The effect of iodine deficiency on test scores and child mortality in rural India

Work in progress, please do not cite.

Wiktoria Tafesse, University of Sussex *

December 14, 2016

Abstract

Iodine deficiency has a large impact on human capital attainment. This paper applies a differences in differences strategy using exogenous variation from changes in a nation-wide iodine-fortification policy in India, comparing test scores of school-aged children in naturally iodine sufficient and deficient districts over time. Children in iodine poor districts who were exposed to an exogenous drop in iodine- fortified salt in early life, are 1-8 percentage points less likely to be able to do any math or reading. More adverse effects are found for girls. In addition, girls were found to be less likely to have been enrolled in school and more likely to have died as an infant.

*Department of Economics, University of Sussex, Department of Economics University of Sussex, Brighton BN1 9SL, W.Tafesse@sussex.ac.uk.

1 Introduction

Iodine is one of the essential elements required for normal human growth and development and iodine deficiency is now recognized by the WHO as the most common preventable cause of brain damage. Almost two billion people worldwide, the majority living in developing regions such as South Asia and Sub Saharan Africa, are estimated to be at risk (Rodgers et al., 2002). The effects of iodine deficiency range from mild intellectual blunting to cretinism, a condition that includes gross mental retardation and other physical defects. Intrauterine iodine deficiency is well established as the cause of lower cognitive abilities and the effects of fetal iodine deficiency disorder (IDD) are irreversible. Medical trials show that inadequate supply of iodine in utero permanently reduces IQ, regardless of subsequent supplementation (Andersson M, 2012; Cao et al., 1994). It is therefore of great economic importance to study the impact of iodine deficient disorders (IDD) in early life on human capital attainment in developing countries as this hidden form of malnutrition might hinder children of reaching their full potential. Unlike other micro-nutrients iodine does not occur naturally in specific foods; rather, it is present in the soil and is ingested through foods grown on that soil. Thus, iodine deficiency is mainly geographically determined. Soils from mountain ranges, areas with high rainfall and frequent flooding are particularly likely to be iodine deficient. The food grown in iodine deficient regions can never provide enough iodine to the population and live-stock living there.

The most common public health policy is iodine-fortification of table salt as to ensure recommended daily average intake of iodine. As is often the case in developing countries, such policies are often not properly enforced or sustained. India carries the largest burden of IDD in the world and despite the country's long history of combating IDD, India is not an exception with regards to unsustainable iodine fortification policies. At least 249 million people, including 8 million newborns, are still unprotected from the consequences of IDD in India(Andersson M, 2012). The government of India started fortifying salt with iodine on a national scale in the 1980's and subsequently enacted a nationwide ban on the sale and consumption of non-iodized salt for human consumption in the late 1990's. Due to political resistance to the ban, it was revoked in 2000. This led to a significant drop in the consumption of iodised salt with more than 20 percentage points. The ban was reinstated again in 2005 due to pressure from NGO's. As many studies show that even mild iodine deficiency in early life has a persistent and detrimental effect on children's cognitive development, this study utilize the variation in the Indian iodine fortification policies as a natural experiment to measure the causal effect of iodine deficiency in early life on the changes in test scores of children in iodine deficient and iodine sufficient districts during different policy regimes. I apply a DiD analysis stemming from the geographical variation in predisposition to IDD along with the temporal variation in a public health policy combating IDD. Therefore, the great variation in geography, climate and topography in the Indian subcontinent provides much variation in the spatial susceptibility to IDD, generating results that should be generalizable to to other developing countries.

The causal relationship of iodine deficiency disorders and other diseases, such as hookworm, malaria, influenza, on human capital development and labour market outcomes, has gained more interest in economic studies in the past decade, see (Feyrer et al., 2013; Bleakley, 2007; Politi, 2010, 2015; Cutler et al., 2010; Almond, 2006). These papers have examined the effect of he introduction of a medical technology in early life on schooling attainment, adult literacy rates, and proxies for IQ for military draftees using historical data. The schooling outcomes studied in previous papers on the impact of iodine deficiency are rather crude and do not allow for an understanding of the intensive margin of human capital development during childhood. The main contribution of this study is two-fold. First, instead of estimating the impact of iodine deficiency on schooling completion rates or results from military admission tests, I study the impact of iodine on cognitive attainment during the most important time of human capital formation - test scores of school aged children. It is cognitive skills of the population rather than schooling attainment which is an important driver of individual earnings, the distribution of income and economic growth (Eric A. Hanushek, 2008). In particular, it is important to study this relationship given the evidence on early-life on dynamic skill production and life cycle labour outcomes suggested by Heckman (2006, 2007). Second, this paper is the first to study the impact of the implementation of a large scale national iodine policy on human capital generation in a developing country. I study the implication of when such a policy is not enforced. In several low- and middle income countries, where IDDs had been eliminated by fortification programmes previously, policies eventually faltered, and IDDs recurred. Thus, sustainability of such programs is absolutely critical (Karmarkar et al., 2012).

The results from this study show that a lack of an iodine fortification policy decreases the probability of being enrolled in primary school (for girls), increases the probability of children not being able to do any math or reading in iodine deficient districts and increases the probability of dying as an infant, or under the age of 3, for girls. No effects are found for the overall continuous math and reading scores, suggesting that children at the lower end of the cognition distribution were affected disproportionately. Even though the magnitudes of these effects are not large, they are indicative of that not only the initiation of a policy but the enforcement and continuation of such a policy on a nation wide scale is of large significance not only for health but for the accumulation of human capital.

2 Previous literature

The first paper in Economics to have studied the effects of iodine deficiency in early life on human capital attainment is Field et al. (2009). Field et al. (2009) uses the roll-out of a maternal supplementation program in Tanzania to estimate the effect of iodine supplementation in utero on schooling outcomes. They find that iodine supplementation led to an increase in schooling attainment and that the effect was larger for girls. Their results corroborate lab studies on rats that find more adverse effects of iodine deficiency in utero on female foetuses than on male foetuses fetal neurodevelopment and behavioral outcomes (Arnold J. Friedhoff et al. (2000) and earlier studies on humans also find gender differences, Bautista et al. (1982) and Shrestha and West (1994). More recent papers have identified the effect of iodine deficiency on human capital attainment by using the initiation of iodine fortification of table salt in conjunction with geographic variation of naturally occurring susceptibility to iodine deficiency as a natural experiment (Politi, 2010, 2015). The identification from this strand of literature originates from papers studying the effect of the eradication of other non-communicable diseases. The seminal paper by Bleakley (2007) studied a hookworm eradication program in the American south. He finds that areas with higher levels of hookworm infection prior to the eradication program experienced greater increases in school enrolment, attendance, literacy and returns to education after the intervention. Cutler et al. (2010) use the Indian national malaria eradication program in the 1950's as a quasi- experiment and exploit geographic variation in malaria prevalence prior to the eradication campaign. They find no effects for literacy or primary school completion but they do observe modest relative increases in economic status for prime age men. Moreover, malaria eradication led to higher labour productivity and adult income but mixed evidence was found for years of schooling in United States, Brazil, Colombia, and Mexico (Bleakley, 2010). Lucas (2010) finds that malaria eradication increases female education and literacy rates Paraguay and Sri Lanka. The effects of technological innovations in public health have heterogeneous effects on human capital attainment, schooling-completion rates and income depending on the disease studied. However, it is known that iodine deficiency directly reduces the production of human capital which makes it important to study the effects of this particular form of malnutrition.

Feyrer et al. (2013) estimate the impact of iodine fortification of salt in the U.S. on the probability of being accepted to the Air Forces. Using these tests as a proxy for IQ, they find that salt iodisation in the US raised IQ by approximately one standard deviation corresponding to up to 15 IQ points. Feyrer et al. (2013) use the interaction of goitre prevalence in state with birth year dummies as treatment. Draftee data on goitre prevalence is used as a proxy for the degree of naturally occurring iodine content in the soil and groundwater. They find that Individuals from high goitre states are 3.8-10 percentage point more likely to enter Air Forces compared to earlier cohorts. Feyrer et al. (2013) do not find any effect of iodisation on education levels. However, this study excludes women from the analysis and does not investigate in the most critical time period of cognitive skill-formation - childhood. Moreover, they did not find a positive effect on schooling attainment which is not consistent with the findings in Field et al. (2009) and Politi (2010). Using the same identification strategy as Feyrer et al. (2013), Adhvaryu et al. (2016) find that incomes for cohorts who benefited from iodized salt access went up by 11 %; labour force participation rose by roughly 0.75 percentage points; and the probability of working more than 50 weeks in a year went up by over 1 percentage point. These impacts were driven entirely by females. They find large impacts on economic outcomes early in women's adult lives and muted effects later in life. Women married at later ages and experienced a small increase in educational attainment. Using the introduction of iodised salt in Switzerland, Politi (2010) finds that cohorts born after the introduction of iodized salt in previously highly iodine deficient areas were more likely to graduate from secondary and tertiary education and the effect is larger for girls. Using the same DiD set up, Politi (2015) shows that iodine fortification increased the probability to enter top-tier occupations with higher cognitive demands for cohorts in previously iodine endemic areas. As a result, wages of these cohorts were higher, accounting for about 1.9% of annual median earnings, or 2 % of Swiss GDP per capita in 1991.

3 Iodine Deficiency Disorders

Iodine is needed to regulate thyroid hormone availability. The thyroid hormones are essential to proper development and differentiation of all cells in the human body. The thyroid gland in the neck uses iodine to produce thyroid hormones, which are released into the blood stream to control metabolism (the conversion of oxygen and calories to energy). Optimal iodine intake as recommended by the WHO is: a daily dose of 90 μg for infants of 0-59 months, 120 μg for ages 6 to 12, 150 μg for older ages (which is the amount found in half a teaspoon of iodized salt), and 200 μg for pregnant and lactating women (M Andersson and Zupan, 2007). Endemic cretinism occurs if iodine intake is below 20 μ g/day (Hetzel, 1983). The thyroid gland secretes 80 micrograms of iodine per day in the form of thyroid hormones. The stored hormones can meet the body requirements for up to 3 months (Ahad and Ganie, 2010). About 150 μg /day is sufficient to prevent clinical manifestation of iodine deficiency disorders for at least several months even if iodine would become absent from the diet (Mezgebu et al., 2012). The human body cannot store iodine as it is excreted in the urine (M Andersson and Zupan, 2007). In adults, the most noticeable symptom of iodine deficiency is the enlargement of the thyroid gland which is called goitre. When the thyroid does not receive sufficient amounts of iodine it adapts by enlarging in order to maximize the use of available iodine.[1] Prior to the implementation of any public health policies combating IDD, endemic goitre was a clear proxy of the iodine content of the soil and water. It was noted very early on that endemic goitre was exceedingly common in some well-defined areas in the Indian sub continent and researchers started to acknowledge that the cause of goitre was in the soil and water supply (Stott, Bhatia, 1930). Some goitres are reversible, especially in young individuals. A landmark study in the Kangra Valley provided a clear understanding of the efficacy of iodised salt to decrease goitre prevalence.

The most important biological role played by thyroxin is in the early foetal stage of life-, the first 1000 days of life, from conception until the age of two. The requirement of thyroid hormone for the development of the central nervous system needed for intellectual functioning is most critical in utero as it influences the myelination and density of neural networks established in the developing brain (Zimmerman, n.d.). Iodine deficiency in utero also leads to physical defects such as cretinism, deaf-mutism, abortions, stillbirths, congenital anomalies, increased perinatal mortality, increased infant mortality etc. However, the overwhelming consensus in the medical literature is that the damage from IDD in utero is mostly cognitive and physical outcomes s are more likely to occur under extreme deprivation (Zimmerman, n.d.). In particular, animal studies indicate that cognition is sensitive to iodine deficiency exclusively during early fetal life (prior to midgestation), whereas growth and psychomotor development are believed to be most affected by deficiency in infancy (Isa Zaleha et al. 2000; Cao et al. 1994). Meta-analysis from medical trials and community based assessment of iodine intervention trials show that the average IQ of iodine deficient groups is 13.5 points lower than non-deficient groups. - and iodine supplementation improves performance on cognitive tests (Kapil, 2007).

There is also convincing evidence from intellectual gains of supplementing moderately and mild iodine deficient populations in utero and in childhood as laboratory studies indicate a continuous process by which fetal brain development is sensitive to minor adjustments in thyroid hormoneZimmermann (2011). Results from a randomized trial in New Zeeland showed that iodine supplementation of young children improved perceptual reasoning in mildly iodine-deficient children after only 28 weeks (Gordon et al., 2009). Mild maternal iodine deficiency is now hypothesized to reduce intelligence quotients by a

[1]Some vegetables have been coined as goitrogens; they block thyroidal uptake of iodine and thus lead to goitre. Examples are cassava, and some species of millet and crucieferous vegetables. Most of these goitrogens are not of clinical importance unless they are consumed in large amounts or there is coexisting iodine deficiency (Zimmermann et al., n.d.).

noticeable margin. In areas of even mild to moderate iodine deficiency, total body iodine stores decline gradually from the first to the third trimester of pregnancy (Brander et al., 2003). One study found that women who consumed iodised salt prior to 2 years before pregnancy had 6 times lower risk of maternal thyroid failure compared to mother's who started consuming Iodised salt (IS) during pregnancy (Moleti et al., 2008).

Politi (2010) develops an iodine response function of the start of iodine fortification of a population for different forms of IDD running from cretinism to mild intellectual impairment. According to the model, a higher level of treatment, such as widespread use of iodized salt, will affect more subtle outcomes, such as school graduation rates. As the mechanism of higher graduation rates are thought to be higher cognitive attainment, it is likely that the variation in iodised salt consumption among populations with a higher coverage of iodised salt will affect IQ rather than the prevalence of cretinism and deaf-mutism.

4 Identification Strategy

The identification strategy used for this study differs from previous papers as I investigate in the effects of an exogenous drop in the availability of iodized salt due to the abolishment of a nation-wide ban on the consumption of non-iodized salt. Children residing in naturally iodine deficient areas, who were in early life when the ban was abolished, are likely to have a reduced cognitive capability compared to children who live in iodine sufficient areas. In this section, I first describe the temporal variation stemming from changes in bans on non-IS, and then I describe the spatial variation of IDD in India.

