The Impact of Iodine Deficiency Eradication on Schooling: Evidence from the Introduction of Iodized Salt in Switzerland

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Abstract

I study the impact of salt iodization in Switzerland on graduation rates. The programme, which began in 1922 and continues to this day, was the first wide-reaching nutritional intervention ever to take place. Iodine deficiency in utero causes mental retardation, and correcting the deficiency is expected to increase the productivity of a population by increasing its cognitive ability. The exogenous increase in cognitive ability brought about by the iodization program is also useful in the context of disentangling the effects of innate ability and education on later-life outcomes. I identify the impact of iodization on graduation rates by exploiting pre-existing geographic variation in the prevalence of iodine deficiency, as well as spatial and temporal variation in the introduction of iodized salt across Swiss cantons. By looking at sharp, discontinuous increases in iodized salt circulation I show that the eradication of iodine deficiency in previously deficient areas significantly increased graduation rates from upper secondary and tertiary education. My results are robust to falsification tests and different measures of iodine deficiency.

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"Quodque magis mirum, sunt qui non corpora tantum Verum animos etiam valeant mutare liquores."

"And what is more wonderful, there are waters that have the power to change not only the body but also the mind."

Ovid, Metamorphoses, lib. XV., 317-318. [Taken from Langer (1960)]

1 Introduction

It is easy to take public health policies in developed countries today for granted. Yet, it was not so long ago that many of the public health measures that we consider fundamental today were first put into place in order to deal with similar issues that developing countries face today. Food fortification efforts are a prime example of such public health interventions, aiming to curb various nutritional deficiencies in the population. This paper studies the impact of salt iodization in Switzerland, which was the first major nutritional intervention to ever take place, and which paved the way for other similar initiatives, such as the fortification of milk with vitamins A and D in the USA. I study the cognitive impact of salt iodization in Switzerland, which has not been studied before, even though the iodization programme was and remains a big success, and a paradigm for similar iodine supplementation programmes in other countries.

Iodine deficiency is the leading cause of preventable mental retardation in the world today. The WHO estimates that nearly 50 million people suffer some degree of mental impairment due to iodine deficiency[1]. Two billion people, one third of the world's population, are at risk, in the sense that their iodine intake is considered insufficient. According to WHO's Global Database on Iodine Deficiency, more than 285 million children receive inadequate amounts of iodine in their diet [2]. Despite efforts to decrease the prevalence of iodine deficiency in the 1990s, there are still 38 million children born annually at the risk of developing iodine deficiency disorders. The most vulnerable areas in the world are South Asia and Central and

[1]Source: WHO, http://www.who.int/features/qa/17/en/index.html.

[2]Source: de Benoist et al., eds (2004).

Eastern Europe (UNICEF 2008). Even in the UK there have been some recent troubling reports of high prevalence of iodine deficiency among schoolchildren, pregnant women and women of child-bearing age (see, for example, Bath et al. (2013), Bath and Rayman (2013), and Vanderpump et al. (2011)).

Iodine Deficiency Disorders (IDD) is a generic name given to all defects resulting from a lack of iodine in the diet. The consequences of iodine deficiency are both visible and invisible; cretinism, goiter, short stature, and deaf-mutism are among the defects related to iodine deficiency that are easily detectable. However, iodine deficiency in utero and the first three months of life results in various degrees of brain damage that might be harder to observe in an affected population. In a meta-analysis of 21 studies, Bleichrodt and Born (1994) estimate that eliminating iodine deficiency increases average IQ by 13.5 points. Such an improvement in cognitive ability should be reflected in economic outcomes through increased human capital in the form of health, which will affect one's educational attainment and labor productivity.

Switzerland presents itself as a great case study. Due to its geography, Switzerland had rates of iodine deficiency that ranked among the highest in the world, and it was the first country to introduce iodized salt in 1922. Iodized salt proved a cost-effective measure to eradicate visible goiter, deaf-mutism, and cretinism, which were endemic before its introduction. The invisible effects of iodine deficiency on mental development and cognitive ability were not fully understood at the time, and public health authorities did not know that they were fighting against mental retardation as well as endemic goiter. As a result of the countrywide iodization campaign, there were no more endemic cretins born after 1930, deaf-mutism rates dropped significantly, and goiter disappeared in children and young recruits (Bürgi et al. 1990). I make use of the clear institutional setting and the availability of large, comprehensive datasets in order to look at schooling outcomes of Swiss born individuals. I find that, apart from its effects on cretinism, deaf-mutism and goiters, salt iodization also had a significant impact on graduation rates from secondary and tertiary education for those cohorts affected by iodine supplementation.

I combine microdata from the comprehensive 1970 Swiss Census with data on the pre-existing variation of iodine deficiency across Swiss localities. I identify the effect of iodization on graduation rates by exploiting differences in the timing of adoption of iodized salt across Swiss cantons. Using annual, canton-level data on the circulation of iodized salt sales I examine how the adoption of iodized salt affected schooling outcomes by looking at sharp jumps in iodized salt sales, and then comparing education outcomes for cohorts born right before and right after these sudden changes. The Swiss iodization programme started almost a century ago, so it provides a relatively rare insight into how health conditions in utero affect economically significant outcomes across the life cycle.

This paper's contribution can also be seen in a different light. The successful campaign for the eradication of iodine deficiency provides a rare opportunity to examine the effects of an "injection of IQ" on schooling outcomes. Iodization had a significant impact on the cognitive ability of people born in the worst-afflicted regions of Switzerland. Heckman and Vytlacil (2001) describe some problems in the identification of returns to schooling, apart from the usual omitted-ability bias. The real problem, they note, "is that ability and schooling appear to be inseparable –all interaction and no main effects– even if ability is perfectly observed". The advent of iodized salt made whole cohorts, namely those born after the intervention in previously deficient areas, smarter, through its effect on brain development in utero. In this light, by using the eradication of iodine deficiency as a shock to cognitive ability in Switzerland, we can decouple ability and schooling levels, and study the effects of the former on the latter.

I find that iodization increased the probability of graduating from upper-secondary and tertiary education for those born in previously highly-deficient areas by around 1 percentage point and 0.7 percentage points respectively. The baseline graduation rates are about 55% for upper secondary education and 13% for tertiary education. My estimates suggest that iodization alone explains 6.7% of the total increase in graduation rates from upper secondary education, and 8.2% of the total increase in graduation rates from tertiary education in treated areas observed over the period of examination. These results are robust to falsification tests, and tests using different measures of iodine deficiency. There is strong overall evidence that eradicating iodine deficiency had a significant impact on the educational attainment of cohorts born after the introduction of iodized salt in those regions where one would expect to find such an effect, namely regions which were highly deficient prior to the intervention.

The rest of the paper is organized as follows: section 2 provides a short review of the relevant literature from Economics. Section 3 provides some background on iodine deficiency disorders and the Swiss campaign for salt iodization. Section 4 describes the data from the 1970 Swiss Census, as well as the dataset on the pre-existing prevalence of iodine deficiency across Swiss municipalities. Section 5 discusses the data on salt circulation, and develops a simple model of iodine response to describe how different dosages of iodine might affect different outcomes in the population. Section 6 describes the identification strategy and presents the empirical findings. Section 7 presents three robustness checks which corroborate the main results. Section 8 provides an interpretation of the findings, and section 9 concludes.

2 Related literature

I explore the link from better health to improved economic performance by quantifying the effects of a wide-reaching public health intervention. There is an ever-growing strand of literature in Economics showing that public health programs can have sizable effects on diverse outcomes of the treated populations, so that, from a policymaking point of view, they constitute wise investments with large returns. For example, Miguel and Kremer (2001) study the effects of introducing deworming drugs in Kenyan schools on student absenteeism, showing the importance of positive externalities arising from lower infection rates, which are all too often not taken into account by conventional cost-benefit analyses. In another paper drawing from history of public health in developed countries, Bleakley (2006) examines the effects of eradicating hookworm in the American South, and also finds positive effects on school attendance and future earnings. Finally, Lucas (2010) studies the effects of two malaria eradication programmes, one in Paraguay and another in Sri Lanka, and finds evidence of increased female educational attainment and female literacy as a result of the lower prevalence of the disease. In terms of the iodization programme in Switzerland, rarely can one find such a wide-reaching and large-scale public health campaign.

I concentrate attention on the effects of irreversible mental damage resulting from iodine deficiency in utero and the first three months of life. In that respect, this paper is closely related to the ever-expanding literature on the importance of fetal and early age health inputs on subsequent economic outcomes (see Almond and Currie (2011) for an excellent overview of the literature, its contributions and remaining open questions). There is ample evidence that the economic and health environment into which one is born has an important effect in later life outcomes. One important example of this literature is Douglas Almond's paper on the long-lasting effects of the Spanish Influenza of 1918 (Almond 2006). Using U.S. Census data, Almond exploits the sharp timing and the geographic variation in the severity of the pandemic. He finds that the cohorts exposed to the virus in utero display lower education attainment rates, lower income and socioeconomic status, higher rates of physical disability and increased dependence on state transfer programs. In another paper, Case and Paxson (2008) highlight the importance of in utero and early childhood health inputs for the adult height of an individual, which in turn is associated with higher earnings. In particular, taller children perform better on cognitive ability tests, and this higher performance explains a big part of the variation in earnings later in life. Maccini and Yang (2009) show that environmental conditions, in particular weather shocks in an agricultural economy around the time of one's birth can affect education and adult socio-economic outcomes, to the extent that they affect household income and food availability for the newborn.

In another paper on the Swiss iodization campaign I examine the impact of the generalised use of iodized salt on occupational patterns (Politi 2012). I find that cohorts treated by iodized salt were more likely to select into higher-paying occupations, such as managerial and professional positions, as well as occupations with higher cognitive demands. The research on the effects of iodization on occupational outcomes complements the one on graduation rates, presented here. Taken together, the two papers show the effects of iodization on both early and later life outcomes.

In a related paper, Field et al. (2009) study the in utero effects of a recent iodine supplementation programme on educational attainment in Tanzania, and they find that it increased grade attainment for children 10-14 years old by 0.35-0.56 years. Interestingly, Field et al. (2009) find bigger effects for females, which could be due either to biological differences or differences associated with intra-household resource allocation and social responses to increased cognition of males and females. My paper provides limited support for a bigger effect of iodization on females, but this result is not robust to the stricter specifications which I employ. In addition, the programme in Tanzania reached at most 25% of the population, whereas the iodization campaign in Switzerland was wider-reaching. In 1949, which is the last cohort that I include in my sample, 79% of all consumed salt was iodized, reaching 100% of total salt sales in many cantons. Finally, because the intervention in Switzerland happened over 90 years ago, the individuals in my sample were old enough to have completed tertiary education. Therefore I can estimate the impact of iodization on upper secondary and tertiary education, which is a different educational margin than the one studied by Field et al. (2009).

3 Background on Iodine Deficiency Disorders and Salt Iodization in Switzerland

Iodine is a necessary micronutrient, found in very small quantities in the human body[3]. Most of the body's iodine is located in the thyroid gland. Iodine is essential in the synthesis of the two thyroid hormones, thyroxine (T4) and Triiodothyronine (T3). These two hormones regulate metabolism and "play a determining part in early growth and development of most organs, especially of the brain" (Delange 2001).

When the thyroid does not receive sufficient amounts of iodine it adapts by enlarging in order to maximize the use of available iodine. This enlargement is called a goiter. Goiters can occur at any point in one's lifetime, whenever the intake of iodine is not sufficient[4]. Some goiters are reversible if iodine intake increases to adequate levels, especially for young individuals[5]. Reversing goiter in adults is harder and potentially dangerous, especially when they have been subject to iodine deficiency for many years. A sudden, large intake of iodine by a chronically deficient individual might lead to thyroid cancer.

Goiter is a visible and, to some extent, reversible consequence of iodine deficiency. Apart from goiter, however, iodine deficiency in utero and the first three months of life can have irreversible consequences on cognitive development. Inadequate levels of maternal iodine intake during pregnancy result in various degrees of cognitive impairment for the foetus. Deaf-mutism is another consequence of iodine deficiency. In the worst case scenario, severe iodine deficiency causes cretinism. Cretinism is an acute condition characterized by a combination of mental retardation, stunting and physical deformation. Cretins are often deaf-mute and have goiters. In endemic areas, cretinism can affect up to 15% of the population (de Benoist

[3]The recommended daily intake of iodine is 50μg for people aged 0-6 months, 90μg for people aged 6 months-6 years, 120μg for ages 7 to 10, 150μg during adolescence and adulthood, and 200-300μg during pregnancy and lactation (World Health Organization 1996).

[4]For adults, adequate iodine intake is in the range of 100-199μg/day. There are three degrees of iodine deficiency: mild (50-99μg/day), moderate (20-49μg/day) and severe (<20μg/day) (ICCIDD, UNICEF and WHO 2001, Table 5, p.36.).

[5]By providing iodine to schoolchildren, numerous studies have shown that their goiters disappeared. See, for example, Marine and Kimball (1921) for details on their 1917 experiment in Akron, Ohio.

et al., eds 2004). Iodine deficiency in pregnancy is also linked to a higher risk of miscarriage, stillbirths, low birth weight and increased perinatal and infant mortality[1].

Bleichrodt and Born (1994) estimate that the average IQ of iodine-deficient groups is 13.5 points lower than that of non-deficient groups. This estimate is based on a meta-analysis of 21 studies of the effect of iodine deficiency on cognitive ability. These studies are observational, however, so this estimate does not correspond to experimental results. Also, since this is an estimated effect on the average, it is unclear how the entire distribution of IQ is affected. Still, given this widely cited estimate, iodine deficiency should have sizable economic effects for any afflicted population. Correcting the deficiency corresponds to a big cognitive gain.

Endemic goiter and endemic cretinism[6] are primarily explained by the geological characteristics of a location. The main store of iodine is the ocean. As ocean water evaporates, iodine reaches the soil through rainfall. Therefore, geographic areas close to the ocean provide adequate amounts of iodine because the air, the drinking water and the soil are naturally rich in iodine. On the contrary, regions subject to heavy rain or affected by glaciation during the last Ice Age may be iodine-poor due to soil erosion. It takes thousands of years for rain water to replenish the superficial layers of soil with iodine, so the iodine content of the soil and water of regions subject to ground erosion could be inadequate. For example, the Andes, the Alps, the Pyrenees, and the Himalayas are iodine-poor (Koutras et al. 1980)[7]. In Switzerland, particularly, accounts of goiter and cretinism date back to antiquity[8]. However, the link between goiter and cretinism was not put forward until much later. Goiter was often

[6]Endemic goiter and cretinism occur when their prevalence in the population exceeds 10%.

[7]Goiter might also occur as a result of the consumption of certain foods. For example, vegetables in the Cruciferae family (such as cabbage and turnip) are known to have goitrogenic properties. Geologic factors seem responsible for the goitrogenic content of both food and water in some areas. Regular and high consumption of such foods can cause the thyroid gland to enlarge. Goiters may also be caused by an excess of iodine consumption, although this is rare. Genetic predisposition also seems to play a secondary role in the appearance of goiter. Goiters caused by these factors are sporadic and do not occur regularly in a population. On the contrary, endemic goiter and endemic cretinism are the result of iodine deficiency.

[8]Writers as far back as the 1st century BC wrote about a swelling of the neck, found in people living in the Swiss Alps. For example, the architect Vitruvius wrote: "[...] the Medulli in the Alps have a kind of water, from drinking which they get a swelling of the neck" (Langer 1960, p.10-11, translated from Vitruvius, P.M., *De Architectura*, lib. VIII, 3, 20).

confounded with other diseases visible in the neck[9].

During Napoleonic Wars, the low performance of Swiss recruits for the French Army troubled Napoleon and the local authorities in today's canton of Valais. Under Napoleon's orders, a survey was conducted, according to which there were 4,000 cretins among 70,000 inhabitants (this is a very high prevalence of 5.7%)[10]. Since then, other epidemiologic studies followed, usually focusing on recruits or schoolchildren in a confined geographic area[11]. These studies revealed how widespread goiter was in Switzerland. However, the standards of goiter and cretinism classification differed from author to author, so it is impossible to make meaningful comparisons of goiter prevalence across localities. For consistency it is best to rely on information from a single source. One such source of information on goiter prevalence throughout Switzerland is Bircher's monograph, published in 1883. Bircher personally collected and published goiter data from recruits during the period 1875-1880 for all towns and villages in Switzerland, and noticed that even localities adjacent to each other could differ a lot in their goiter prevalence (Bircher 1883). I use this rich database to construct measures of iodine deficiency across localities prior to iodine supplementation.

