162}
Mean	26.2059	26.2059	26.2059	26.2059	26.6042	26.6042	27.2759	26.1558
Birth cohort FE	No	No	Yes	Yes	Yes	Yes	Yes	Yes
Birth municipal FE	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Covariate group 1	No	No	No	Yes	Yes	Yes	Yes	Yes
Covariate group 2	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	0.0406	0.0440	0.1546	0.1422	0.1631
Observations	499,892	499,892	499,892	499,892	314,392	314,392	130,540	119,233

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 after considering the results for these three outcomes that we cannot reject the null hypothesis that fluoride does *not* have an effect on cognitive development.

Table 10 and *Table 11* studies outcomes which are more long-term: Annual income and employment status in 2014. These are the outcome variables for which we have the largest number of observations since all cohorts 1985–1992 are included. 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. We now 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 annual income in *Table 10*, the point estimates are often statistically significant, and the coefficients are always positive. If we look at column 6, the point estimate equals 0.0044, meaning that income increases by 4.4 percent if fluoride increases by 1 mg/l. This is not a negligible effect and the estimate should be considered as economically significant. The reduced form estimate in *Table 10* may be compared to Glied and Neidell (2010), who find that women who drink 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. An increase in fluoride by 1 mg/l would yield a similar increase in log annual income as roughly half a year of additional education according to the results in *Table 10*.

In *Table 11* 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 0.0022 and statistically significant. If fluoride is increased by 1 mg/l, then the probability that the

Table 10: Annual log labor income in SEK

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Fluoride up until year 2014 (0.1 mg/l)	0.0053 (0.0031)* [0.0023]** <0.0007>*** {0.0031}*	0.0035 (0.0014)** [0.0026] <0.0008>*** {0.0010}***	0.0040 (0.0014)*** [0.0028] <0.0008>*** {0.0011}***	0.0053 (0.0016)*** [0.0015]*** <0.0008>*** {0.0012}***	0.0041 (0.0015)*** [0.0018]** <0.0010>*** {0.0013}***	0.0044 (0.0015)*** [0.0019]** <0.0010>*** {0.0012}***	0.0033 (0.0022) [0.0021] <0.0010>*** {0.0020}	0.0015 (0.0042) [0.0039] <0.0010>*** {0.0026}
Mean	11.9124	11.9124	11.9124	11.9124	11.9237	11.9237	11.8415	11.9555
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
Covariate group 1	No	No	No	Yes	Yes	Yes	Yes	Yes
Covariate group 2	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	0.0936	0.0985	0.1047	0.1280	0.1175
Observations	634,793	634,793	634,793	634,793	390,219	390,219	67,456	140,663

Notes: Individuals are born between 1985 and 1992, i.e., between age 22-29. Individuals with a yearly labor 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. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

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}***	0.0026 (0.0007)*** [0.0005]*** <0.0004>*** {0.0005}***	0.0020 (0.0006)*** [0.0006]*** <0.0004>*** {0.0005}***	0.0022 (0.0006)*** [0.0006]*** <0.0004>*** {0.0005}***	0.0016 (0.0010) [0.0011] <0.0008>** {0.0008}**	0.0018 (0.0018) [0.0015] <0.0008>** {0.0011}
Mean	0.7346	0.7346	0.7346	0.7346	0.7481	0.7481	0.7123	0.7603
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
Covariate group 1	No	No	No	Yes	Yes	Yes	Yes	Yes
Covariate group 2	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	0.0472	0.0504	0.0582	0.0689	0.0595
Observations	728,074	728,074	728,074	728,074	440,048	440,048	76,422	158,504

Notes: Individuals are born between 1985 and 1992, i.e., between age 22-29. 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. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

person is employed is increased by 2.2 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.

We now continue to a subsample analysis for the last two outcomes, where we restrict our sample to those who are 27–29 years old in 2014 since these older individuals are more established on the labor market. 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 elementary education up to upper secondary school, but not higher. We also split each category for men and women. We have included all fixed effects and covariates in all of the specifications except for the first column in *Table 12* and *Table 13*.

We see that the estimates for income varies between these different samples and the point estimates are not always statistically significant for all standard error specifications. The overall message is that fluoride has a positive effect. The effect overall seems to be larger for non-academics, and slightly larger for males. The same subsample analysis is also conducted for employment status. We find an effect for those without an academic education, but the effect for women in this case seems to be larger than the effect for

Table 12: Annual log labor income in SEK (subsample)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Fluoride up until year 2014 (0.1 mg/l)	-0.0006	0.0066	0.0070	0.0059	0.0038	0.0041	0.0036
	(0.0012)	(0.0017)***	(0.0020)***	(0.0037)	(0.0026)	(0.0044)	(0.0035)
	[0.0012]	[0.0026]**	[0.0019]***	[0.0065]	[0.0027]	[0.0035]	[0.0030]
	<0.0008>	<0.0019>***	<0.0020>***	<0.0036>*	<0.0025>	<0.0040>	<0.0033>
	{0.0012}	{0.0018}***	{0.0019}***	{0.0038}	{0.0025}	{0.0040}	{0.0034}
Mean	12.1639	12.1562	12.3998	11.8025	12.2238	12.3541	12.1366
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
Covariate group 1	No	Yes	Yes	Yes	Yes	Yes	Yes
Covariate group 2	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	0.1148	0.0351	0.0364	0.0578	0.0793	0.0517
Observations	216,779	73,867	43,743	30,124	50,286	20,154	30,132

Notes: Individuals with a yearly income below 1,000 SEK or 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. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 13: Employment status (subsample)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Fluoride up until year 2014 (0.1 mg/l)	0.0010	0.0039	0.0037	0.0044	-0.0003	0.0011	-0.0013
	(0.0008)	(0.0008)***	(0.0010)***	(0.0013)***	(0.0010)	(0.0017)	(0.0012)
	[0.0004]***	[0.0008]***	[0.0009]***	[0.0018]**	[0.0010]	[0.0014]	[0.0011]
	<0.0003>***	<0.0007>***	<0.0009>***	<0.0013>***	<0.0009>	<0.0015>	<0.0012>
	{0.0008}	{0.0007}***	{0.0009}***	{0.0013}***	{0.0010}	{0.0017}	{0.0011}
Mean	0.8156	0.8207	0.8433	0.7893	0.8564	0.8345	0.8715
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
Covariate group 1	No	Yes	Yes	Yes	Yes	Yes	Yes
Covariate group 2	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	0.0331	0.0402	0.0340	0.0406	0.0674	0.0383
Observations	245,116	84,001	48,943	35,058	53,856	21,912	31,944

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. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

males for those without an academic education.

One remaining objection is that the estimates are still not representative for the lifetime income and probability of being employed. In the appendix, we therefore run an analysis including those are born 1980–1984 who are 30–34 years old. For these individuals we do not have data on place of residence on SAMS level for the first five years, but we have data on where they lived on the parish level (a larger geographical area), meaning that the identification becomes a bit less clear for the first years. The estimates for this specification vary a bit depending on whether we include fixed effects or covariates. The results in section A4 in the appendix confirm the main analysis when we include all fixed effects and covariates, namely that fluoride has a positive effect on income and employment and that the effects seems to be driven by the effects for non-academic males.

To conclude, we find zero-effects on cognitive and non-cognitive ability and math points. Our results indicate that fluoride does not have adverse negative effect on cognitive ability for the fluoride levels we consider. However, we find that fluoride has positive effects on income and employment status which indicate that better dental health is a positive factor on the labor market. The results we present here are reduced form results. In section A7 in the appendix we run analysis where we rescale the estimates using our dental health data.

As mentioned, we have also run the analysis for other health outcomes, which are presented and discussed in section A6 in the appendix. These health outcomes are defined on the chapter level in ICD10 for diagnoses and for drugs in ATC for more specific conditions. All of these results points in one direction, namely that fluoride does not seem to have any negative effects.

7 Robustness analysis

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. 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 A8 and section A9 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 do 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. In section A10 in the appendix, we 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 still small in size. For annual income and employment status, we estimate positive coefficients as in the main analysis, but the estimated point estimates are generally smaller in magnitude and not statistically significant in this specification.

We have also run an analysis for an alternative income measure in section A11 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.

Since we exclude individuals with an income below 1,000 SEK in our income estimations, we test if the fluoride level have an effect on the likelihood of being included in the sample in section A12. All in all, a higher fluoride level increases the likelihood of earning an annual income above 1,000 SEK, i.e., the results point in the same direction as the main analysis that fluoride increase the income.

Furthermore, we also run a specification where we only look at those SAMS which had one and only one water plant and where we have full information from 1985 from the municipalities in section A13 namned *Most conservative specification*. 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 income and employment status, the point estimates varies between different specifications and we no longer have statistically significant results. This is probably a result of having fewer observations and a selective sample.

We also address the potential threat to our identification strategy that fluoride as an environmental factor that can be intergenerationally transmitted. To address this problem, we rerun all our specifications only including individuals that were adopted in section A14 in the appendix. The estimates are more noisy in this case since we are left with much fewer observations. We often estimate positive point estimates with regards to income and employment in line with the main analysis. The point estimates for cognitive and non-cognitive ability and math points are now negative but never statistically significant. These results should be interpreted with caution given that they are only based on a much smaller sample.

Finally, we have run specifications with family fixed effects. The variation in fluoride now stems from different moving patterns within a family. We exclude all those who have half-siblings since these may reside in different areas not because of moving but because they have different parents. The results for this specification are a bit puzzling. The empirical results points in different directions depending on the outcome variable. For math points, we now find positive point estimates which are not statistically significant. However, for cognitive and non-cognitive ability the point estimates are negative and large, but not statistically significant. In contrast to the results in the main specification the standard errors are much larger which make the estimates difficult to interpret. For income and employment status, we have some negative, very large and statistically significant effects for the less conservative specifications, but the point estimates moves towards zero and becomes statistically insignificant when other fixed effects and covariates are included. The reader should note that these analyses are based on a selective sample.[33] Given the overall imprecise estimates for this robustness analysis, the fact that the estimates varies for different specifications and the fact that we use a selective sample makes us all in all not willing to change our conclusion from the main analysis.