4.1 Temporal Variation: Changes in Iodine Fortification Policies

Iodine fortification of salt in India dates back to the 1950's in the most goitre endemic areas. In 1962, the National Goitre Control Programme was launched with attempt to provide IS to identified goitre endemic districts. However, the programme was considered a low priority due to the perception of goitre being primarily a cosmetic concern (Pandav, Moorthy, Sankar, Anand, Karmarkar and Prakash, 2003). In 1983, the eradication of goitre was included in the Prime Minister's 20-point National Development Programme and The Central Council of Health, also made a recommendation in 1983 that as all states were IDD prone, iodised salt should be made available to the entire population (Pandav, Moorthy, Sankar, Anand, Karmarkar and Prakash, 2003). The process of nationwide iodization of salt was started in a phased manner from April, 1986 (Pandav et al., 2013). Research providing evidence of other adverse health effects besides goitre, led to a change in the policy and a higher priority. In 1992, the NGCP was renamed the National Iodine Deficiency Disorders Control Programme (NIDDCP), reflecting the government's commitment to eliminating the whole spectrum of IDD (Pandav et al. 2003; Ministry of Health and Family Welfare 2006). The proportion of consumption households consuming IS has been increasing since the 1980's causing a decline in goitre prevalence in previously endemic areas. A study conducted of children in 15 districts all over India, in 1997-2000 indicated average prevalence of 4.78 % of goitre and 0.18% of deaf-mutism/ cretinism which is a decline from 1984-1986 when the respective rates were 21% goitre and 0.7% cretinism (Toteja, 2003).

In 1997, the Government of India (GOI) enacted a national ban on the sale and storage of non-iodized salt for edible purposes. The ban was enforced by the Food and Drug Administration, and would penalise any shopkeeper who stocks non-iodised salt(Kapil et al., 2006). However, the ban did not have a very large effect on salt consumption as the largest salt producing state of Gujarat, was hit by a cyclone in 1997 and later by an earthquake. Iodised salt legislation is known for being very controversial in India by appearing to force the population to pay higher prices it resembles the old colonial salt taxes. In 2005, the price of ordinary salt is about Rs 2 to Rs 3 per kg, whereas the price of iodised salt is about Rs 7 per kg. In October 2000, the GOI withdrew the central ban on non-iodized salt with the motivation that "matters of public health should be left to informed choice and not enforced". It is largely because of the misconception that IS has to be refined and it was lobbyism from individuals who have strong roots in the independence movement that led the ban to be removed (Wheeler and van der Haar, 2004). The state government of Gujarat lifted the ban and despite that most states kept the ban, non-iodized salt became freely available as over 80% of all salt in India is produced in Gujarat.[2] Due to lacking mechanisms to control the iodine content in salt, the proportion of households consuming adequately iodized salt dropped significantly during 2001-2004 until when the ban was reimposed in 2005 despite most states keeping state bans. The proportion of households consuming adequately iodised salt dropped from 70.3% in 1997 to 29.6% in the period 2000- 2004 (Rah et al., 2013). The national coverage reached 51% in 2005–2006 and increased to 71% in 2009. (IIPS & Macro International 2007, UNICEF 2011).

Due to institutional and infrastructure heterogeneity across states, the changes in the bans did not affect all states in the same way. The southern state of Kerala never imposed a state level ban and therefore did not experience any change. Salt transported by rail is

[2] Arunachal Pradesh also lifted the ban. Orissa lifted the ban initially but reimposed it after 6 months.

subjected to monitoring and registration of the producer, whereas salt transported by road is much harder to oversee and control. As per the GOI policy the controls of iodine content of salt rakes are only obligatory in transport by rail and not road. Salt transported within the state is mostly transported by road. In all the three primary salt producing states, Gujarat, Tamil Nadu and Rajasthan, over 25% salt consumed had nil iodine. Gujarat was the only major state producer that revoked the state ban. Besides meeting its own requirement, Gujarat caters to the iodised salt requirement of the North Eastern States, West Bengal, Bihar, Uttar Pradesh, Madhya Pradesh, Maharashtra, Goa, Rajasthan, Delhi Jammu and Kashmir and Orissa. Salt exported from Gujarat to states within a distance of 500 km is mainly transported by road resulting in a reduced probability of the salt to be checked for iodine content (Vir, 2011, p.586). Therefore, Gujarat and states near Gujarat are likely to have experienced a sharper reduction in iodised salt availability due to the revoking of the ban, and therefore more adverse effects on education. North Eastern states (Sikkim, Mizoram, Meghalaya, Nagaland, Tripura, Arunachal Pradesh, Manipur and Assam) and West Bengal that use a "nominee system" which has ensured a continuance of high coverage of iodised salt. The nominee system consists of appointed traders procure salt for the states for their importation of salt. Access to this system is biased in favour of the larger, registered salt producers who are more likely to have their salt dispatches undergo inspections. The salt is being checked by the Salt Commissioner's Office (Vir, 2011, p.586). In association with the allocation within the nominee system, it appears from NFHS III (2005-2006) that monitoring of iodised salt procured by these states is better than in remaining part of the country due to the "nominee system" for procurement of salt in the north east and West Bengal as well as the fact that salt to these far off regions of north east, and states such as Jammu and Kashmir and Bihar moves primarily by rail and not road (Vir, 2011).[3]

Even though the changes in IS consumption are not as sharp as in the contexts studied in previous research, the changes in iodine fortification policies are likely to have affected the brain development of children in early life in naturally iodine deficient areas as the prevalence of IDD in endemic areas higher than in for example (Feyrer et al., 2013). In addition, Adhvaryu et al (2016) find very similar effects from salt iodisation in the US on labour market outcomes for cohorts in-utero during the start of salt iodization in the U.S., where IS coverage was low, and later cohorts who faced almost 100% coverage of iodised salt. Moreover, it adds to the literature evaluating the effects of not only implementing a policy but ensuring sustainable, wide reaching and consistent policy implementation.[4]

[3]Other policies might have additionally affected the changes in iodised salt. in April 2001, the freight for transporting salt by rail experienced a price hike which led to an increase in transportation by road. Moreover, potassium iodate bas been supplied for free to selected iodisation units by some donors since 2005 (Pandav et al., 2013).

[4]Politi (2015) showed that iodine fortification of salt affected human health with variation in area level prevalence of goitre and other thyroid related diseases such as death due to thyroid related diseases

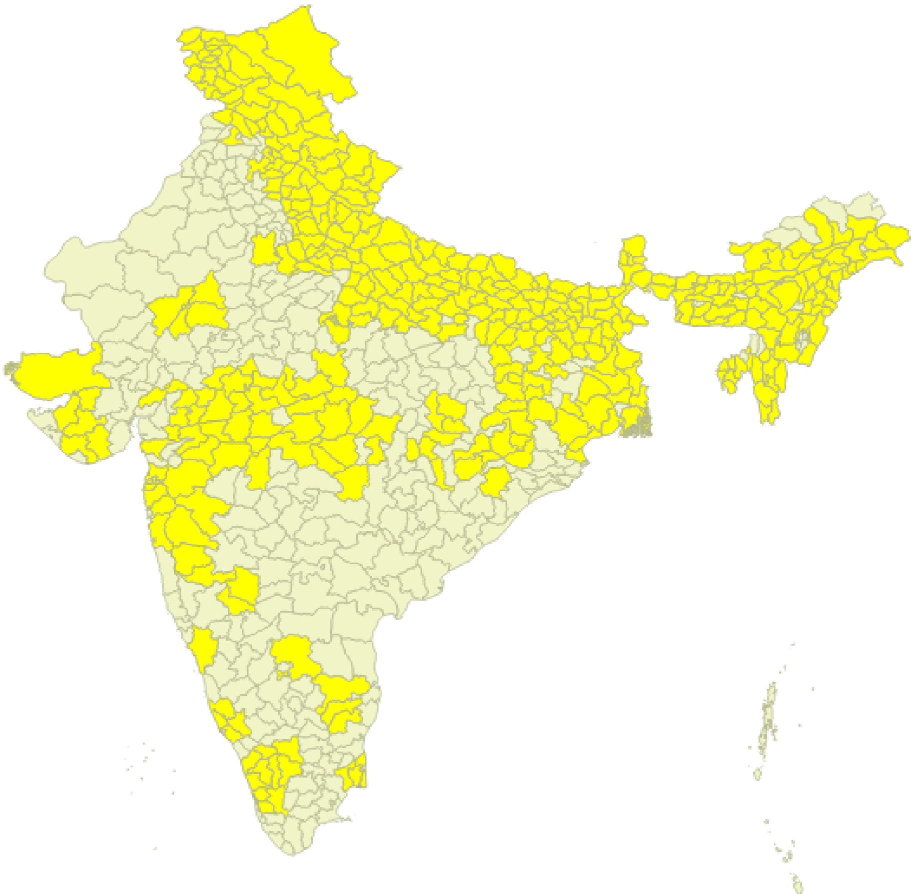
4.2 The Geography of Iodine Deficiency in India

Most iodine in soils is derived from the atmosphere where, in turn, it has been derived from the oceans that contain the highest concentration of iodide (Fuge, 2007). In major parts of India, deficiency of iodine in soil-water ecosystem is due to heavy rainfall, steep gradient and poor vegetation cover resulting in quick run-off and little time for transfer of iodine. Deficiency of iodine in source areas is also related to the chemical composition of rock and soil. The low levels of iodine in soil in the Himalayan foothills is due to ground erosion by glaciation during the last ice age, which stripped the soil of its iodine. Because it takes thousands of years for rain water to replenish the superficial layers of soil with iodine, the iodine-content of the soil and water of mountainous regions is extremely low (Fuge, 2007). However, various characteristics of a soil can lead to different iodine-fixation points where the iodine from the soil is fixed in the soil and not taken up by the roots of plants and thus not transferred to humans (Johnson, n.d.). Due to heterogeneity in iodine availability in the soil to humans and due to the lack of nationally representative statistics of the iodine content in soil and groundwater, the best measure for low local iodine availability is the prevalence of palpable IDD among humans. Feyrer et al. (2013); Politi (2010, 2015) both use the most visible sign of IDD per area - goitre rates per geography to define areas that are likely to benefit from iodine fortification or not. The world's classic and most intense goitre endemic belt is located in India. The Himalayan goitre belt runs along the southern slopes, foothills and adjacent plains of the Himalayas, extending over 2,400 from Kashmir to the Naga Hills. The level of iodide in the drinking water is extremely low in the endemic zone, no value being higher than 3 gm/L and most values considerably below this (Pandav and Kochupillai, 1982). Other areas than the Himalayas such as the west coast of India is likely to contain iodine deficient areas due to heavy rainfalls, alluvial soils and less saline ground waters (British Geological Survey; Groundwater Quality: Northern India, NERC 2004). I use the goitre endemic geographies as defined in (McCarrison, 1915) shown in Figure 1 which then has been re-mapped in Figure 2 as a source of identifying districts that are goitre endemic prior to any policy changes.

such as exophtalmic goiter as a cause of iodine supplementation after a long duration of iodine deficiency. However, as the identification of the temporal changes in this study relies on a shorter time frame it is almost impossible to prove that the timing in the changes in the IS policy is correlated with visible goitre as goitre has a long latency period. For instance, in central Switzerland, after three decades of salt iodisation, the prevalence of goitre was still 75% in 50 – 60 year-olds.

Figure 1: Sub Himalayan Goitre Belt as mapped by Mccarrison (2015)

Figure 2: Goitre Districts



McCarrison (1915) provides extensive evidence of the historical geography of goitre in India. He writes that his map of goitre prevalence is based on the figures by civil surgeons of districts.

> Through the kindness of Administrative Medical Officers, and with the generous assistance of Civil Surgeons, I have been enabled to collect detailed information regarding the prevalence and distribution of goitre in almost every part of British India. It is the purpose of the present paper to record the results of this inquiry in a compact form and to consider what light is thrown upon the etiology of the disease by a study of its distribution in India.

There is no description of the size of the area the dots in the map represent in neither the article or in any of Sir McCarrisson's archived documents. Therefore, I construct a binary treatment variable, where a district containing at least one dot is denoted as goitre endemic and districts with no dots is denoted to be non-endemic. This is likely to underestimate the intensity of goitre endemicity of districts. The goitre endemic locations provided by McCarrison (1915) resemble the locations of iodine deficient areas presented in Pandav and Kochupillai (1982) reviewing sub-national studies conducted prior to iodine-fortification. Moreover, after naitonal iodine fortification started the majority of districts have been found to be iodine deficient (Pandav et al., 2013). The two previous papers on iodine deficiency relying on a similar identification strategy benefit from better data on historical goitre rates. Feyrer et al. (2013) utilize goitre rates of army draftees across all localities in the U.S. and Politi (2010) use a highly detailed monograph covering all of Switzerland to indicate areas that are likely to benefit from salt iodisation. As Gallup and Sachs (2001) point out, the most severely affected countries often lack high-quality data on the disease burden. India, in similarity to other developing countries today does not have repeatedly collected data on IDD or on other diseases such as malaria. McCarrison's goitre map in (McCarrison, 1915), is the largest nationally representative survey of goitre before any IDD eradication policy commenced in India. As previously mentioned, this information heavily understates the historical goitre rate as more districts have been found to be IDD endemic with time despite the implementation of public health policies combating IDD.

5 Data

I use survey data to investigate in the effects of the changes in the ban on IS on the proportion of households consuming salt with and adequate amount of iodine. Data from the National Family Health Survey (NFHS) II and III from 1998-2000, and 2005-2006 is used along with the District Health Level Surveys (DHLS) II and III, from 2002-2004 and 2007-2008. These surveys are representative of the Indian population at the district level, however the NFHS- III does not contain district level identifiers.

Unlike the bulk of the literature on the human capital effects of disease, I will directly assess early cognitive skill formation rather than relying on long-term human capital or schooling outcomes. Therefore I use test score data from the Annual Status of Education Report (ASER), a yearly survey devoted to documenting the status of education among children in rural India. Annual household surveys began in 2005, and have been conducted yearly. The data comprise a repeated cross-section. In each year, the survey is conducted between September-November, and covers a random sample of 20-30 households in 20 villages in each of India's roughly 580 rural districts and is representative at the district level. I use data from 2009-2014 as the data prior to 2007 is not available to the public domain and the surveys from 2007 and 2008 does not contain information on village level characteristics such as the existence of a government primary school and an anganwadi in the village which is likely to affect both schooling and health. [5] ASER tests all children of ages 5-16 in their homes in September-November for each survey. The content of the ASER assessments is aligned to Grades 1 and 2 for reading and Grades 1, 2, and 3 or 4 for arithmetic. Since the same assessments are also administered to children in Grade 3 or higher, 7 an adaptive testing approach is used. Administration of the reading test begins at the Grade 1 passage level and the administration of the arithmetic test begins at the Grade 2 subtraction level. If the child performs to a satisfactory standard, the child is given the task at the next level, i.e. Grade 2 passage for reading and Grade 3/4 level division for arithmetic. If the child does not perform to a satisfactory standard, the child is given the task at the lower level, i.e. reading simple words for reading and two digit number recognition for arithmetic. Hence, the level of the task administered is adapted to match the child's ability level. The reading assessment consists of 4 levels of mastery: letters, words, a short paragraph (a class 1 level text), and a short story (a class 2 level text). Similarly, the math assessment consists of four levels: single-digit number recognition , double-digit number recognition, two-digit subtraction with carry over, and three digit by one digit division. For both tests separately, the child is marked at the highest level he or she can do comfortably with scores ranging from 0 to 4: a score of 0

[5] Moreover, there was a change in how math test performance was evaluated between the first two survey years and the subsequent 6 years

means that the child can not do even the most basic level, a 4 means that he or she can do level 4 in the respective subject.