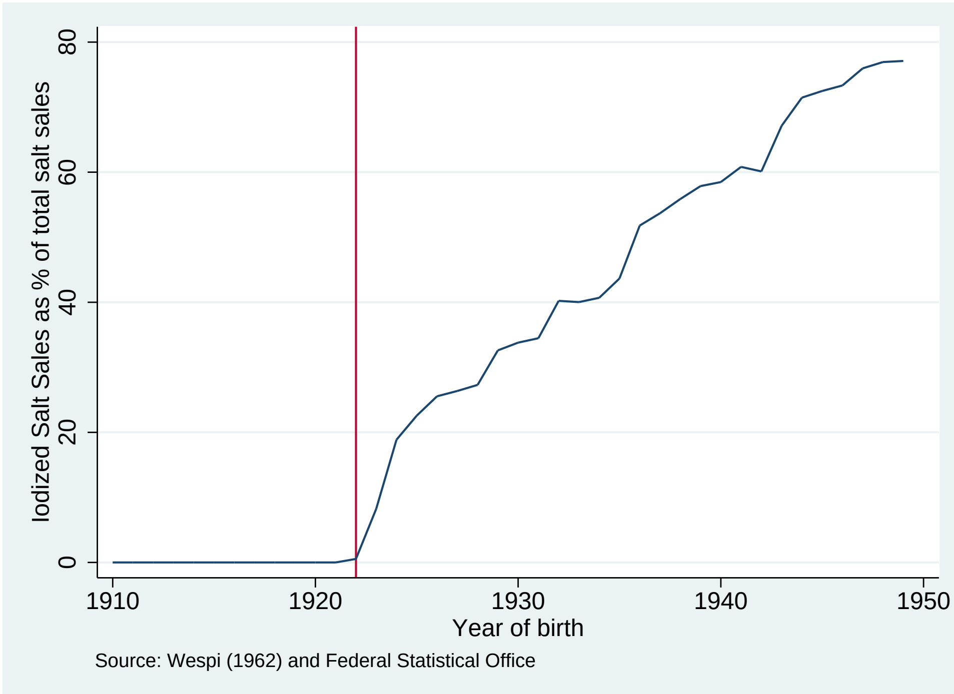
Because of the documented high prevalence of goiter and cretinism in Switzerland, the medical profession and public health authorities focused attention on their etiology and on ways to provide prophylaxis to the population. The idea that endemic goiter is due to iodine deficiency was first put forward in 1846, by Jean-Louis Prévost and A.C. Maffoni (Prévost and Maffoni 1846). A Swiss Committee for the study of goiter was established in 1907. At that time, goiter was still attributed to some agent in the drinking water, even though experiments with iodine supplementation for the treatment of goiter were already taking place in France and, later, in the USA. The first larger-scale iodine supplementation

[9] For instance, some writers attributed goiter to a lack of minerals in the water or thought that it was the result of rickets. Others came closer to the true cause, linking cretinism to distance from the sea and to air quality (Langer 1960).

[10] Taken from Bürgi et al. (1990), original reference is: Merke, F. (1971) Geschichte und Ikonographie des endemisches Kropfes und Kretinismus. Berne: H. Huber.

[11] For example, Theodor Kocher published a goiter study of schoolchildren in Bern in 1889, which revealed a total goiter prevalence ranging from 20% to 100% (Kocher 1889).

Figure 1: Iodized salt circulation in Switzerland



program took place from 1917 to 1922 in Akron, Ohio[12]. Right before his death in 1917, Kocher suggested goiter treatment with small doses of iodine (Bürgi et al. 1990).

Iodized salt started circulating in Switzerland in 1922[13]. The first canton to iodize salt was Appenzell Ausserrhoden, where iodization started in February 1922, with the initiative of a local doctor, H. Eggenberger. In June 1922 the Swiss Committee for the study of goiter recommended the addition of small amounts of iodine in salt and the additional weekly consumption of iodine tablets by schoolchildren. At the same time consumption of the "new salt" would remain voluntary and non-iodized salt would still be available (Bürgi et al. 1990). In November 1922 United Swiss Rhine Salt Works (USRSW)[14] started adding

[12]Schoolgirls from 5th grade and above were given sodium iodide regularly, in the form of syrup, under the direction of David Marine and his assistant, O.P. Kimball. When it began, this intervention was very controversial, but its undeniable success paved the way for larger-scale programs in the USA and in Europe.

[13]Almost simultaneously, fortification of salt with iodine began in the USA, where iodized salt first appeared in 1924.

[14]USRSW was "the exclusive supplier of salt to 24 of the 25 cantons" of Switzerland, the exception being the canton of Vaud (Bürgi et al. 1990, p.582).

iodine to salt (5μg KI or 3.75μg I per kg salt) and selling the new product at the same price as non-iodized salt. Even before that date, though, iodine prophylaxis had become popular, following results of small-scale iodine supplementation programmes in Switzerland and the USA.

After the recommendations of the Swiss Committee for the study of goiter, and the success of salt iodization in Appenzell Ausserrhoden, other cantons started amending their constitutions, as required, in order to allow the sale of iodized salt in their markets. Figure 1 is a graph showing the population-weighted average iodized salt sales as a percentage of total salt sales in Switzerland[15]. As is clear from Figure 1, iodized salt became popular fast. Not all cantons introduced iodized salt simultaneously, though. Figure 2 shows how iodized salt spread spatially over time in Switzerland, starting from Appenzell Ausserrhoden in 1922[16].

The reluctance of some cantons to allow the sale of iodized salt within their borders is undoubtedly linked to the controversy surrounding iodine supplementation (Bürgi et al. 1990). In particular, after doctors started prescribing iodide to their patients in order to fight goiter in the early stages of experimentation with iodine, toxic symptoms from overdosing triggered opposition to the universal use of iodine. In the USA, iodine supplementation coincided with a spike in goiter-related surgeries and deaths, which then subsided[17] (Feyrer et al. 2008).

[15] I use 1970 Census canton population data as weights.

[16] On a national scale, the iodine content of salt was raised in subsequent years, to 7.5μg in 1962 and to 15μg iodide per kg salt in 1980 (Bürgi et al. 1990).

[17] This adverse consequence of iodine supplementation was due to the existence of nodular goiters in the population. Nodular goiters were caused by chronic iodine deficiency. Nodular goiters may become toxic following a sudden increase in iodine intake after a long period of deprivation. This side-effect of iodization is known as iodine-induced hyperthyroidism).

Figure 2: The circulation of iodized salt over time in Switzerland

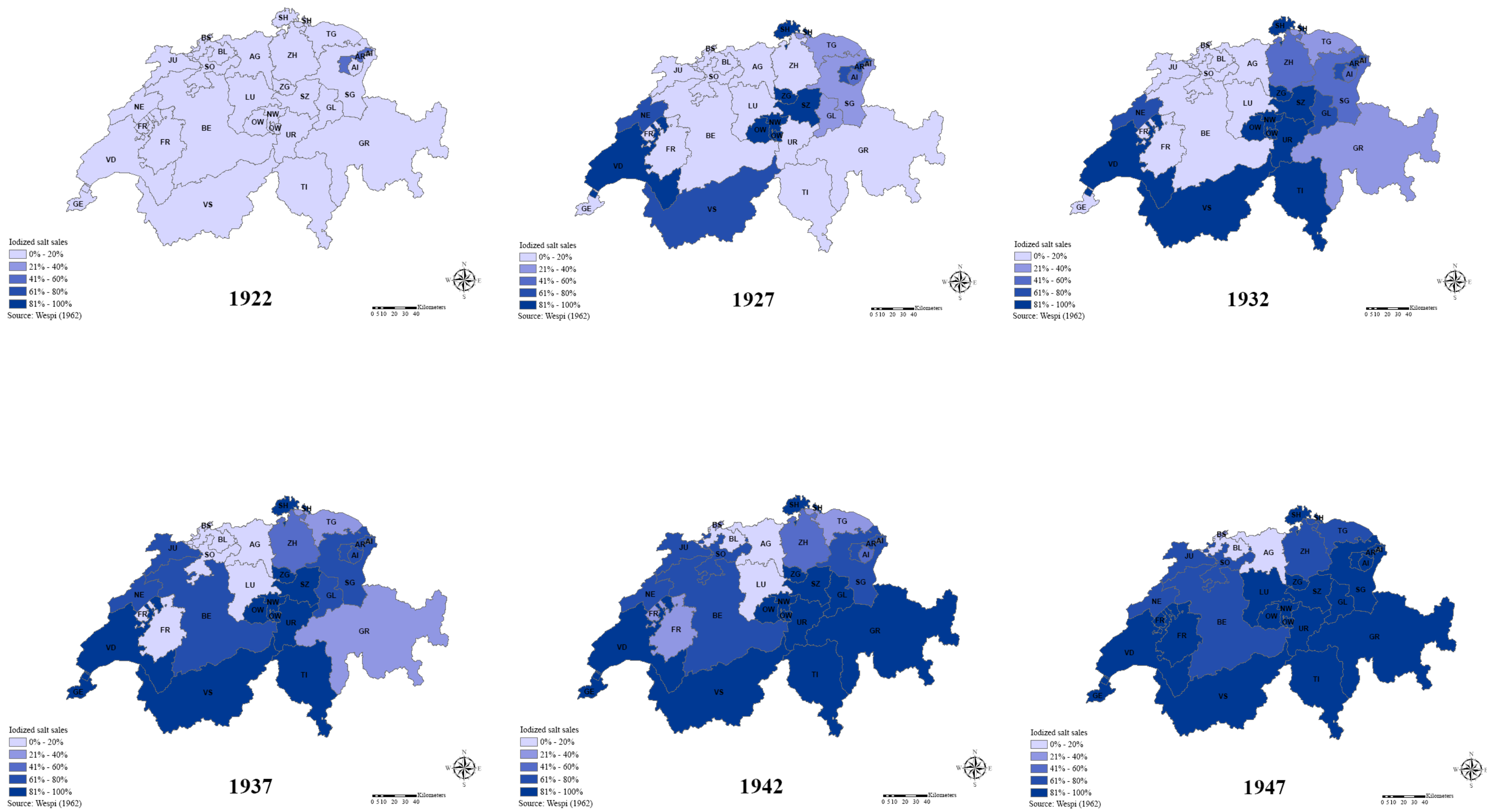
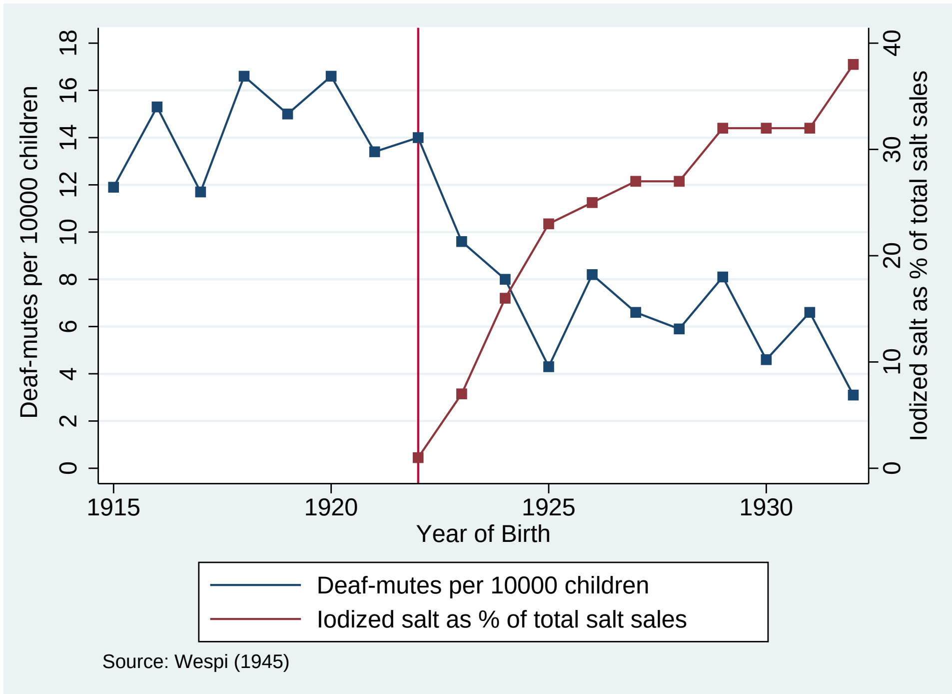


Figure 3: Deaf-mutism and Iodized Salt circulation



As a result of salt iodization "no new endemic cretins born after 1930 have been identified" (Bürgi et al. 1990, p.577). In Appenzell-Ausserrhoden the prevalence of goiter in newborns fell from 20% to 6.4% within the first year after iodization. The prevalence dropped further when, in later years, the iodine content of salt was raised. The beneficial effects on iodization were also seen in the increased height of 6-year-olds entering school, as well as young recruits. In the city of Lausanne, 23.7% of young recruits had large goiters in 1924/1925, but the figure had dropped to 0.2% by 1983-1987 (Bürgi et al. 1990).

The success of the iodization campaign is reflected very clearly in the drop in the number of deaf-mutes among children born after 1922. Wespi (1945)[18] collected a near-complete count of deaf-mute schoolchildren who attended specialized institutions during the period 1922-1942, along with data on their year of birth and their parents' residence at the time (assumed to be the children's canton of birth). Since most admissions occur at the ages 7-10, Wespi limited his analysis to children born in the period 1915-1932. Figure 3 is a plot of

[18] I am grateful to Prof. Dr. Hans Bürgi for kindly sharing this source with me.

the prevalence of deaf-mutism in each cohort born in 1915-1932, using Wespi's data, against the country-wide circulation of iodized salt. It is clear from this figure that the prevalence of deaf-mutism among schoolchildren decreased rapidly for those born after 1922, which coincides with the introduction of iodized salt.

Finally, a very important fact to keep in mind is that, even though iodine supplementation aimed to protect against goiters, the crucial role of iodine in mental development was not understood until the final decades of the 20th century. When large-scale interventions of iodine supplementation began in Switzerland and the USA in the 1920s, the objective was goiter eradication. It was not known at the time that the fight against goiters was also a fight against mental retardation.

4 Data: The 1970 Swiss Census and Bircher's monograph

The main source of data is the complete 1970 Swiss Census (Federal Statistical Office 1970). Switzerland is a federation made up of 26 cantons, subdivided in 184 districts and 2896 municipalities. The 1970 Census contains detailed information on an individual's year and municipality of birth, as well as other geographic, demographic, work and migration variables. In particular, I know the municipality and year of birth for each individual. Having detailed information on the place of birth is important, since the location of the mother during her pregnancy will determine the extent to which she got adequate amounts of iodine in her diet[19].

I limit the sample to all Swiss-born individuals interviewed in the 1970 Census, who were born before 1950. I estimate the effects of iodization both on all cohorts but also on

[19]Unfortunately, the Swiss Census asks no income questions. Swiss income data can be found in the Swiss Labor Survey or the Swiss Household Panel, but these datasets cannot be used here, because the former does not include place of birth as a question, while the latter is too recent (the first wave of interviews took place in 1999).

