The effects of the generalized use of iodized salt on occupational patterns in Switzerland

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Abstract

I estimate the long-term impact of the first large-scale nutritional supplementation program, salt iodization, which took place in Switzerland in the 1920s and 1930s. Iodized salt improved the health environment in utero, and it eradicated mental retardation caused by insufficient iodine intake. By exploiting variation in the pre-existing prevalence of iodine deficiency, as well as differences in the timing of the intervention across Swiss cantons, I show that cohorts born in previously highly deficient areas after the introduction of iodized salt were more likely to enter top-tier occupations with higher cognitive demands. As a result, wages of these cohorts were higher, accounting for about 1.9% of annual median earnings, or 2% of Swiss GDP per capita in 1991.

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1 Introduction

Nutrition is inextricably linked to a population's health capital. Malnutrition, especially when it occurs early in life, can have serious detrimental effects on a person's lifetime productivity and economic prospects. Micronutrient deficiencies are a common source of malnutrition, caused by insufficient intake of necessary vitamins and minerals. Iodine is one such micronutrient. This paper estimates the long-term impact of correcting iodine deficiency using the historical experience of Switzerland, which was heavily afflicted before the nationwide adoption of iodized salt in the 1920s and 1930s.

Lack of iodine causes many disorders, the most common of which is an enlargement of the thyroid gland when there is not enough iodine for the production of hormones which regulate metabolism. This enlargement is called a goiter. Other symptoms include short stature and deaf-mutism. However, the most important consequence of iodine deficiency is brain damage, which is irreversible and can go unnoticed in a population. Iodine deficiency results in various degrees of mental underdevelopment when it occurs in utero and early life. Cretinism, which is an acute form of mental retardation, often coupled with goiter and deaf-mutism, occurs when iodine deficiency in utero is most severe. I focus on the detrimental effects of iodine deficiency in utero and estimate the impact of improving the intrauterine health environment, via improving cognitive ability, on long-term outcomes.

Iodine deficiency is the leading cause of preventable mental retardation in the world today (for a recent assessment of the status of iodine deficiency disorders worldwide see Andersson, Karumbunathan and Zimmermann (2012)). The WHO estimates that nearly 50 million people suffer some degree of mental impairment due to a lack of iodine in their diets.[1] According to WHO's Global Database on Iodine Deficiency, nearly a third of the worldwide population, including 241 million children, receive inadequate amounts of iodine in their diet.[2] Despite ongoing efforts to decrease the prevalence of iodine deficiency, there are still

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

[2]Source: Andersson et al. (2012).

32 countries affected, and progress has been very slow in certain regions, especially in Africa. The most vulnerable areas are South Asia and Central and Eastern Europe (UNICEF 2008).

Although iodine deficiency is mostly eradicated in developed countries today,[3] the picture looked quite different in early 20th century. Many countries, for reasons related to their geography, had "pockets" of endemic iodine deficiency within their boundaries. For example, in the US, the area around the Great Lakes, as well as some Northwestern states, had rates of iodine deficiency that were similar to those recorded in the Swiss Alps. Indeed, Switzerland was the worst-afflicted country in the world, because its soil had been stripped of its iodine content in many localities during the last Ice Age.

This paper estimates the effects of iodine deficiency eradication on occupational patterns using data from the 1970 Swiss Census. Switzerland was the first country in the world to introduce iodized salt in 1922. It was the first large-scale, nationally coordinated nutritional supplementation program. Iodized salt proved a cost-effective measure to eradicate endemic goiters. 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 in addition to endemic goiter. As a result of the countrywide iodization campaign endemic cretinism was eradicated for cohorts born after 1930, deaf-mutism rates dropped significantly, and goiter disappeared in children and young army recruits (Bürgi, Supersaxo and Selz 1990). Salt iodization also had a significant impact on graduation rates of those born in highly-deficient areas, particularly females (Politi 2014). In this paper I find that long-term occupational outcomes were also affected, reflecting a shift towards higher-paying occupations with higher cognitive demands.