8 Discussion

It is always more difficult to conclude a zero-effect. In this section we will further discuss our effects on cognitive ability. Since earlier papers have focused on cognitive ability, we restrict our discussion to this outcome. Given the economic take in this paper, let us monetarize our results by translating the estimated effects into annual income. To make our estimates comparable with earlier studies, we standardize cognitive ability around 0 with a standard deviation on 1. Our 95 % confidence interval for our normalized variable ranges from (-0.1296–0.0386) for the specification without covariates and fixed effects and (-0.0122–0.0723) with fixed effects and covariates included for an increase of 1 mg/l of fluoride. Let us now compare this with the estimated effects of cognitive ability on income in Table 1 in Lindqvist and Vestman (2011). We chose to focus on column 5 since this is the specification where cognitive ability is included separately. The estimated effect of one standard deviation increase in cognitive ability yields 10.4 percent increase in wages in Lindqvist and Vestman (2011). If we multiply their result with ours for cognitive ability, our estimated effect of fluoride on cognitive ability translates into an effect on income with a confidence interval between (-0.0135–0.0040) for the specification without fixed effects and covariates, and (-0.0013–0.0075) for the specification with covariates and fixed effects. This is much less than our estimated reduced form results of fluoride on income, which should be interpreted as the overall net effect of fluoride.

Another way to evaluate this is to look at earlier studies that have found statistically significant results and compare the precision of the estimates. Let us go back to the meta-study Choi et al. (2012) that we discussed in the introduction. Our study includes over 80,000 observations when we do not include covariates or fixed effects, and about 47,000 observations with covariates and fixed effects. This may be compared to the largest study reviewed in Choi et al. (2012) where the number of observations was 907. We may also compare our results to the ones reviewed in Choi et al. (2012). Our standardized confidence intervals includes the 0 and are much tighter than the 95% standardized confidence intervals in earlier studies reviewed in Choi et al. (2012).

[33] If we take cognitive ability for instance, the variation in fluoride now stems from brothers born between 1985–1987 where the family has moved before age 18.

We may also compare our results to Broadbent et al. (2015) who 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, our confidence intervals are (-1.8560–0.5546) for the specifications without covariates or fixed effects and (-0.1776–1.0311) for the specifications with all covariates and fixed effects, when fluoride is increased by 1 mg/l.

Based on this discussion, we are confident to claim that we have estimated a zero-effect on cognitive ability.

9 Conclusion

We have investigated the effects of fluoride on outcomes related to the central nervous system and more long-term labor market outcomes. Taking all together, we find a zero-effect of fluoride on cognitive ability, non-cognitive ability and points on the national test in math. For income and employment status we find evidence of a positive effect of fluoride, which is 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.

These results are policy relevant for developed countries, because water authorities seldom consider fluoridating the drinking water above 1.5 mg/l. Based on the overall results we find, the policy implications are that fluoride exposure through the drinking water either in the form of natural levels or artificial fluoridation is a good mean of improving dental health without risking negative side effects on cognitive development.

Future studies should try to establish where the dangerous level of fluoride begins. Since we know that fluoride is lethal and dangerous in 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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Appendix

A1 Data: Individual level

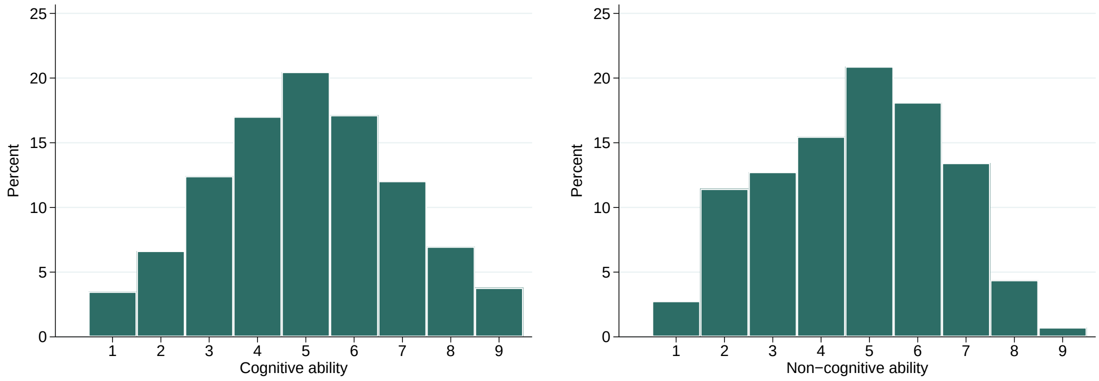

Figure A1: Distribution of cognitive and non-cognitive abilities.

Table A1: Descriptive statistics of dental outcomes

	Mean	SD	Max	Min
Visits dental clinic	66.31	24.31	100.00	0.00
Basic check-ups	59.42	25.92	100.00	0.00
Risk evaluation, health improvement measures	64.78	24.64	100.00	0.00
Disease prevention	12.82	18.97	100.00	0.00
Disease treatment	31.31	23.21	100.00	0.00
Dental surgical measures	6.33	11.66	100.00	0.00
Root canal treatment	2.75	7.67	100.00	0.00
Orthognathic treatment	1.37	5.50	100.00	0.00
Repair treatment	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: Repairs	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

A2 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 A2 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 1 mg/l (which is a large increase), the probability that the individual has moved between SAMS within a municipality is 4.9 percentage points lower according to row 1 in *Table A2*. However the probability of moving between municipalities increases by 1.3 percentage points. There does not seem to be any clear or systematic patterns. We have also conducted a comparison in difference in means for first time movers. The mean fluoride level prior of moving was approximately 0.33 mg/l and after moving the mean was 0.34 mg/l. Hence, there is no evidence that people move from high fluoride areas.

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

	F. (0.1 mg/l)
Move within municipality	-0.00488 (0.00408)
Municipal Move	0.0000907 (0.00262)
County Move	0.00139 (0.00158)
# moves within municipality	-0.00372 (0.00808)
# moves between municipalities	0.00133 (0.00427)
# moves between counties	0.00241 (0.00223)
Average years SAMS	0.0184 (0.0354)
Average years municipality	-0.0330 (0.0364)
Average year county	-0.0368 (0.0229)
Observations	728,074

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 (563,683 observations).

In *Table A3* 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 A4 and *Table A5* displays a similar analysis for the years of immigration for the parents. This variable is also predetermined, where we run the balance test for various dummy variables for mothers and fathers respectively. We focus on where the individual was born and calculate the share of immigrants that arrived for each year. All shares are then included into a single regression.

We do not find support 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. For example, the share of immigrant fathers from outside a nordic country decreases with 0.0238 if fluoride is increased by 1 mg/l. This is a small decrease. 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 1 mg/l, the number of water plants would increase by 0.2 water plants. In practice, this is a zero-effect. With regards to *Table A4* and *Table A5*, there is no evidence that municipalities reroute fluoride to certain immigration cohorts. The share in this case is expressed between 0 and 100. Some results are statistically significant, but most point estimates are small in magnitude (below 0.1 mg/l). Let us take the first row in *Table A5* as an example. If the share of immigrant fathers that arrived to Sweden in 1945 increases by 1 percentage point of the SAMS population (a large increase), the fluoride level to that SAMS would be 0.08 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 A3: 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 8,017 and 8,597.

Table A4: Fathers' immigration year

	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 A5: Mothers' immigration year

	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 A6*, with cohort 1985 as benchmark. We also include sibling order for those with at least one sibling (twins removed). We have three statistically significant results, but the point estimates are very small. Those born in 1992 received on average 0.007 mg/l lower fluoride than those born in 1985. In terms of economic significance, this is a zero-effect and below the measurable precision level of fluoride.

Table A6: Balance test. Cohorts and sibling order

	F. (0.1 mg/l)
Cohort 1986	0.00862
	(0.0121)
Cohort 1987	-0.00460
	(0.0151)
Cohort 1988	0.00761
	(0.0164)
Cohort 1989	-0.00533
	(0.0157)
Cohort 1990	-0.0340**
	(0.0164)
Cohort 1991	-0.0180
	(0.0180)
Cohort 1992	-0.0742***
	(0.0199)
Sibling order	0.0414*
	(0.0214)

Notes: Standard errors clustered at the municipal level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. The number of observation is 728,074 for the cohorts and 418,109 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 in *Table A7* to see if the fluoride treatment level for men without cognitive and non-cognitive ability scores differs from those who enlisted. We also run the test for taking the math test in ninth grade (for both males and females). In conclusion, there is no evidence of such sorting.

Table A7: Balance test. Missing test scores

	F. (0.1 mg/l)
No Cog. ab.	0.000744
	(0.000791)
No Non-Cog. ab.	-0.000131
	(0.000306)
No math test	-0.000178
	(0.000910)

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 374,597 and for the last outcome 567,151.

In *Table A9*, 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 clear 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 A8 of the sales of bottled water discussed in the empirical framework section is also presented here.

Table A8: 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 A9: 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.

A3 Results: Dental health

In this subsection we present additional results for dental health.

Table A10: 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 A11: Dental outcomes 2013. Additional specifications. Weighted regressions

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
CheckUps	-0.3635*	-0.0626	-0.0101	-0.0159	0.0261	0.0106	0.0160
	(0.2016)	(0.0550)	(0.0512)	(0.0503)	(0.0390)	(0.0408)	(0.0415)
DentalSurgery	0.0093	-0.0160	-0.0046	-0.0039	-0.0215	-0.0196	-0.0218
	(0.0307)	(0.0125)	(0.0163)	(0.0161)	(0.0151)	(0.0156)	(0.0148)
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)	(0.0057)	(0.0057)
Prosthesis	-0.0176***	-0.0108***	-0.0161***	-0.0156***	-0.0115***	-0.0094***	-0.0094***
	(0.0043)	(0.0022)	(0.0030)	(0.0030)	(0.0028)	(0.0031)	(0.0031)
OrthodontReplace	-0.0051**	-0.0021*	-0.0031**	-0.0031**	-0.0018	-0.0019	-0.0018
	(0.0024)	(0.0011)	(0.0015)	(0.0015)	(0.0015)	(0.0018)	(0.0018)
DiCheckUpsEval	-0.3032*	-0.0671	-0.0126	-0.0174	0.0086	-0.0063	-0.0026
	(0.1685)	(0.0478)	(0.0444)	(0.0438)	(0.0346)	(0.0370)	(0.0375)
DiDentHealth	-0.1990	-0.0252	0.0026	0.0005	0.0021	0.0108	0.0111
	(0.1325)	(0.0305)	(0.0294)	(0.0295)	(0.0232)	(0.0265)	(0.0266)
DiDiseasePain	-0.2500*	-0.0829*	-0.0642	-0.0633	-0.0554	-0.0655*	-0.0661*
	(0.1396)	(0.0439)	(0.0394)	(0.0396)	(0.0336)	(0.0360)	(0.0361)
DiRepairs	-0.1770*	-0.1034***	-0.1049**	-0.1028**	-0.0981***	-0.0777**	-0.0818**
	(0.0929)	(0.0375)	(0.0449)	(0.0450)	(0.0371)	(0.0391)	(0.0375)
DiRehabHab	-0.0121**	-0.0095***	-0.0114***	-0.0114***	-0.0096***	-0.0079**	-0.0080**
	(0.0050)	(0.0026)	(0.0035)	(0.0035)	(0.0033)	(0.0036)	(0.0036)
MedianRemaining	-0.0172**	-0.0085***	-0.0133***	-0.0128***	-0.0078***	-0.0063***	-0.0063***
	(0.0069)	(0.0021)	(0.0023)	(0.0026)	(0.0018)	(0.0018)	(0.0018)
MedianIntact	-0.0165	-0.0038	-0.0125*	-0.0131*	-0.0046	-0.0057	-0.0047
	(0.0196)	(0.0066)	(0.0076)	(0.0075)	(0.0056)	(0.0056)	(0.0051)
Covariate group 1	No	No	No	No	Yes	Yes	Yes
Covariate group 2	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	435,248	435,248

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 are 725,004 (column 1-5) and 435,248 (column 6 and 7).