Table 1: Summary Statistics: graduation rates

	Whole sample		
	Born before 1922	Born after 1922	Total
Number of observations	1,503,277	1,583,010	3,086,287
Obligatory education	99.74%	99.77%	99.75%
Secondary education	47.00%	61.86%	54.62%
Tertiary education	9.03%	17.02%	13.13%
	Males		
	Born before 1922	Born after 1922	Total
Number of observations	706,047	797,210	1,503,257
Obligatory education	99.78%	99.78%	99.78%
Secondary education	62.85%	74.20%	68.87%
Tertiary education	11.96%	19.67%	16.05%
	Females		
	Born before 1922	Born after 1922	Total
Number of observations	797,230	785,800	1,583,030
Obligatory education	99.70%	99.76%	99.73%
Secondary education	32.96%	49.33%	41.09%
Tertiary education	6.43%	14.33%	10.35%

Source: Federal Statistical Office (1970).

a smaller age range, which is unlikely to be affected by selection into longevity[20]. I use two education outcomes; indicator variables for completing upper-level secondary education, and completing tertiary education. Obligatory education consists of 6 years of primary education and 3 years of lower-secondary education, and it is universal. Upper-level secondary education[21] ranges between an extra 3 to 5 years after having completed 9 years of obligatory education, depending on whether someone is preparing for university-level education or just completing a professional apprenticeship. Tertiary-level education corresponds to a minimum of 13 years of schooling, and includes studies in colleges, universities, but also upper-level vocational schools.

[20] If selection into longevity is correlated with higher levels of education, my estimates will be biased downwards.

[21] I will henceforth refer to upper-level secondary education simply as "secondary education", but it is understood that lower-level secondary education is part of obligatory schooling in Switzerland.

Table 2: Summary Statistics: (continued): graduation rates by region

	Whole sample			
	Born before 1922		Born after 1922	
	High goiter	Other regions	High goiter	Other regions
Number of observations	373,156	1,130,121	402,148	1,180,862
obligatory education	99.72%	99.74%	99.75%	99.77%
secondary education	44.89%	47.69%	60.17%	62.43%
tertiary education	8.64%	9.16%	17.14%	16.98%
	Males			
	Born before 1922		Born after 1922	
	High goiter	Other regions	High goiter	Other regions
Number of observations	176,895	529,152	202,422	594,788
obligatory education	99.77%	99.78%	99.75%	99.78%
secondary education	60.25%	63.72%	72.06%	74.93%
tertiary education	11.20%	12.22%	19.30%	19.80%
	Females			
	Born before 1922		Born after 1922	
	High goiter	Other regions	High goiter	Other regions
Number of observations	196,261	600,969	199,726	586,074
obligatory education	99.68%	99.71%	99.75%	99.76%
secondary education	31.05%	33.58%	48.12%	49.74%
tertiary education	6.34%	6.47%	14.95%	14.11%

Notes: High-goiter regions are defined as those districts belonging to the top 25% of the population-weighted goiter distribution. Source: Federal Statistical Office (1970).

Tables 1 and 2 provide summary statistics for the whole sample, as well as separately by gender. Obligatory education was universal; more than 99% of the population completed at least 9 years of schooling. Secondary education was less pervasive, but still rather common, as roughly one in two got to this level of schooling. When it comes to tertiary education, however, even if we look at the younger cohorts, those born after iodization, we see that only one in five men attended a higher education establishment. The rates for women are consistently lower, even though the percentage of women advancing to secondary and tertiary levels of education grew by more than the corresponding percentages for men over my period of examination.

I match Census data with district-level data on goiter rates, as a measure of underlying iodine deficiency in Switzerland prior to salt iodization. These data come from a monograph written by H. Bircher and published in 1883 (Bircher 1883). Bircher collected data on goiter in Swiss recruits during the period 1875-1880, for every municipality (village) in every district of every canton in Switzerland. For each locality, he listed the total number of recruits with goiter that enlisted in the 6-year period, from 1875 to 1880. I use Bircher's data on goiter prevalence among male recruits as a proxy for the underlying geographic distribution of iodine deficiency.

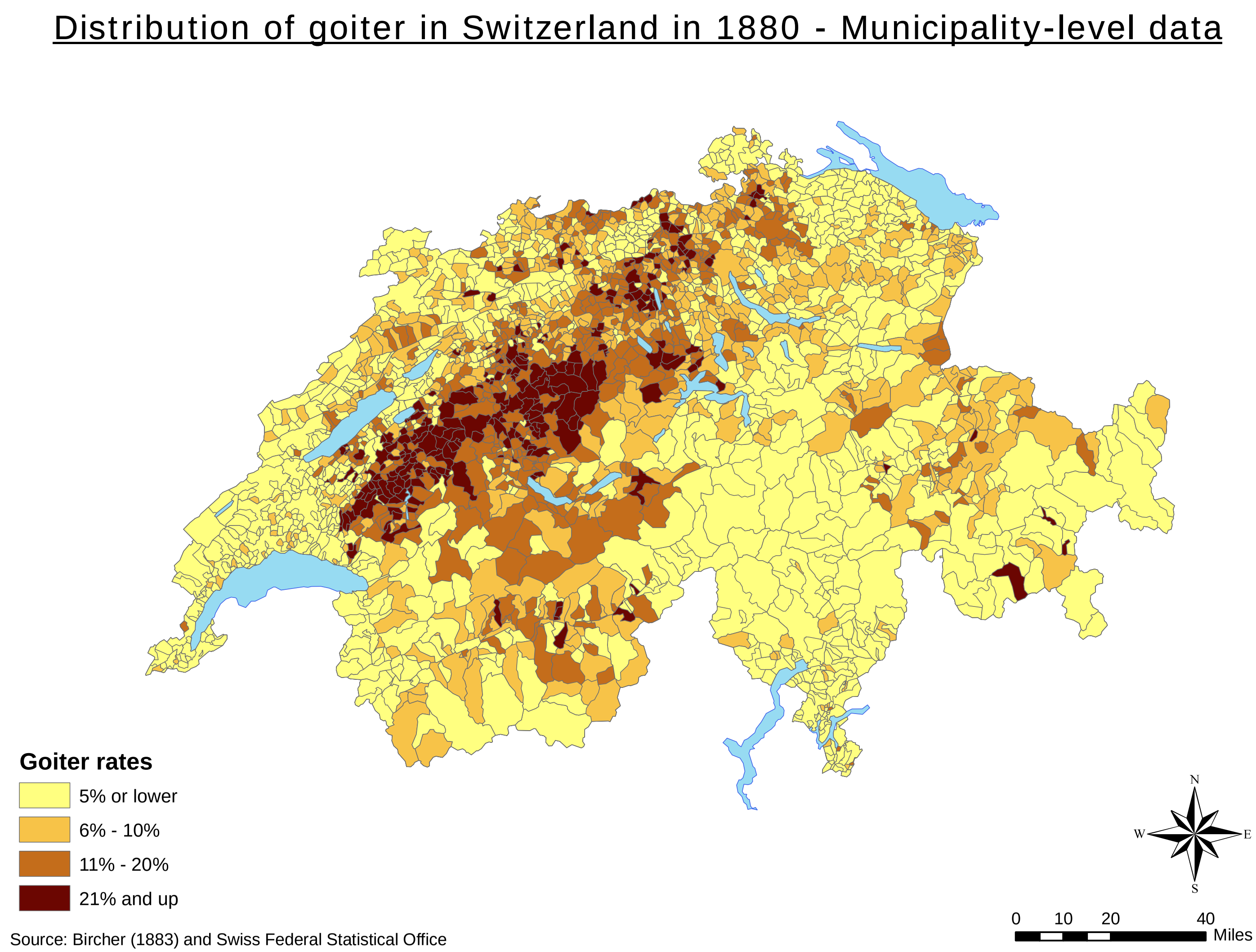
Bircher's data confirm the link between iodine deficiency and goiter prevalence in Switzerland. For example, the canton of Ticino, in the southernmost part of Switzerland, ranked the lowest in goiter prevalence. This is to be expected, given Ticino's proximity to the Mediterranean Sea. Another canton with unusually low goiter prevalence is Vaud. Historically, Vaud had an exclusive salt mine, which was rich in iodine (Bürgi et al. 1990, p.581). Table A.1 in the Appendix lists population-weighted goiter rates at the canton level.

Bircher's raw data provide information at the municipality level. However, to deal with mergers and divisions of municipalities since the publication of Bircher's study, I aggregate the information one administrative level up and compute goiter rates at the district level[22]. Figure 4 is a map of Switzerland, showing the geographic variation in goiter, as depicted by Bircher's data at the municipality level. It is evident from the map that regions around the Swiss Alps were the ones that were most affected by goiter, whereas regions close to the Mediterranean were not deficient in iodine[23].

[22]See section A.1 in the Appendix for a description of Bircher's method of computing goiter rates in a locality from raw data on recruits, which I follow, with an example.

[23]When constructing the map some municipalities had missing goiter data. In most cases this was due to the fact that municipalities have merged or subdivided since the data on goiter was collected. For municipalities which merged I recalculated the goiter prevalence of the new municipality based on the goiter data from the old municipalities which merged together. For new municipalities which arose when an old municipality was separated into smaller ones I assigned the old municipality's goiter number to all the resulting new municipalities. After this exercise there were still some municipalities with no data. To those I assigned the average goiter prevalence for the district in which they belong. This was only done for illustration purposes in the map of Figure 4; in the econometric analysis all goiter data are aggregated to the district level.

Figure 4: Bircher's Data on goiter in recruits



Bircher's data on goiter prevalence are old and prone to measurement error. The data were collected in 1875-1880, so that the goiter distribution in Switzerland right before iodization might have looked quite different. Also, to the extent that cretins and youths with extreme cases of goiter did not enlist in the army in the first place, the data on goiter might be understating the degree of iodine deficiency for some badly-afflicted regions. They might therefore give a distorted picture of the relative position of two localities with respect to their pre-existing variation in goiter rates.

Although measurement error might be an issue, Bircher's data correlate well with estimates of the iodine content of soil and water across localities, whenever such measures have been available (Bürgi et al. 1990). In that respect, Bircher's data paints an accurate picture of the variation in underlying iodine deficiency across Swiss localities, even if the goiter rate for each district is mismeasured. The most complete collection of data on the iodine content of rocks, soil, water, air, and produce in Switzerland is von Fellenberg's study (Von Fellenberg 1926). I cannot use the data from that study as an alternative to Bircher's data in my analysis, because, although measurements are taken from locations all over Switzerland, the type of rocks or plants that are sampled in each location are different, which makes comparisons impossible[24].

Von Fellenberg does, however, collect information on the iodine content of drinking water across six municipalities. I use those data in a robustness check of my results in section 7.1. Von Fellenberg's data on the iodine content of drinking water, together with the corresponding goiter data from Bircher (at the municipality and also the district level) are shown on Table 3, listed from high to low iodine content. Table 3 displays the strong correlation between von Fellenberg's measurements, taken right before iodized salt started circulating, and goiter rates, as recorded by Bircher many years earlier.

Bircher's goiter data also correlate well with measures of deaf-mutism prior to iodization. Table 4 shows results from a regression of average canton-level data on deaf-mutism for

[24]What is considered high iodine content for one type of rock, for example, might not be the same as for another type.

Table 3: Iodine content of water and goiter rates in select localities in Switzerland

Municipality (District, Canton)	Iodine content of water (μg I per litre)	Goiter in municipality	Goiter in district
Effingen (Brugg, Aargau)	2.54	0	5.52
La Chaux-de-Fonds (La Chaux-de-Fonds, Neuchâtel)	1.40	3.53	3.41
Kaisten (Laufenburg, Aargau)	0.69	13.97	7.44
Bern (Bern, Bern)	0.17	12.02	15.01
Hunzenschwil (Lenzburg, Aargau)	0.15	17.52	17.46
Signau (Signau, Bern)	0.067	17.29	24.40

Sources: Von Fellenberg (1926) and Bircher (1883).

cohorts born 1915-1922 (taken from Wespi (1945)) on the logarithm of canton-level goiter (taken from from Bircher (1883)), as well as the same regression using deaf-mutism data for cohorts born 1923-1932, after iodization had begun[25]. Figure 5 is a graphical representation of these results. Rates of deaf-mutism (per 10,000 people) for cohorts born prior to iodization (1915-1922) correlate positively with rates of goiter in recruits, even though the goiter data were collected many decades earlier[26]. On the contrary, deaf-mutism rates for cohorts born after iodization (1923-1932) are not significantly correlated with goiter rates.

Given the high correlation of Bircher's data with other measures of iodine deficiency, it is unlikely that measurement error is a serious issue. Even so, in order to minimize the effects of any measurement error in Bircher's data, rather than using the goiter rate directly, I break the Census sample down in broad categories according to a district's goiter rate, and check that my results are not sensitive to the classification. Also, in some specifications I only use

[25]There are only 25 cantons in these regressions, because the canton of Jura had not yet been formed.

[26]Wespi (1945) speculates that this positive relationship might even be understated, because in highly-deficient areas admission into special institutions may have been incomplete. This could have been the case if in these highly-affected areas endemic deaf-mutes also had other medical or learning impediments, preventing them from attending a school.

Table 4: Correlation of canton-level goiter in 1880 and deaf-mutism before and after iodization

	(1) Deaf-mutes per 10,000 born 1915-1922	(2) Deaf-mutes per 10,000 born 1923-1932
Log goiter in canton	3.849*	0.689
	[1.876]	[1.114]
Constant	7.174*	5.149**
	[3.793]	[2.252]
Observations	25	25
R-squared	0.155	0.016

Notes: Standard errors in brackets. *** p<0.01, ** p<0.05, * p<0.1 Observations are weighted by total canton births in 1922. Source: Wespi (1945) and Bircher (1883).

data in the top and bottom tails of the goiter distribution, so that a district's exact position in the distribution of goiter rates doesn't matter very much.

Figure 6 is a population-weighted histogram of goiter prevalence in 1880, as it appears in my sample. Each observation from the 1970 Census is matched to an observation from Bircher's data, according to one's district of birth. The red line in Figure 6 marks the 75th percentile cutoff in my sample, which corresponds to a goiter prevalence of 11.7%. For my analysis, I consider any district with a goiter prevalence equal to 11.7% or higher to be a "high-goiter district". Outcomes are similar when I modify this cutoff level to reflect the top 20% or 30% of the population-weighed goiter distribution.

Given that iodized salt was first introduced in 1922 and was followed by an extensive informational campaign led by the Swiss Committee for the study of goiter, I look for preliminary evidence of the impact of iodization in a Differences in Differences framework. In particular, I check whether individuals born in high-goiter districts after 1922 had a higher probability of graduating from secondary and tertiary education compared to the rest of the population. I expect high-goiter districts to be the ones benefiting from the introduction of iodized salt, since underlying iodine deficiency was the most severe in those regions. On the