6 Econometric Framework

I present the econometric model used to identify an effect of iodine availability in early life on test scores, below:

$$\text{BASIC TEST SCORES}_{idt} = \alpha_0 + \delta \text{NON IODISED}_t + \gamma \text{ENDEMIC}_d + \theta(\text{NONIODISED}_t * \text{ENDEMIC}_d) + \beta X_{idt} + \phi_d + \phi_{yob} + \phi_{d*yob} + \phi_{survey} + \phi_{survey*yob} + \mu_{idt}$$

The outcome variables labelled as *BASIC TEST SCORES* for child i in district d in year t, is a binary variable denoting basic literacy and numeracy skills. Regressions are estimated for numeracy and literacy separately. The basic literacy score takes on the value 1 if the child recognizes letters and above (words, a short paragraph (a class 1 level text), and a short story (a class 2 level text) and 0 if the child cannot recognize letters. The basic numeracy score takes on the value 1 if the child can recognize single-digit numbers or above (double-digit number recognition, two-digit subtraction with carry over, and three digit by one digit division) or 0 if the child cannot recognize single digit numbers. I also estimate the effect on enrolment and probability of having dropped out. The regressions include primary school aged children 5-10 years old in rural areas as the ASER survey only samples rural areas.

NON-IODISED is a binary variable taking the value 1 if the child was in early life during no ban on consuming non-IS. NON-IODISED=0 if the respondents were in early life during no nationwide policy enforcing iodisation of table salt. As the ASER dataset do not provide information on month of birth I will define the timing of “early life” to be year of birth and one year prior to birth. Children born during the largest drop resulting from no fortification policy in place, 2002-2004 constitute the treatment group. As it is difficult to estimate a statistically significant effect using individual year of birth dummies given the effect size of the treatment, I aggregate the cohorts into different policy states to form bigger groups of treatment and control. The main regression results are divided into two parts;
a) the effect of children in early life with a ban in place, pre-2000 and post-2005 compared to children in early life with no ban in place, during no ban on non-IS. b) the effect of the re-instatement of the ban - comparing children in early life during no ban pre-2005 to children post-2005, and;

I do not investigate in the effect of the removal of the ban comparing children born pre-2000 to children born during 2002-2004 due to the weather catastrophes affecting salt production in Gujarat around the implementation of the ban in 1997 and the removal of the ban in 2000. The revoking of the ban took place in September 2000 but the NFHS-II data show large proportion of households consuming adequately iodised salt in 2000 thus the removal of the ban had a lagged effect on the drop in the consumption of IS. When estimating the effects of the re-instatement of the ban in 2005, primary school aged children born in 2006 and 2007 constitute the control group. Since these changes occurred in a small window of time, this method is "cleaner" than previous papers that use a window of time of several decades, as there are fewer possible confounding effects taking place within same small time frame. The limitations with utilizing a natural experiment within a short duration of time of different policy regimes, is that the treatment effects at various ages and years might be confounded due to the storage and depletion of iodine of the mother (Field et al., 2009), prior to pregnancy and of children in childhood. Children in areas naturally poor in iodine availability are those whose test scores are likely to drop as a result of less available iodine added to their food during their mos critical time of brain development. ENDEMIC is a binary variable for a child living in a goitre endemic district as depicted in Figure 2. The coefficient of interest is the interaction term θ capturing the effect of being in early life during no nationwide iodine fortification policy in in IDD endemic districts on test scores in reading and math.

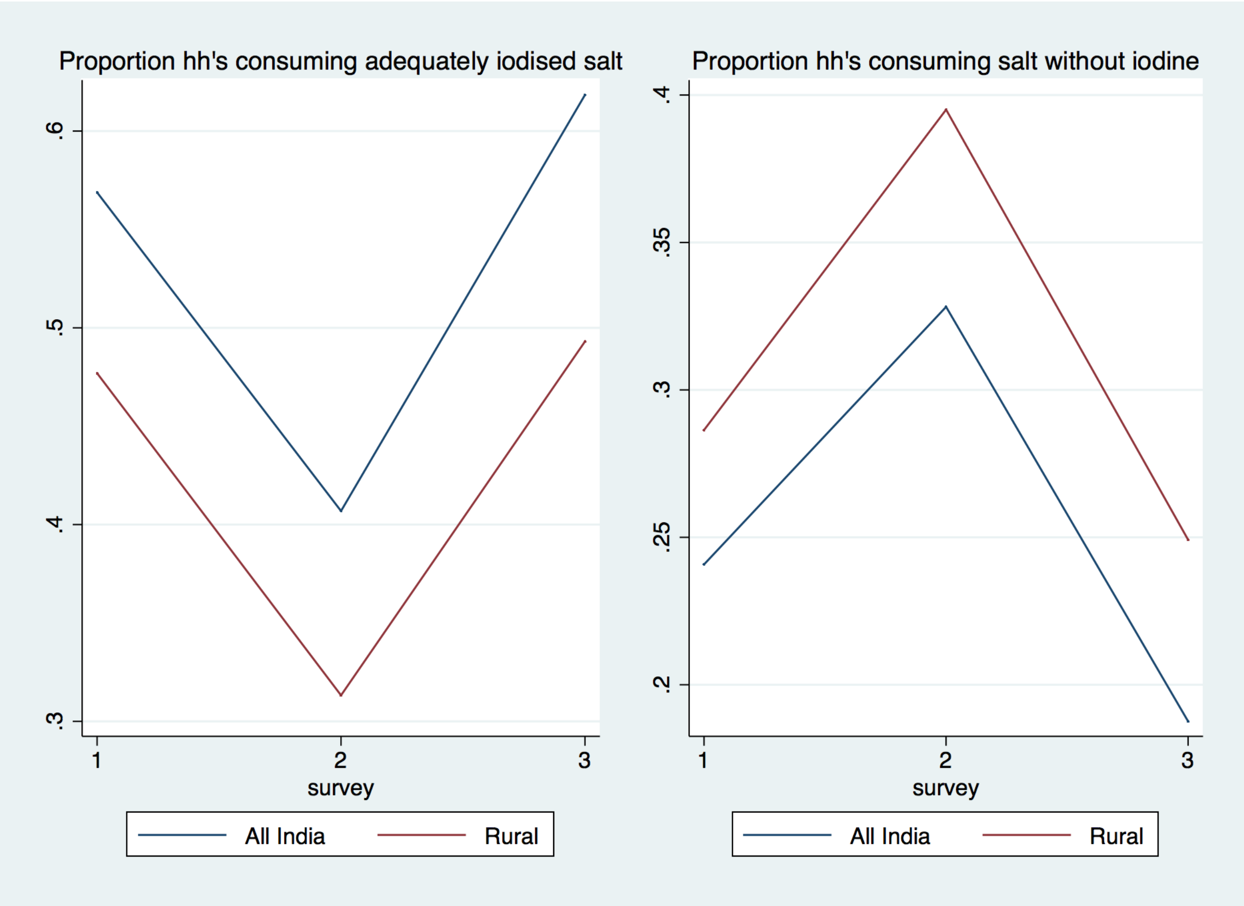
The following fixed effects are included; , ϕ_{d} is a district fixed effect, ϕ_{yob} denotes a year of birth fixed effects are added. $\phi_{\mathrm{d*yob}}$, an interaction between birth year fixed effects and survey year indicator variables is added to control for changes in education for different years, and this also controls for the age of the child taking the ASER test. I account for whether pre-existing trends could be driving the observed drop in test scores in the goitre endemic districts by including district- specific time trends in equation so that the coefficient on NON-IODISED * ENDEMIC is estimated from the variation around linear district time trends. In addition, households level control variables such as the material of the house as a proxy of the wealth of the household. "Pucca" denotes a house made of durable materials such as brick, stones or cement, "Kutcha" denotes a house made of less durable materials such as mud, reeds, or bamboo, and "Semi-Pucca" denotes something in between. Hence, Kutcha is a proxy for relatively low economic status. Moreover, I add additional control variables such as years of maternal education and household size as well as individual child controls such as birth order. To net out differential supply side factors in educational and health services, dummy variables for whether there is a government primary school and an Anganwadi is present in the village are included.

An Anganwadi centre is part of the Indian public health care system and provides basic health care. Anganwadi centres are also involved in activities directly related to nutrition and schooling of young children, such as; nutrition education, supplementation and pre-school activities. I cluster standard errors at district level to control for within-district serial correlation. The regressions are estimated separately for girls and boys due to the heterogeneous gender effects found in previous papers. Moreover, the analysis will be carried out for children up 10 years of age as the most difficult reading and math tasks correspond to what is expected from a second grader in primary school.

7 Descriptive Statistics

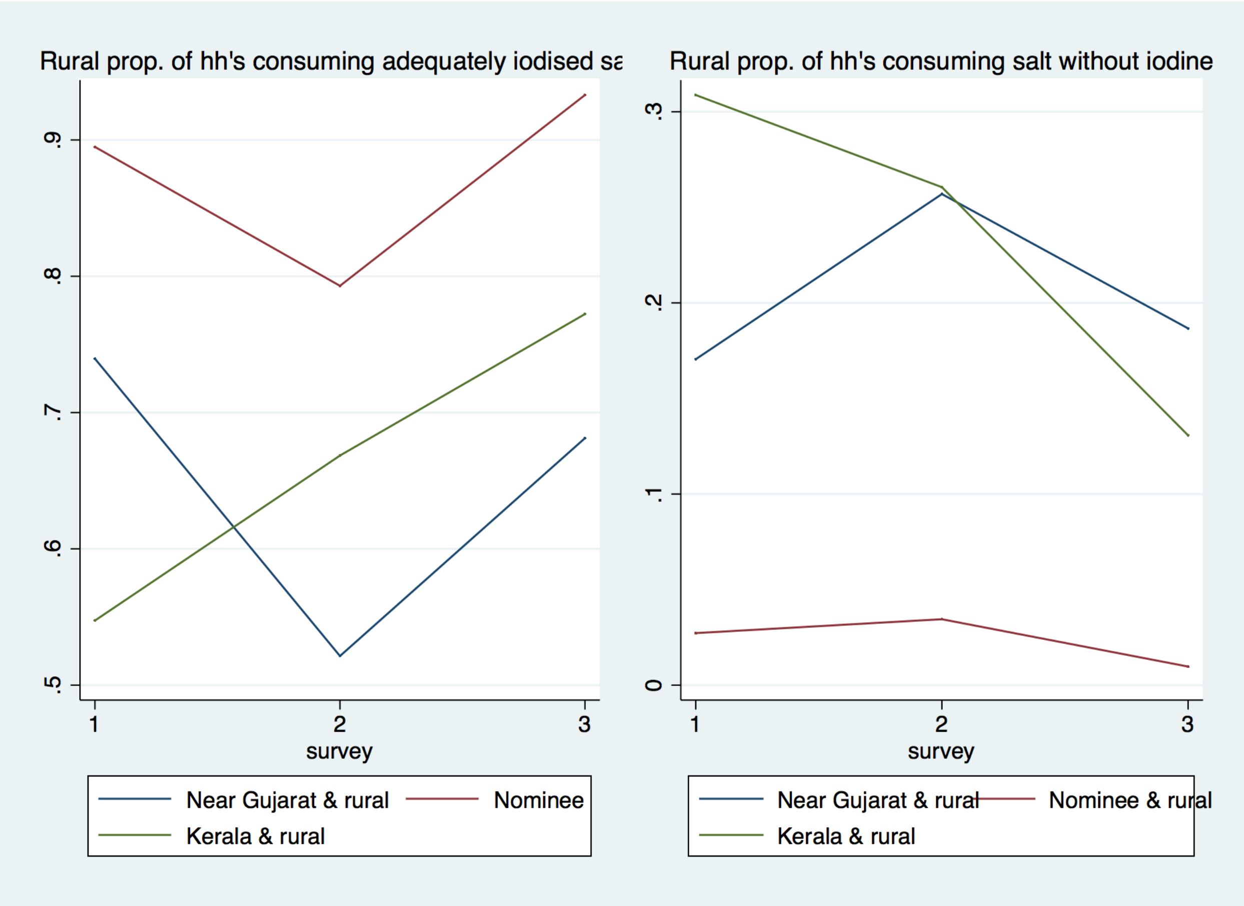
From Figure 3 one observes a sharp drop in the proportion of Indian households consuming adequately iodised salt in the DLHS survey of 2002-2004, compared to the NFHS 1998-2000 and the NFHS 2005-2006. The drop in IS is in line with the removal of the ban from around 57 % of all households consuming adequately IS when the first ban was implemented, to 41% when the ban was revoked to over 60 % of all households consuming adequately IS when the ban was re-instated again. As the ASER test score data is only collected for rural households, and the main analysis is carried out for rural households, I plot the changes in IS for rural households only, depicted by the red line, in Figure 3. Rural households experienced an even larger drop in IS as a result of the abolishment of the ban in 2000. IS coverage decreased from 48% in 1998-2000 to 32% of in 2002-2004. The average proportion of rural households consuming adequately iodised salt in 2005-2006, when the ban was re-instated is almost identical to the proportion of rural households consuming IS when the ban was first implemented. Plotting the proportion of households who consume no iodised salt show a similar picture. 28% of rural households consumed non-IS during the first ban, 39% during no ban and it dropped to 25% when the ban was re-introduced again.

Figure 3: Nationwide consumption of adequately iodized salt and non-iodized salt over time



I plot the trends in IS consumption for rural households that were never subjected to any bans - in Kerala, in states with a ”nominee’ system of salt procurement allowing for a more stable supply of IS, and in states that should have been more severly affected by the changes in bans; Gujarat and states within 500 km distance to Gujarat; Rajasthan, Uttar Pradesh, Madhya Pradesh and Maharahstra, see Figure 4. The graphs confirm the differential coverage of iodised salt over time. Nominee-states experienced a drop of around 11% while states relying on road transport from Gujarat experienced a drop of over one quarter when the ban was revoked, compared to when a ban was in place. There was no change in the upward trend of IS consumption in Kerala. A larger discrepancy between nominee states and states close to Gujarat is found in the proportion of households consuming salt without any iodine.