Table A12: Dental outcomes 2008. Main outcomes. Weighted regressions

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Visit	-2.3819**	-0.0094	-0.0544	-0.1228	0.3737	0.2321	0.2924
	(0.9978)	(0.2545)	(0.3992)	(0.3900)	(0.3392)	(0.3439)	(0.3410)
Repair	-0.4461	-0.3960*	-0.3079	-0.2778	-0.3678	-0.4808	-0.5027
	(0.4539)	(0.2015)	(0.3277)	(0.3278)	(0.2968)	(0.3256)	(0.3189)
RiskEvaluation	-2.5889**	-0.0158	-0.0938	-0.1646	0.3567	0.1992	0.2610
	(1.0831)	(0.2649)	(0.4114)	(0.4011)	(0.3489)	(0.3510)	(0.3511)
DiseasePrevention	-2.7806*	0.2148	0.2625	0.2434	0.1889	0.2071	0.2457
	(1.5433)	(0.2577)	(0.5424)	(0.5425)	(0.3502)	(0.3768)	(0.3712)
DiseaseTreatment	0.7981	0.0019	-0.2339	-0.1992	-0.3111	-0.4776*	-0.4792*
	(0.6791)	(0.1626)	(0.2517)	(0.2506)	(0.2362)	(0.2731)	(0.2728)
RootCanal	-0.1575	-0.0721	-0.1270	-0.1114	-0.0570	-0.0364	-0.0453
	(0.1006)	(0.0481)	(0.0796)	(0.0803)	(0.0722)	(0.0847)	(0.0841)
Covariate group 1	No	No	No	No	Yes	Yes	Yes
Covariate group 2	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	335,687	335,687	335,687	335,687	335,687	192,975	192,975

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 are 335,687 (column 1-5) and 192,975 (column 6 and 7).

Table A13: Dental outcomes 2008. Additional specifications. Weighted regressions

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
CheckUps	-2.8652**	0.1945	0.0302	-0.0574	0.5860	0.3901	0.4699
	(1.2202)	(0.2930)	(0.4519)	(0.4403)	(0.3870)	(0.3867)	(0.3866)
DentalSurgery	-0.2571	-0.2090***	-0.3171***	-0.2915***	-0.3083***	-0.3394***	-0.3574***
	(0.1753)	(0.0784)	(0.1079)	(0.1080)	(0.1061)	(0.1278)	(0.1261)
Orthognathic	-0.1309**	0.0207	-0.0661	-0.0649	0.0049	-0.0044	-0.0028
	(0.0548)	(0.0311)	(0.0403)	(0.0405)	(0.0420)	(0.0510)	(0.0508)
Prosthesis	-0.0251	0.0066	-0.0278	-0.0237	0.0010	0.0144	0.0135
	(0.0379)	(0.0253)	(0.0348)	(0.0349)	(0.0339)	(0.0408)	(0.0407)
OrthodontReplace	-0.0294*	-0.0308***	-0.0392***	-0.0396***	-0.0375***	-0.0398**	-0.0396**
	(0.0162)	(0.0081)	(0.0112)	(0.0112)	(0.0121)	(0.0154)	(0.0154)
DiCheckUpsEval	-2.5889**	-0.0158	-0.0938	-0.1646	0.3567	0.1992	0.2610
	(1.0831)	(0.2649)	(0.4114)	(0.4011)	(0.3489)	(0.3510)	(0.3511)
DiDentHealth	-1.3861	0.3730	0.5994	0.5900	0.3119	0.3643	0.4019
	(1.2635)	(0.2265)	(0.4893)	(0.4889)	(0.2994)	(0.3356)	(0.3321)
DiDiseasePain	-0.7863	-0.1631	-0.5904**	-0.5555*	-0.3601	-0.5287*	-0.5278*
	(0.5878)	(0.1776)	(0.2912)	(0.2902)	(0.2449)	(0.2734)	(0.2736)
DiRepairs	-0.5358	-0.4949**	-0.4261	-0.3908	-0.5146	-0.6307*	-0.6607**
	(0.4692)	(0.2129)	(0.3458)	(0.3460)	(0.3164)	(0.3441)	(0.3355)
DiRehabHab	-0.0636	-0.0266	-0.0427	-0.0426	-0.0288	0.0084	0.0072
	(0.0479)	(0.0273)	(0.0386)	(0.0386)	(0.0377)	(0.0472)	(0.0473)
MedianRemaining	-0.4245***	-0.0497***	-0.2175***	-0.2136***	-0.0368**	-0.0296	-0.0306
	(0.1457)	(0.0149)	(0.0590)	(0.0596)	(0.0183)	(0.0213)	(0.0214)
MedianIntact	-0.0759	0.1321***	0.0627	0.0551	0.0929*	0.1109*	0.1206**
	(0.2200)	(0.0369)	(0.0684)	(0.0688)	(0.0518)	(0.0566)	(0.0556)
Covariate group 1	No	No	No	No	Yes	Yes	Yes
Covariate group 2	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	333,749	333,749	333,749	333,749	333,749	191,902	191,902

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 are 335,687 (column 1-5) and 192,975 (column 6-7) except for MedianIntact, for which the observations are 333,749 and 191,902 respectively.

In *Table A14*, 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.[34] 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

[34] The data originates from the open data published at the website of The National Board Board of Health and Welfare and is much less fined grained. It does not contain any personal information.

to us on the municipal level because it is not part of our main dental dataset, meaning that we cannot include any covariates or fixed effects on the individual level. 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 direction than expected. However, no point estimates are statistically significant with the exception of one that is significant at the 10 percent level.

Table A14: 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.

A4 Results: Labor market outcomes for older cohorts

Table A15 and *Table A16* include cohorts born 1980–1984. *Table A17* and *Table A18* displays the results for subsample analysis where we look at academics and non-academics as well as men and women separately. Note that a few parishes crosses municipal borders, meaning that we add more measurement error into our fluoride measure.

Table A15: Log income

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Fluoride up until year 2014 (0.1 mg/l)	-0.0019	-0.0034	-0.0031	0.0030	0.0047	0.0035	-0.0009	0.0102
	(0.0010)*	(0.0013)***	(0.0013)**	(0.0014)**	(0.0021)**	(0.0021)*	(0.0086)	(0.0034)***
Mean	12.3290	12.3290	12.3290	12.3290	12.3281	12.3281	12.3352	12.3240
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
Covariate group 1	No	No	No	Yes	Yes	Yes	Yes	Yes
Covariate group 2	No	No	No	No	Yes	No	Yes	Yes
Sample	All	All	All	All	All	Col 6	SAMS stayers	SAMS movers
R^2	0.0000	0.0026	0.0059	0.0882	0.1076	0.1021	0.2470	0.1331
Observations	168,336	168,336	168,336	168,336	71,182	71,182	2,408	21,100

Notes: Standard errors in parenthesis are clustered at the municipal of birth. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table A16: Employment status

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Fluoride up until year 2014 (0.1 mg/l)	0.0006	-0.0003	-0.0002	0.0018	0.0021	0.0017	0.0049	0.0021
	(0.0005)	(0.0005)	(0.0005)	(0.0005)***	(0.0007)***	(0.0007)**	(0.0038)	(0.0014)
Mean	0.8690	0.8690	0.8690	0.8690	0.8828	0.8828	0.8353	0.8819
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
Covariate group 1	No	No	No	Yes	Yes	Yes	Yes	Yes
Covariate group 2	No	No	No	No	Yes	No	Yes	Yes
Sample	All	All	All	All	All	Col 6	SAMS stayers	SAMS movers
R^2	0.0000	0.0059	0.0077	0.0269	0.0332	0.0252	0.2150	0.0492
Observations	188,127	188,127	188,127	188,127	78,386	78,386	2,848	23,286

Notes: Standard errors in parenthesis are clustered at the municipal of birth. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table A17: Log income (subsample)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Fluoride up until year 2014 (0.1 mg/l)	-0.0019	0.0073	0.0106	0.0023	0.0033	0.0038	0.0045
	(0.0010)*	(0.0027)***	(0.0027)***	(0.0052)	(0.0032)	(0.0036)	(0.0049)
Mean	12.3290	12.2758	12.5172	11.9159	12.3943	12.6634	12.2110
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
Covariate group 1	No	Yes	Yes	Yes	Yes	Yes	Yes
Covariate group 2	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	0.1319	0.0478	0.0477	0.1094	0.0944	0.0569
Observations	168,336	39,435	23,603	15,832	31,671	12,830	18,841

Notes: Standard errors in parenthesis are clustered at the municipal of birth. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table A18: Employment status (subsample)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Fluoride up until year 2014 (0.1 mg/l)	0.0006	0.0041	0.0051	0.0030	-0.0007	-0.0026	0.0004
	(0.0005)	(0.0010)***	(0.0011)***	(0.0018)*	(0.0010)	(0.0016)*	(0.0012)
Mean	0.8690	0.8585	0.8811	0.8260	0.9172	0.9098	0.9223
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
Covariate group 1	No	Yes	Yes	Yes	Yes	Yes	Yes
Covariate group 2	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	0.0000	0.0422	0.0546	0.0489	0.0376	0.0827	0.0382
Observations	188,127	44,618	26,295	18,323	33,615	13,751	19,864

Notes: Standard errors in parenthesis are clustered at the municipal of birth. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

A5 Results: Non-linear effects

In *Figure A3–Figure A5* the effect for each fluoride level is displayed for the dental healths outcomes and the outcomes in the main analysis. 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 5 or 6 in the tables in the main analysis. 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. Since we divide the fluoride levels into different dummy variables, the 95 % interval for each interval point contains less variation meaning that these confidence intervals are not directly comparable to the standard errors in the tables for the main analysis.