Figure 5: Deaf-mutism and 1883 Goiter Prevalence before and after iodization

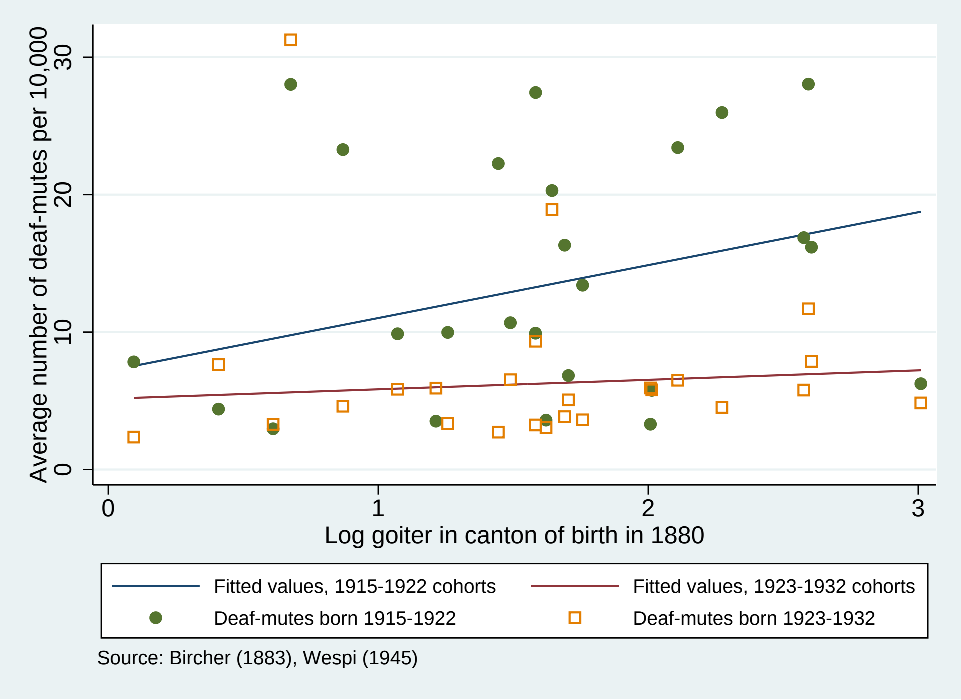
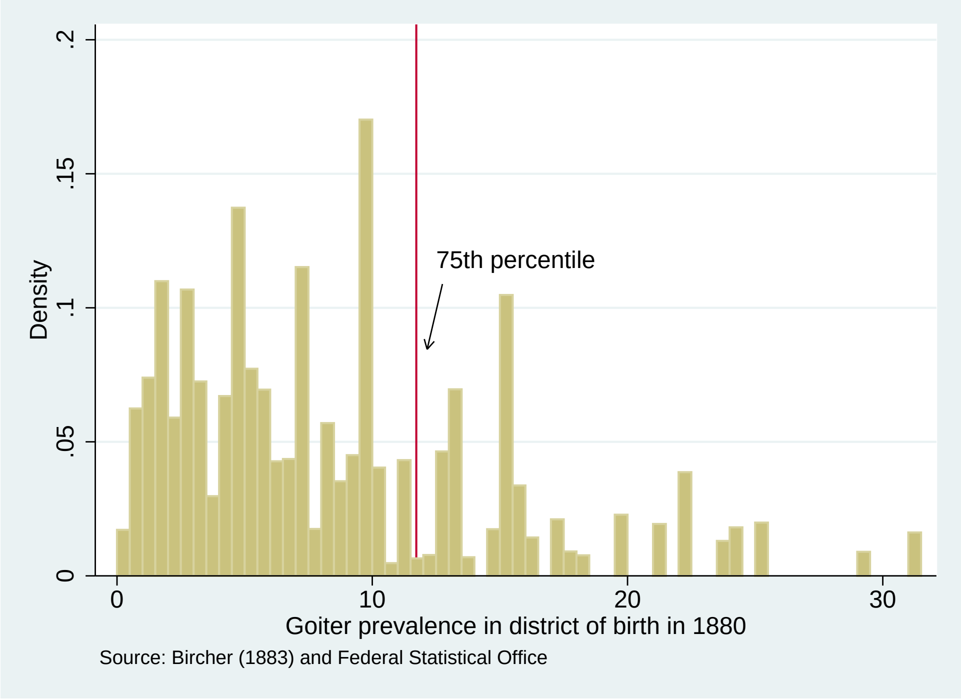


Figure 6: Histogram of goiter prevalence in Switzerland



contrary, people born in low-goiter districts were less likely to benefit from the treatment, since their iodine intake in utero was already higher.

The variable of interest is always the interaction term between two indicator variables: being born in a high-goiter district and being born after 1922. First, I run a "raw", regression-unadjusted Differences in Differences regression. Then I introduce district and cohort of birth fixed effects. Finally, in the most demanding specification, I also introduce a district-specific linear trend. The initial, "raw" specification attributes any difference in graduation rates between high-goiter districts and the rest of the country for cohorts born after 1922 to iodization. District of birth fixed effects control for any omitted district-specific, time-invariant characteristics, which might affect an individual's education. Cohort fixed effects control for any unobservable, country-wide characteristics that are common to each cohort in my sample. Finally, a district-specific linear time trend removes the effect of factors which change gradually over time at the district level, which might affect the educational outcomes of cohorts born in a given district. Such factors include, for example, better access to educational opportunities over time, improving general health conditions, and ever-lowering transportation and communication costs within a district. I first look for preliminary evidence of the impact of iodization for the sample as a whole, and then separately for each gender. I also trim the sample to only include cohorts born 1910-1935.

More specifically, for my more demanding specification, I run the following regression for an individual i born in district d in year y:

$outcome_{idy} = \alpha + \beta \cdot$ *1 (Born in high-goiter district) X 1 (Born after 1922)*

+ *District of birth Fixed Effects*

+ *District of birth linear time trend*

+ *Cohort of Birth Fixed Effects* $+\epsilon_{idy}$

The outcomes which I look at are graduation from secondary and tertiary education. The coefficient of interest is β. The coefficient β will capture the departure of educational outcomes for those born in high-goiter districts after 1922 from the rest of the population.

Disturbance terms are clustered at the district-cohort level. Table 5 shows Differences in Differences estimates for secondary education, and table 6 shows the relevant results for tertiary education. Columns (1) to (3) are estimates for all cohorts, and columns (4) to (6) present results for the trimmed sample of those born in 1910-1935. The top panel shows results for the sample as a whole, the middle panel shows results for males, and the bottom panel shows results for females.

Tables 5 and 6 show that, once we include district and cohort fixed effects, there was a departure from trend for high-goiter districts after 1922. Whether we look at all cohorts, or only at the cohorts born closer to 1922, the probability of graduating from secondary education in the most demanding specification (the one including district-specific trends) increases by between 1 and 1.6 percentage points, whereas the effect is smaller for the probability of graduating from tertiary education, estimated at just above 0.4 percentage points. The middle and bottom panels show that these effects are driven by females.

For women born after 1922 in high-goiter districts, the probability of graduating from secondary-level education increases by 2.75 percentage points. This is a big change; the percentage of women graduating from secondary education increased by 11.8 percentage points for those born after 1922 in high-goiter districts compared to earlier cohorts (see Table 2). The coefficient on secondary education for women indicates that almost one-sixth or 16% of this change was due to iodization. The change in probability for tertiary education is only 0.64 percentage points. Given that tertiary education graduation rates for women born in high-goiter districts increased by 8.61 percentage points over this period, the contribution of iodization corresponds to roughly 7% of the total change in graduation rates. When we limit the sample to women born in 1910-1935, the effect on secondary education falls by more than half. This drop in the coefficient is consistent with the evidence on circulation of iodized salt in high-goiter districts, which had not reached its peak by 1935. Therefore we expect cohorts born after 1935 to be relatively more affected by iodization than only those cohorts born in 1922-1935. I use data on iodized salt circulation in my main results, as they

Table 5: Secondary education: Differences in Differences estimates

	secondary education (1)	secondary education (2)	secondary education (3)	secondary education (4)	secondary education (5)	secondary education (6)
High goiter X Born after 1922	0.537 [1.09]	0.687*** [0.223]	1.59*** [0.352]	0.936 [1.61]	1.14*** [0.229]	1.05*** [0.387]
High goiter	-2.80*** [0.792]	-	-	-3.48*** [1.17]	-	-
Born after 1922	14.7*** [0.616]	-	-	4.39*** [0.919]	-	-
Cohort FE	NO	YES	YES	NO	YES	YES
District FE	NO	YES	YES	NO	YES	YES
District Trends	NO	NO	YES	NO	NO	YES
Observations	3086287	3086287	3086287	1435764	1435764	1435764
R^2	0.023	0.090	0.092	0.003	0.072	0.073
Males only						
	(1)	(2)	(3)	(4)	(5)	(6)
High goiter X Born after 1922	0.593 [0.970]	0.632** [0.256]	0.273 [0.371]	0.178 [1.42]	0.346 [0.274]	0.506 [0.492]
High goiter	-3.47*** [0.741]	-	-	-3.39*** [1.04]	-	-
Born after 1922	11.2*** [0.511]	-	-	3.65*** [0.747]	-	-
Cohort FE	NO	YES	YES	NO	YES	YES
District FE	NO	YES	YES	NO	YES	YES
District Trends	NO	NO	YES	NO	NO	YES
Observations	1503257	1503257	1503257	721813	721813	721813
R^2	0.016	0.082	0.086	0.003	0.071	0.072
Females only						
	(1)	(2)	(3)	(4)	(5)	(6)
High goiter X Born after 1922	0.906 [1.25]	1.05*** [0.277]	2.75*** [0.475]	1.81 [1.88]	2.04*** [0.305]	1.29** [0.529]
High goiter	-2.53*** [0.845]	-	-	-3.71*** [1.36]	-	-
Born after 1922	16.2*** [0.740]	-	-	4.71*** [1.14]	-	-
Cohort FE	NO	YES	YES	NO	YES	YES
District FE	NO	YES	YES	NO	YES	YES
District Trends	NO	NO	YES	NO	NO	YES
Observations	1583030	1583030	1583030	713951	713951	713951
R^2	0.028	0.112	0.114	0.003	0.094	0.095

Notes: Coefficients correspond to changes in percentage points. Robust standard errors in brackets, clustered at the district-cohort level. High-goiter is an indicator variable for a district of birth within the top 25% of the population-weighted goiter distribution. *** p<0.01, ** p<0.05, * p<0.1
Source: Federal Statistical Office (1970) and Bircher (1883).

Table 6: Tertiary education: Differences in Differences estimates

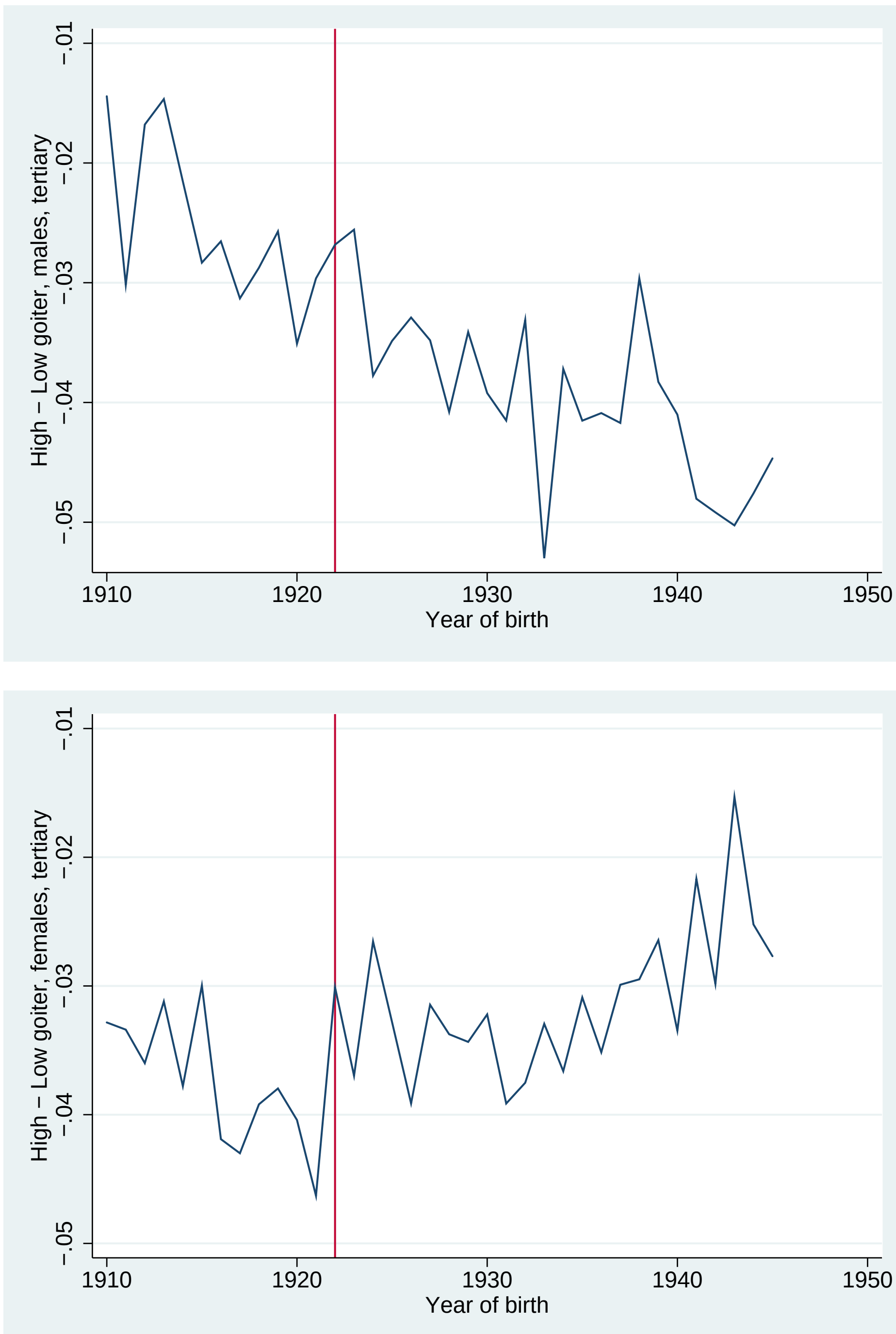
	tertiary education (1)	tertiary education (2)	tertiary education (3)	tertiary education (4)	tertiary education (5)	tertiary education (6)
High goiter X	0.683*	0.706***	0.404**	0.385	0.418***	0.474*
Born after 1922	[0.377]	[0.119]	[0.196]	[0.490]	[0.139]	[0.260]
High goiter	-0.519**	-	-	-0.706**	-	-
	[0.231]			[0.337]		
Born after 1922	7.82***	-	-	4.08***	-	-
	[0.223]			[0.304]		
Cohort FE	NO	YES	YES	NO	YES	YES
District FE	NO	YES	YES	NO	YES	YES
District Trends	NO	NO	YES	NO	NO	YES
Observations	3086287	3086287	3086287	1435764	1435764	1435764
R^2	0.014	0.030	0.030	0.004	0.018	0.019
Males only						
	(1)	(2)	(3)	(4)	(5)	(6)
High goiter X	0.529	0.534***	0.0992	0.123	0.195	0.162
Born after 1922	[0.464]	[0.171]	[0.295]	[0.595]	[0.202]	[0.389]
High goiter	-1.02***	-	-	-0.876**	-	-
	[0.286]			[0.410]		
Born after 1922	7.58***	-	-	5.11***	-	-
	[0.273]			[0.351]		
Cohort FE	NO	YES	YES	NO	YES	YES
District FE	NO	YES	YES	NO	YES	YES
District Trends	NO	NO	YES	NO	NO	YES
Observations	1503257	1503257	1503257	721813	721813	721813
R^2	0.011	0.031	0.032	0.005	0.022	0.022
Females only						
	(1)	(2)	(3)	(4)	(5)	(6)
High goiter X	0.963**	0.999***	0.640***	0.676	0.672***	0.708**
Born after 1922	[0.380]	[0.149]	[0.232]	[0.429]	[0.169]	[0.307]
High goiter	-0.128	-	-	-0.561*	-	-
	[0.192]			[0.291]		
Born after 1922	7.65***	-	-	2.94***	-	-
	[0.210]			[0.283]		
Cohort FE	NO	YES	YES	NO	YES	YES
District FE	NO	YES	YES	NO	YES	YES
District Trends	NO	NO	YES	NO	NO	YES
Observations	1583030	1583030	1583030	713951	713951	713951
R^2	0.017	0.034	0.035	0.003	0.016	0.017

Notes: Coefficients correspond to changes in percentage points. Robust standard errors in brackets, clustered at the district-cohort level. High-goiter is an indicator variable for a district of birth within the top 25% of the population-weighted goiter distribution. *** p<0.01, ** p<0.05, * p<0.1
Source: Federal Statistical Office (1970) and Bircher (1883).

Figure 7: Secondary education, males and females, difference between high-and low goiter districts

source: *Bircher (1883) and 1970 Swiss Census*

Figure 8: Tertiary education, males and females, difference between high-and low goiter districts



source: *Bircher (1883) and 1970 Swiss Census* are a more detailed proxy for iodine intake for each locality.

Figures 7 and 8 are graphical representations of the preliminary evidence of Tables 5 and 9. They show the regression-adjusted difference in cohort-specific coefficients between high- and non-high-goiter districts for secondary (Figure 7) and tertiary education (Figure 8), by gender. They show how the probability of graduating from secondary and tertiary education changed for each birth cohort, after controlling for district fixed effects and a district-specific trend. In the case of secondary education, for both males and females, there is a clear departure from trend starting around 1922, which coincides with the launch of the iodization campaign, and which continues as iodized salt spread around the country. For tertiary education, males do not seem affected, but for females there is, again, a change in the trend right around 1922.

5 Iodized salt sales and iodine response function

The campaign for iodine supplementation began in 1922, and, as reflected by the decrease in deaf-mutism rates described in section 3, it had strong and immediate effects. Iodized salt started circulating in 1922, and the Swiss Committee for the study of goiter recommended iodine supplementation through iodized salt or iodine tablets. The graphs and Differences in Differences estimates in section 4 also show that graduation outcomes in high-goiter regions diverged from the rest of the country for cohorts born after 1922.