Figure 4: Consumption of adequately iodized salt and non-iodized salt over time: Heterogeneous effects



In Table 1 I show proportions of households consuming adequately iodised salt over the years 1998-2006 for rural IDD endemic and non-IDD endemic districts. This descriptive analysis is based on the information of time of survey from 3 household surveys and is not representative on district level on an annual basis. However, it serves as an indicator of IS consumption per year. The average proportion of households consuming IS in both groups are not significantly different from each other. We notice that the coverage of iodised salt has followed the same trend in goitre endemic and non endemic districts. The coverage of iodised salt was highest in 2000 and dropped greatly in 2003.The drop was significantly greater for goitre endemic areas, where coverage was 0.12 compared to 0.24 for non-endemic areas in 2003. On the other hand, the increase in IS consumption was significantly greater for endemic districts compared to non-endemic districts as a result of the revoking of the ban in 2006.

Table 1: Descriptive Statistics - IS consumption in endemic and non-endemic districts

	Goitre endemic	Non-endemic
Proportion of HH consuming IS, all years	0.31	0.30
Proportion of HH consuming IS in 1998	0.42	0.44
Proportion of HH consuming IS in 1999	0.50	0.41
Proportion of HH consuming IS in 2000	0.64	.
Proportion of HH consuming IS in 2002	0.27	0.27
Proportion of HH consuming IS in 2003	0.18	0.25
Proportion of HH consuming IS in 2004	0.29	0.29
Proportion of HH consuming IS in 2005	0.39	0.41
Proportion of HH consuming IS in 2006	0.47	0.37
Observations	2785977	1296571

Summary statistics are provided for children born before 2000 in endemic and non - endemic districts are presented in Table 2. We note that math and reading scores were higher in non-endemic areas and that there is a higher proportion of children that can do the most difficult reading and math task in the non-endemic districts. Households in IDD endemic districts tend to be bigger and there is a marginally smaller fraction of villages with a primary school or anganwadi in endemic districts. The two groups are otherwise very similar.

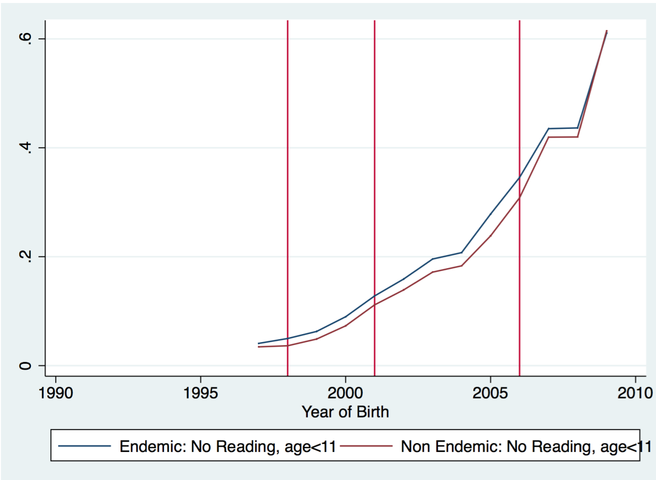
Table 2: Descriptive Statistics

Descriptive Statistics		
	Endemic Districts	Non Endemic Districts
Child has been enrolled	0.98	0.98
Child has dropped out	0.05	0.05
No Math	0.03	0.03
Math Score	3.08	3.17
Division	0.49	0.52
Cannot Read	0.04	0.03
Reading Score	3.32	3.42
Reads std.2 level Text	0.65	0.68
Age of child	12.80	12.63
Girl	0.46	0.46
Maternal educ	3.15	3.13
HH size	6.71	6.09
Gvt primary school in vlg	0.92	0.94
Anganwadi in vlg	0.97	1.00
Observations	1273045	664462

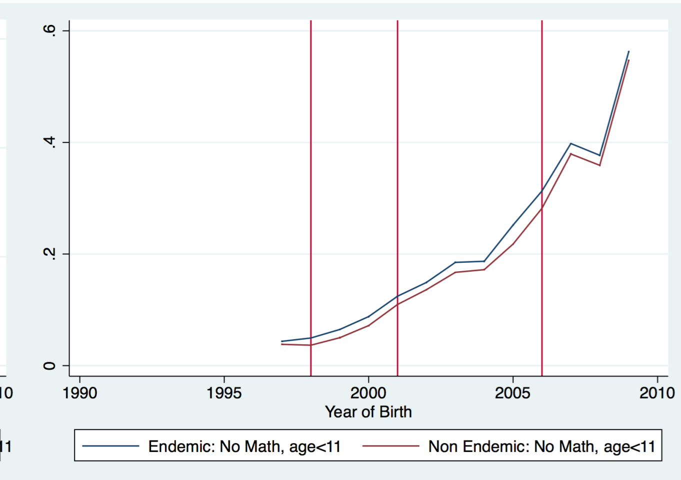
In Figure 5 below the trends in the various test scores are graphed for children in IDD endemic and non-endemic districts. For all outcomes, one can clearly observe parallel trends prior to 1997, and then large diverging trends in the proportion of children not knowing any maths or how to read and in the average reading - and math scores for cohorts born in 2000-2005, thus being in-utero or at an early age during the abolishment of the ban.

Figure 5: Test Scores for Pooled Sample.

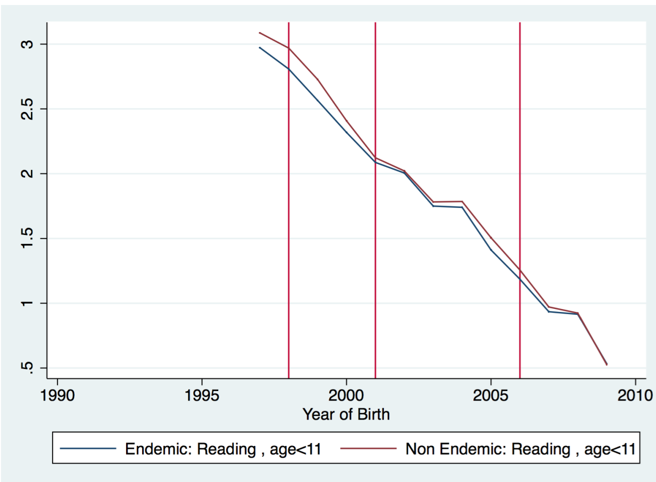
(a) Prop of children that cannot read



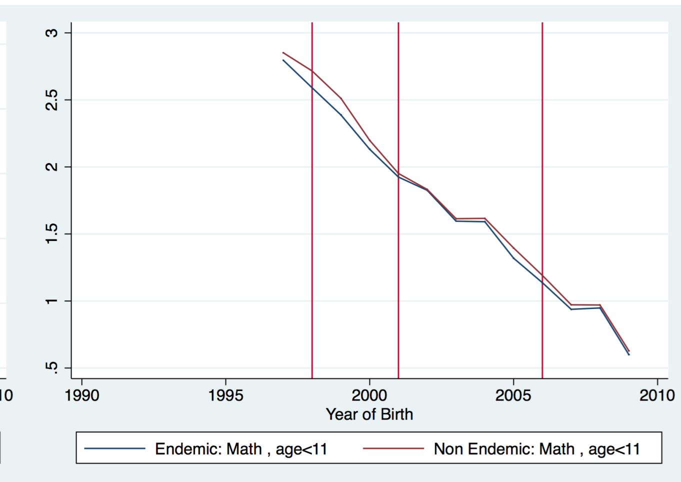
(b) Prop of children that does not know maths



(c) Trends in continuous reading scores



(d) Prop of children that does not know any numbers or maths



8 Results

The DiD results from Equation 1 point to that girls residing in IDD endemic districts are 0.4 percentage point less likely to be enrolled in primary school, taking into account the cohorts covered by the first ban in the control group. Strictly evaluating the effects of the re-introduction of the ban, excluding cohorts covered by the first ban implemented in 1997, we find that girls are 1 percentage point less likely to have been enrolled in primary school and boys are 0.6 percentage points less likely. No effects were found for drop out rates, see Table 3.

Girls born in endemic districts during no ban, are 1.3 percentage points less likely to have basic numeracy skills and 1.9 percentage less likely to have basic literacy skills. When comparing only children during no ban to children that were born when the ban was re-instated again, the estimates are larger, see Table 4. Nonetheless, the estimates are always smaller for boys who are 1 percentage point less likely of being able to do basic maths and 1.6 -2.2 percentage points less likely to be able to recognize letters or more. I also estimate the effect on continuous test scores but although the coefficients on the reading scores are negative for girls, they are not statistically significant, see Table 8. A potential explanation to why the estimates increase when we exclude children born during the first ban from the control group might be that these children were still at an impressionable young age when the ban was revoked. The larger effects on cognitive outcomes for girls corroborates findings in previous literature, see Field et al. (2009) and (Lavy et al., 20136). The fact that estimates are only statistically significant for the most basic literacy and numeracy outcomes and not for the continuous measure of test scores might be driven by children in the lower end of the test score distribution being disproportionally affected by the removal of the ban.

Table 3: Effect on Enrolment and Dropping out

	(1) ENROLLED	(2) DROP OUT	(3) ENROLLED	(4) DROP OUT	(5) ENROLLED	(6) DROP OUT	(7) ENROLLED	(8) DROP OUT
NON-IODIZED (TOTAL) * IDD ENDEMIC	-0.004***	0.001			-0.002	-0.000		
	(0.001)	(0.001)			(0.001)	(0.001)		
NON-IODIZED * IDD ENDEMIC			-0.010***	0.002			-0.006**	0.001
			(0.002)	(0.002)			(0.002)	(0.001)
Maternal Educ	0.001***	-0.000***	0.001***	-0.000***	0.001***	-0.000***	0.001***	-0.000***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Semi-Pucca	0.005***	-0.002***	0.005***	-0.002***	0.004***	-0.002***	0.004***	-0.001***
	(0.001)	(0.000)	(0.001)	(0.000)	(0.001)	(0.000)	(0.001)	(0.000)
Pucca	0.007***	-0.003***	0.007***	-0.002***	0.005***	-0.002***	0.005***	-0.002***
	(0.001)	(0.000)	(0.001)	(0.000)	(0.001)	(0.000)	(0.001)	(0.000)
Gvt primary school in vlg	0.005***	-0.001	0.005***	-0.000	0.004***	-0.001	0.003**	-0.001
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Anganwadi in vlg	0.002*	-0.002*	0.002	-0.002	0.001	-0.001	0.001	-0.001
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Size of HH	0.000	-0.000***	0.000	-0.000***	-0.000	-0.000*	-0.000	-0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Birth Order	-0.001***	0.000**	-0.001**	0.000	-0.001***	0.001***	-0.001***	0.000**
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Observations	405889	405889	340947	340947	474775	474775	394723	394723
R^2	0.990	0.020	0.990	0.017	0.991	0.015	0.992	0.013

Standard errors in parentheses. Robust Standard Errors Clustered on District. Columns 1-4 are estimated for the sub sample of girls. Columns 5-8 are estimated for the sub sample of boys. Year of Birth, Survey year, survey year*year of birth linear district trends.

* $p < .10$, ** $p < .05$, *** $p < .01$

Table 4: The effect of no ban on iodised salt on the basic literacy and numeracy skills.

	(1) MATH	(2) READ	(3) MATH	(4) READ	(5) MATH	(6) READ	(7) MATH	(8) READ
NON-IODIZED (TOTAL) * IDD ENDEMIC	-0.013***	-0.019***			-0.010**	-0.016***		
	(0.004)	(0.005)			(0.004)	(0.005)		
NON-IODIZED * IDD ENDEMIC			-0.023**	-0.032***			-0.018	-0.022*
			(0.011)	(0.012)			(0.011)	(0.012)
Maternal Educ	0.009***	0.010***	0.010***	0.011***	0.008***	0.009***	0.009***	0.010***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Semi-Pucca	0.036***	0.035***	0.038***	0.038***	0.035***	0.036***	0.037***	0.040***
	(0.002)	(0.002)	(0.003)	(0.003)	(0.002)	(0.002)	(0.003)	(0.003)
Pucca	0.060***	0.063***	0.066***	0.068***	0.057***	0.061***	0.063***	0.068***
	(0.003)	(0.003)	(0.003)	(0.003)	(0.002)	(0.003)	(0.003)	(0.003)
Gvt primary school in vlg	0.013***	0.015***	0.014***	0.016***	0.010***	0.014***	0.012***	0.016***
	(0.004)	(0.004)	(0.005)	(0.005)	(0.004)	(0.004)	(0.004)	(0.004)
Anganwadi in vlg	0.010**	0.009**	0.010**	0.009**	0.006	0.006*	0.005	0.006
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
Size of HH	-0.001**	-0.001***	-0.001**	-0.001**	-0.001**	-0.001***	-0.001**	-0.001**
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Birth Order	0.008***	0.008***	0.008***	0.009***	0.008***	0.008***	0.009***	0.009***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Observations	405889	405889	340947	340947	474775	474775	394723	394723
R^2	0.874	0.864	0.857	0.845	0.880	0.868	0.862	0.847

Standard errors in parentheses. Robust Standard Errors Clustered on District. Columns 1-4 are estimated for the sub sample of girls. Columns 5-8 are estimated for the sub sample of boys. Year of Birth, Survey year, survey year*year of birth linear district trends.

* $p < .10$, ** $p < .05$, *** $p < .01$

8.1 Heterogenous Effects of the ban

I split the sample into Gujarat and states within a radius of 500 km of Gujarat; Maharashtra, Madhya Pradesh, Uttar Pradesh and Rajasthan, and into states under the "nominee system", as to investigate whether states that suffered a larger drop in IS consumption also experienced larger decreases in test scores. The findings are in line with the expectations, states close to Gujarat experienced the most adverse effects. The negative effects on basic literacy scores have increased, see Table 9. The removal of the ban is associated with a decrease in the probability of knowing any math with 1.9-5.2 percentage points for girls and 1.5-3.8 percentage points for boys. Girls are 2.3 -5.1 percentage points less likely of being able to know basic literacy and boys are 1.7 percentage points less likely to do so, respectively, see Table 9 in the Appendix. In line with our prior, no negative effects are found for basic literacy and numeracy for school aged children in states with a nominee system of salt procurement which entails controlled rail transportation. On the contrary, positive effects were found on girls' basic reading skills, see Table 10.