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.

The conclusion after looking at the non-linear effects for the main outcome variables is that the effect up until 1.5 mg/l is always close to zero for our three measures for cognitive development. 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.

In the tables below the figures, we present results for regressions where fluoride has been divided into quartiles for the outcomes in the main analysis. 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.[35]

[35] We have also created corresponding non-linear effects tables and figures for all dental outcomes. These tables are available from the authors upon request.

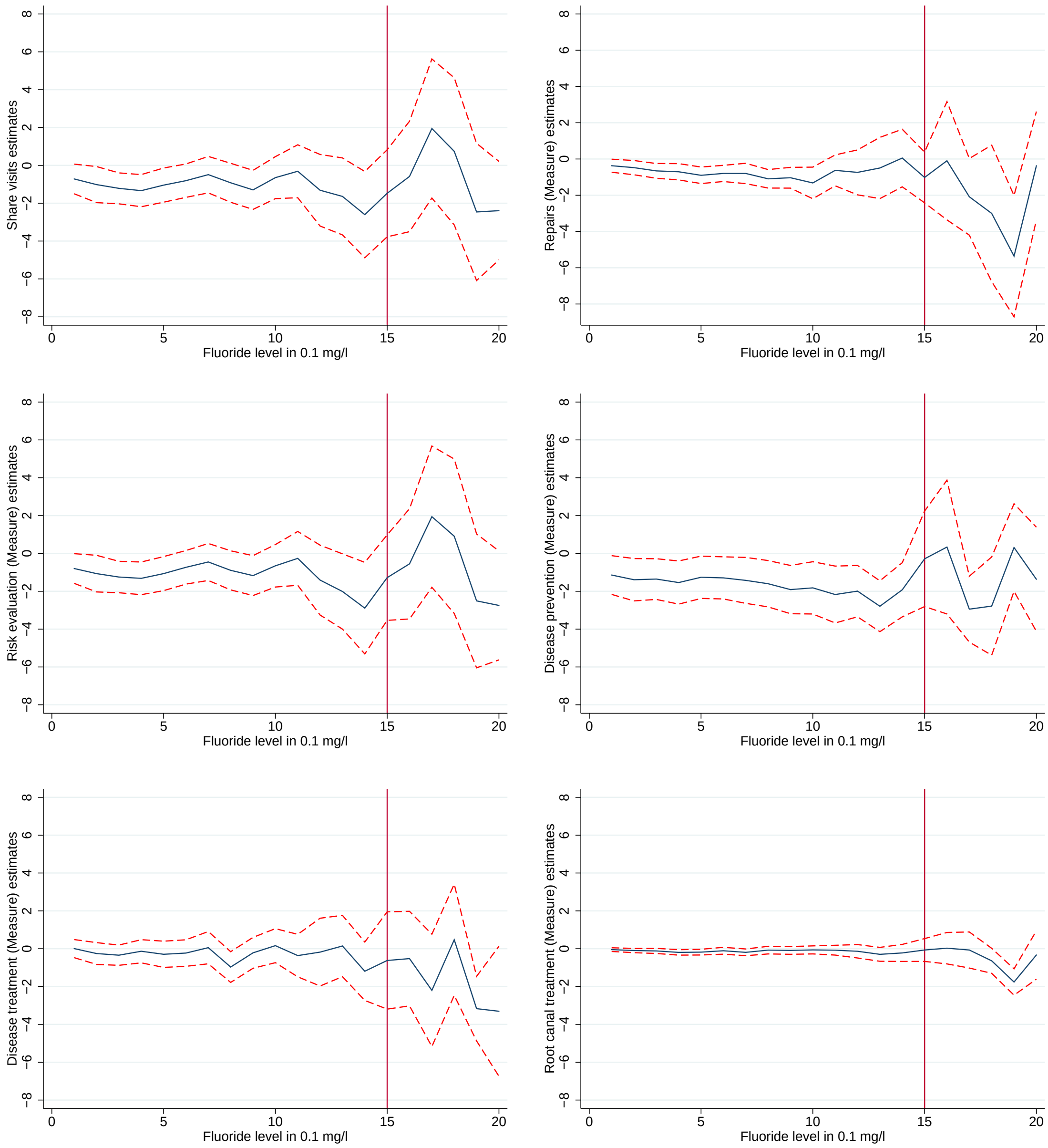

Figure A2: Non-linear effects: Dental health estimates.

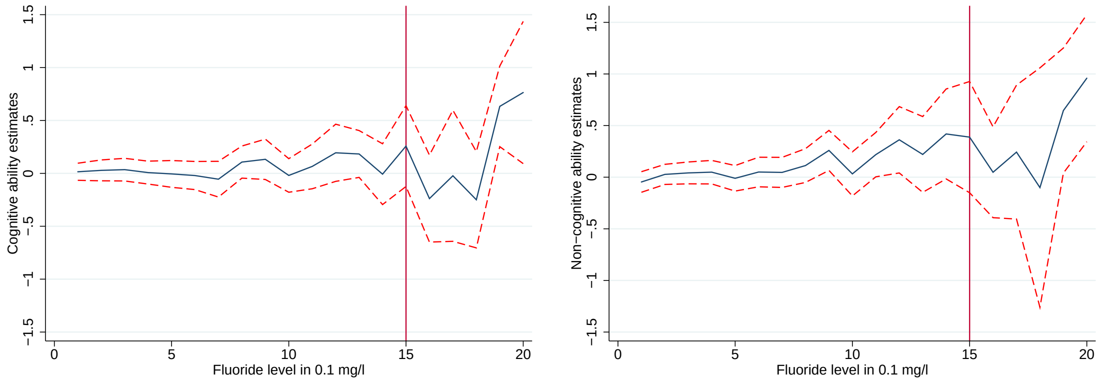

Figure A3: Non-linear effects for ability measures.

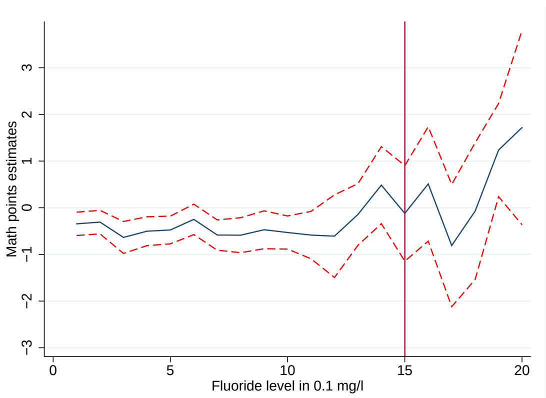

Figure A4: Non-linear math points estimates.

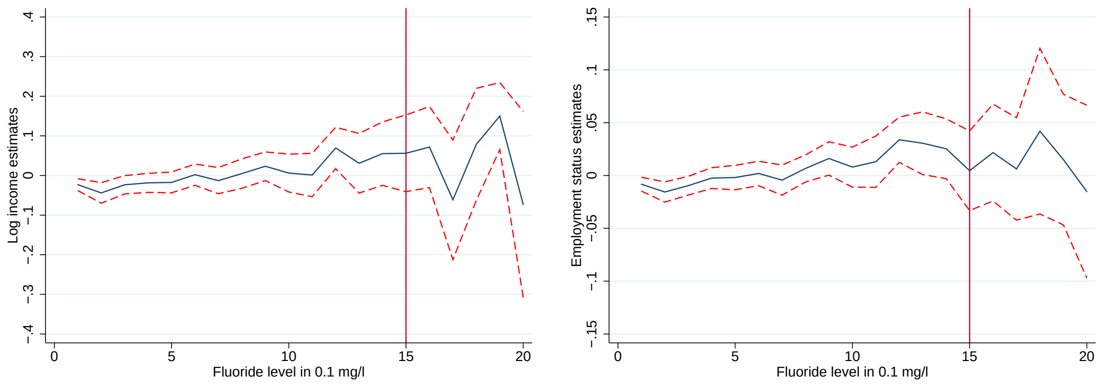

Figure A5: Non-linear effects labor market outcomes.

Table A19: Cognitive ability

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Fluoride 2nd quartile	0.1362**	0.0534	0.0507	0.0240	0.0496*	0.0243	0.0237
	(0.0662)	(0.0416)	(0.0421)	(0.0417)	(0.0298)	(0.0548)	(0.0495)
Fluoride 3nd quartile	-0.1650**	-0.0545	-0.0530	-0.0478	-0.0255	-0.0195	-0.0612
	(0.0712)	(0.0340)	(0.0339)	(0.0360)	(0.0274)	(0.0496)	(0.0567)
Fluoride 4nd quartile	0.0097	0.0195	0.0192	-0.0102	0.0048	0.0716	0.0880
	(0.0516)	(0.0262)	(0.0261)	(0.0373)	(0.0297)	(0.0472)	(0.0753)
Mean	5.0067	5.0067	5.0067	5.0447	5.0447	5.1000	4.9517
Birth cohort FE	No	No	Yes	Yes	Yes	Yes	Yes
Birth municipal FE	No	Yes	Yes	Yes	Yes	Yes	Yes
Covariate group 2	No	No	No	No	Yes	Yes	Yes
Sample	All	All	All	Col 5	All	SAMS stayers	SAMS movers
R^2	0.0012	0.0217	0.0240	0.0287	0.1624	0.1644	0.1684
Observations	81,776	81,776	81,776	47,241	47,241	18,894	17,864