I use canton-level annual panel data on iodized salt circulation as a more disaggregated measure of iodine uptake after 1922. These data, shown in Table A.2 in the Appendix, come from a paper published in 1962 by H. J. Wespi[27], and consist of annual, canton-level information on iodized salt sales as a percentage of total salt sales (Wespi 1962). The data shown on Table A.2 cover the period 1922-1949, since in my analysis I only use cohorts born before 1950.

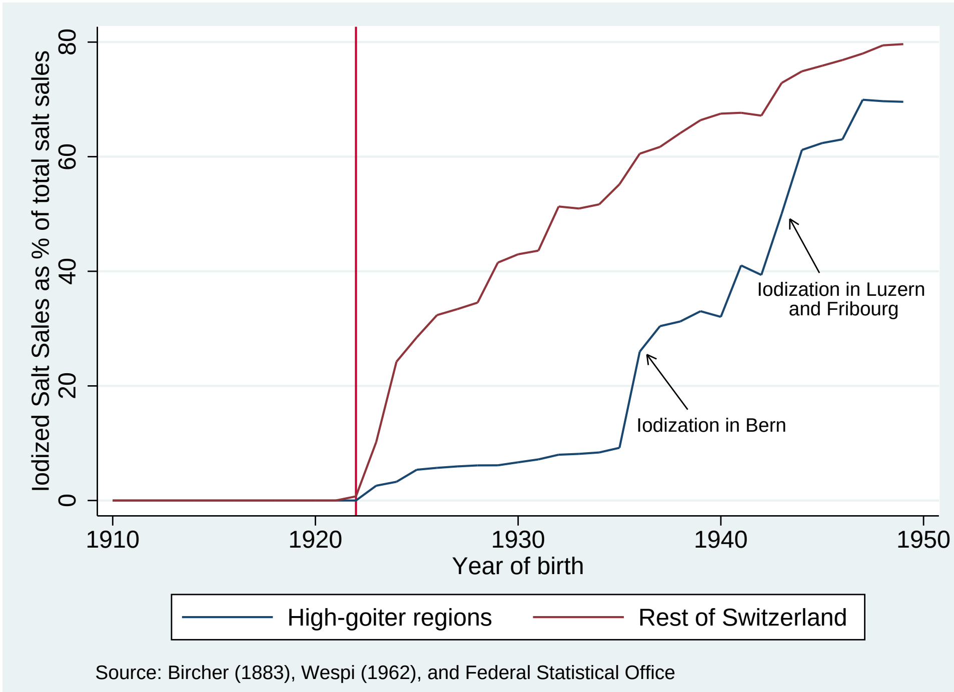
[27] M.D. and Chief Doctor of Women's Clinic in Aarau. Incidentally, H.J. Wespi was the son-in-law of H. Eggenberger, the doctor who first introduced iodized salt in Appenzell-Ausserrhoden in 1922. I am grateful to Prof. Dr. Hans Bürgi for providing me with H. J. Wespi's paper, which contained these data.

The data on salt circulation show how widespread the use of the "new salt" was at each point in time. For the country as a whole, the transition to iodized salt was gradual. For most cantons, however, there is a small window of time marked by a sharp increase in iodized salt consumption, and iodized salt makes up the majority of salt sales thereafter. I exploit these "jumps" in iodized salt circulation in the main empirical analysis of section 6. The data in Table A.2 also indicate that the timing of adoption of iodized salt differed across cantons; some cantons, such as Nidwalden and Schaffhausen, iodized early, whereas others, such as Aargau, Basel-Stadt and Basel-Land, were much slower in their adoption. Each canton had to amend its constitution to allow the sale of iodized salt within its borders (Bürgi et al. 1990), and this amendment did not happen everywhere at the same time.

The adoption of iodized salt was not without controversy at the time (Bürgi et al. 1990), and this can explain the difference in the timing of iodization across cantons. Iodized salt and iodine supplementation in general were regarded with some suspicion in the initial stages of their introduction, because they were linked to a spike in thyroid-related deaths. Indeed, a sudden, uncontrolled increase in iodine intake in individuals who have been chronically exposed to iodine deficiency can cause the thyroid gland to produce excessive amounts of thyroid hormone, leading to thyrotoxicosis, which might be fatal. Feyrer et al. (2008) have documented a significant spike of thyroid-related deaths in the USA following the introduction of iodized salt in 1924. These deaths, as expected, were concentrated on older cohorts, who were chronically iodine deficient.

The reluctance to adopt iodized salt due to fears of overdosing is expected to be bigger in cantons where goiter was more prevalent. Indeed, this is manifested in the data on iodized salt circulation. High-goiter cantons introduced iodized salt later than the rest of the country. Figure 9 shows population-weighted yearly averages of iodized salt sales, separately for high-goiter districts and the rest of the country, and confirms that high-goiter districts were located to a large extent in cantons which iodized relatively late. In Figure 9 there is one jump in salt circulation in high-goiter districts around 1936, and another one after 1942.

Figure 9: Iodized salt circulation in high-goiter districts

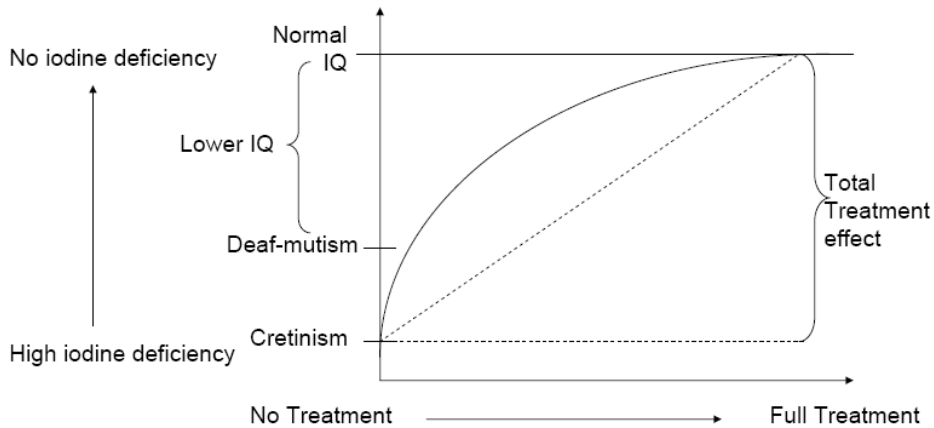


The first jump is driven by the adoption of iodized salt in the canton of Bern, which was populous and heavily afflicted by goiter, and where iodized salt sales rose from 11% in 1935 to 54% of total salt sales in 1936. Similarly, the second jump in Figure 9 corresponds to the adoption of iodized salt in Luzern and Fribourg.

The fact that iodization had immediate effects on deaf-mutism seems at odds with the fact the most deficient areas did not adopt iodized salt promptly after its introduction. Bürgi et al. (1990) note that, even before iodized salt circulated widely, iodine supplements were available, so that cohorts born after 1922 were partially treated, even if iodized salt circulation around their birth was low. High-goiter cantons were, therefore, exposed to an initial, informational shock in 1922, when the Swiss Committee for the study of Goiter issued recommendations, and iodine tablets were available over the counter. Complete, universal treatment came later, when iodized salt was introduced in these areas[28].

[28]It is possible that, within a canton, selection into treatment during the first phase of iodization was non-random. For example, access to information about the benefits of iodine supplementation for pregnant women may have been correlated with one's socioeconomic status, so that districts where a bigger proportion

Figure 10: Iodine response function



A theoretical model of iodine response, where the outcomes of treatment are non-linear, would reconcile the early drop in deaf-mutism with the later adoption of iodized salt. In particular, it might be easier to eradicate acute conditions such as cretinism and deaf-mutism with low levels of iodine supplementation, whereas more subtle outcomes related to cognitive ability, such as school graduation rates, might require a more complete and universal degree of treatment. In the medical literature, to the best of my knowledge, there is no discussion of how varying doses of iodine during pregnancy affect outcomes differently.

Such a model is graphically depicted in Figure 10. The vertical axis corresponds to the level of iodine deficiency in a locality, and the horizontal axis to the degree of iodine treatment. Non-deficient areas are located on the upper right part of the graph, and increased iodine availability will not increase average IQ in their population. A highly deficient area with endemic goiter and cretinism, on the other hand, would be on the lower left part, and

of the population was well-informed had a faster uptake of iodine supplements. To the extent that these cross-district population differences are permanent, their impact on graduation rates is absorbed by district fixed effects. Non-random selection into treatment is not a concern in later stages, when iodized salt was widely used. At this point it is useful to repeat that the cognitive impact of iodine supplementation was not known, so it is not likely that individuals selected into iodine treatment due to their taste for higher levels of education.

would benefit from increased iodine intake. As iodine supplementation becomes widespread, the high-goiter area will become less and less deficient, and once treatment is complete, it will reach the upper right part of the graph. The adjustment, though, doesn't have to be linear in terms of the impact of iodization on cognitive outcomes. According to this model, it will be relatively easy to cure cretinism and deaf-mutism with low doses of iodine, but it will be harder and it will take higher levels of treatment to restore the population's cognitive ability to normal levels. Education levels will be mostly affected once treatment brings an area to the flatter part of the curve.

6 Results: using iodized salt sales to identify the effect of iodization

Given that canton-level data on the circulation of iodized salt give a more disaggregated picture of iodine treatment at a given point in time, I first introduce iodized salt sales at the canton level directly as a regressor in a linear probability model of graduating from secondary and tertiary education. As a "cleaner" test, I then exploit the sharp jumps in iodized salt sales which occurred at different points in time for each canton.

In particular, initially I control for the percentage of iodized salt sales in total salt sales one year prior to birth in one's canton of birth. I also control for canton and cohort fixed effects, to remove the effect of any omitted variables that are canton- or cohort-specific. In addition, I introduce a canton time trend, to control for any other gradual changes that might have affected schooling outcomes in a canton over time. In short, I run the following regression for an individual i born in canton c in year y:

$outcome_{idy} = \alpha + \beta \cdot$ *Iodized salt 1 year prior to birth*

$+$ *Canton of birth Fixed Effects*

$+$ *Canton of birth linear time trend*

$+$ *Cohort of Birth Fixed Effects* $+\epsilon_{idy}$, where $outcome_{idy}$ is an indicator variable for having graduated from secondary/tertiary education, and disturbance terms are clustered at the canton-cohort level. I first run this regression for the whole sample and all areas, and then separately by gender. I also run the regression separately for high- and low-goiter districts. High-goiter districts correspond to the top quartile of the population-weighted goiter distribution, whereas low-goiter districts correspond to the bottom quartile[29].

Table 7 shows estimates from this regresion[30]. Table 7 shows that iodized salt is not correlated with secondary graduation rates for the county as a whole. However, if we look separately at the upper and lower tails of the goiter distribution a different picture emerges.

The probability of graduating from secondary and tertiary education if one was born in a high-goiter district after universal use of iodized salt increases by 1.5 and 1.9 percentage points, respectively. Similarly to the preliminary Differences in Differences estimates of Section 4 this increase is largely driven by the effect of iodine supplementation on females, particularly for secondary education. The coefficients for males and females are not statistically different from each other in the case of tertiary education.

In Table 7 the point estimates for tertiary are higher than for secondary education, although they are not statistically different from each other (except for males). This is contrary to the Differences in Differences estimates of Section 4, but both sets of results are consistent with the iodine response model outlined in Section 5. Secondary-level graduation rates might have been easier in the first stage of the intervention, which corresponds to increased awareness and the "informational shock" which occurred in 1922, when iodized salt circulation was not very high. However, once iodine prophylaxis became universal and complete with the advent of iodized salt, it affected "harder-to-achieve" outcomes, such as graduation from tertiary education.

[29]Results are very similar if the cut-offs for high-goiter districts are changed to the top 20% (or bottom 20% for low-goiter districts) or top 30% (or bottom 30% for low-goiter districts) of the population-weighted goiter distribution.

[30]The number of observations has decreased compared to the Differences in Differences regressions of Section 4 because there are missing data on the percentage of iodized salt sales for Fribourg in years 1934-1936.

Table 7 shows that tertiary education was affected by iodization throughout Switzerland, not just in highly deficient regions (though high goiter regions benefited more from iodization). The model outlined in Section 5 is also consistent with these results. Graduation from tertiary education is a more subtle indicator of cognitive gains than deaf-mutism or graduation from lower levels of education, so we expect even less deficient areas to be affected by iodization in that respect. Interestingly, the gains from iodization for tertiary education are not different across genders for the most iodine deficient regions (and males seem to benefit in less deficient areas too). This result differs from the conclusions of Field et al. (2009), who find consistently larger effects for females.

The transition to iodized salt happened rapidly for most cantons. For example, iodized salt sales in Luzern went from 5% to 54% to 100% of total salt sales in a period of only two years, from 1942 to 1944. I exploit these sharp jumps in iodized salt sales and the fact that they occurred at different times across cantons in order to identify the effect of iodization on education. This method is "cleaner" than a simple regression of outcomes on iodized salt sales, as there are fewer possible confounding effects taking place within a small time frame in a particular canton.

I define the "jump year" in iodized salt sales as the first year in which iodized salt sales exceeded 50% of total salt sales. For most cantons, this is also the year that corresponds to the highest R^2 in canton-specific regressions identifying a structural break in the time series of iodized salt sales. In Table A.2, where iodized salt circulation is shown for each canton, the "jump year" in iodized salt sales is shown in bold[31]. Section A.2 in the Appendix includes more details on the definition of "jump year" in each canton.

Based on the year of the jump in iodized salt sales, which is particular to each canton, I construct a new variable, age relative to iodization, which is common across all people born in the same canton in the same year, but will generally be different across cohorts born in different cantons. Figure 11 shows the population-weighted average percentage of iodized

[31]The cantons of Basel-Stadt, Basel-Land and Aargau did not have a jump in iodized salt sales until 1954, 1950, and 1952 respectively, so all cohorts in my sample born in those cantons are considered non-treated.