9 IV

It is not unlikely that the historical binary indicator of iodine deficiency per district suffers from measurement error. As previously discussed, there is not sufficient information about the sampling methods nor the collection of the data on goitre prevalence. In similarity with Cutler et al. (2010), I instrument for pre-treatment prevalence of the disease environment using topological, climatic and hydro-geological determinants. This is a valid strategy provided that the measurement error in the geographical data is uncorrelated with that of the spatial information on goitre prevalence in McCarrison (1915). This is a reasonable assumption given the drastically different contexts and methods of data collection. The iodine content in soils is decided mainly by soil type and locality. Most iodine in soils is derived from the atmosphere where, in turn, it has been derived from the oceans. Iodine deficiency in soil-water ecosystem is due to; heavy rainfall, steep gradient and poor vegetation cover resulting in quick run-off and little time for transfer of iodine. Deficiency of iodine in is also related to the chemical composition of rock and soil (Fuge, 2007). Iodine-deficient soils are common in mountainous areas (Zimmermann, 2009), as soil erosion and leaching leads to iodine deficient soils and hilly topography encourages natural erosion of the surface layers, which reduces the possibility of a deep soil (Nyle C. Brady, 1996, pp.48-49). Other factors affecting soil-loss are total rainfall and rainfall intensity which are enhanced if there is little vegetative cover as commonly observed in mountainous soils (Nyle C. Brady, 1996, pp. 570). Drinking water accounts for 10-20%

of total iodine intake (Rasmussen et al., 2002). The majority of iodine concentration in the groundwater stems from organic matter decomposition in the marine strata with sea water influence (Wen et al., 2013). High concentrations of iodine in ground waters can be found in saline waters such as coastal and arid or semi-arid areas (Wateraid, 2004). Therefore, I instrument goitre endemicity with average elevation and ground water salinity per district. The elevation data comes from the Shuttle Radar Topography Mission from FAO Harmonized World Soil Database v 1.2. The location of the degree of saline ground waters has been geo-traced from a map from the Central Ground Water Board measuring groundwater quality in shallow aquifers of India (CGB, 2010). As rainfall is a predictor of iodine content in soil and groundwater I have included rainfall data for annual rainfall in 2001 from the Ministry of Earth Sciences India Meteorological Department in the first stage. The regression results of the first stage are presented in Table 5 and confirms that the instruments are indeed relevant and consistent with, predictors of iodine deficiency as observed in Johnson (n.d.); Fuge (2007). The precipitation variable is just barely insignificant in predicting goitre endemicity and is therefore not included in the final set of IV's. [6]

Table 5: Ecological Determinants of Pre-Eradication Goitre Endemicity

	(1) Sum stats	(2) IDD Endemic	(3) IDD Endemic
1/Salinity	0.755	0.568***	0.536***
	(0.2659)	(0.073)	(0.079)
1/(Elevation^2)	0.00074	-8.570**	-7.457*
	(0.00465)	(4.179)	(4.280)
Average precipitation per month (metres)	0.430		0.179
	(0.1928)		(0.109)
Constant		0.146**	0.093
		(0.059)	(0.066)
Observations	594	590	569
R^2		0.105	0.109
F-stat		34.27	22.97

Standard errors in parentheses

Robust Standard Errors Clustered on District.

* $p < .10$, ** $p < .05$, *** $p < .01$

The IV results indicate that girls were 1.0-2 percentage points less likely to have been enrolled in primary school, see Table 11 in the Appendix. The removal of the ban on non-fortified salt decreased the probability of girls mastering basic numeracy skills with

[6] Including precipitation as a predictor of IDD endemic district does not change the the second stage estimates.

5 - 8.4 percentage points, and basic literacy with 7.3 - 12.7 percentage points. Boys are 4.7 percentage points less likely of recognizing single digit numbers or mastering more difficult numeracy skills and 6.4 - 8 percentage points less likely of recognizing a letter or being able to read, see Table **??**. When instrumenting for goitre endemicity negative and statistically significant effects are found for reading scores for girls. Girls born in 2002-2004 had a 0.167 lower reading score than girls born in 2006-2007 in predicted goitre endemic areas, see Table 12. IV analysis for the sub-sample of children born in Gujarat and states close to Gujarat results in a magnified negative effect on the probability of entering school girls, see Table 13. TSLS estimates show that girls are 4.7 - 9.1 percentage points less likely to know any maths and 8.5 - 14.9 percentage points less likely of being able to do any reading in states more affected by the removal of the ban on non-IS. Boys are 5.2 percentage points less likely of being able to recognize numbers or more, but the effect is only significant when the earlier control cohorts are excluded. There is a consistent effect on reading scores for boys, they are 8.1 - 10.2 percentage points less likely to have mastered basic literacy skills, see Table 14/ in the Appendix.

Table 6: Effect of the removal of the ban on non-iodised salt basic numeracy and literacy scores.

	(1) MATH	(2) READ	(3) MATH	(4) READ	(5) MATH	(6) READ	(7) MATH	(8) READ
NON-IODIZED (TOTAL) * IDD ENDEMIC	-0.050***	-0.073***			-0.047***	-0.064***		
	(0.014)	(0.016)			(0.014)	(0.015)		
NON-IODIZED * IDD ENDEMIC			-0.084**	-0.127***			-0.045	-0.080**
			(0.034)	(0.038)			(0.033)	(0.035)
Maternal Educ	0.009***	0.010***	0.010***	0.011***	0.008***	0.009***	0.009***	0.010***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Semi-Pucca	0.036***	0.035***	0.038***	0.038***	0.035***	0.036***	0.037***	0.040***
	(0.002)	(0.002)	(0.003)	(0.003)	(0.002)	(0.002)	(0.003)	(0.003)
Pucca	0.060***	0.062***	0.066***	0.068***	0.057***	0.061***	0.063***	0.068***
	(0.003)	(0.003)	(0.003)	(0.003)	(0.002)	(0.003)	(0.003)	(0.003)
Gvt primary school in vlg	0.013***	0.015***	0.014***	0.016***	0.011***	0.014***	0.012***	0.016***
	(0.004)	(0.004)	(0.005)	(0.005)	(0.004)	(0.004)	(0.004)	(0.004)
Anganwadi in vlg	0.010**	0.009**	0.010**	0.009**	0.006*	0.006*	0.005	0.006
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
Size of HH	-0.001**	-0.001***	-0.001**	-0.001**	-0.001**	-0.001***	-0.001**	-0.001**
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Birth Order	0.008***	0.008***	0.008***	0.009***	0.008***	0.008***	0.009***	0.009***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Observations	405889	405889	340947	340947	474775	474775	394723	394723
R^2	0.874	0.864	0.857	0.845	0.880	0.868	0.862	0.847

Standard errors in parentheses. Robust Standard Errors Clustered on District. Columns 1-4 are estimated for the sub sample of girls. Columns 5-8 are estimated for the sub sample of boys. Year of Birth, Survey year, survey year*year of birth linear district trends.

* $p < .10$, ** $p < .05$, *** $p < .01$

10 Robustness

The DiD estimates are only valid if the variation in IS policies does not coincide with the timing of policies on malnutrition or affecting cognition and schooling. As the capacity to benefit from IS is defined to be on district level, nationwide educational policies, such as The Right to Education act (mandating school enrolment for school-aged children), and the ban on grade-detention should not constitute threats to identification. In similarity, the mid-day meal programme was implemented at state level in all Indian public primary schools by 2006. I conduct several robustness checks to test for other potential drivers of the main results. Maternal education is an important determinant of children's test scores but should not have been greatly affected by an iodine fortification policy in adulthood. Estimating the effects of the DiD as specified in Equation 1 on years of maternal education does not lead to any statistically significant effects. Moreover, I compare children that were born in 2000 to children born 2006 which are the cohorts of children in early life when the iodine coverage rates were very high and rather similar. No differential effects are found for these cohorts, see Table 15. I investigate in whether the DiD estimates are driven by differential health care investments or varying disease or sanitation environments of children in IDD prone districts coinciding with the removal of the ban. Equation 1 is estimated on the following left hand side variables; BCG-vaccination, Measles vaccination, Vitamin A Supplementation and incidence of diarrhea two weeks prior to the survey. Data from the DLHS2 and DLHS3 on the last and last to second child is used for the analysis. The regression results are presented in Tables 16. All estimates but one are statistically insignificant. When comparing the cohorts before and after the removal of the ban in 2000 we notice that the probability of receiving vaccination against BCG is 5.7 percentage points higher in goitre endemic districts for the treated birth cohorts, see Table 16.

10.1 Child Mortality

Iodine deficiency in-utero and later in early life can increase peri-, neonatal-, and infant mortality rates. Existing studies find that iodine supplementation reduces infant mortality in the range of 25-60%, depending on iodine severity (Zimmermann, 2012). Therefore I investigate in the effect of the removal of the non-IS ban on child mortality. I estimate the probability of a child being alive, where the maximum age is 3 years, and the probability of an infant dying before 1 year of age (infant mortality) using Equation 1. I use the birth histories of children born up to 3 years prior to the DLHS 2 (2002-2004) and DLHS 3 (2007-2008). The removal of the ban decreased the likelihood of girls in endemic districts being alive with 0.9 percentage points and increased their probability of dying with the same magnitude, see Table 7. When excluding the cohorts who were in early life during a ban, I find that girls in endemic districts are 3 percentage points more likely not to be alive and 2.6 percentage points more likely to have died in their first year of life. [7] The estimates on infant and under 3 mortality are smaller than the effects found in related studies. Iodisation of irrigation water in a severely iodine deficient area of China decreased the infant mortality rate by half (DeLong et al., 1997) and similar estimates where found from injecting pregnant women with iodised oil in Zaire (Zimmermann, 2012). Despite the small number of previous studies allowing for a causal interpretation, it is reasonable to assume that the smaller effects on child mortality found in this paper is due to the lower rate of average iodine deficiency per district in India during the period of study. The results are in line with Lavy et al. (20136) who find that exposure to better environmental conditions in utero, especially iodine sufficiency, is more critical for girls in terms of effects on human capital attainment and child mortality, than for boys. This also corroborates other research findings on gender differences in infant mortality from developing countries where girls are found to be more sensitive to aggregate economic shocks during pregnancy relative to boys (Baird et al., 2011). Moreover, the findings also indicate that previous papers estimating the effect of iodine supplementation on human capital attainment might underestimate the average effect due to selection effects. When splitting the sample into states with predominantly road transportation from Gujarat and boys and girls no statistically significant effects are found for infant and child mortality. As this is potentially due to the lack of power, I pool the sample of boys and girls and estimate the effects of the removal of the ban separately for Gujarat and states within 500 km of Gujarat and for states with a nominee system ensuring the control of iodine content through rail transportation. Once again, larger effects are found for states affected by the removal of the ban to a larger extent. When including cohorts in early life during the first and second ban as control groups I find that children in endemic districts, in Gujarat or states close to Gujarat, were 0.9 percentage points more likely of dying before the age of one year old. When children in the first ban are excluded, the effect on infant mortality barely becomes statistically insignificant but a negative statistically significant effect is found for the probability of the child being alive of -0.029 up to age three, see columns 1- 4 in Table 18. No effects on child mortatlity are found for states with higher controls of the transportation of iodised salt, see see columns 5-8 in Table 18.

[7] The inclusion of birth histories up to age 3 was chosen as only births up to 3 years prior to the survey are reported in DLHS 3. Due to the lack of harmonization between the surveys I have identified children dying up to 305 days (the maximum age of death in days) in the DLHS 3 as children dying in their first year of life as reported in DLHS 2. However, as month of death is reported in the DLHS 2, I also generate an outcome variable being the probability of dying within 10 months of age to create a consistent measure with the latter survey. Changing the infant mortality outcome to being the probability of dying in month 10 or earlier, does not change the estimates on infant mortality, see Table 17.

Table 7: Effect of no ban on non-IS on child mortality.

	(1) Child Alive	(2) Died Before 1	(3) Child Alive	(4) Died Before 1	(5) Child Alive	(6) Died Before 1	(7) Child Alive	(8) Died Before 1
ENDEMIC *NON-IODIZED (TOTAL)	-0.009**	0.009**			-0.004	0.004		
	(0.004)	(0.003)			(0.003)	(0.003)		
ENDEMIC *NON-IODIZED			-0.030**	0.029**			-0.007	0.008
			(0.012)	(0.012)			(0.012)	(0.012)
Semi-Pucca	0.007***	-0.007***	0.006***	-0.006**	0.006***	-0.006***	0.006**	-0.006**
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Pucca	0.013***	-0.012***	0.011***	-0.011***	0.015***	-0.015***	0.013***	-0.013***
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Mother's age at birth	0.001***	-0.001***	0.001***	-0.001***	0.002***	-0.002***	0.001***	-0.001***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Maternal Educ	0.002***	-0.002***	0.002***	-0.002***	0.002***	-0.001***	0.001***	-0.001***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Birth Order	-0.007***	0.007***	-0.009***	0.009***	-0.003***	0.003***	-0.007***	0.007***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Singleton Birth	0.149***	-0.135***	0.127***	-0.110***	0.147***	-0.131***	0.129***	-0.109***
	(0.007)	(0.006)	(0.008)	(0.007)	(0.007)	(0.006)	(0.008)	(0.007)
Gvt Primary School in vlg	0.002	-0.002	0.003	-0.003	-0.002	0.003	-0.005	0.005
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
health facility available-icds (anganwadi)	0.004	-0.004	0.001	-0.001	-0.002	0.002	0.001	-0.001
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Observations	61045	61442	42216	42610	67781	68349	46702	47265
R^2	0.959	0.082	0.964	0.080	0.956	0.080	0.960	0.079

Standard errors in parentheses. Robust Standard Errors Clustered on District. Columns 1-4 are estimated for girls and columns 5-8 are estimated for boys. Year of Birth, Survey year, survey year*year of birth linear district trends.

11 Conclusions

Utilizing variations from a nationwide policy on iodine fortification of salt in India, this study shows that children exposed to an exogenously lower iodine coverage in areas that are naturally poor in iodine availability, are 1-8 percentage points less likely to have mastered basic numeracy and literacy skills. A lower likelihood of being enrolled in primary school is also found for girls and more adverse effects on test scores are also found for girls. The removal of a policy enforcing iodine fortification of salt increased child and infant mortality for girls. The more adverse effects for girls are in line with medical and provides some insight into the gender gap in schooling attainment and child mortality rates in India.

The findings are robust to placebo regressions where the outcome variables are other health outcomes in early life and the application of IV analysis to deal with potential measurement error in the definition of IDD endemic districts. Moreover, outcomes are stronger in states that were more severely affected by the removal of the ban due to infrastructure allowing for no control of the iodisation of salt. Adverse effects on test scores are found despite the study relying on smaller changes in iodine fortification coverage where iodine fortification was already in place, compared to previous papers using the start of nationwide iodine fortification. This suggests that there are social and economic benefits of eradicating moderate and mild iodine deficiency and in ensuring sustainability of such policies in developing countries.

References

Ahad, F. and Ganie, S. A. (2010), 'Iodine, iodine metabolism and iodine deficiency disorders revisited', *Indian Journal of Endocrinology and Metabolism* **14**(1), 13–17.

Almond, D. (2006), 'Is the 1918 influenza pandemic over? longterm effects of in utero influenza exposure in the post1940 u.s. population', *Journal of Political Economy* **114**(4), 672–712.