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

Table A20: Non-cognitive ability

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Fluoride 2nd quartile	-0.0188	-0.0542	-0.0546	-0.0609	-0.0405	-0.0265	-0.0258
	(0.0656)	(0.0341)	(0.0340)	(0.0377)	(0.0354)	(0.0650)	(0.0625)
Fluoride 3nd quartile	-0.0685	0.0184	0.0188	0.0411	0.0577*	0.0946	0.0731
	(0.0663)	(0.0312)	(0.0311)	(0.0356)	(0.0314)	(0.0582)	(0.0763)
Fluoride 4nd quartile	0.0605	0.0262	0.0265	0.0247	0.0344	0.0455	0.1419**
	(0.0428)	(0.0256)	(0.0255)	(0.0363)	(0.0337)	(0.0553)	(0.0636)
Mean	4.7340	4.7340	4.7340	4.7957	4.7957	4.9343	4.7161
Birth cohort FE	No	No	Yes	Yes	Yes	Yes	Yes
Birth municipal FE	No	Yes	Yes	Yes	Yes	Yes	Yes
Covariate group 2	No	No	No	No	Yes	Yes	Yes
Sample	All	All	All	Col 5	All	SAMS stayers	SAMS movers
R^2	0.0003	0.0175	0.0176	0.0213	0.0699	0.0767	0.0810
Observations	66,375	66,375	66,375	38,527	38,527	15,431	14,408

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

Table A21: Math points

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Fluoride 2nd quartile	-0.0304	-0.2689**	-0.2557*	-0.2562*	-0.3143**	-0.2242**	-0.0900	-0.3207**
	(0.2728)	(0.1348)	(0.1375)	(0.1368)	(0.1320)	(0.1000)	(0.1529)	(0.1453)
Fluoride 3nd quartile	-0.9212***	-0.3043**	-0.3026**	-0.2999**	-0.2471*	-0.1546	0.0698	-0.1359
	(0.3259)	(0.1202)	(0.1188)	(0.1184)	(0.1278)	(0.1065)	(0.1383)	(0.1267)
Fluoride 4nd quartile	0.0787	0.1091	0.1171	0.1173	-0.0289	0.0654	-0.0139	0.0808
	(0.2536)	(0.0947)	(0.0963)	(0.0962)	(0.0956)	(0.0906)	(0.1048)	(0.1281)
Mean	26.2059	26.2059	26.2059	26.2059	26.6042	26.6042	27.2759	26.1558
Birth cohort FE	No	No	Yes	Yes	Yes	Yes	Yes	Yes
Birth municipal FE	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Covariate group 1	No	No	No	Yes	Yes	Yes	Yes	Yes
Covariate group 2	No	No	No	No	No	Yes	Yes	Yes
Sample	All	All	All	All	Col 6	All	SAMS stayers	SAMS movers
R^2	0.0028	0.0231	0.0405	0.0408	0.0442	0.1547	0.1422	0.1631
Observations	499,892	499,892	499,892	499,892	314,392	314,392	130,540	119,233

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

Table A22: Annual log income in SEK

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Fluoride 2nd quartile	-0.0224	0.0074	-0.0211**	-0.0152	-0.0151	-0.0125	0.0073	0.0288*
	(0.0290)	(0.0107)	(0.0105)	(0.0100)	(0.0104)	(0.0099)	(0.0213)	(0.0167)
Fluoride 3nd quartile	0.0394	0.0112	0.0065	0.0132	0.0118	0.0142	0.0330	0.0244*
	(0.0255)	(0.0081)	(0.0064)	(0.0120)	(0.0123)	(0.0125)	(0.0208)	(0.0138)
Fluoride 4nd quartile	0.0194	0.0127**	0.0208***	0.0225***	0.0195***	0.0191***	0.0085	0.0065
	(0.0150)	(0.0059)	(0.0057)	(0.0055)	(0.0066)	(0.0065)	(0.0182)	(0.0128)
Mean	11.9124	11.9124	11.9124	11.9124	11.9237	11.9237	11.8415	11.9555
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
Covariate group 1	No	No	No	Yes	Yes	Yes	Yes	Yes
Covariate group 2	No	No	No	No	No	Yes	Yes	Yes
Sample	All	All	All	All	Col 6	All	SAMS stayers	SAMS movers
R^2	0.0004	0.0066	0.0528	0.0936	0.0986	0.1047	0.1281	0.1176
Observations	634,793	634,793	634,793	634,793	390,219	390,219	67,456	140,663

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

Table A23: Employment status

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Fluoride 2nd quartile	-0.0052	0.0038	-0.0047	-0.0049	-0.0044	-0.0028	0.0020	0.0113
	(0.0121)	(0.0045)	(0.0044)	(0.0041)	(0.0042)	(0.0040)	(0.0079)	(0.0076)
Fluoride 3nd quartile	0.0107	0.0020	0.0005	0.0027	0.0028	0.0040	0.0034	0.0113*
	(0.0109)	(0.0034)	(0.0030)	(0.0049)	(0.0045)	(0.0045)	(0.0083)	(0.0059)
Fluoride 4nd quartile	0.0107	0.0073***	0.0098***	0.0129***	0.0110***	0.0111***	0.0092	0.0099
	(0.0074)	(0.0027)	(0.0028)	(0.0028)	(0.0030)	(0.0030)	(0.0077)	(0.0062)
Mean	0.7346	0.7346	0.7346	0.7346	0.7481	0.7481	0.7123	0.7603
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
Covariate group 1	No	No	No	Yes	Yes	Yes	Yes	Yes
Covariate group 2	No	No	No	No	No	Yes	Yes	Yes
Sample	All	All	All	All	Col 6	All	SAMS stayers	SAMS movers
R^2	0.0003	0.0069	0.0322	0.0472	0.0504	0.0582	0.0689	0.0597
Observations	728,074	728,074	728,074	728,074	440,048	440,048	76,422	158,504

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

A6 Results: Additional health outcomes

The purpose of this paper is primarily to study human capital development where we have focused on cognitive and non-cognitive abilities, math test scores and labor market outcomes. 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. Malin and Till (2015) has previously studied and found a connection between fluoride and the prevalence of ADHD. There has been a discussion in the earlier medical literature whether fluoride is associated with osteoporosis and hip fracture, see Näsman et al. (2013).

Our medical background section contained a review of earlier animal trials which found that fluoride induced behavioral and memory changes in rats that had been exposed to fluoride. Based on earlier literature, we study similar outcomes. We focus the analysis in this subsection on the chapter level in ICD10 for diagnoses in the outpatient and the inpatient register. We also estimate the effect of fluoride on the prevalence of prescription of drugs for more specific conditions. The ATC and ICD codes that we have included in the analysis are shown in *Table A25* and *Table A24* respectively, for the years 1987–2010 for the in- and outpatient register (the ICD codes) and for the years 2005-2009 for the medical drugs register (the ATC codes). The reader should note that we have more missings SAMS for the entire health analysis. Covariates originates from the year 2013.

Table A24: ICD codes for diagnoses

Diagnosis	ICD10
Psychiatric	F
Neurological	G
Skeleton and muscular	M

Table A25: ATC codes for drugs

Drug	ATC
ADHD	N06B
Antidepressants	N06A
Antipsychotics	N05A

Table A26: Descriptive statistics for health outcomes

	Mean	SD
ADHD medication	0.01	0.11
Antidepressants	0.06	0.25
Antipsychotics	0.01	0.10
Psyciatric diagnoses	0.12	0.32
Neurological diagnoses	0.04	0.19
Musculoskeletal diagnoses	0.13	0.34
Observations	726,737	

Notes: We only use information on the chapter level. See *Table A24* and *Table A25*.

Table A27: Prescription of drugs

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
ADHD medication	0.0000	-0.0001	-0.0001	-0.0002	-0.0002	-0.0002	-0.0002	0.0000
	(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	-0.0004	-0.0003	-0.0004	-0.0004	-0.0001
	(0.0003)	(0.0002)	(0.0002)	(0.0002)*	(0.0002)	(0.0002)*	(0.0003)	(0.0005)
	<0.0001>**	<0.0002>	<0.0002>	<0.0002>**	<0.0002>	<0.0002>**	<0.0002>*	<0.0004>
Antipsychotics	0.0000	-0.0001	-0.0001	-0.0001	-0.0001	-0.0001	0.0000	0.0001
	(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>	<0.0002>
Covariate group 1	No	No	No	Yes	Yes	Yes	Yes	Yes
Covariate group 2	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: The treatment is fluoride between birth and age 16. Fluoride is expressed as 0.1 mg/l. 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 220,446 and 726,737.

Table A28: Diagnosis from either the inpatient and the outpatients registers.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Psyciatric diagnoses	0.0006	-0.0001	-0.0002	-0.0006	-0.0005	-0.0007	-0.0004	-0.0002
	(0.0006)	(0.0004)	(0.0004)	(0.0004)	(0.0004)	(0.0004)*	(0.0003)	(0.0008)
	<0.0002>***	<0.0002>	<0.0002>	<0.0002>***	<0.0002>**	<0.0002>***	<0.0003>	<0.0005>
Neurological diagnoses	0.0002	0.0001	0.0001	-0.0000	-0.0000	-0.0001	0.0002	-0.0001
	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0002)	(0.0003)
	<0.0001>**	<0.0001>	<0.0001>	<0.0001>	<0.0001>	<0.0001>	<0.0002>	<0.0003>
Musculoskeletal diagnoses	-0.0006	-0.0005	-0.0005	-0.0006	-0.0005	-0.0005	-0.0003	-0.0005
	(0.0004)	(0.0002)**	(0.0002)**	(0.0003)**	(0.0003)*	(0.0003)*	(0.0004)	(0.0006)
	<0.0002>***	<0.0002>**	<0.0002>**	<0.0002>***	<0.0002>*	<0.0002>*	<0.0003>	<0.0005>
Covariate group 1	No	No	No	Yes	Yes	Yes	Yes	Yes
Covariate group 2	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: The treatment is fluoride between birth and age 16. Fluoride is expressed as 0.1 mg/l. 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 220,446 and 726,737.

In conclusion, we do not find that fluoride has any economically significant effects on these health outcomes. Some point estimates are statistically significant, but they are all very small is magnitude. 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. We also present non-linear effects for these outcomes below.