Table 7: Salt sales and education: Coefficient on Iodized Salt 1 year prior to birth

	Whole sample					
	Secondary education			Tertiary education		
	All areas	High goiter	Low goiter	All areas	High goiter	Low goiter
	(1)	(2)	(3)	(4)	(5)	(6)
Iodized salt one year	-0.156	1.52***	-0.341	0.495**	1.92***	0.864**
prior to birth	[0.375]	[0.529]	[0.528]	[0.236]	[0.480]	[0.408]
Cohort FE	YES	YES	YES	YES	YES	YES
Canton FE	YES	YES	YES	YES	YES	YES
Canton Trends	YES	YES	YES	YES	YES	YES
Observations	3,078,907	768,353	756,364	3,078,907	768,353	756,364
R-squared	0.0708	0.0602	0.0745	0.0263	0.0259	0.0364

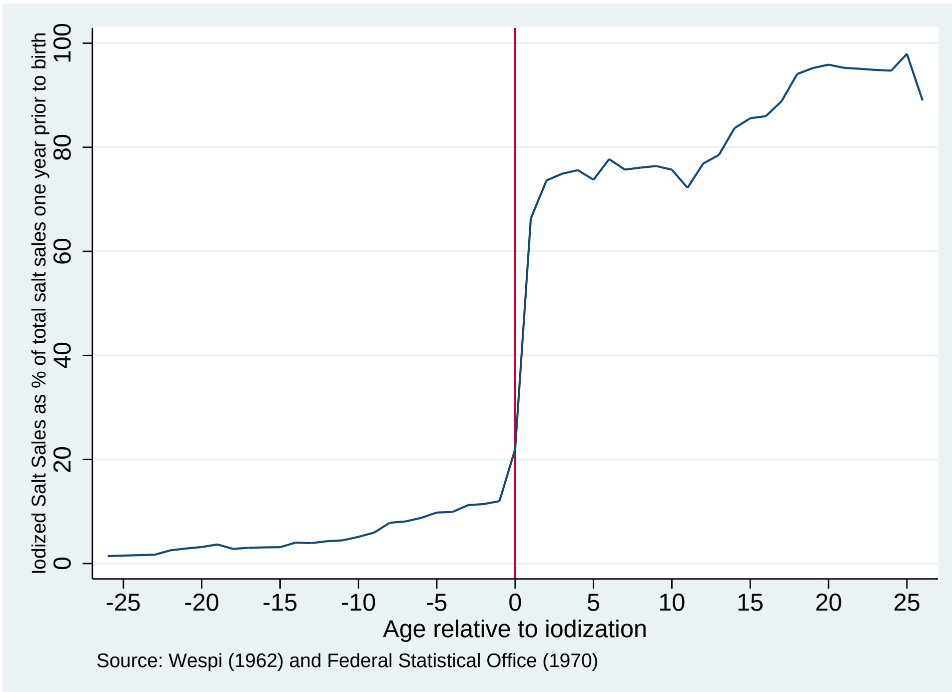
	Males only					
	Secondary education			Tertiary education		
	All areas	High goiter	Low goiter	All areas	High goiter	Low goiter
	(1)	(2)	(3)	(4)	(5)	(6)
Iodized salt one year	-0.0412	0.919	0.210	0.398	1.81**	1.65***
prior to birth	[0.369]	[0.660]	[0.563]	[0.338]	[0.720]	[0.525]
Cohort FE	YES	YES	YES	YES	YES	YES
Canton FE	YES	YES	YES	YES	YES	YES
Canton Trends	YES	YES	YES	YES	YES	YES
Observations	1,499,495	375,772	367,747	1,499,495	375,772	367,747
R-squared	0.0654	0.0583	0.0653	0.0265	0.0242	0.0379

	Females only					
	Secondary education			Tertiary education		
	All areas	High goiter	Low goiter	All areas	High goiter	Low goiter
	(1)	(2)	(3)	(4)	(5)	(6)
Iodized salt one year	-0.534	1.95***	-1.05	0.565**	2.04***	0.0598
prior to birth	[0.468]	[0.687]	[0.681]	[0.242]	[0.467]	[0.422]
Cohort FE	YES	YES	YES	YES	YES	YES
Canton FE	YES	YES	YES	YES	YES	YES
Canton Trends	YES	YES	YES	YES	YES	YES
Observations	1,579,412	392,581	388,617	1,579,412	392,581	388,617
R-squared	0.0851	0.0688	0.097	0.0307	0.033	0.0385

Notes: Coefficients correspond to changes in percentage points. Robust standard errors in brackets. Disturbance terms clustered at the canton-cohort level. High goiter includes individuals born in districts in the top quartile of the population-weighted goiter distribution. Low goiter includes individuals born in districts in the bottom quartile of the population-weighted goiter distribution. *** p<0.01, ** p<0.05, * p<0.1
Source: Federal Statistical Office (1970) and Bircher (1883).

salt sales one year prior to birth, plotted against age relative to iodization. At relative age 0, iodized salt sales jump from around 22% to around 66%.

Figure 11: Iodized salt sales by age relative to iodization



I exploit the jumps in sales of iodized salt and check how being born in a high-goiter district after a jump in iodized salt sales (at the canton level) affects one's educational achievement. Tables 8 and 9 show results of a regression of educational outcomes of an indicator variable equal to 1 if someone was born in a high-goiter district after a jump in iodized salt sales, controlling for district and cohort of birth fixed effects, as well as a district-specific time trend. I run the following regression for an individual i born in district d in year y:

$outcome_{idy} = \alpha + \beta \cdot$ *1 (Born in high-goiter district) X 1 (Born after jump in sales of iodized salt)*

+ *District of birth Fixed Effects*

+ *District of birth linear time trend*

+ *Cohort of Birth Fixed Effects* $+\epsilon_{idy}$, where outcomes are the probability of graduating from secondary and tertiary education, and where disturbance terms are clustered at the district-cohort level. As before, I include district of birth fixed effects to control for unobserved, district-specific, time-invariant characteristics that affect graduation rates. I also include cohort fixed effects to control for country-wide shocks that affect each cohort differently. In some more demanding specifications I allow cohort-specific shocks to be different for those born in high goiter districts compared to the rest of the population.

First, I run the regression on the whole sample, and then for males and females separately. I first use the whole sample and then only the sub-sample of those people born within ten years of the jump in iodized salt sales. In columns (1) and (3) of Tables 8 and 9 I use cohort fixed effects that are common for high-goiter districts and the rest of the country, whereas in columns (2) and (4) I allow cohort fixed effects to be different for high-goiter districts. Thus, in my most demanding specification I only include cohorts born within 10 years from the jump in iodized salt sales in each canton, and I include separate cohort fixed effects for those born in high-goiter districts.

Tables 8 and 9 show that, in the most demanding specification, the probability of graduating from secondary education grew by 0.9 percentage points for people born in high-goiter districts after a jump in iodized salt sales. When I allow for gender-specific effects, the gain for secondary education is between 1 and 1.1 percentage points, but it is very similar across genders. Point estimates for tertiary education are more consistent across specifications and, for the most demanding specification of column (4) in Table 9, the estimated effect of iodization is 0.7 percentage points. The gender-specific estimates are, again, very similar and range between 0.7 and 0.9 percentage points, but they are only significant at the 10% level. In specifications where I use the whole sample, the coefficients for females are higher, between 1.25 and 2 percentage points, and they drive the results for the whole population. The estimates for males are not statistically significant in these specifications.

Taken together, the results of Tables 8 and 9 show that, as a result of iodization, cohorts

Table 8: Secondary education: Differences in Differences "Jumps" estimates

	secondary education (1)	secondary education (2)	secondary education (3)	secondary education (4)
(High goiter) X (Born after jump)	0.739** [0.302]	-0.0809 [0.380]	0.435 [0.361]	0.895** [0.363]
Cohort FE	YES	YES	YES	YES
District FE	YES	YES	YES	YES
District Trends	YES	YES	YES	YES
Separate Cohort FE for high goiter	NO	YES	NO	YES
Observations	3086287	3086287	1066040	1066040
R^2	0.092	0.092	0.073	0.073
Males only				
	(1)	(2)	(3)	(4)
(High goiter) X (Born after jump)	0.320 [0.338]	-0.123 [0.436]	1.08** [0.487]	1.12** [0.510]
Cohort FE	YES	YES	YES	YES
District FE	YES	YES	YES	YES
District Trends	YES	YES	YES	YES
Separate Cohort FE for high goiter	NO	YES	NO	YES
Observations	1503257	1503257	537619	537619
R^2	0.086	0.086	0.070	0.070
Females only				
	(1)	(2)	(3)	(4)
(High goiter) X (Born after jump)	0.871** [0.408]	-0.0383 [0.530]	0.0972 [0.546]	1.01* [0.563]
Cohort FE	YES	YES	YES	YES
District FE	YES	YES	YES	YES
District Trends	YES	YES	YES	YES
Separate Cohort FE for high goiter	NO	YES	NO	YES
Observations	1583030	1583030	528421	528421
R^2	0.114	0.115	0.094	0.094

Notes: Coefficients correspond to changes in percentage points. Robust standard errors in brackets, clustered at the district-cohort level. High-goiter is an indicator variable for a district of birth within the top 25% of the population-weighted goiter distribution. *** p<0.01, ** p<0.05, * p<0.1
Source: Federal Statistical Office (1970) and Bircher (1883).

Table 9: Tertiary education: Differences in Differences "Jumps" estimates

	tertiary education (1)	tertiary education (2)	tertiary education (3)	tertiary education (4)
(High goiter) X	1.19***	0.835***	0.534*	0.708**
(Born after jump)	[0.216]	[0.258]	[0.298]	[0.315]
Cohort FE	YES	YES	YES	YES
District FE	YES	YES	YES	YES
District Trends	YES	YES	YES	YES
Separate Cohort FE for high goiter	NO	YES	NO	YES
Observations	3086287	3086287	1066040	1066040
R^2	0.030	0.031	0.019	0.019
Males only				
	(1)	(2)	(3)	(4)
(High goiter) X	0.294	0.456	0.462	0.869*
(Born after jump)	[0.321]	[0.390]	[0.469]	[0.505]
Cohort FE	YES	YES	YES	YES
District FE	YES	YES	YES	YES
District Trends	YES	YES	YES	YES
Separate Cohort FE for high goiter	NO	YES	NO	YES
Observations	1503257	1503257	537619	537619
R^2	0.032	0.032	0.023	0.023
Females only				
	(1)	(2)	(3)	(4)
(High goiter) X	1.97***	1.25***	0.706*	0.717*
(Born after jump)	[0.274]	[0.332]	[0.422]	[0.431]
Cohort FE	YES	YES	YES	YES
District FE	YES	YES	YES	YES
District Trends	YES	YES	YES	YES
Separate Cohort FE for high goiter	NO	YES	NO	YES
Observations	1583030	1583030	528421	528421
R^2	0.035	0.035	0.022	0.022

Notes: Coefficients correspond to changes in percentage points. Robust standard errors in brackets, clustered at the district-cohort level. High-goiter is an indicator variable for a district of birth within the top 25% of the population-weighted goiter distribution. *** p<0.01, ** p<0.05, * p<0.1

Source: Federal Statistical Office (1970) and Bircher (1883).

born in highly deficient areas were about 1 percentage point more likely to graduate from secondary education and about 0.7 percentage points more likely to receive tertiary education. In Section A.2 in the appendix I run the same regression restricting the sample to only those cantons that had a well-defined, sharp jump in iodized salt sales. Results (shown in Tables A.3 and A.4) are very similar to those of Tables 8 and 9.

7 Robustness checks and placebo tests

I conduct three robustness checks to corroborate the empirical findings outlined above. First, for a few municipalities where available, I use the iodine content of drinking water as an alternative measure of underlying iodine deficiency. The iodine content of drinking water is arguably less prone to measurement error than goiter prevalence in recruits. Second, I run a placebo test using individuals recorded in the 1970 Swiss Census, who were not born in Switzerland, and so should not have been affected by iodization in a systematic way. I randomly assign these individuals to Swiss municipalities and then check if their graduation rates can be "explained" by underlying iodine deficiency and iodization status in those (randomly assigned) municipalities around their year of birth. Finally, I use World War II as a falsification exercise. I check if cohorts born during wartime are affected differentially across high- and low-goiter areas. These robustness checks and their results are outlined below.

7.1 Using an alternative measure of iodine deficiency

As an alternative measure of iodine deficiency, I use data on the iodine content of drinking water across six Swiss municipalities from the cantons of Aargau, Neuchâtel and Bern, as recorded in Von Fellenberg (1926). These measurements were taken around the time of salt iodization, in August 1922 and June 1923[32], but unfortunately the study was only conducted

[32]In Bern measurements were taken over a longer period of time, from June 1922 to December 1924, on six occasions. For those localities where multiple measurements were taken, I use the average of all

in the six municipalities mentioned above, rather than across the country.

The iodine content of drinking water, as an proxy for iodine deficiency in a population, is less prone to measurement error compared to observed goiter in recruits. First, it is less reliant on human judgement, since it depends on readings from scientific equipment at a specific moment in time[33]. In addition, the iodine content of drinking water does not suffer from selection bias, in the way that Army goiter data potentially do. Nevertheless, as shown in Table 3, measures of the iodine content of water correlate well with goiter prevalence in the same municipalities, as recorded earlier by Bircher (1883). This highly positive correlation lends further credibility to Bircher's data as reasonable measures of the regional variation in underlying iodine deficiency in Switzerland before the adoption of iodized salt (both at the municipality and the district level). The measurements from the canton of Aargau also correlate well with independent measures of goiter prevalence taken earlier by Dieterle et al. (1913).

I replicate the earlier analysis focusing on the 6 municipalities for which there is information on the iodine content of drinking water. For comparison, I also conduct the analysis using goiter data from Bircher (1883) at the municipality, rather than the district level. The results are shown in Tables 10, 11, and 12. Columns (1) and (3) use Bircher's data on municipality-level goiter, whereas columns (2) and (4) use von Fellenberg's data on the iodine content of drinking water. Columns (1) and (3) look at secondary education, whereas columns (2) and (4) look at tertiary education.

Table 10 is a Differences in Differences exercise, using the fact that iodized salt was first introduced in 1922, to check whether those municipalities where drinking water had a lower iodine content had higher graduation rates after 1922 compared to municipalities where the iodine content was higher. I include cohort fixed effects to control for country-wide secular changes in graduation rates, as well as municipality fixed effects and municipality-specific trends, to control for unobserved permanent differences between municipalities, as

measurements.

[33]The way the measurements were taken is described in ample detail in Von Fellenberg (1926).

Table 10: Robustness check: Differences in Differences estimates using iodine content of water

	secondary education (1)	secondary education (2)	tertiary education (3)	tertiary education (4)
(Born after 1922) X	0.414	-	0.203*	-
(Goiter in municipality)	[0.256]		[0.118]	
(Born after 1922) X	-	-2.89	-	-1.29
(Iodine content of water)		[1.87]		[0.874]
Cohort FE	YES	YES	YES	YES
Municipality FE	YES	YES	YES	YES
Municipality Trends	YES	YES	YES	YES
Observations	103523	103523	103523	103523
R^2	0.054	0.054	0.021	0.021
Males only				
	(1)	(2)	(3)	(4)
(Born after 1922) X	0.176	-	0.187	-
(Goiter in municipality)	[0.361]		[0.115]	
(Born after 1922) X	-	-1.78	-	-1.52*
(Iodine content of water)		[2.60]		[0.849]
Cohort FE	YES	YES	YES	YES
Municipality FE	YES	YES	YES	YES
Municipality Trends	YES	YES	YES	YES
Observations	49711	49711	49711	49711
R^2	0.042	0.042	0.023	0.023
Females only				
	(1)	(2)	(3)	(4)
(Born after 1922) X	0.412**	-	0.0822	-
(Goiter in municipality)	[0.184]		[0.164]	
(Born after 1922) X	-	-2.38*	-	-0.135
(Iodine content of water)		[1.30]		[1.20]
Cohort FE	YES	YES	YES	YES
Municipality FE	YES	YES	YES	YES
Municipality Trends	YES	YES	YES	YES
Observations	53812	53812	53812	53812
R^2	0.064	0.064	0.030	0.030

Notes: Coefficients correspond to changes in percentage points. Robust standard errors in brackets. Disturbance terms clustered at the municipality-cohort level. *** p<0.01, ** p<0.05, * p<0.1

Source: Federal Statistical Office (1970), Von Fellenberg (1926) and Bircher (1883).

Table 11: Robustness check: Iodine content of water X Goiter / Iodine Water Content

	secondary education (1)	secondary education (2)	tertiary education (3)	tertiary education (4)
(Goiter in municipality) X	0.203	-	0.434***	-
(Iodized salt one year prior to birth)	[0.177]		[0.0822]	
(Iodine content of water in municipality) X	-	-6.21***	-	-2.30*
(Iodized salt one year prior to birth)		[1.84]		[1.31]
Cohort FE	YES	YES	YES	YES
Municipality FE	YES	YES	YES	YES
Municipality Trends	YES	YES	YES	YES
Observations	103523	103523	103523	103523
R^2	0.054	0.054	0.021	0.021
Males only				
	(1)	(2)	(3)	(4)
(Goiter in municipality) X	0.0983	-	0.170	-
(Iodized salt one year prior to birth)	[0.227]		[0.145]	
(Iodine content of water in municipality) X	-	-7.61***	-	-3.16***
(Iodized salt one year prior to birth)		[2.26]		[1.06]
Cohort FE	YES	YES	YES	YES
Municipality FE	YES	YES	YES	YES
Municipality Trends	YES	YES	YES	YES
Observations	49711	49711	49711	49711
R^2	0.042	0.042	0.023	0.023
Females only				
	(1)	(2)	(3)	(4)
(Goiter in municipality) X	0.215	-	0.614***	-
(Iodized salt one year prior to birth)	[0.154]		[0.107]	
(Iodine content of water in municipality) X	-	-3.31**	-	-0.421
(Iodized salt one year prior to birth)		[1.65]		[1.82]
Cohort FE	YES	YES	YES	YES
Municipality FE	YES	YES	YES	YES
Municipality Trends	YES	YES	YES	YES
Observations	53812	53812	53812	53812
R^2	0.064	0.064	0.031	0.030

Notes: Coefficients correspond to changes in percentage points. Robust standard errors in brackets. Disturbance terms clustered at the municipality-cohort level. *** p<0.01, ** p<0.05, * p<0.1
Source: Federal Statistical Office (1970), Von Fellenberg (1926) and Bircher (1883).