Andersson M, Karumbunathan V, Z. M. (2012), 'Global iodine status in 2011 and trends over the past decade.', *Journal of Nutrition* (142), 744–50.

Baird, S., Friedman, J. and Schady, N. (2011), 'Aggregate income shocks and infant mortality in the developing world.', *Review of Economics Statistics* **93**(3), 847 – 856.

Bleakley, H. (2007), 'Disease and development: Evidence from hookworm eradication in the american south', *The Quarterly Journal of Economics* **122**(1), 73–117.

Bleakley, H. (2010), 'Malaria eradication in the americas: A retrospective analysis of childhood exposure', *American Economic Journal: Applied Economics* **2**(2), 1–45.

Brander, L., Als, C., Buess, H., Haldimann, F., Harder, M., Hänggi, W., Herrmann, U., Lauber, K., Niederer, U., Zürcher, T., Bürgi, U. and Gerber, H. (2003), 'Urinary iodine concentration during pregnancy in an area of unstable dietary iodine intake in switzerland.', *J Endocrinol Invest* **26**(5), 389–96.

Cao, X.-Y., Jiang, X.-M., Dou, Z.-H., Rakeman, M. A., Zhang, M.-L., O'Donnell, K., Ma, T., Amette, K., DeLong, N. and DeLong, G. R. (1994), 'Timing of vulnerability of the brain to iodine deficiency in endemic cretinism', *New England Journal of Medicine* **331**(26), 1739–1744.

CGB (2010), ground water quality in shallow aquifers of india, Report, Central ground water board ministry of water resources.

Cutler, D., Fung, W., Kremer, M., Singhal, M. and Vogl, T. (2010), 'Early-life malaria exposure and adult outcomes: Evidence from malaria eradication in india', *American Economic Journal: Applied Economics* **2**(2), 72–94.

DeLong, G. R., Leslie, P. W., Wang, S.-H., Jiang, X.-M., Zhang, M.-L., abdul Rakeman, M., Jiang, J.-Y., Ma, T. and Cao, X.-Y. (1997), 'Effect on infant mortality of iodination of irrigation water in a severely iodine-deficient area of china', *The Lancet* **350**(9080), 771 – 773.

Eric A. Hanushek, L. W. (2008), 'The role of cognitive skills in economic development', *Journal of Economic Literature* **46**(3), 607–668.

Feyrer, J., Politi, D. and Weil, D. N. (2013), The cognitive effects of micronutrient deficiency: Evidence from salt iodization in the united states, Working Paper 19233, National Bureau of Economic Research.

Field, E., Robles, O. and Torero, M. (2009), 'Iodine deficiency and schooling attainment in tanzania', *American Economic Journal: Applied Economics* **1**(4), 140–69.

Fuge, R. (2007), 'Iodine deficiency: An ancient problem in a modern world', *AMBIO: A Journal of the Human Environment* **36**(1), 70–72.

Gordon, R. C., Rose, M. C., Skeaff, S. A., Gray, A. R., Morgan, K. M. and Ruffman, T. (2009), 'Iodine supplementation improves cognition in mildly iodine-deficient children', *The American Journal of Clinical Nutrition* **90**(5), 1264–1271.

Hetzel, B. (1983), 'Iodine deficiency disorders (idd) and their eradication', *The Lancet* **322**(8359), 1126 – 1129.

Johnson, C. C. (n.d.), The geochemistry of iodine and its application to environmental strategies for reducing the risks from iodine deficiency disorders (idd), Technical report.

Kapil, U. (2007), 'Health consequences of iodine deficiency', *Sultan Qaboos University Medical Journal* **7**(3), 267–272.

Kapil, U., Singh, P. Dwivedi, S. N. and Pathak, P. (2006), 'Status of iodine nutriture and universal salt iodisation at beneficiaries levels in kerala state, india', *Journal of Indian Medical Assoc iation* **4**(104), 165–7.

Karmarkar, M. G., Pandav, C. S., , Yadav, K. and Kumar, R. (2012), 'Mission approach to achieve sustainable elimination of iodine deficiency disorders (idd) in india', *World Journal of Endocrine Surgery* **26**(203), 145 – 148.

Lavy, V., Schlosser, A. and Shany, A. (20136), Out of africa: Human capital consequences of in utero conditions, Working Paper 1, Maurice Falk Institute for Economic Research in Israel.

Lucas, A. M. (2010), 'Malaria eradication and educational attainment: Evidence from paraguay and sri lanka', *American Economic Journal: Applied Economics* **2**(2), 46–71.

M Andersson, B de Benoist, F. D. and Zupan, J. (2007), 'Prevention and control of iodine deficiency in pregnant and lactating women and in children less than 2-years-old: conclusions and recommendations of the technical consultation', *Public Health Nutrition:* **12A**(10), 1606–1611.

McCarrison, R. (1915), 'The distribution of goitre in india', *Indian J. med. Res* **x**(2), 778.

Mezgebu, Y., Mossie, A., Rajesh, P. and Beyene, G. (2012), ‘Prevalence and severity of iodine deficiency disorder among children 6–12 years of age in shebe senbo district, jimma zone, southwest ethiopia’, *Ethiopian Journal of Health Sciences* **22**(3), 196–204.

Moleti, M., Presti, V. P. L., Campolo, M. C., Mattina, F., Galletti, M., Mandolfino, M., Violi, M. A., Giorgianni, G., Domenico, D. D., Trimarchi, F. and Vermiglio, F. (2008), ‘Iodine prophylaxis using iodized salt and risk of maternal thyroid failure in conditions of mild iodine deficiency’, *The Journal of Clinical Endocrinology & Metabolism* **93**(7), 2616–2621.

Nyle C. Brady, R. R. W. (1996), *The Nature and Properties of Soils*, Pearson Prentice Hall.

Pandav, C. S. and Kochupillai, N. (1982), ‘Endemic goitre in india: Prevalence, etiology, attendant disabilities and control measures.’, *Indian Journal of Pediatrics* **50**(397), 259–271.

Pandav, C. S., Yadav, K., Srivastava, R., Pandav, R. and Karmarkar, M. (2013), ‘Iodine deficiency disorders (idd) control in india’, *The Indian Journal of Medical Research* **138**(3), 418–433.

Politi, D. (2010), The impact of iodine deficiency eradication on schooling: Evidence from the introduction of iodized salt in switzerland, Working Paper 200, School of Economics University of Edinburgh.

Politi, D. (2015), The effects of the generalized use of iodized salt on occupational patterns in switzerland, Working Paper 200, School of Economics University of Edinburgh.

Rah, J. H., Anas, A. M., Chakrabarty, A., Sankar, R., Pandav, C. S. and Aguayo, V. M. (2013), ‘Towards universal salt iodisation in india: achievements, challenges and future actions’, *Maternal and Child Nutrition* **11**(4), 483–496.

Rasmussen, L. B., Ovesen, L., Bülow, I., Jørgensen, T., Knudsen, N., Laurberg, P. and Perrild, H. (2002), ‘Dietary iodine intake and urinary iodine excretion in a danish population: effect of geography, supplements and food choice’, *British Journal of Nutrition* **87**(1), 61–69.

Rodgers, A., Vaughan, P., Prentice, T., Edejer, T., Evans, D. and Lowe, J. (2002), The world health report 2002: reducing risks, pro- moting healthy life., Report, World Health Organization.

Vir, S. C., ed. (2011), *Public Health Nutrition in Developing Countries*, Woodhead Publishing India.

Wateraid (2004), Groundwater quality: Northern india, Report, British Geological Survey.

Wen, D., Zhang, F., Zhang, E., Wang, C., Han, S. and Zheng, Y. (2013), 'Arsenic, fluoride and iodine in groundwater of china', *Journal of Geochemical Exploration* **135**, 1 – 21.

Wheeler, S. and van der Haar, F. (2004), household wealth and iodised salt consumption: Iodised salt at any price?, Report, Network for sustained elimination of iodine deficiency.

Zimmerman, M. (n.d.).

Zimmermann, M. B. (2009), 'Iodine deficiency', *Endocrine Reviews* **30**(4), 376–408.

Zimmermann, M. B. (2011), 'The role of iodine in human growth and development', *Seminars in Cell and Developmental Biology* **22**(6), 645 – 652.

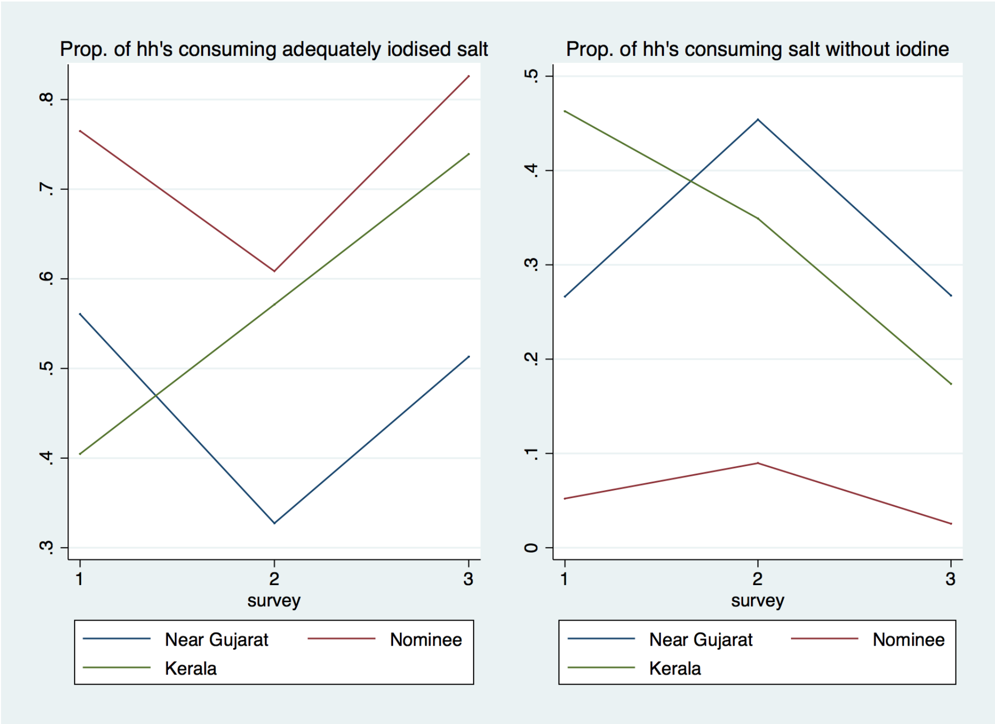
Zimmermann, M. B. (2012), 'The effects of iodine deficiency in pregnancy and infancy', *Paediatric and Perinatal Epidemiology* **26**(1), 108–117.

Zimmermann, M. B., Jooste, P. L. and Pandav, C. S. (n.d.), 'Iodine-deficiency disorders', *The Lancet* **372**(9645), 1251–1262.
Pandav et al.

Pandav, C., Moorthy, D., Sankar, R., Anand, K., Karmarkar, M. and Prakash, R. (2003), National iodine deficiency disorders control programme, national health programme series 5., Report, National Institute of Health and Family Welfare: New Delhi.

A Appendix

Figure 6: Consumption of iodized salt over time



A.1 Regression Results

Table 8: Effect of ban on continuous test scores

	(1) MATH	(2) READ	(3) MATH	(4) READ	(5) MATH	(6) READ	(7) MATH	(8) READ
NON-IODISED (TOTAL) * IDD ENDEMIC	0.005	-0.007			0.017	0.006		
	(0.016)	(0.018)			(0.016)	(0.016)		
NON-IODISED * IDD ENDEMIC			0.016	-0.033			0.013	0.007
			(0.025)	(0.031)			(0.027)	(0.031)
Maternal Educ	0.048***	0.055***	0.049***	0.056***	0.045***	0.049***	0.045***	0.050***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Semi-Pucca	0.132***	0.154***	0.123***	0.148***	0.141***	0.170***	0.134***	0.167***
	(0.007)	(0.008)	(0.007)	(0.009)	(0.007)	(0.008)	(0.008)	(0.009)
Pucca	0.277***	0.313***	0.266***	0.307***	0.283***	0.312***	0.276***	0.310***
	(0.008)	(0.010)	(0.009)	(0.010)	(0.008)	(0.009)	(0.009)	(0.010)
Gvt primary school in vlg	0.055***	0.032**	0.046***	0.030*	0.047***	0.026*	0.043***	0.023
	(0.013)	(0.016)	(0.014)	(0.017)	(0.013)	(0.014)	(0.013)	(0.015)
Anganwadi in vlg	0.032***	0.046***	0.034***	0.044***	0.033***	0.049***	0.033***	0.047***
	(0.012)	(0.014)	(0.012)	(0.014)	(0.011)	(0.013)	(0.011)	(0.013)
Size of HH	-0.003***	-0.003***	-0.002**	-0.002**	-0.003***	-0.003***	-0.002**	-0.002**
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Birth Order	0.036***	0.038***	0.034***	0.036***	0.038***	0.037***	0.035***	0.035***
	(0.003)	(0.004)	(0.003)	(0.004)	(0.003)	(0.004)	(0.003)	(0.004)
Observations	405889	405889	340947	340947	474775	474775	394723	394723
R^2	0.806	0.791	0.784	0.765	0.810	0.792	0.786	0.762

Standard errors in parentheses. Robust Standard Errors Clustered on District. Columns 1-4 are estimated for the sub sample of girls. Columns 5-8 are estimated for the sub sample of boys. Year of Birth, Survey year, survey year*year of birth linear district trends.

* $p < .10$, ** $p < .05$, *** $p < .01$

A.1.1 Transport Heterogeneity

Table 9: Effect of the removal of the ban on Gujarat and states within 500 km of Gujarat.