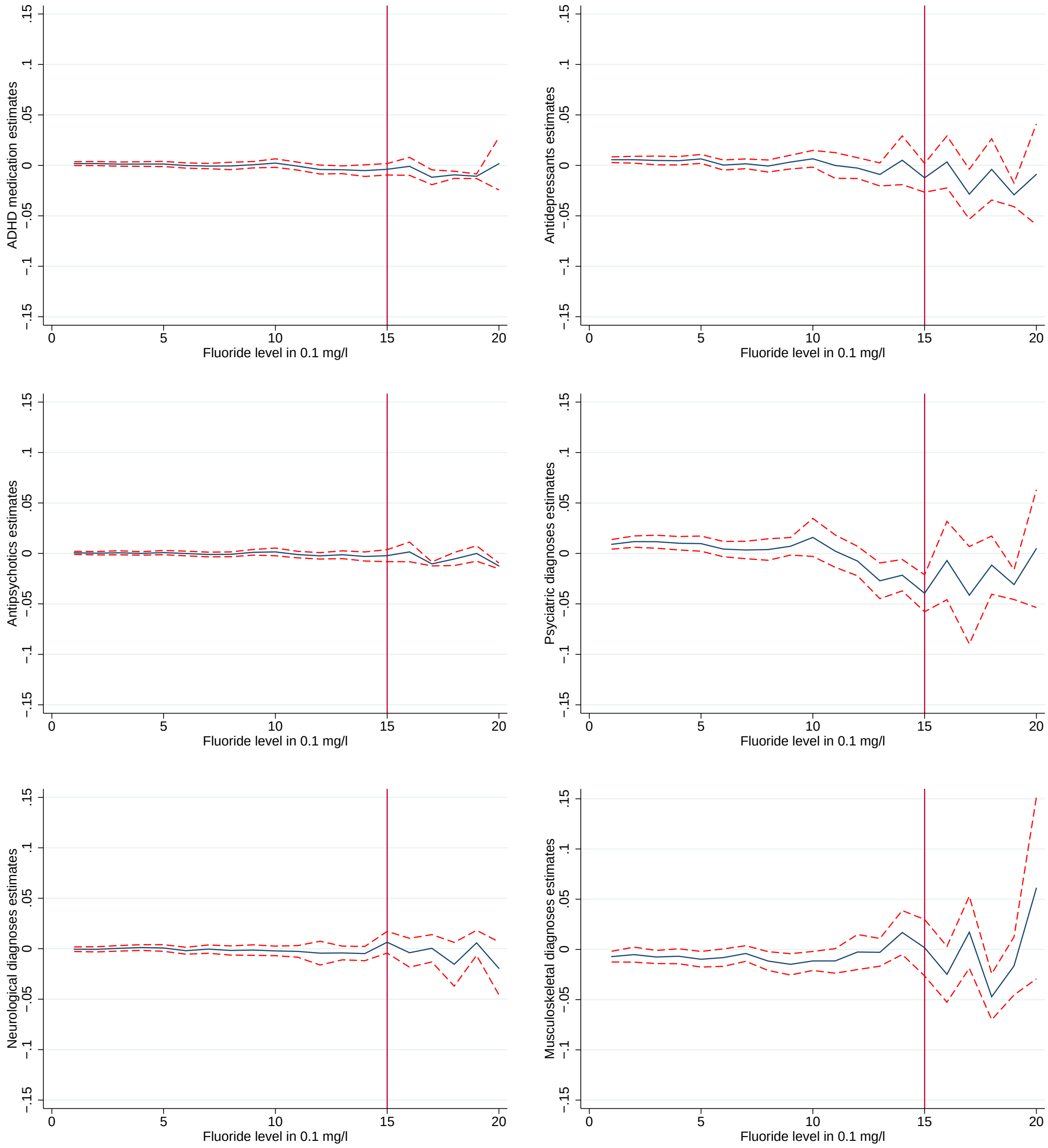

Figure A6: Non-linear effects: Additional health outcomes estimates.

A7 Results: Interpreting the reduced form for labor market status

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 try to move away from the reduce form interpretation and try to assess the magnitude for our estimates for log income and employment status. We do this by estimating the

2SLS estimates using fluoride as an instrument for dental repairs. This is however not an IV in the 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 2SLS as a method to rescale the size of the reduced form.

Dental repairs 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. In *Table A29* 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 dataset. 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 dental repairs is about 18 percent (with a median of 17 percent).

Table A29: Annual log income in SEK

	OLS Log income	FS Dental fillings	RF Log income	2SLS Log income
Dental repairs	0.0005			-0.0205
	(0.0002)***			(0.0281)
	<0.0002>***			<0.0070>***
Fluoride		-0.1624	0.0033	
		(0.0830)*	(0.0033)	
		<0.0325>***	<0.0009>***	
F stat. Municipality		3.83		
F stat. SAMS		25.01		
Sample	All			
Dental repairs	0.0000			0.2719
	(0.0002)			(2.9733)
	<0.0000>			<1.3703>
Fluoride		-0.0114	-0.0031	
		(0.1225)	(0.0018)	
		<0.0573>	<0.0015>**	
F stat. Municipality		0.01		
F stat. SAMS		0.04		
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 A30: Employment status

	OLS Employment	FS Dental fillings	RF Employment	2SLS Employment
Dental fillings	0.0005			-0.0151
	(0.0001)***			(0.0175)
	<0.0000>***			<0.0040>***
Fluoride		-0.1671	0.0025	
		(0.0844)**	(0.0019)	
		<0.0326)***	<0.0004>***	
F stat. Municipality		3.92		
F stat. SAMS		26.23		
Sample	All			
Dental fillings	0.0004			-0.0630
	(0.0001)***			(0.4281)
	<0.0001>***			<0.1809>
Fluoride		-0.0206	0.0013	
		(0.1248)	(0.0013)	
		<0.0577>	<0.0006>*	
F stat. Municipality		0.03		
F stat. SAMS		0.13		
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 A29*, we find that when dental repairs increases by 1 percentage point, income decreases by 2 percent on the same aggregate level. 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 2SLS uninterpretable. We have the same problem when we cluster the standard errors on the muncipal level.[36]

[36] 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.

A8 Robustness analysis: Distance of SAMS

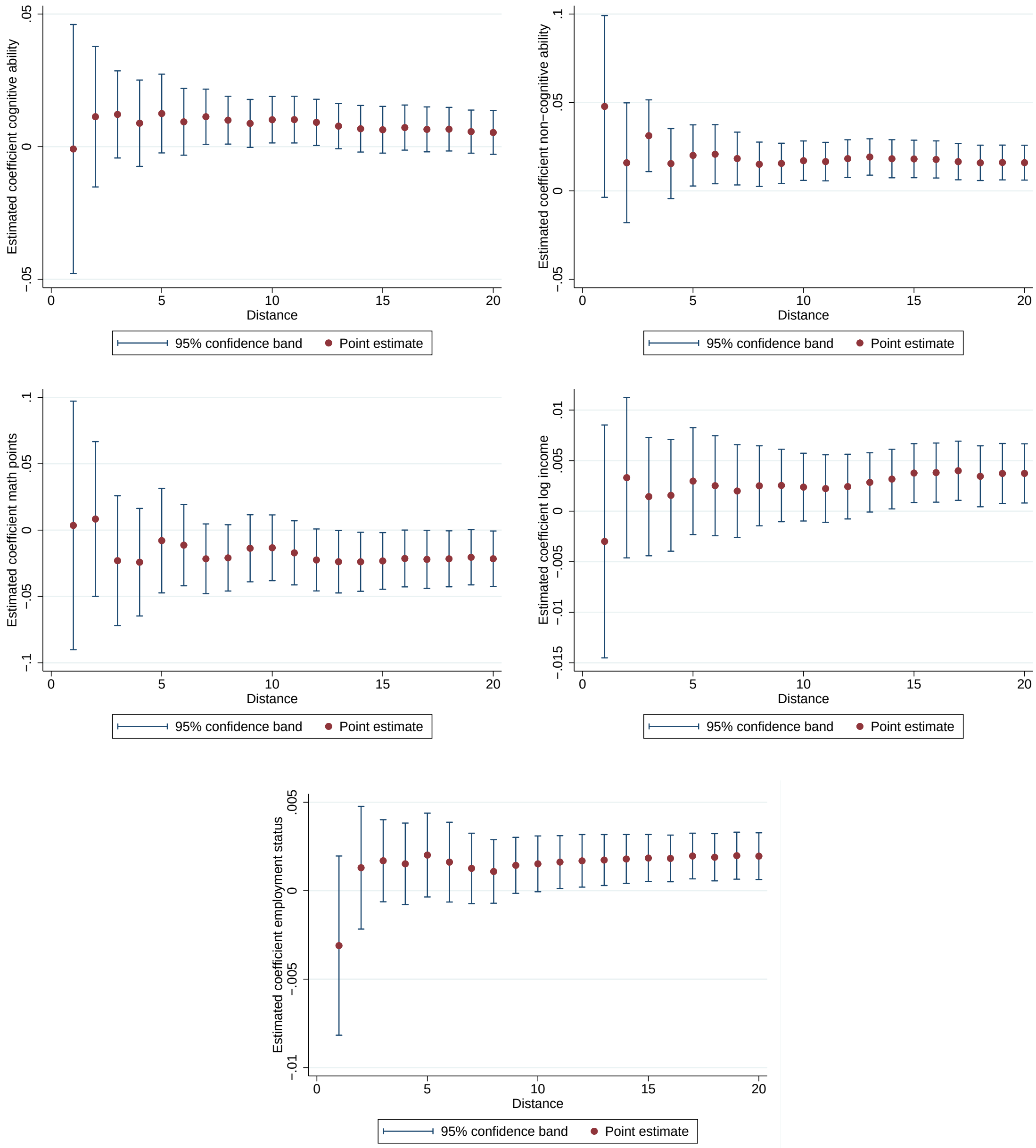

Figure A7: Estimates for different geographical distances from water plant. The X-axis corresponds to distances in kilometers between water plant and the center point of the SAMS.