Table 12: Robustness check: Differences in Differences "jump" estimates using iodine content of water

	secondary education (1)	secondary education (2)	tertiary education (3)	tertiary education (4)
(Born after jump) X	0.0923	-	0.252***	-
(Goiter in municipality)	[0.106]		[0.0515]	
(Born after jump) X	-	-4.14***	-	-1.56*
(Iodine content of water)		[1.22]		[0.879]
Cohort FE	YES	YES	YES	YES
Municipality FE	YES	YES	YES	YES
Municipality Trends	YES	YES	YES	YES
Observations	103523	103523	103523	103523
R^2	0.053	0.054	0.021	0.021
Males only				
	(1)	(2)	(3)	(4)
(Born after jump) X	0.00196	-	0.0875	-
(Goiter in municipality)	[0.138]		[0.0873]	
(Born after jump) X	-	-5.21***	-	-2.16***
(Iodine content of water)		[1.51]		[0.736]
Cohort FE	YES	YES	YES	YES
Municipality FE	YES	YES	YES	YES
Municipality Trends	YES	YES	YES	YES
Observations	49711	49711	49711	49711
R^2	0.042	0.042	0.023	0.023
Females only				
	(1)	(2)	(3)	(4)
(Born after jump) X	0.130	-	0.369***	-
(Goiter in municipality)	[0.0936]		[0.0670]	
(Born after jump) X	-	-2.11*	-	-0.282
(Iodine content of water)		[1.12]		[1.22]
Cohort FE	YES	YES	YES	YES
Municipality FE	YES	YES	YES	YES
Municipality Trends	YES	YES	YES	YES
Observations	53812	53812	53812	53812
R^2	0.064	0.064	0.030	0.030

Notes: Coefficients correspond to changes in percentage points. Robust standard errors in brackets. Disturbance terms clustered at the municipality-cohort level. *** p<0.01, ** p<0.05, * p<0.1

Source: Federal Statistical Office (1970), Von Fellenberg (1926) and Bircher (1883).

well as municipality-specific secular increases in graduation rates over time. The coefficient of interest is an interaction term between the iodine content of water (or goiter as recorded in Bircher's data) in the municipality of birth and an indicator variable for those born after 1922.

Table 11 includes similar controls, but introduces iodized salt sales as a percentage of total salt sales (one year prior to birth) directly as a regressor, interacted with the iodine content of drinking water (or goiter) in the municipality of birth. Table 11 checks if iodized salt made more of a difference for those municipalities where the iodine content of drinking water was lower.

Table 12 is similar to Table 10, but now identification relies on jumps in sales of iodized salt at the cantonal level. For most cantons, these jumps marked the irreversible transition into iodized salt as the most commonly used salt. In table 12 the coefficient of interest is the interaction between the iodine content of drinking water (or goiter) in one's municipality of birth and an indicator variable for those cohorts born after the jump in sales of iodized salt.

The results are largely in line with the main results, as analyzed in Section 6. I expect the coefficients related to the iodine content of drinking water to be negative, as a higher level of iodine content in drinking water means that a municipality is less vulnerable to iodine deficiency disorders, and therefore stands to gain less from iodization. On the contrary, coefficients related to goiter should be positive. This is what we observe in Tables 10, 11, and 12. The coefficients on goiter are positive, whereas the coefficients on iodine content of water are negative. The coefficients are not always statistically significant, which is not a surprise given that the sample size is much smaller and a lot of variation is removed with the inclusion of the fixed effects and trends. As expected, results in tables 11 and 12 are stronger, since they rely on more disaggregated, canton-specific measures of iodization. In addition, the coefficients on the iodine content of drinking water tend to have stronger statistical significance compared to the ones of goiter. This is partly due to the fact that, in this subsample, the iodine content of drinking water displays bigger variation (the coefficient of variation is 1.7 times bigger than that of goiter).

The sets of coefficients of columns (1) and (3) (corresponding to goiter) are not directly comparable to those in columns (2) and (4)(corresponding to the iodine content of drinking water). Moving from a iodine-rich (or goiter-free) to an iodine-poor (or high-goiter) municipality corresponds to a change in the iodine content of water of roughly 2.5μg I per litre, or a decrease of goiter in recruits of about 17 percentage points. So the estimated coefficients on goiter would need to be multiplied by about 6.8 for their value to be comparable to that of the coefficients on iodine content of water. As can be seen from Tables 10, 11, and 12, the estimated effect using the iodine content of drinking water is, in most specifications, bigger than the effect measured using goiter, especially for secondary education. Given that the iodine content of drinking water is a more reliable proxy of iodine deficiency than recorded goiter in recruits, this means that the main results might be understating the impact of iodization on highly deficient areas.

7.2 Using an untreated population as a falsification test

The second set of robustness checks that I perform utilizes the subsample of respondents in the 1970 Swiss Census, who were not born in Switzerland. I randomly assign "municipalities of birth" (hence "districts of birth" as well) to these individuals, and then repeat the main analysis, as outlined in Section 6. Individuals not born in Switzerland would not have benefited from the Swiss iodization programme in utero, so I do not expect to find any significant systematic relationship between their education outcomes and goiter or iodization status in their assigned municipality (or district) of birth. I present the results of this falsification test in Tables 13, 14, and 15.

Table 13 is a Differences in Differences exercise, where the coefficient of interest corresponds to being born after 1922 in a high-goiter district. Table 14 introduces the percentage of total salt sales that corresponded to iodized salt (one year prior to birth) in the canton of birth directly as a regressor, for those individuals assigned to a district at the top 25% of

Table 13: Falsification test: Differences in Differences estimates with sample not born in Switzerland

	Whole sample		Males only		Females only	
	secondary education (1)	tertiary education (2)	secondary education (3)	tertiary education (4)	secondary education (5)	tertiary education (6)
(High goiter) X	0.185	0.329	0.725	0.382	-0.397	0.226
(Born after 1922)	[0.509]	[0.358]	[0.752]	[0.592]	[0.700]	[0.433]
Cohort FE	YES	YES	YES	YES	YES	YES
District FE	YES	YES	YES	YES	YES	YES
District Trends	YES	YES	YES	YES	YES	YES
Observations	835,198	835,198	411,180	411,180	424,018	424,018
R-squared	0.005	0.003	0.020	0.010	0.005	0.006

Notes: Falsification test where location of birth is randomly assigned. Coefficients correspond to changes in percentage points. Robust standard errors in brackets. Disturbance terms clustered at the district-cohort level. High-goiter is an indicator variable for a district within the top 25% of the population-weighted goiter distribution. *** p<0.01, ** p<0.05, * p<0.1
Source: Federal Statistical Office (1970) and Bircher (1883).

Table 14: Falsification test: Estimates of iodized salt for high-goiter districts using sample non born in Switzerland

	Whole sample		Males only		Females only	
	secondary education (1)	tertiary education (2)	secondary education (3)	tertiary education (4)	secondary education (5)	tertiary education (6)
Iodized salt one year	-0.706	1.00**	-0.778	0.803	-0.724	1.17**
prior to birth	[0.573]	[0.503]	[0.926]	[0.852]	[0.860]	[0.566]
Cohort FE	YES	YES	YES	YES	YES	YES
Canton FE	YES	YES	YES	YES	YES	YES
Canton Trends	YES	YES	YES	YES	YES	YES
Observations	151,440	151,440	78,960	78,960	72,480	72,480
R-squared	0.003	0.002	0.004	0.006	0.003	0.003

Notes: Falsification test where location of birth is randomly assigned. Coefficients correspond to changes in percentage points. Robust standard errors in brackets. Disturbance terms clustered at the canton-cohort level. High-goiter is an indicator variable for a district within the top 25% of the population-weighted goiter distribution. *** p<0.01, ** p<0.05, * p<0.1
Source: Federal Statistical Office (1970) and Bircher (1883).

Table 15: Falsification test: Differences in Differences "jump" estimates using sample not born in Switzerland

	secondary education (1)	secondary education (2)	tertiary education (3)	tertiary education (4)
(High goiter) X	-0.253	-0.0615	0.315	0.678**
(Born after jump)	[0.362]	[0.451]	[0.250]	[0.308]
Cohort FE	YES	YES	YES	YES
District FE	YES	YES	YES	YES
District Trends	YES	YES	YES	YES
Separate Cohort FE for high goiter	NO	YES	NO	YES
Observations	835,198	835,198	835,198	835,198
R-squared	0.005	0.005	0.003	0.003
	Males only			
	(1)	(2)	(3)	(4)
(High goiter) X	-0.171	0.0524	0.423	0.646
(Born after jump)	[0.539]	[0.628]	[0.378]	[0.451]
Cohort FE	YES	YES	YES	YES
District FE	YES	YES	YES	YES
District Trends	YES	YES	YES	YES
Separate Cohort FE for high goiter	NO	YES	NO	YES
Observations	411,180	411,180	411,180	411,180
R-squared	0.020	0.020	0.010	0.010
	Females only			
	(1)	(2)	(3)	(4)
(High goiter) X	-0.481	-0.318	0.173	0.728*
(Born after jump)	[0.509]	[0.657]	[0.341]	[0.429]
Cohort FE	YES	YES	YES	YES
District FE	YES	YES	YES	YES
District Trends	YES	YES	YES	YES
Separate Cohort FE for high goiter	NO	YES	NO	YES
Observations	424,018	424,018	424,018	424,018
R-squared	0.005	0.005	0.006	0.006

Notes: Location of birth is randomly assigned. Coefficients correspond to changes in percentage points. Robust standard errors in brackets. Disturbance terms clustered at the district-cohort level. High-goiter is an indicator variable for a district within the top 25% of the population-weighted goiter distribution. *** p<0.01, ** p<0.05, * p<0.1
Source: Federal Statistical Office (1970) and Bircher (1883).

the population-weighted goiter distribution. Table 15 exploits jumps in sales of iodized salt to identify jumps in graduation rates in high-goiter districts.

As expected, Table 13 shows that there is no systematic difference between those born after 1922 and assigned to a high-goiter district compared to the rest of the sample. In tables 14 and 15 there are some significant coefficients driven by female tertiary education, but they are never significant at the 1% level (which one would expect, given the size of the sample), and they are much smaller in magnitude than the corresponding coefficients in the main analysis. If we take all of these results together, there is no consistent evidence that a sample of individuals born outside of Switzerland benefited from iodization in a way similar to the one that Swiss-born people did, lending further credibility to the results of Section 6.

7.3 Comparing cohorts born around World War II

As a final robustness check, I check that my results are not driven by systematic, differential changes in high- and low-goiter cantons around the same time period as iodization. One possibility is that my results are driven by cohorts born around World War II (WWII). The hypothesis is that the effects of the war are not washed away by cohort fixed effects. Switzerland remained famously neutral during WWII, and was mostly unharmed by it (though there were some isolated incidents of mistaken air bombings in areas close to the the border with Germany). In this respect, there is no reason to expect that outcomes of cohorts born during WWII would differ systematically from surrounding cohorts born in the same area, assuming everything else was constant.

I use cohorts born in 1930-1949 and conduct a Differences in Differences exercise, to check whether cohorts born during WWII (born 1940-1945) in high-goiter districts have differentially different outcomes from the rest of the population. I include cohort and district of birth fixed effects, as well as a linear district-specific trend, as I do in the main regressions of Section 6. The results are presented in Table 16. As expected, there is no evidence that my results are driven by the potential effect of the war on high-goiter regions. There are

Table 16: Falsification test with WWII cohort

	Whole sample		Males only		Females only	
	secondary education (1)	tertiary education (2)	secondary education (3)	tertiary education (4)	secondary education (5)	tertiary education (6)
(High goiter) X	0.0513	0.159	-0.382	0.251	0.413	0.0909
(Born during WWII)	[0.200]	[0.201]	[0.269]	[0.291]	[0.307]	[0.254]
Cohort FE	YES	YES	YES	YES	YES	YES
District FE	YES	YES	YES	YES	YES	YES
District Trends	YES	YES	YES	YES	YES	YES
Observations	1,186,879	1,186,879	597,652	597,652	589,227	589,227
R-squared	0.058	0.015	0.052	0.024	0.080	0.016

Notes: Coefficients correspond to changes in percentage points. Robust standard errors in brackets, clustered at the district-cohort level. High-goiter is an indicator variable for a district within the top 25% of the population-weighted goiter distribution. Sample includes Swiss-born individuals born in 1930-1949 and interviewed in the 1970 Swiss Census. *** p<0.01, ** p<0.05, * p<0.1
Source: Federal Statistical Office (1970) and Bircher (1883).

no systematic differences between cohorts born during WWII in high-goiter regions and the rest of the population born after 1930 (inclusive)[34].

8 Interpretation of coefficients

There is strong evidence that iodine provision in previously deficient regions had a significant impact on the educational attainment of cohorts exposed to it. Even in the strictest specification of Section 6 the probability of graduating from secondary education increased by around 1 percentage point, whereas the same number for tertiary education is around 0.7 percentage points. Given that secondary school graduation rates increased by about 15 percentage points for those born after 1922 compared to those born before 1922 in high-goiter districts, iodization alone contributed about 6.7% of that change. If tertiary education increased by 0.7 percentage points, then, given that the change in graduation rates between

[34]Note that I do not include the entire sample made up of cohorts born both before and after iodization, because I do expect cohorts born during WWII in high-goiter areas to have better outcomes, other things constant, compared to cohorts born before iodization in high-goiter areas. I limit my sample to cohorts born after iodized salt was introduced in most cantons to mitigate this confounding effect.

those born before and after 1922 in high-goiter districts was 8.5 percentage points, iodization is responsible for about 8.2% of the total change in graduation rates from tertiary education in high-goiter districts.

The estimated effects are large given that they refer to graduation rates, rather than years of schooling. For example, graduating from secondary education implies three to five years of post-obligatory education. Given that graduation from secondary education implies, say, four years of additional schooling, and assuming that the change in the probability of getting another year of schooling does not depend on the level of schooling, then the estimated change in the probability of getting another year of schooling is much bigger than 1 percentage point, and closer to 30 percentage points.

Results are consistently strong for females, whereas they are not as consistent for males. Also, in some cases the estimates for females are bigger than for males. So there is some evidence that iodization affected females more than males. However, this result is not robust to the more demanding specifications of Section 6. The fact that gender differences in estimated effects are not robust to "cleaner" tests is a departure from the results of Field et al. (2009), who find bigger effects for female schooling during a recent iodine supplementation programme in Tanzania. One must keep in mind, however, that the educational margin that I examine here (upper secondary and tertiary education) is different than the one in Field et al. (2009), where most sampled individuals were of primary or lower secondary school age.

The effect on educational outcomes identified in the previous sections of this paper arises from increased health capital in utero and early life. Health investments at such an early stage have been shown to have a significant impact later in one's lifetime, but I cannot distinguish whether this effect comes from increased innate cognitive ability alone, better treatment at home and school (before even reaching upper-secondary and tertiary levels of education), or a combination of the two. It is possible, for example, that a smarter cohort received different parental and teacher attention in childhood and early adolescence, in which case the initial effect of iodization was magnified by responses coming from one's social environment, which increased their potential for higher educational attainment even more than the initial improvement in cognitive ability.

In addition, I cannot preclude the possibility that iodization, through its effect on goiter eradication, might have increased productivity in ways other than cognition. After all, iodine supplementation was advertised as a way to combat goiters, and it was celebrated as a success even before the cognitive gains from the adoption of iodized salt were taken into account. An additional effect of iodization, such as goiter reduction, would have affected not just the cohorts born after iodization, but also those older cohorts who were young enough to benefit from iodization through a reduction or disappearance of their goiters. My identification strategy treats these cohorts as part of the control group, so any such non-cognitive gains are not reflected in my estimates. I isolate the in utero effect of iodization on cognitive ability, which, in this sense, is a lower bound of the total effect of iodization on productivity.