I combine data from the comprehensive 1970 Swiss Census with data on wages and occupational characteristics. I identify the effect of iodization on occupational outcomes by exploiting variation in the pre-existing prevalence of iodine deficiency, and also differences in the timing of adoption of iodized salt across Swiss cantons. My findings suggest that

[3] There are exceptions: recent data from Italy and the UK suggest that there is mild iodine deficiency in those countries (Andersson et al. 2012).

iodization accounts for about a third of the shift in occupational choices observed during this period. The implied effects on productivity are substantial; they correspond to 1.9% of median earnings, or 2% of Swiss GDP per capita in 1991.

The economics literature has made important contributions in the study of the "fetal origins hypothesis", the idea that conditions in utero matter for health outcomes later in life. These contributions consist not just of introducing methodological improvements, but also of expanding on the set of outcomes that researchers look into. Very often, these outcomes focus on early life and childhood. There are fewer studies looking at long-term outcomes. Almond and Currie (2011) describe analyses of long-term effects of interventions affecting fetal health as "low-hanging fruit", precisely because there is not much empirical evidence on that front. This paper addresses this gap directly. In addition, in considering the long-term effects of a nationwide policy intervention, rather than a rare natural experiment, such as a natural disaster, this paper speaks directly to policymakers, as well as to academics interested in population health.

The rest of the paper is organized as follows: Section 2 provides some background on iodine deficiency disorders and briefly describes the campaign for salt iodization in Switzerland. Section 3 describes the data that I use in my analysis. Section 4 outlines my identification strategy. I present the results of the main econometric analysis in section 5. Section 6 presents two robustness checks. I discuss my findings in section 7. Section 8 concludes.

2 Background on Iodine Deficiency Disorders and the Swiss Iodization Campaign

Iodine is a necessary micronutrient, found in very small quantities in the human body. Most of the body's iodine is located in the thyroid gland. Iodine is essential in the synthesis of the two thyroid hormones which regulate metabolism. These hormones "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, and it is one of the many symptoms of iodine deficiency. Goiters can occur at any point in one's lifetime, whenever iodine intake is not sufficient. Some goiters are reversible, especially in young individuals. Reversing goiter in adults is harder, especially when they have been subject to iodine deficiency for many years. I use historical data on goiter prevalence among military recruits across Switzerland as a measure of pre-existing geographical variation in iodine deficiency.

Goiter is a visible effect of iodine deficiency. Apart from goiter, however, iodine deficiency can have irreversible consequences if it occurs in utero and in the first three months of life. In this paper I focus on the in utero effect of iodine deficiency on cognitive ability and mental development. Iodine deficiency in utero results in various degrees of mental retardation and abnormal brain development, which could even go undetected in a population. Severe iodine deficiency can cause cretinism, an acute condition characterized by a combination of mental retardation, deaf-mutism, stunting, and physical deformation. In a widely publicized meta-analysis using 21 studies, Bleichrodt and Born (1994) estimate that the average IQ of iodine-deficient groups is 13.5 points lower than that of non-deficient groups. These medical studies are based, however, on observational data, so their correlational results are not the product of a pre-conceived research design. My econometric analysis uses a natural experiment related to the historical iodine supplementation program in Switzerland.

There is some evidence from the economics literature, which relies on natural experiments for "cleaner" identification, that iodine prophylaxis has sizable beneficial effects on cognitive ability. Feyrer, Politi and Weil (2013) find that iodization in the US can explain about a decade's worth of the "Flynn effect", the secular rise in IQ rates observed in developed countries over the course of the 20th century. Field, Robles and Torero (2009), looking at a recent iodine supplementation program in Tanzania, find that the intervention increased years of schooling for the affected cohorts, with larger estimated effects for girls. In this paper I focus on labor market outcomes such as occupational choice and occupational characteristics. Such longer-term outcomes have remained unexplored in the literature, either because of data limitations or because not enough time has passed from the onset of more recent supplementation efforts.

Endemic goiter and endemic cretinism are primarily due to the geographic location of a population. The main store of iodine is the ocean. As ocean water evaporates, iodine falls on the upper layers of soil through rainfall. Therefore, geographic areas close to the ocean are naturally rich in iodine. On the contrary, regions subject to heavy rain or intense glaciation in the past 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 such regions remains low. Regions naturally poor in iodine include mountainous areas such as the Andes, the Alps, the Pyrenees, and the Himalayas (Koutras, Matovinovic and Vought 1980). Because local geology (rather than individual behavior) is the main factor behind endemic iodine deficiency, pre-existing spatial variation in iodine deficiency is an exogenous determinant of the expected benefit from iodine supplementation.