A9 Robustness analysis: Area of SAMS

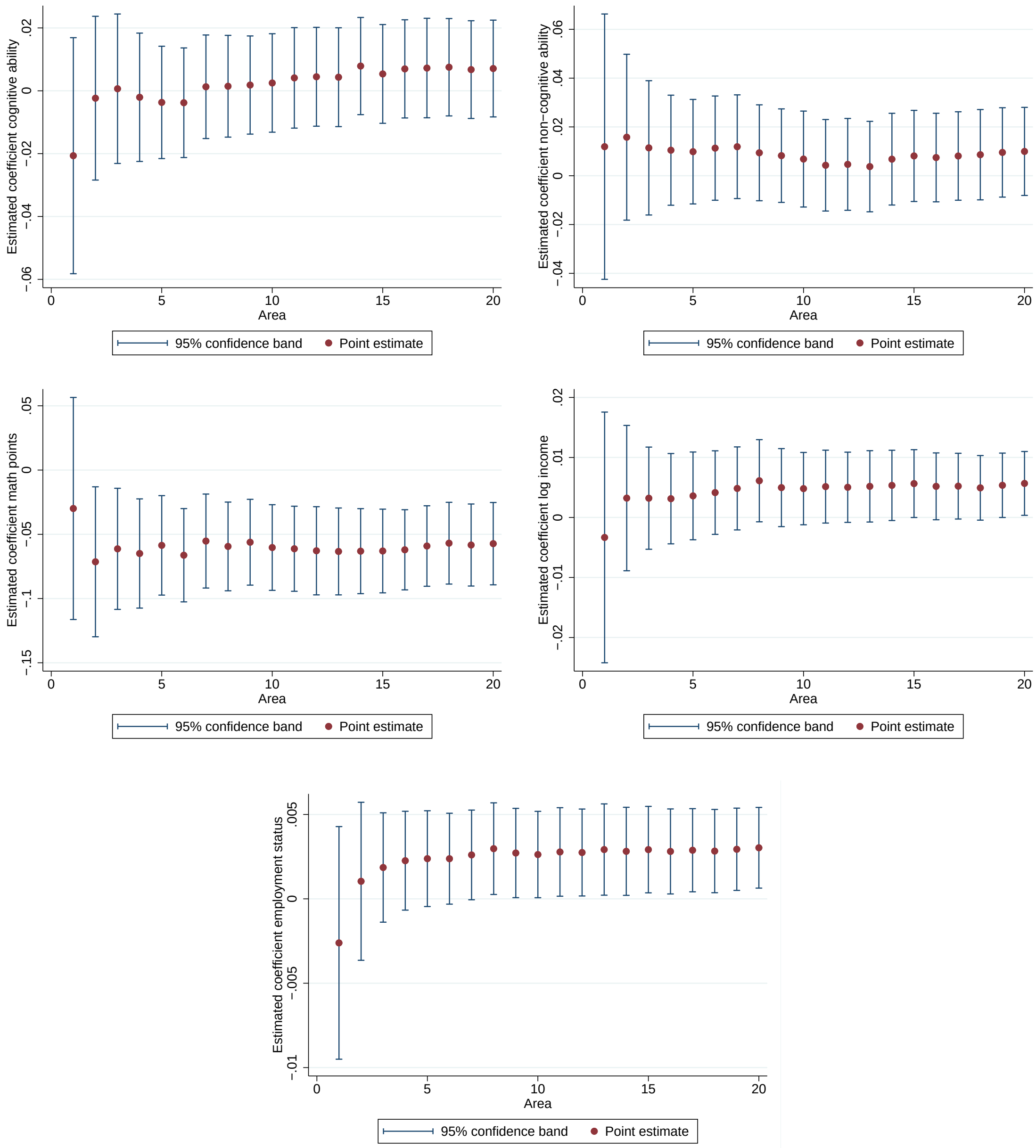

Figure A8: Estimates for different geographical areas SAMS. The X-axis corresponds to areas in square kilometers.

A10 Robustness analysis: Confirmed water source

Table A31: 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	0.0147*	0.0212**	0.0080	0.0370**
	(0.0109)	(0.0081)	(0.0080)	(0.0079)	(0.0087)	(0.0106)	(0.0183)
Mean	4.9744	4.9744	4.9744	4.9987	4.9987	5.1059	4.8895
Birth cohort FE	No	No	Yes	Yes	Yes	Yes	Yes
Birth municipal FE	No	Yes	Yes	Yes	Yes	Yes	Yes
Covariate group 2	No	No	No	No	Yes	Yes	Yes
Sample	All	All	All	Col 5	All	SAMS stayers	SAMS movers
R^2	0.0009	0.0282	0.0311	0.0360	0.1681	0.1782	0.1738
Observations	18,922	18,922	18,922	11,263	11,263	5,552	4,958

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

Table A32: 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	0.0214	0.0275	0.0309**	0.0121
	(0.0096)	(0.0121)	(0.0121)	(0.0150)	(0.0170)	(0.0120)	(0.0282)
Mean	4.7752	4.7752	4.7752	4.8331	4.8331	4.9701	4.6852
Birth cohort FE	No	No	Yes	Yes	Yes	Yes	Yes
Birth municipal FE	No	Yes	Yes	Yes	Yes	Yes	Yes
Covariate group 2	No	No	No	No	Yes	Yes	Yes
Sample	All	All	All	Col 5	All	SAMS stayers	SAMS movers
R^2	0.0000	0.0248	0.0248	0.0318	0.0840	0.0901	0.0983
Observations	15,246	15,246	15,246	9,144	9,144	4,548	4,002

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

Table A33: 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	-0.0572*	-0.0240	0.0027	-0.0519
	(0.0558)	(0.0288)	(0.0270)	(0.0270)	(0.0298)	(0.0275)	(0.0291)	(0.0319)
Mean	26.3590	26.3590	26.3590	26.3590	26.6075	26.6075	27.3036	25.9322
Birth cohort FE	No	No	Yes	Yes	Yes	Yes	Yes	Yes
Birth municipal FE	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Covariate group 1	No	No	No	Yes	Yes	Yes	Yes	Yes
Covariate group 2	No	No	No	No	No	Yes	Yes	Yes
Sample	All	All	All	All	Col 6	All	SAMS stayers	SAMS movers
R^2	0.0075	0.0370	0.0584	0.0586	0.0598	0.1578	0.1484	0.1657
Observations	113,378	113,378	113,378	113,378	74,597	74,597	37,877	32,614

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

Table A34: 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*	0.0029*	0.0016	0.0017	0.0057	0.0033
	(0.0042)	(0.0018)	(0.0015)	(0.0017)	(0.0022)	(0.0022)	(0.0038)	(0.0031)
Mean	11.9470	11.9470	11.9470	11.9470	11.9513	11.9513	11.8401	11.9775
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
Covariate group 1	No	No	No	Yes	Yes	Yes	Yes	Yes
Covariate group 2	No	No	No	No	No	Yes	Yes	Yes
Sample	All	All	All	All	Col 6	All	SAMS stayers	SAMS movers
R^2	0.0002	0.0088	0.0531	0.1023	0.1066	0.1116	0.1447	0.1284
Observations	145,385	145,385	145,385	145,385	93,028	93,028	19,174	38,351

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

Table A35: 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*	0.0015*	0.0009	0.0011	0.0021	0.0027
	(0.0019)	(0.0007)	(0.0007)	(0.0008)	(0.0011)	(0.0012)	(0.0014)	(0.0017)
Mean	0.7525	0.7525	0.7525	0.7525	0.7622	0.7622	0.7122	0.7712
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
Covariate group 1	No	No	No	Yes	Yes	Yes	Yes	Yes
Covariate group 2	No	No	No	No	No	Yes	Yes	Yes
Sample	All	All	All	All	Col 6	All	SAMS stayers	SAMS movers
R^2	0.0002	0.0093	0.0356	0.0540	0.0572	0.0645	0.0828	0.0679
Observations	164,626	164,626	164,626	164,626	104,032	104,032	21,650	43,152

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

A11 Robustness analysis: Alternative income measure

Table A36: Annual income, “Förvärvsinkomst”

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Fluoride up until year 2014 (0.1 mg/l)	0.0041	0.0012	0.0033**	0.0042***	0.0034**	0.0036**	0.0041*	0.0018
	(0.0030)	(0.0017)	(0.0015)	(0.0016)	(0.0015)	(0.0014)	(0.0021)	(0.0039)
Mean	12.1037	12.1037	12.1037	12.1037	12.0860	12.0860	11.9034	12.1024
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
Covariate group 1	No	No	No	Yes	Yes	Yes	Yes	Yes
Covariate group 2	No	No	No	No	No	Yes	Yes	Yes
Sample	All	All	All	All	Col 6	All	SAMS stayers	SAMS movers
R^2	0.0001	0.0104	0.1125	0.1434	0.1431	0.1505	0.1500	0.1540
Observations	813,294	813,294	813,294	813,294	466,468	466,468	70,601	163,432

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

A12 Robustness analysis: Income above 1,000 SEK

Table A37: Income above 1,000 SEK

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Fluoride up until year 2014 (0.1 mg/l)	0.0001	-0.0002	-0.0001	0.0013***	0.0013***	0.0016***	0.0005	0.0012*
	(0.0005)	(0.0003)	(0.0003)	(0.0003)	(0.0003)	(0.0004)	(0.0006)	(0.0007)
Mean	0.8766	0.8766	0.8766	0.8766	0.8900	0.8900	0.8813	0.8898
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
Covariate group 1	No	No	No	Yes	Yes	Yes	Yes	Yes
Covariate group 2	No	No	No	No	No	Yes	Yes	Yes
Sample	All	All	All	All	Col 6	All	SAMS stayers	SAMS movers
R^2	0.0000	0.0033	0.0052	0.0119	0.0108	0.0185	0.0221	0.0176
Observations	916,201	916,201	916,201	916,201	518,434	518,434	79,270	181,790

Notes: The outcome variable is a dummy which takes the value 1 if the individual has an income above 1,000 SEK during 2014, and zero otherwise. Standard errors clustered at the municipal level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

A13 Robustness analysis: Most conservative specification

Table A38: Cognitive ability

	(1)	(2)	(3)	(4)	(5)
Fluoride up until age 18 (0.1 mg/l)	-0.0188	0.0123	0.0120	0.0089	0.0089
	(0.0111)*	(0.0168)	(0.0165)	(0.0166)	(0.0166)
Mean	4.9905	4.9905	4.9905	4.9208	4.9208
Birth cohort FE	No	No	Yes	Yes	Yes
Birth municipal FE	No	Yes	Yes	Yes	Yes
Covariate group 2	No	No	No	Yes	Yes
Sample	All	All	All	Col 5	All
R^2	0.0017	0.0664	0.0720	0.2695	0.2695
Observations	1,992	1,992	1,992	1,187	1,187

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

Table A39: Non-cognitive ability

	(1)	(2)	(3)	(4)	(5)
Fluoride up until age 18 (0.1 mg/l)	-0.0134	0.0071	0.0073	0.0222	0.0222
	(0.0136)	(0.0134)	(0.0134)	(0.0198)	(0.0198)
Mean	4.8369	4.8369	4.8369	4.8838	4.8838
Birth cohort FE	No	No	Yes	Yes	Yes
Birth municipal FE	No	Yes	Yes	Yes	Yes
Covariate group 2	No	No	No	Yes	Yes
Sample	All	All	All	Col 5	All
R^2	0.0008	0.0949	0.0951	0.1617	0.1617
Observations	1,625	1,625	1,625	981	981