	(1) MATH	(2) READ	(3) MATH	(4) READ	(5) MATH	(6) READ	(7) MATH	(8) READ
NON-IODISED (TOTAL) * IDD ENDEMIC	-0.019***	-0.023***			-0.015**	-0.017**		
	(0.007)	(0.008)			(0.006)	(0.007)		
NON-IODISED * IDD ENDEMIC			-0.052***	-0.051***			-0.038**	-0.027
			(0.017)	(0.019)			(0.017)	(0.018)
Maternal Educ	0.011***	0.011***	0.012***	0.013***	0.010***	0.011***	0.011***	0.012***
	(0.000)	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)	(0.000)	(0.000)
Semi-Pucca	0.045***	0.047***	0.048***	0.050***	0.041***	0.041***	0.045***	0.046***
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
Pucca	0.075***	0.077***	0.081***	0.083***	0.069***	0.072***	0.075***	0.080***
	(0.004)	(0.004)	(0.005)	(0.005)	(0.004)	(0.004)	(0.005)	(0.005)
Birth Order	0.008***	0.009***	0.010***	0.010***	0.009***	0.009***	0.010***	0.010***
	(0.001)	(0.001)	(0.002)	(0.002)	(0.001)	(0.001)	(0.001)	(0.001)
Gvt primary school in vlg	0.016**	0.015**	0.016**	0.014*	0.015***	0.014***	0.016***	0.017***
	(0.006)	(0.007)	(0.007)	(0.008)	(0.005)	(0.005)	(0.006)	(0.006)
Anganwadi in vlg	0.007	0.010	0.004	0.009	0.001	0.007	-0.001	0.007
	(0.007)	(0.007)	(0.007)	(0.007)	(0.006)	(0.006)	(0.007)	(0.007)
Size of HH	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Observations	166373	166373	139260	139260	201819	201819	166515	166515
R^2	0.842	0.835	0.818	0.809	0.856	0.847	0.832	0.819

Standard errors in parentheses. Robust Standard Errors Clustered on District. All regressions are estimated for children in Gujarat or states within 500 km of Gujarat. Columns 1-4 are estimated for the sub sample of girls Columns 5-8 are estimated for the sub sample of boys. Year of Birth, Survey year, survey year*year of birth linear district trends. * $p < .10$, ** $p < .05$, *** $p < .01$

Table 10: Effect of the removal of the ban on nominee states with rail transportation.

	(1) MATH	(2) READ	(3) MATH	(4) READ	(5) MATH	(6) READ	(7) MATH	(8) READ
NON-IODISED (TOTAL) * IDD ENDEMIC	0.019	0.018*			0.025	0.008		
	(0.014)	(0.010)			(0.016)	(0.014)		
NON-IODISED * IDD ENDEMIC			0.055	0.061*			0.061	0.029
			(0.054)	(0.033)			(0.038)	(0.031)
Maternal Educ	0.007***	0.009***	0.008***	0.009***	0.007***	0.007***	0.007***	0.008***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Semi-Pucca	0.019***	0.021***	0.021***	0.024***	0.027***	0.032***	0.030***	0.036***
	(0.004)	(0.005)	(0.005)	(0.005)	(0.004)	(0.004)	(0.004)	(0.004)
Pucca	0.032***	0.046***	0.036***	0.051***	0.044***	0.050***	0.049***	0.056***
	(0.005)	(0.006)	(0.006)	(0.007)	(0.005)	(0.005)	(0.005)	(0.006)
Birth Order	0.003*	0.006***	0.002	0.006***	0.004**	0.005***	0.005**	0.006***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Gvt primary school in vlg	0.021**	0.022**	0.024**	0.024**	0.017**	0.026***	0.018**	0.029***
	(0.009)	(0.009)	(0.010)	(0.010)	(0.007)	(0.008)	(0.008)	(0.009)
Anganwadi in vlg	0.016**	0.012*	0.016*	0.012	0.012*	0.008	0.012*	0.008
	(0.008)	(0.007)	(0.008)	(0.008)	(0.006)	(0.006)	(0.007)	(0.007)
Size of HH	-0.001*	-0.002***	-0.001*	-0.002***	-0.001*	-0.001**	-0.001	-0.001*
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Observations	61266	61266	51785	51785	69060	69060	57997	57997
R^2	0.921	0.910	0.911	0.900	0.920	0.909	0.910	0.898

Standard errors in parentheses. Robust Standard Errors Clustered on District. All regressions are estimated for children in 8 North Eastern States and West Bengal. Columns 1-4 are estimated for the sub sample of girls Columns 5-8 are estimated for the sub sample of boys. Year of Birth, Survey year, survey year*year of birth linear district trends. * $p < .10$, ** $p < .05$, *** $p < .01$

A.1.2 IV

Table 11: TSLS effects on enrolment

	(1) ENROLLED	(2) DROP-OUT	(3) ENROLLED	(4) DROP-OUT	(5) ENROLLED	(6) DROP-OUT	(7) ENROLLED	(8) DROP- OUT
NON-IODIZED (TOTAL) * IDD ENDEMIC	-0.010***	0.003			-0.005	-0.000		
	(0.004)	(0.002)			(0.003)	(0.002)		
NON-IODIZED * IDD ENDEMIC			-0.020**	0.003			-0.012	-0.003
			(0.008)	(0.005)			(0.008)	(0.004)
Maternal Educ	0.001***	-0.000***	0.001***	-0.000***	0.001***	-0.000***	0.001***	-0.000***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Semi-Pucca	0.005***	-0.002***	0.005***	-0.002***	0.004***	-0.002***	0.004***	-0.001***
	(0.001)	(0.000)	(0.001)	(0.000)	(0.001)	(0.000)	(0.001)	(0.000)
Pucca	0.007***	-0.003***	0.007***	-0.002***	0.005***	-0.002***	0.005***	-0.002***
	(0.001)	(0.000)	(0.001)	(0.000)	(0.001)	(0.000)	(0.001)	(0.000)
Gvt primary school in vlg	0.005***	-0.001	0.005***	-0.000	0.004***	-0.001	0.004**	-0.001
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Anganwadi in vlg	0.002*	-0.002*	0.002	-0.002	0.001	-0.001	0.001	-0.001
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Size of HH	0.000	-0.000***	0.000	-0.000***	-0.000	-0.000*	-0.000	-0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Birth Order	-0.001***	0.000*	-0.001**	0.000	-0.001***	0.001***	-0.001***	0.000**
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Observations	405889	405889	340947	340947	474775	474775	394723	394723
R^2	0.990	0.020	0.990	0.017	0.991	0.015	0.992	0.013

Standard errors in parentheses. Robust Standard Errors Clustered on District. Columns 1-4 are estimated for the sub sample of girls. Columns 5-8 are estimated for the sub sample of boys. Year of Birth, Survey year, survey year*year of birth linear district trends.

* $p < .10$, ** $p < .05$, *** $p < .01$

Table 12: Effect of ban on test scores Sample of girls and boys - 10 years and below

	(1) MATH	(2) MATH	(3) READ	(4) READ	(5) MATH	(6) MATH	(7) READ	(8) READ
NON-IODIZED (TOTAL) * IDD ENDEMIC	-0.114	0.054	-0.167*	0.027				
	(0.078)	(0.079)	(0.094)	(0.088)				
NON-IODISED * IDD ENDEMIC					-0.003	0.022	-0.029	0.004
					(0.046)	(0.045)	(0.051)	(0.046)
Maternal Educ	0.049***	0.045***	0.056***	0.050***	0.048***	0.045***	0.055***	0.049***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Semi-Pucca	0.123***	0.134***	0.148***	0.167***	0.132***	0.141***	0.154***	0.170***
	(0.007)	(0.008)	(0.009)	(0.009)	(0.007)	(0.007)	(0.008)	(0.008)
Pucca	0.266***	0.277***	0.308***	0.310***	0.276***	0.283***	0.313***	0.312***
	(0.009)	(0.009)	(0.010)	(0.010)	(0.008)	(0.008)	(0.010)	(0.009)
Birth Order	0.034***	0.035***	0.036***	0.035***	0.036***	0.038***	0.038***	0.037***
	(0.003)	(0.003)	(0.004)	(0.004)	(0.003)	(0.003)	(0.004)	(0.004)
Gvt primary school in vlg	0.046***	0.043***	0.030*	0.023	0.055***	0.047***	0.032**	0.026*
	(0.014)	(0.013)	(0.017)	(0.015)	(0.014)	(0.013)	(0.016)	(0.014)
Anganwadi in vlg	0.034***	0.033***	0.044***	0.047***	0.032***	0.033***	0.046***	0.049***
	(0.012)	(0.011)	(0.014)	(0.013)	(0.012)	(0.011)	(0.014)	(0.013)
Size of HH	-0.002**	-0.002**	-0.002**	-0.002**	-0.003***	-0.003***	-0.003***	-0.003***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Observations	340947	394723	340947	394723	405889	474775	405889	474775
R^2	0.784	0.786	0.765	0.762	0.806	0.810	0.791	0.792

Standard errors in parentheses. Robust Standard Errors Clustered on District. Columns 1-4 are estimated for the sub sample of girls. Columns 5-8 are estimated for the sub sample of boys. Year of Birth, Survey year, survey year*year of birth linear district trends.

* $p < .10$, ** $p < .05$, *** $p < .01$

Table 13: IV Results: Effect of no ban on enrolment in Gujarat and states close to Gujarat. Sample of girls and boys - all ages

	(1) Child has been enrolled	(2) Child has been enrolled	(3) Child has been enr
NON-IODISED (TOTAL) * IDD ENDEMIC	-0.030***		-0.020***
	(0.009)		(0.007)
NON-IODISED * IDD ENDEMIC		-0.051***	
		(0.019)	
Maternal Educ	0.001***	0.001***	0.001***
	(0.000)	(0.000)	(0.000)
Semi-Pucca	0.007***	0.007***	0.006***
	(0.001)	(0.001)	(0.001)
Pucca	0.010***	0.010***	0.008***
	(0.001)	(0.001)	(0.001)
Birth Order	-0.001	-0.001	-0.001
	(0.001)	(0.001)	(0.000)
Gvt primary school in vlg	0.006***	0.005**	0.005**
	(0.002)	(0.002)	(0.002)
Anganwadi in vlg	0.002	0.001	-0.001
	(0.003)	(0.002)	(0.002)
Size of HH	-0.000	-0.000	-0.000
	(0.000)	(0.000)	(0.000)
Observations	166373	139260	201819
R^2	0.987	0.987	0.989

Standard errors in parentheses

Robust Standard Errors Clustered on District. Year of Birth, Survey year, survey year*year of birth linear district tre

* $p < .10$, ** $p < .05$, *** $p < .01$

Table 14: IV-Results: Effect of the removal of the ban on Gujarat and states within 500 km of Gujarat.

	(1) MATH	(2) READ	(3) MATH	(4) READ	(5) MATH	(6) READ	(7) MATH	(8) READ
NON-IODISED (TOTAL) * IDD ENDEMIC	-0.047**	-0.086***			-0.052***	-0.081***		
	(0.023)	(0.028)			(0.020)	(0.025)		
NON-IODISED * IDD ENDEMIC			-0.091*	-0.149**			-0.054	-0.102**
			(0.051)	(0.063)			(0.048)	(0.052)
Maternal Educ	0.011***	0.011***	0.012***	0.013***	0.010***	0.011***	0.011***	0.012***
	(0.000)	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)	(0.000)	(0.000)
Semi-Pucca	0.045***	0.047***	0.048***	0.050***	0.041***	0.041***	0.045***	0.046***
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
Pucca	0.075***	0.077***	0.081***	0.083***	0.069***	0.072***	0.075***	0.080***
	(0.004)	(0.004)	(0.005)	(0.005)	(0.004)	(0.004)	(0.005)	(0.005)
Birth Order	0.009***	0.009***	0.010***	0.010***	0.009***	0.009***	0.010***	0.010***
	(0.001)	(0.001)	(0.002)	(0.002)	(0.001)	(0.001)	(0.001)	(0.001)
Gvt primary school in vlg	0.016**	0.015**	0.016**	0.014*	0.015***	0.014***	0.016***	0.017***
	(0.006)	(0.007)	(0.007)	(0.008)	(0.005)	(0.005)	(0.006)	(0.006)
Anganwadi in vlg	0.006	0.009	0.004	0.009	0.001	0.007	-0.001	0.007
	(0.007)	(0.007)	(0.007)	(0.007)	(0.006)	(0.006)	(0.007)	(0.007)
Size of HH	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Observations	166373	166373	139260	139260	201819	201819	166515	166515
R^2	0.842	0.835	0.818	0.809	0.856	0.847	0.832	0.819

Standard errors in parentheses

Robust Standard Errors Clustered on District. Year of Birth, Survey year, survey year*year of birth linear district trends.

* $p < .10$, ** $p < .05$, *** $p < .01$

A.2 Robustness regressions

A.2.1 Robustness: Placebo Regressions

Table 15: Placebo Effect of ban: Maternal Education and Comparing cohorts born in 2000 to cohorts born in 2006. Sample of girls and boys - 10 years and below

	(1) Maternal Education	(2) Maternal Education	(3) MATH	(4) READ	(5) MATH	(6) READ
NON-IODIZED (TOTAL) * IDD ENDEMIC	0.011					
	(0.030)					
[1em] NON-IODIZED * IDD ENDEMIC		-0.000				
		(0.066)				
BAN1 VS BAN2			-0.189	-0.709	0.980	0.734
			(0.926)	(0.966)	(4.956)	(6.016)
Maternal Educ			0.011***	0.012***	0.011***	0.012***
			(0.000)	(0.000)	(0.000)	(0.000)
Semi-Pucca	1.153***	1.165***	0.036***	0.037***	0.034***	0.032***
	(0.031)	(0.032)	(0.004)	(0.004)	(0.004)	(0.004)
Pucca	2.784***	2.859***	0.074***	0.078***	0.066***	0.067***
	(0.047)	(0.048)	(0.004)	(0.004)	(0.004)	(0.004)
Birth Order	0.010	0.010	0.014***	0.016***	0.014***	0.016***
	(0.009)	(0.010)	(0.002)	(0.002)	(0.002)	(0.002)
Gvt primary school in vlg	0.084*	0.074	0.023***	0.022***	0.006	0.008
	(0.049)	(0.052)	(0.006)	(0.007)	(0.007)	(0.007)
Anganwadi in vlg	0.285***	0.288***	-0.003	-0.007	0.018***	0.012**
	(0.044)	(0.045)	(0.007)	(0.006)	(0.006)	(0.006)
Size of HH	-0.024***	-0.022***	-0.000	-0.001	0.000	-0.000
	(0.004)	(0.004)	(0.001)	(0.001)	(0.000)	(0.000)
Observations	880664	735670	103394	103394	120392	120392
R^2	0.555	0.563	0.844	0.832	0.848	0.835

Standard errors in parentheses. Robust Standard Errors Clustered on District.
Year of Birth, Survey year, survey year*year of birth linear district trends.
* $p < .10$, ** $p < .05$, *** $p < .01$

A.2.2 Robustness: Vaccination, Supplementation and Diarrhea

Table 16: Pooled Sample - Robustness Checks - Vaccinations and Diarrhea

	(1) bcg	(2) measl	(3) vita	(4) diarrhea_recently	(5) bcg	(6) measl	(7) vita	(8) diarrhea_recently
NON-IODIZED * IDD ENDEMIC	0.057**	0.006	0.006	-0.003				
	(0.028)	(0.033)	(0.033)	(0.013)				
NON-IODIZED (TOTAL) * IDD ENDEMIC					0.003	0.013	0.013	-0.008
					(0.012)	(0.016)	(0.016)	(0.006)
Maternal Educ	0.009***	0.007***	0.007***	0.000	0.011***	0.010***	0.010***	-0.000
	(0.001)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Gvt Prim school in vlg	0.021***	0.018***	0.018***	-0.008**	0.020***	0.018***	0.018***	-0.006*
	(0.006)	(0.005)	(0.005)	(0.004)	(0.005)	(0.005)	(0.005)	(0.003)
Girl	-0.012***	-0.009***	-0.009***	-0.006***	-0.015***	-0.012***	-0.012***	-0.006***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Birth Order by motherid	0.003	-0.004	-0.004	-0.011***	-0.006*	-0.009***	-0.009***	0.018***
	(0.005)	(0.005)	(0.005)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Anganwadi in vlg	0.019***	0.011***	0.011***	0.001	0.020***	0.011***	0.011***	0.003
	(0.005)	(0.004)	(0.004)	(0.003)	(0.005)	(0.004)	(0.004)	(0.003)
Semi-pucca	0.037***	0.025***	0.025***	0.001	0.040***	0.030***	0.030***	0.000
	(0.003)	(0.003)	(0.003)	(0.002)	(0.003)	(0.003)	(0.003)	(0.002)
Pucca	0.044***	0.037***	0.037***	-0.001	0.053***	0.049***	0.049***	-0.001
	(0.005)	(0.004)	(0.004)	(0.003)	(0.004)	(0.004)	(0.004)	(0.003)
Observations	175567	175507	175507	175170	217804	217711	217711	217861
R^2	0.587	0.472	0.472	0.194	0.633	0.527	0.527	0.192

Standard errors in parentheses

Robust Standard Errors Clustered on District. Year of Birth, interview year, interview year*year of birth linear district trends.