In this paper I focus on the iodine supplementation program in Switzerland, which began in the 1920s. Due to its geography and geological history, Switzerland was known for its high prevalence of goiter and cretinism since ancient times.[4] 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. A survey conducted under Napoleon's orders showed an extremely high prevalence of cretinism in the population (Bürgi et al. 1990). Further studies revealed that Switzerland had a much higher rate of goiter and cretinism than any of its neighboring countries (Italy, France, Germany). The worst afflicted regions in Switzerland had rates of iodine deficiency which were comparable to deficient regions in many developing

[4]Roman writers mention it in their works. For example, Roman poet Juvenal (1st century AD) asked: "Quis tumidum guttur miratur in Alpibus?" ("Who wonders at a swelling of the neck in the Alps?"). Architect Vitruvius (1st century BC) wrote: "Aequiculis in Italia et in Alpibus nationi Medullorum est genus aquae, quam qui bibunt afficiuntur turgidis gutturibus." ("The Aequi in Italy and the Medulli in the Alps have a kind of water, from drinking which they get a swelling of the neck.") These quotes come from Langer (1960).

countries (see Kelly and Snedden (1960) for an account of the geographical distribution of endemic iodine deficiency many decades after the successful Swiss supplementation program).

Following many studies documenting the issue of goiter in Switzerland, 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 US.[5] Swiss data on goiter prevalence confirmed the link between iodine deficiency and goiter prevalence.[6] Right before his death in 1917, Theodor Kocher, a prominent professor of surgery in Bern and Nobel laureate for his work on the thyroid gland, advocated the treatment of goiter with small doses of iodine (Bürgi et al. 1990).

Thus, by the time iodized salt became widely available, medical science had established a link between iodine deficiency and endemic goiter. However, the crucial role of iodine in mental development was not understood until more than a century later. When large-scale interventions of iodine supplementation took place around the 1920s and after, the objective was goiter eradication. People did not know that they were also fighting against mental retardation, and iodized salt was advertised as a means to reduce goiters, especially in children. This is important for my identification, because cantonal authorities and parents did not know that by tackling iodine deficiency in utero they would improve the cognitive development of their offspring.

Iodized salt started circulating in Switzerland in 1922. Almost simultaneously, fortification of salt with iodine began in the USA, where iodized salt first appeared in 1924. Both interventions eliminated endemic cretinism and goiter in children, and they decreased goiter

[5]Ancient civilizations, such as the Greeks and the Chinese, used iodine-rich foods and plants, such as seaweed, to treat the swelling of the neck. Iodine has been explicitly used in the treatment of goiter since Bernard Courtois isolated it as an element in 1811.

[6]For example, Ticino had very low rates of iodine deficiency. Located in the southernmost part of Switzerland, Ticino borders Italy and enjoys a milder climate, proximity to the Mediterranean Sea and possibly more iodine-rich foods coming from Italy than the rest of the country. Another canton with unusually low goiter prevalence was Vaud. Historically, Vaud had an exclusive salt mine, which happened to be rich in iodine (Bürgi et al. 1990, p.581). The naturally occurring high iodine content of the salt produced in Vaud explains the low goiter prevalence there.

prevalence in adults. However, they were associated with an initial spike in goiter-related surgeries and deaths, which later subsided. Feyrer et al. (2013) document a near-doubling of the goiter-related death rate in the initial years of iodized salt circulation in the US.[7] In fact, after doctors started prescribing iodide to their patients in order to fight goiter, toxic side-effects resulting from over-dosing triggered opposition to the universal use of iodine (Bürgi et al. 1990). These large-scale nutritional supplementation programs, the first of their kind on both sides of the Atlantic ocean, were not without controversy.