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

Table A40: Math points

	(1)	(2)	(3)	(4)	(5)	(6)
Fluoride up until age 16 (0.1 mg/l)	-0.0457	0.0463	0.0412	0.0406	0.0139	0.0071
	(0.0192)**	(0.0273)*	(0.0270)	(0.0269)	(0.0270)	(0.0237)
Mean	26.6661	26.6661	26.6661	26.6661	26.8122	26.8122
Birth cohort FE	No	No	Yes	Yes	Yes	Yes
Birth municipal FE	No	Yes	Yes	Yes	Yes	Yes
Covariate group 1	No	No	No	Yes	Yes	Yes
Covariate group 2	No	No	No	No	Yes	Yes
Sample	All	All	All	All	Col 6	All
R^2	0.0005	0.0288	0.0513	0.0519	0.0565	0.1322
Observations	12,661	12,661	12,661	12,661	8,589	8,589

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

Table A41: Annual log income

	(1)	(2)	(3)	(4)	(5)	(6)
Fluoride up until year 2014 (0.1 mg/l)	-0.0042	0.0022	0.0026	0.0028	0.0015	0.0019
	(0.0048)	(0.0045)	(0.0044)	(0.0039)	(0.0060)	(0.0058)
Mean	11.9282	11.9282	11.9282	11.9282	11.9312	11.9312
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
Covariate group 1	No	No	No	Yes	Yes	Yes
Covariate group 2	No	No	No	No	Yes	Yes
Sample	All	All	All	All	Col 6	All
R^2	0.0002	0.0175	0.0455	0.1527	0.1654	0.1754
Observations	6,955	6,955	6,955	6,955	4,694	4,694

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

Table A42: Employment status

	(1)	(2)	(3)	(4)	(5)	(6)
Fluoride up until year 2014 (0.1 mg/l)	-0.0013	-0.0009	-0.0009	-0.0008	-0.0007	-0.0008
	(0.0012)	(0.0018)	(0.0019)	(0.0019)	(0.0020)	(0.0019)
Mean	0.7474	0.7474	0.7474	0.7474	0.7518	0.7518
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
Covariate group 1	No	No	No	Yes	Yes	Yes
Covariate group 2	No	No	No	No	Yes	Yes
Sample	All	All	All	All	Col 6	All
R^2	0.0001	0.0154	0.0229	0.0840	0.0925	0.1014
Observations	7,802	7,802	7,802	7,802	5,222	5,222

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

A14 Robustness analysis: Analysis with adoptees only

Table A43: 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	-0.0819	-0.0512	-0.2691	-0.1837
	(0.0218)	(0.0645)	(0.0651)	(0.0742)	(0.0805)	(0.2311)	(0.1394)
Mean	4.2947	4.2947	4.2947	4.3346	4.3346	4.1856	4.4634
Birth cohort FE	No	No	Yes	Yes	Yes	Yes	Yes
Birth municipal FE	No	Yes	Yes	Yes	Yes	Yes	Yes
Covariate group 2	No	No	No	No	Yes	Yes	Yes
Sample	All	All	All	Col 5	All	SAMS stayers	SAMS movers
R^2	0.0015	0.3402	0.3443	0.4956	0.5612	0.7949	0.8716
Observations	526	526	526	257	257	97	82

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

Table A44: 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	-0.0648	-0.0643	-0.0789	-0.3185
	(0.0206)	(0.0648)	(0.0645)	(0.0971)	(0.1096)	(0.2837)	(0.2179)
Mean	4.4914	4.4914	4.4914	4.6786	4.6786	4.6429	4.6393
Birth cohort FE	No	No	Yes	Yes	Yes	Yes	Yes
Birth municipal FE	No	Yes	Yes	Yes	Yes	Yes	Yes
Covariate group 2	No	No	No	No	Yes	Yes	Yes
Sample	All	All	All	Col 5	All	SAMS stayers	SAMS movers
R^2	0.0030	0.3767	0.3840	0.5542	0.5908	0.9264	0.8791
Observations	407	407	407	196	196	70	61

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

Table A45: 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	-0.1518	-0.0852	-0.0943	-0.1331	0.0136
	(0.0934)	(0.1325)	(0.1308)	(0.1319)	(0.1749)	(0.1683)	(0.2803)	(0.4103)
Mean	23.7463	23.7463	23.7463	23.7463	24.1101	24.1101	24.6987	23.6292
Birth cohort FE	No	No	Yes	Yes	Yes	Yes	Yes	Yes
Birth municipal FE	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Covariate group 1	No	No	No	Yes	Yes	Yes	Yes	Yes
Covariate group 2	No	No	No	No	No	Yes	Yes	Yes
Sample	All	All	All	All	Col 6	All	SAMS stayers	SAMS movers
R^2	0.0002	0.1265	0.1493	0.1503	0.2309	0.2503	0.4266	0.4003
Observations	2,089	2,089	2,089	2,089	1,172	1,172	521	383

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

Table A46: 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	0.0067	0.0086	0.0715	0.0034
	(0.0070)	(0.0092)	(0.0090)	(0.0103)	(0.0165)	(0.0158)	(0.0689)	(0.0622)
Mean	11.8656	11.8656	11.8656	11.8656	11.8400	11.8400	11.6916	11.8300
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
Covariate group 1	No	No	No	Yes	Yes	Yes	Yes	Yes
Covariate group 2	No	No	No	No	No	Yes	Yes	Yes
Sample	All	All	All	All	Col 6	All	SAMS stayers	SAMS movers
R^2	0.0014	0.0799	0.1190	0.2191	0.3329	0.3385	0.6476	0.4593
Observations	3,176	3,176	3,176	3,176	1,564	1,564	288	507

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

Table A47: 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	-0.0003	0.0072	0.0077	0.0106	0.0318
	(0.0026)	(0.0045)	(0.0044)	(0.0047)	(0.0075)	(0.0073)	(0.0214)	(0.0199)
Mean	0.7006	0.7006	0.7006	0.7006	0.6929	0.6929	0.6040	0.6933
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
Covariate group 1	No	No	No	Yes	Yes	Yes	Yes	Yes
Covariate group 2	No	No	No	No	No	Yes	Yes	Yes
Sample	All	All	All	All	Col 6	All	SAMS stayers	SAMS movers
R^2	0.0001	0.0761	0.0950	0.1843	0.2977	0.3056	0.6255	0.4171
Observations	3,814	3,814	3,814	3,814	1,879	1,879	346	613

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

A15 Robustness analysis: Analysis with family fixed effects

Note that we now have included sibling order dummies for some specifications. Also note that we have dropped all families with half-siblings because these individuals might live in different households which would be problematic when we use within-family variation of the fluoride treatment.

Table A48: Cognitive ability

	(1)	(2)	(3)	(4)	(5)
Fluoride up until age 18 (0.1 mg/l)	-0.1513	-0.1893	-0.1835	-0.2140	-0.2153
	(0.6962)	(0.7931)	(0.7375)	(1.0285)	(1.0357)
Mean	5.0497	5.0497	5.0497	5.1372	5.1372
Birth cohort FE	No	No	Yes	Yes	Yes
Birth municipal FE	No	Yes	Yes	Yes	Yes
Covariate group 2	No	No	No	No	Yes
Sample	All	All	All	Col 5	All
R^2	0.9692	0.9716	0.9724	0.9728	0.9728
Observations	26,627	26,627	26,627	17,511	17,511

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

Table A49: Non-cognitive ability

	(1)	(2)	(3)	(4)	(5)
Fluoride up until age 18 (0.1 mg/l)	-0.3438	-0.3257	-0.3036	-0.3157	-0.3142
	(1.0963)	(1.2150)	(1.1794)	(1.7218)	(1.7328)
Mean	4.7172	4.7172	4.7172	4.8031	4.8031
Birth cohort FE	No	No	Yes	Yes	Yes
Birth municipal FE	No	Yes	Yes	Yes	Yes
Covariate group 2	No	No	No	No	Yes
Sample	All	All	All	Col 5	All
R^2	0.9661	0.9689	0.9691	0.9707	0.9707
Observations	21,603	21,603	21,603	14,307	14,307

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

Table A50: Math points

	(1)	(2)	(3)	(4)	(5)	(6)
Fluoride up until age 16 (0.1 mg/l)	0.0643	0.0597	0.0326	0.0335	0.1339	0.1334
	(0.1986)	(0.2062)	(0.2109)	(0.2107)	(0.2451)	(0.2440)
Mean	25.8621	25.8621	25.8621	25.8621	26.2801	26.2801
Birth cohort FE	No	No	Yes	Yes	Yes	Yes
Birth municipal FE	No	Yes	Yes	Yes	Yes	Yes
Covariate group 1	No	No	No	Yes	Yes	Yes
Covariate group 2	No	No	No	No	No	Yes
Sample	All	All	All	All	Col 6	All
R^2	0.7787	0.7799	0.7850	0.7850	0.7877	0.7882
Observations	164,879	164,879	164,879	164,879	106,605	106,605

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

Table A51: Annual log income

	(1)	(2)	(3)	(4)	(5)	(6)
Fluoride up until year 2014 (0.1 mg/l)	-0.0324***	-0.0307***	-0.0129	-0.0035	0.0011	0.0010
	(0.0099)	(0.0095)	(0.0084)	(0.0100)	(0.0113)	(0.0113)
Mean	11.9498	11.9498	11.9498	11.9498	11.9666	11.9666
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
Covariate group 1	No	No	No	Yes	Yes	Yes
Covariate group 2	No	No	No	No	No	Yes
Sample	All	All	All	All	Col 6	All
R^2	0.6203	0.6218	0.6364	0.6543	0.6557	0.6558
Observations	295,672	295,672	295,672	295,672	194,791	194,791

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

Table A52: Employment status

	(1)	(2)	(3)	(4)	(5)	(6)
Fluoride up until year 2014 (0.1 mg/l)	-0.0140***	-0.0133***	-0.0079***	-0.0022	-0.0004	-0.0004
	(0.0033)	(0.0032)	(0.0029)	(0.0036)	(0.0039)	(0.0039)
Mean	0.7518	0.7518	0.7518	0.7518	0.7654	0.7654
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
Covariate group 1	No	No	No	Yes	Yes	Yes
Covariate group 2	No	No	No	No	No	Yes
Sample	All	All	All	All	Col 6	All
R^2	0.5801	0.5813	0.5902	0.5966	0.5987	0.5988
Observations	335,595	335,595	335,595	335,595	217,889	217,889

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