Iodized salt was introduced in Switzerland before the link between iodine intake in utero and cognitive ability was established. This makes it unlikely that selection into treatment affects my estimates. Salt iodization also happened at a time when food trade was more limited than today, so that consuming iodine-rich food in an iodine-poor area was not very likely. Finally, although it affected different areas at different times, the introduction of iodized salt represented a wide-reaching public health campaign which affected all areas of the country. This, in conjunction with the fact that the importance of iodine supplementation was not fully realized at the time, make it unlikely that selective migration in order to receive treatment might have biased the results. To sum up, the particulars of the intervention in Switzerland, together with the substantial pre-existing geographic variation in the prevalence of iodine deficiency, provide me with natural treatment and control groups and with a research design allowing for the study of the long-term impact of iodine deficiency on human capital accumulation and productivity.

9 Concluding remarks

The treatment of iodine deficiency in Switzerland provides us with a rare opportunity to examine how an exogenous increase in the cognitive ability of a population translates into higher schooling. The potential non-linearity of treatment is also noteworthy. While low levels of treatment might cure acute conditions, such as cretinism and deaf-mutism, it takes a well-orchestrated public health campaign to affect more subtle outcomes, such as schooling and graduation levels.

A cost-benefit analysis is beside the point here; iodized salt was clearly cost-effective, even if one only considers the reduction in medical costs related to goiters and other iodine-related disorders, let alone factoring in the benefits of increased cognition and productivity. Prof. Dr. Hans Bürgi estimates that, had it not been for iodine prophylaxis, the cost of homes providing for cretins and the medical bills related to iodine deficiency disorders would have been around 270 million 2005 Swiss Francs. The cost of adding iodine to salt, on the other hand, amounted to a total of 1.4 million Swiss Francs in 2005[35].

The late 1990s saw significant improvements in iodized salt availability in the world, and UNICEF estimates that 70% of people in the world consumed iodized salt in 2000, whereas less than 20% did so back in 1990. However, iodine deficiency remains the single most easily preventable cause of mental retardation today, and 38 million children are born annually at the risk of developing iodine deficiency disorders (UNICEF 2008). Even in developed countries such as the UK, there is recent evidence of iodine deficiency in schoolchildren (Vanderpump et al. 2011). Additional recent UK-based research also found that many pregnant women are iodine deficient, and that this impacts their offspring's cognitive ability (Bath et al. 2013). The historical experience of Switzerland, the success of the informational campaign, the details of its salt iodization programme and its beneficial impact on the population can serve as a paradigm for countries fighting with iodine deficiency today.

[35] Personal communication to the author by Prof. Dr. Hans Bürgi.

Appendices

A.1 Computation of district goiter rates from Bircher's raw data

In his monograph, Bircher (1883) proposes a mapping from raw data on goiter in recruits to measures of goiter rates in the municipality where they came from. I adopt his approach, after having aggregated observations at the district level, to deal with mergers and divisions of municipalities which occurred between 1880 and 1970.

Bircher's approach is the following: the raw data consists of the total number of recruits with goiter from a given locality over a period of 6 years, from 1875 to 1880 (inclusive). This number is therefore divided by 6, to give the yearly average number of recruits with goiter from each locality. In addition, Bircher estimates that each recruit corresponds to approximately 100 inhabitants, so the average yearly number of recruits is multiplied by 100 to give the estimate of inhabitants with goiter in each locality. This number is then divided by the total population in that locality in 1880, and then multiplied by 100 to provide a percentage. The formula for computing the prevalence of goiter in a locality is therefore: goiter in locality $= \frac{\text{number of goitrous recruits in locality} \times 100 \times 100}{6 \times \text{population in locality}}$.

For example, the raw total number of recruits with goiter coming from the municipalities which made up the district of Zürich was 506 for the period 1875-1880, or 84.3 per year. Given that the district of Zürich had 86,890 inhabitants in 1880, the goiter rate for the district of Zürich is calculated at 9.71%.

Table A.1 presents summary statistics on the goiter rate and the population in each canton. The goiter rate is calculated as a weighted average of district-specific goiter rates, weighted by each district's population, as recorded in the 1970 Swiss Census.

Table A.1: Goiter rates and number of observations by canton

Canton	Goiter rate in canton (weighted by 1970 population)	Number of observations
Zürich	8.69	401656
Berne	14.38	540017
Luzern	13.32	163472
Uri	1.97	23668
Schwyz	4.59	54857
Obwalden	4.24	17358
Nidwalden	4.87	15925
Glarus	4.87	26672
Zug	9.71	26395
Fribourg	20.16	130704
Solothurn	7.38	120707
Basel-Stadt	7.45	95673
Basel-Landschaft	5.36	73803
Schaffhausen	3.03	38522
Ap. Ausserrhoden	5.38	40949
Ap. Innerrhoden	3.37	13807
St. Gallen	5.77	232667
Graubünden	3.61	99746
Aargau	13.91	221113
Thurgau	2.43	103106
Ticino	1.15	109378
Vaud	1.96	216993
Valais	5.68	120191
Neuchâtel	5.21	80368
Genève	1.50	71884
Jura	2.96	46656
Total Switzerland	8.49	3086287

Sources: Bircher (1883) and Federal Statistical Office (1970)

A.2 Jumps in iodized salt sales

The "jump year" in iodized salt sales is the first year in which iodized salt sales exceeded 50% of total salt sales. For most cantons, this is also the year that corresponds to the highest R^2 in canton-specific regressions identifying a structural break in the time series of iodized salt sales. Table A.2 shows panel data on iodized salt circulation, taken from Wespi (1962). For each canton, the "jump year" in iodized salt sales is shown in bold. Basel-Stadt, Basel-Land and Aargau did not have a jump in iodized salt sales until 1954, 1950, and 1952 respectively, so all cohorts in my sample born in those cantons are considered non-treated.

The cantons for which the jump in sales of iodized salt does not coincide with the best-fitting structural break in iodized salt sales are Glarus, Ap. Ausserrhoden, Ap. Innerrhoden, St. Gallen, Thurgau, and Valais. The first four had a gradual adoption of iodized salt, and the best-fitting structural break was estimated in 1943, 1947, 1946, and 1947 respectively. By that time iodized salt already accounted for more than 85% of total salt sales in those cantons. Consequently, these years clearly do not correspond to the onset of iodization. In Thurgau, the best-fitting structural break was identified for 1947, but I take 1946 to correspond to the "jump year", when iodized salt sales went from 46% to 67% of total salt sales. In Valais, I treat 1925 as the "jump year", when iodized salt sales rose from 33% to 63% of total salt sales, rather than the best-fitting year, 1929, when iodized salt sales already accounted for 80% of total salt sales.

Tables A.3 and A.4 repeat the regressions shown in tables 8 and 9, using only those cantons where a "clean jump" in iodized salt sales is observed, meaning that the "jump year" is the best-fitting year in structural break tests, and corresponds to the first year in which iodized salt accounts for most salt sales. In particular, Tables A.3 and A.4 omit observations from Glarus, Ap. Ausserrhoden, Ap. Innerrhoden, St. Gallen, Thurgau and Valais. The results are very similar to those shown in Tables 8 and 9. Omitting the cantons where iodization was more gradual does not make a difference in the estimated impact of iodization.

Table A.2: Annual iodized salt sales as a percentage of total salt sales in Swiss cantons

Year	ZH	BE	LU	UR	SZ	NW	OW	GL	ZG	FR	SO	BS	BL
1922	0	0	0	0	0	0	0	0	0	0	0	0	0
1923	18	1	5	0	0	47	7	4	23	0	1	5	2
1924	21	1	3	0	1	**100**	8	**83**	26	0	2	10	5
1925	18	4	4	0	1	100	8	37	**81**	2	2	12	5
1926	18	4	6	0	**100**	100	50	27	97	2	2	12	11
1927	18	4	6	0	100	100	**100**	37	88	2	3	13	12
1928	17	4	6	0	100	100	100	33	100	3	3	14	9
1929	15	5	7	**100**	100	100	100	41	100	2	3	15	10
1930	13	6	7	100	100	100	100	60	100	2	3	14	34
1931	14	6	8	97	100	100	100	66	100	1	3	13	15
1932	**53**	6	6	97	100	100	100	67	100	3	3	14	14
1933	51	7	8	97	100	100	100	68	100	3	3	14	14
1934	53	8	8	93	100	100	100	70	100	n/a	3	10	12
1935	54	11	8	88	100	100	100	72	100	n/a	3	10	28
1936	52	**54**	8	79	100	100	100	73	100	n/a	4	14	16
1937	53	64	9	90	100	100	100	76	100	3	4	13	15
1938	52	65	7	90	100	100	100	76	100	3	**54**	15	15
1939	53	66	8	88	100	100	100	81	100	4	74	23	18
1940	55	63	8	90	100	100	100	82	100	7	69	25	17
1941	55	73	6	87	100	100	100	87	100	39	58	23	17
1942	48	69	5	88	100	100	100	92	100	31	62	25	18
1943	63	71	**54**	100	100	100	100	94	100	36	65	28	18
1944	67	71	100	100	100	100	100	93	100	50	66	28	18
1945	70	73	81	100	100	100	100	94	100	**76**	67	28	19
1946	70	69	92	100	100	100	100	93	100	76	64	29	18
1947	70	74	97	100	100	100	100	94	100	100	63	27	20
1948	77	73	100	100	100	100	100	95	100	100	60	27	21
1949	77	75	100	100	100	100	100	97	100	100	58	27	21

Year	SH	AR	AI	SG	GR	AG	TG	TI	VD	VS	NE	GE	CH
1922	0	43	0	0	0	0	0	0	0	0	0	0	
1923	4	**55**	34	12	3	4	27	0	25	0	0	0	8
1924	3	75	50	24	6	9	36	0	**100**	33	15	0	16
1925	11	75	50	27	9	11	39	0	100	**63**	**70**	0	22
1926	**100**	67	48	25	9	11	35	0	100	65	70	0	26
1927	100	67	46	26	13	12	34	0	100	75	70	1	29
1928	100	67	**53**	27	16	12	35	0	100	78	70	1	27
1929	100	73	54	47	18	10	36	**100**	100	80	70	1	30
1930	100	74	49	**52**	17	11	32	100	100	87	70	2	34
1931	100	70	51	51	20	13	34	98	100	95	70	3	33
1932	100	77	51	58	22	12	37	100	100	96	70	4	39
1933	96	67	53	55	21	9	35	100	100	100	70	3	38
1934	100	68	39	54	20	10	37	100	100	100	70	27	40
1935	100	69	59	64	21	9	35	100	100	100	70	**66**	40
1936	100	71	64	69	24	11	38	100	100	100	70	90	51
1937	100	71	64	68	24	11	39	100	100	100	70	90	54
1938	100	71	60	68	26	10	39	100	100	100	70	89	55
1939	100	71	62	68	43	10	39	98	100	100	70	88	58
1940	100	68	57	67	**75**	8	36	97	100	100	70	90	59
1941	97	71	59	59	85	7	41	100	100	100	70	89	62
1942	95	70	56	67	86	14	37	100	100	100	70	81	60
1943	100	74	44	78	94	8	36	100	100	100	70	93	64
1944	100	74	48	88	94	7	38	100	100	100	70	91	72
1945	100	77	49	89	93	7	46	100	100	100	70	88	73
1946	100	79	86	91	93	7	**67**	100	100	100	70	88	75
1947	97	87	100	91	96	8	76	100	100	100	67	91	77
1948	96	89	100	93	94	7	84	100	100	100	70	92	78
1949	100	92	100	93	95	7	88	100	100	100	68	93	79

Notes: The canton of Jura used to be part of Bern and was only created as an independent canton in 1979, so it is not listed as a separate canton in this table. Canton abbreviations: ZU: Zürich; BE: Bern; LU: Luzern; UR: Uri; SZ: Schwyz; NW: Nidwalden; OW: Obwalden; GL: Glarus; ZG: Zug; FR: Fribourg; SO: Solothurn; BS: Basel-Stadt; BL: Basel-Land; SH: Schaffhausen; AR: Ap. Ausserrhoden; AI: Ap. Innerrhoden; SG: St.Gallen; GR: Graubünden; AG: Aargau; TG: Thurgau; TI: Ticino; VD: Vaud; VS: Valais; NE: Neuchâtel; GE: Genève; CH: Switzerland as a whole.
Source: Wespi (1962).

Table A.3: Secondary education: Dif in Dif "Jumps" estimates, discrete jumps only

	secondary education (1)	secondary education (2)	secondary education (3)	secondary education (4)
(High goiter) X	0.926***	-0.0809	0.430	0.895**
(Born after jump)	[0.309]	[0.380]	[0.364]	[0.363]
Cohort FE	YES	YES	YES	YES
District FE	YES	YES	YES	YES
District Trends	YES	YES	YES	YES
Separate Cohort FE for high goiter	NO	YES	NO	YES
Observations	2548895	2575567	883310	883310
R^2	0.092	0.092	0.064	0.064
		Males only		
	(1)	(2)	(3)	(4)
(High goiter) X	0.437	-0.123	1.08**	1.12**
(Born after jump)	[0.341]	[0.436]	[0.489]	[0.510]
Cohort FE	YES	YES	YES	YES
District FE	YES	YES	YES	YES
District Trends	YES	YES	YES	YES
Separate Cohort FE for high goiter	NO	YES	NO	YES
Observations	1254216	1254216	445538	445538
R^2	0.084	0.084	0.060	0.060
		Females only		
	(1)	(2)	(3)	(4)
(High goiter) X	1.24***	-0.0383	0.109	1.01*
(Born after jump)	[0.420]	[0.530]	[0.552]	[0.563]
Cohort FE	YES	YES	YES	YES
District FE	YES	YES	YES	YES
District Trends	YES	YES	YES	YES
Separate Cohort FE for high goiter	NO	YES	NO	YES
Observations	1321351	1321351	437772	437772
R^2	0.113	0.113	0.083	0.083

Notes: Coefficients correspond to changes in percentage points. Robust standard errors in brackets, clustered at the district-cohort level. High-goiter is an indicator variable for a district of birth within the top 25% of the population-weighted goiter distribution. *** p<0.01, ** p<0.05, * p<0.1

Source: Federal Statistical Office (1970) and Bircher (1883).

Table A.4: Tertiary education: Dif in Dif "Jumps" estimates, discrete jumps only

	tertiary education (1)	tertiary education (2)	tertiary education (3)	tertiary education (4)
(High goiter) X	1.29***	0.835***	0.475	0.708**
(Born after jump)	[0.223]	[0.258]	[0.300]	[0.315]
Cohort FE	YES	YES	YES	YES
District FE	YES	YES	YES	YES
District Trends	YES	YES	YES	YES
Separate Cohort FE for high goiter	NO	YES	NO	YES
Observations	2575567	2575567	883310	883310
R^2	0.030	0.030	0.016	0.016
Males only				
	(1)	(2)	(3)	(4)
(High goiter) X	0.256	0.456	0.370	0.869*
(Born after jump)	[0.330]	[0.390]	[0.474]	[0.505]
Cohort FE	YES	YES	YES	YES
District FE	YES	YES	YES	YES
District Trends	YES	YES	YES	YES
Separate Cohort FE for high goiter	NO	YES	NO	YES
Observations	1254216	1254216	445538	445538
R^2	0.032	0.032	0.022	0.022
Females only				
	(1)	(2)	(3)	(4)
(High goiter) X	2.20***	1.25***	0.688	0.717*
(Born after jump)	[0.280]	[0.332]	[0.421]	[0.432]
Cohort FE	YES	YES	YES	YES
District FE	YES	YES	YES	YES
District Trends	YES	YES	YES	YES
Separate Cohort FE for high goiter	NO	YES	NO	YES
Observations	1321351	1321351	437772	437772
R^2	0.034	0.034	0.019	0.019

Notes: Coefficients correspond to changes in percentage points. Robust standard errors in brackets, clustered at the district-cohort level. High-goiter is an indicator variable for a district of birth within the top 25% of the population-weighted goiter distribution. *** p<0.01, ** p<0.05, * p<0.1
Source: Federal Statistical Office (1970) and Bircher (1883).

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