The first Swiss canton to provide iodized salt was Appenzell-Ausserrhoden. Iodization there started in February 1922, with the initiative of a local doctor, H. Eggenberger. In June 1922, the Swiss Goiter Committee recommended the addition of small amounts of iodine in salt and the additional weekly consumption of iodine tablets by schoolchildren. In November 1922, the Swiss salt monopoly[8] started adding iodine to salt and selling the new product at the same price as non-iodized salt. Even before that date, though, iodine prophylaxis had become popular by means of tablets or other supplements. After the recommendations of the Swiss Goiter Committee and the success of salt iodization in Appenzell-Ausserrhoden, other cantons soon allowed the sale of iodized salt in their markets.

Not all cantons adopted iodized salt simultaneously, though. For instance, as early as 1925 iodized salt sales in Valais accounted for 63% of total salt sales. In the same year, iodized salt sales in Zürich accounted for 18% of total salt sales, and the corresponding number in Bern was a mere 4%. In some cantons, such as Aargau and Basel-Land, iodized salt sales did not exceed regular salt sales until the 1950s. In 1925 iodized salt sales exceeded regular salt sales in fewer than a quarter of Swiss cantons. By 1955 iodized salt sales exceeded 60% of total salt sales in all cantons, and in many of them only iodized salt was sold and consumed (Wespi 1962).

[7]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).

[8]United Swiss Rhine Salt Works (USRSW) was "the exclusive supplier of salt to 24 of the 25 cantons" of Switzerland, with the exception of Vaud (Bürgi et al. 1990, p.582).

The success of the iodization program was indisputable. According to Bürgi et al. (1990), "no new endemic cretins born after 1930 have been identified" (p.577). Deaf-mutism rates fell sharply for cohorts born after 1922 (see Politi (2014)). In Appenzell-Ausserrhoden, the first canton to provide iodized salt to its inhabitants, 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 (Bürgi et al. 1990).[9] In this paper I ask whether, in addition to health outcomes, iodization also affected the long-term occupational outcomes of cohorts exposed to it, through its effect on the health environment in utero. The following section describes the data that I use in my econometric analysis.

3 Data Description

3.1 Historical Data on Iodine Deficiency and Iodized Salt Sales

To identify the effect of iodization on occupational outcomes, I employ two sources of variation: the first is the naturally-occurring geographical variation in underlying iodine deficiency prior to the generalized use of iodized salt. The second source of variation arises because of differences in the timing of adoption of iodized salt across Swiss cantons.

I use historical data on goiter in army recruits as a source of information on the pre-existing geographical variation in iodine deficiency. In 1883, Swiss physician Heinrich Bircher published a monograph with details on the geographic variation in goiter rates across Switzerland (Bircher 1883). Over the period 1875-1880, he toured every municipality in Switzerland and recorded goiter cases in army recruits.

Bircher's monograph was eye-opening to public health authorities at the time, because it showed the extent of the problem across the country, and also the large variation in goiter prevalence, even among villages within a short distance from each other. The data

[9] For more information on iodine deficiency disorders and their eradication in Switzerland, see Politi (2014).

correlates well with independent measurements of the iodine content of water and soil across Swiss localities, as well as other goiter studies of the population that were done in a few locations (see, for example, von Fellenberg (1926), and the description in Politi (2014)). In section 6.2 I show that Bircher's goiter data correlate negatively with data on the iodine content of water from a few municipalities for which such data are available, and then use these data in a robustness check.

In my main analysis I use Bircher's data because it is superior to other measures of iodine deficiency in Switzerland. It is comprehensive, since it covers all of Switzerland. In addition, measurement is uniform across areas, since all measurements were taken by the same individual in roughly the same period. I have not found a better source of information on the geographic variation in iodine deficiency. For example, even though von Fellenberg (1926) contains a lot of data on the iodine content of rocks, food, and water across Switzerland, it is hard to compare the iodine content of different rocks or vegetables, and the data on the iodine content of water is only available for six municipalities.

Bircher's data are a great source of information on the geographic variation in iodine deficiency, but they cannot be interpreted literally, in the sense that goiter in recruits is generally much lower than goiter in the general population. This is because military data only include data on young, mostly healthy men. Goiters (and thyroid disorders in general) are much more common among women, and the size of a goiter tends to increase with age. In section A.1 I describe how I construct goiter prevalence measures from Bircher's raw data.