* $p < .10$, ** $p < .05$, *** $p < .01$

A.2.3 Robustness: Child Mortality

Table 17: Effect on infant mortality - probability of child dying within 10 months. Sample of girls and boys

	(1) Died within 10 months	(2) Died within 10 months	(3) Died within 10 months	(4) Died within 10 months
NON IODISED * ENDEMIC DISTRICT	0.029**	0.008		
	(0.012)	(0.012)		
NON IODISED ENDEMIC DISTRICT (TOTAL)			0.009**	0.004
			(0.003)	(0.003)
Semi-pucca	-0.006**	-0.006**	-0.007***	-0.006***
	(0.002)	(0.002)	(0.002)	(0.002)
Pucca	-0.011***	-0.013***	-0.012***	-0.015***
	(0.003)	(0.003)	(0.003)	(0.003)
Mother's age at birth	-0.001***	-0.001***	-0.001***	-0.002***
	(0.000)	(0.000)	(0.000)	(0.000)
Maternal Educ	-0.002***	-0.001***	-0.002***	-0.001***
	(0.000)	(0.000)	(0.000)	(0.000)
Birth Order	0.009***	0.007***	0.007***	0.003***
	(0.001)	(0.001)	(0.001)	(0.001)
Singleton	-0.110***	-0.109***	-0.135***	-0.131***
	(0.007)	(0.007)	(0.006)	(0.006)
Gvt Primary School in vlg	-0.003	0.005	-0.002	0.003
	(0.003)	(0.003)	(0.003)	(0.003)
Anganwadi in vlg	-0.001	-0.001	-0.004	0.002
	(0.003)	(0.003)	(0.003)	(0.003)
Observations	42610	47265	61442	68349
R^2	0.080	0.079	0.082	0.080

Table 18: Effect of no ban on non-IS on child mortality for pooled sample.

	(1) Child Alive	(2) Died Before 1	(3) Child Alive	(4) Died Before 1	(5) Child Alive	(6) Died Before 1	(7) Child Alive	(8) Died Before 1
NON-IODISED (TOTAL) * ENDEMIC	-0.008	0.009**			-0.002	0.002		
	(0.005)	(0.005)			(0.006)	(0.006)		
NON-IODISED * ENDEMIC			-0.029*	0.025			0.014	-0.012
			(0.016)	(0.015)			(0.023)	(0.022)
Semi-pucca	0.010***	-0.010***	0.008**	-0.008***	0.008***	-0.008***	0.008**	-0.007**
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Pucca	0.019***	-0.018***	0.018***	-0.017***	0.016***	-0.016***	0.009*	-0.010*
	(0.003)	(0.003)	(0.004)	(0.004)	(0.004)	(0.004)	(0.005)	(0.005)
Mother's age at birth	0.003***	-0.002***	0.002***	-0.002***	0.000*	-0.000	0.000	-0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Maternal Educ	0.001***	-0.001***	0.001***	-0.001***	0.001***	-0.001***	0.001***	-0.001***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Birth Order	-0.006***	0.006***	-0.008***	0.008***	-0.005***	0.005***	-0.007***	0.007***
	(0.001)	(0.001)	(0.002)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Singleton Birth	0.187***	-0.026***	0.170***	-0.003	0.116***	-0.019***	0.114***	-0.009*
	(0.009)	(0.005)	(0.010)	(0.005)	(0.009)	(0.005)	(0.010)	(0.005)
Gvt Primary School in vlg	-0.005	0.004	0.001	-0.001	0.000	0.001	-0.003	0.004
	(0.006)	(0.006)	(0.006)	(0.006)	(0.003)	(0.003)	(0.004)	(0.004)
Anganwadi in vlg	0.008**	-0.008**	0.005	-0.005	0.005	-0.004	0.004	-0.003
	(0.004)	(0.003)	(0.004)	(0.004)	(0.003)	(0.003)	(0.005)	(0.004)
Observations	41814	43668	29498	31352	28895	29921	19117	20140
R^2	0.946	0.073	0.952	0.069	0.967	0.051	0.968	0.050

Standard errors in parentheses. Robust Standard Errors Clustered on District.

Columns 1-4 include children from Gujarat and neighbouring states. Columns 5-8 include children in the 8 North eastern states and West Bengal.

References

Ahad, F. and Ganie, S. A. (2010), 'Iodine, iodine metabolism and iodine deficiency disorders revisited', *Indian Journal of Endocrinology and Metabolism* **14**(1), 13–17.

Almond, D. (2006), 'Is the 1918 influenza pandemic over? longterm effects of in utero influenza exposure in the post1940 u.s. population', *Journal of Political Economy* **114**(4), 672–712.

Andersson M, Karumbunathan V, Z. M. (2012), 'Global iodine status in 2011 and trends over the past decade.', *Journal of Nutrition* (142), 744–50.

Baird, S., Friedman, J. and Schady, N. (2011), 'Aggregate income shocks and infant mortality in the developing world.', *Review of Economics Statistics* **93**(3), 847 – 856.

Bleakley, H. (2007), 'Disease and development: Evidence from hookworm eradication in the american south', *The Quarterly Journal of Economics* **122**(1), 73–117.

Bleakley, H. (2010), 'Malaria eradication in the americas: A retrospective analysis of childhood exposure', *American Economic Journal: Applied Economics* **2**(2), 1–45.

Brander, L., Als, C., Buess, H., Haldimann, F., Harder, M., Hänggi, W., Herrmann, U., Lauber, K., Niederer, U., Zürcher, T., Bürgi, U. and Gerber, H. (2003), 'Urinary iodine concentration during pregnancy in an area of unstable dietary iodine intake in switzerland.', *J Endocrinol Invest* **26**(5), 389–96.

Cao, X.-Y., Jiang, X.-M., Dou, Z.-H., Rakeman, M. A., Zhang, M.-L., O'Donnell, K., Ma, T., Amette, K., DeLong, N. and DeLong, G. R. (1994), 'Timing of vulnerability of the brain to iodine deficiency in endemic cretinism', *New England Journal of Medicine* **331**(26), 1739–1744.

CGB (2010), ground water quality in shallow aquifers of india, Report, Central ground water board ministry of water resources.

Cutler, D., Fung, W., Kremer, M., Singhal, M. and Vogl, T. (2010), 'Early-life malaria exposure and adult outcomes: Evidence from malaria eradication in india', *American Economic Journal: Applied Economics* **2**(2), 72–94.

DeLong, G. R., Leslie, P. W., Wang, S.-H., Jiang, X.-M., Zhang, M.-L., abdul Rakeman, M., Jiang, J.-Y., Ma, T. and Cao, X.-Y. (1997), 'Effect on infant mortality of iodination of irrigation water in a severely iodine-deficient area of china', *The Lancet* **350**(9080), 771 – 773.

Eric A. Hanushek, L. W. (2008), 'The role of cognitive skills in economic development', *Journal of Economic Literature* **46**(3), 607–668.

Feyrer, J., Politi, D. and Weil, D. N. (2013), The cognitive effects of micronutrient deficiency: Evidence from salt iodization in the united states, Working Paper 19233, National Bureau of Economic Research.

Field, E., Robles, O. and Torero, M. (2009), 'Iodine deficiency and schooling attainment in tanzania', *American Economic Journal: Applied Economics* **1**(4), 140–69.

Fuge, R. (2007), 'Iodine deficiency: An ancient problem in a modern world', *AMBIO: A Journal of the Human Environment* **36**(1), 70–72.

Gordon, R. C., Rose, M. C., Skeaff, S. A., Gray, A. R., Morgan, K. M. and Ruffman, T. (2009), 'Iodine supplementation improves cognition in mildly iodine-deficient children', *The American Journal of Clinical Nutrition* **90**(5), 1264–1271.

Hetzel, B. (1983), 'Iodine deficiency disorders (idd) and their eradication', *The Lancet* **322**(8359), 1126 – 1129.

Johnson, C. C. (n.d.), The geochemistry of iodine and its application to environmental strategies for reducing the risks from iodine deficiency disorders (idd), Technical report.

Kapil, U. (2007), 'Health consequences of iodine deficiency', *Sultan Qaboos University Medical Journal* **7**(3), 267–272.

Kapil, U., Singh, P. Dwivedi, S. N. and Pathak, P. (2006), 'Status of iodine nutriture and universal salt iodisation at beneficiaries levels in kerala state, india', *Journal of Indian Medical Assoc iation* **4**(104), 165–7.

Karmarkar, M. G., Pandav, C. S., , Yadav, K. and Kumar, R. (2012), 'Mission approach to achieve sustainable elimination of iodine deficiency disorders (idd) in india', *World Journal of Endocrine Surgery* **26**(203), 145 – 148.

Lavy, V., Schlosser, A. and Shany, A. (20136), Out of africa: Human capital consequences of in utero conditions, Working Paper 1, Maurice Falk Institute for Economic Research in Israel.

Lucas, A. M. (2010), 'Malaria eradication and educational attainment: Evidence from paraguay and sri lanka', *American Economic Journal: Applied Economics* **2**(2), 46–71.

M Andersson, B de Benoist, F. D. and Zupan, J. (2007), 'Prevention and control of iodine deficiency in pregnant and lactating women and in children less than 2-years-old: conclusions and recommendations of the technical consultation', *Public Health Nutrition:* **12A**(10), 1606–1611.

McCarrison, R. (1915), 'The distribution of goitre in india', *Indian J. med. Res* **x**(2), 778.

Mezgebu, Y., Mossie, A., Rajesh, P. and Beyene, G. (2012), ‘Prevalence and severity of iodine deficiency disorder among children 6–12 years of age in shebe senbo district, jimma zone, southwest ethiopia’, *Ethiopian Journal of Health Sciences* **22**(3), 196–204.

Moleti, M., Presti, V. P. L., Campolo, M. C., Mattina, F., Galletti, M., Mandolfino, M., Violi, M. A., Giorgianni, G., Domenico, D. D., Trimarchi, F. and Vermiglio, F. (2008), ‘Iodine prophylaxis using iodized salt and risk of maternal thyroid failure in conditions of mild iodine deficiency’, *The Journal of Clinical Endocrinology & Metabolism* **93**(7), 2616–2621.

Nyle C. Brady, R. R. W. (1996), *The Nature and Properties of Soils*, Pearson Prentice Hall.

Pandav, C. S. and Kochupillai, N. (1982), ‘Endemic goitre in india: Prevalence, etiology, attendant disabilities and control measures.’, *Indian Journal of Pediatrics* **50**(397), 259–271.

Pandav, C. S., Yadav, K., Srivastava, R., Pandav, R. and Karmarkar, M. (2013), ‘Iodine deficiency disorders (idd) control in india’, *The Indian Journal of Medical Research* **138**(3), 418–433.

Politi, D. (2010), The impact of iodine deficiency eradication on schooling: Evidence from the introduction of iodized salt in switzerland, Working Paper 200, School of Economics University of Edinburgh.

Politi, D. (2015), The effects of the generalized use of iodized salt on occupational patterns in switzerland, Working Paper 200, School of Economics University of Edinburgh.

Rah, J. H., Anas, A. M., Chakrabarty, A., Sankar, R., Pandav, C. S. and Aguayo, V. M. (2013), ‘Towards universal salt iodisation in india: achievements, challenges and future actions’, *Maternal and Child Nutrition* **11**(4), 483–496.

Rasmussen, L. B., Ovesen, L., Bülow, I., Jørgensen, T., Knudsen, N., Laurberg, P. and Perrild, H. (2002), ‘Dietary iodine intake and urinary iodine excretion in a danish population: effect of geography, supplements and food choice’, *British Journal of Nutrition* **87**(1), 61–69.

Rodgers, A., Vaughan, P., Prentice, T., Edejer, T., Evans, D. and Lowe, J. (2002), The world health report 2002: reducing risks, pro- moting healthy life., Report, World Health Organization.

Vir, S. C., ed. (2011), *Public Health Nutrition in Developing Countries*, Woodhead Publishing India.

Wateraid (2004), Groundwater quality: Northern india, Report, British Geological Survey.

Wen, D., Zhang, F., Zhang, E., Wang, C., Han, S. and Zheng, Y. (2013), 'Arsenic, fluoride and iodine in groundwater of china', *Journal of Geochemical Exploration* **135**, 1 – 21.

Wheeler, S. and van der Haar, F. (2004), household wealth and iodised salt consumption: Iodised salt at any price?, Report, Network for sustained elimination of iodine deficiency.

Zimmerman, M. (n.d.).

Zimmermann, M. B. (2009), 'Iodine deficiency', *Endocrine Reviews* **30**(4), 376–408.

Zimmermann, M. B. (2011), 'The role of iodine in human growth and development', *Seminars in Cell and Developmental Biology* **22**(6), 645 – 652.

Zimmermann, M. B. (2012), 'The effects of iodine deficiency in pregnancy and infancy', *Paediatric and Perinatal Epidemiology* **26**(1), 108–117.

Zimmermann, M. B., Jooste, P. L. and Pandav, C. S. (n.d.), 'Iodine-deficiency disorders', *The Lancet* **372**(9645), 1251–1262.
Pandav et al.

Pandav, C., Moorthy, D., Sankar, R., Anand, K., Karmarkar, M. and Prakash, R. (2003), National iodine deficiency disorders control programme, national health programme series 5., Report, National Institute of Health and Family Welfare: New Delhi.