In order to minimize the effects of any measurement error in Bircher's data, rather than using the goiter rate directly, I use the data to group Swiss districts according to their goiter prevalence. Goiter prevalence serves as a proxy for underlying iodine deficiency in the population. I classify a district as being "high-goiter" if it belongs to the top 25% of the population-weighted goiter distribution. This corresponds to districts where goiter prevalence was 11.7% or higher. I expect iodization to affect high-goiter districts. On the contrary, I don't expect there to be a treatment effect for non-deficient districts.

Figure 1: Bircher's Data on goiter in recruits

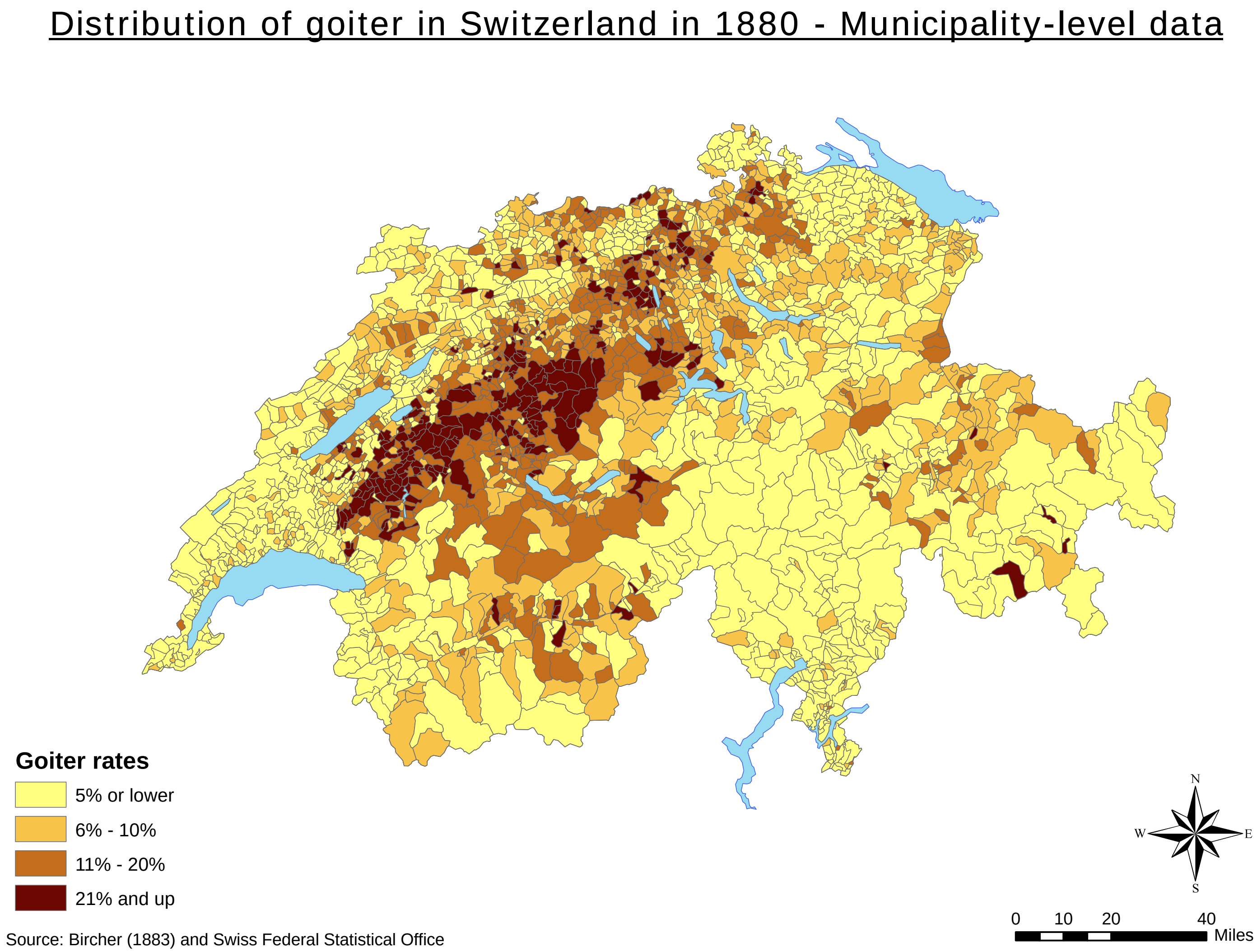


Figure 1 is a map of Switzerland, showing Bircher's data on the geographic variation in goiter. High goiter areas are mostly concentrated along the northern edge of the Alps. Regions closer to the Mediterranean were not deficient in iodine.[10] Table A.1 shows the population-weighted goiter rate in each canton, as well as the proportion of a canton's population that was born in high-goiter districts. As expected, iodine deficiency is geographically concentrated in a few cantons, with pockets of higher prevalence around the map.

The second source of variation that I use in my identification strategy relies on the timing of adoption of iodized salt. I use a panel dataset that documents iodized salt circulation across time in all Swiss cantons. The dataset contains the proportion of total salt sales that correspond to iodized salt from 1922 to 1961. It comes from a medical paper published in 1962 by H.J. Wespi, M.D. and Chief Doctor of Women's Clinic in Aarau (Wespi 1962). Table A.2 displays Wespi's data on iodized salt circulation.

Iodized salt first became available in 1922, but it was not adopted at the same time by all cantons. As Table A.2 shows, some cantons (e.g. Nidwalden and Schaffhausen) were early adopters, whereas other cantons, such as Aargau, Basel-Stadt, and Basel-Land were much slower. The sale of iodized salt had to be approved and allowed by each canton's constitution. Judging from the first year of non-zero iodized salt sales in each canton, not all cantons allowed the sale of iodized salt simultaneously. However, most cantons allowed the use of iodized salt already in 1923. Three more cantons followed suit in 1924, another in 1925, another in 1927, and two more in 1929. So there is not much variation in terms of legislative change at the canton level.

However, actual consumption of iodized salt differed greatly from canton to canton. For example, both Bern and Nidwalden allowed iodized salt to be sold in 1923. However, in Nidwalden there was only iodized salt sold from 1924 onwards, whereas consumption of iodized salt in Bern remained low for many years. In fact, iodized salt sales in Bern did not exceed regular salt sales until 1936. This variation in consumption of iodized salt provides

[10] For illustration purposes, missing municipalities data were assigned the average goiter prevalence in the corresponding district. In the econometric analysis all goiter data are aggregated to the district level.

a proxy of iodine treatment for each cohort born in each canton. As I describe in Section 4 on identification, historical data on changes in mortality and health care provision cannot predict the timing of iodized salt adoption. Thus, early or late adoption of iodized salt was not correlated with other changes in the health environment.

Figure 2 displays a series of six maps of Switzerland at different time periods, showing snapshots of Wespi's data on iodized salt circulation across Swiss cantons over time. Darker areas in the map correspond to higher consumption of iodized salt. As the maps in Figure 2 show, adoption of iodized salt did not follow a specific geographical pattern.

Wespi's iodized salt circulation data, displayed on Table A.2, show that, although iodized salt consumption for the country as a whole increased gradually, at the canton level iodized salt consumption took off within a short window of time, usually spanning two or three years. I use these sudden iodization events in my identification strategy, described in Section 4.

The one canton characteristic that does explain early or late adoption of iodized salt is the pre-existing prevalence of goiter. The data on goiter and iodized salt circulation show that high-goiter cantons adopted iodized salt later than the rest of the country. One plausible explanation for this pattern is that iodine supplementation was a controversial measure in its initial years. This was due to reports from other countries of a spike in thyroid-related deaths following iodine overdosage among older individuals with chronic iodine deficiency. For example, Feyrer et al. (2013) document a significant increase in deaths related to thyroid disease immediately following the introduction of iodized salt in 1924. These goiter deaths were triggered by iodine-induced hyperthyroidism in older individuals suffering from chronic iodine deficiency. It is, therefore, plausible that the medical community in the worst affected cantons was less enthusiastic in its endorsement of iodized salt, due to the perceived risks. Cantons where the stakes were higher are likely to be the ones where the transition took the longer to finally occur, since public debate on the issue would have been more heated, and the local medical community would not have been unanimous in its endorsement.[11]

[11] Politi (2014) provides a more detailed description of Bircher's data on goiter and Wespi's data on iodized salt circulation.

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

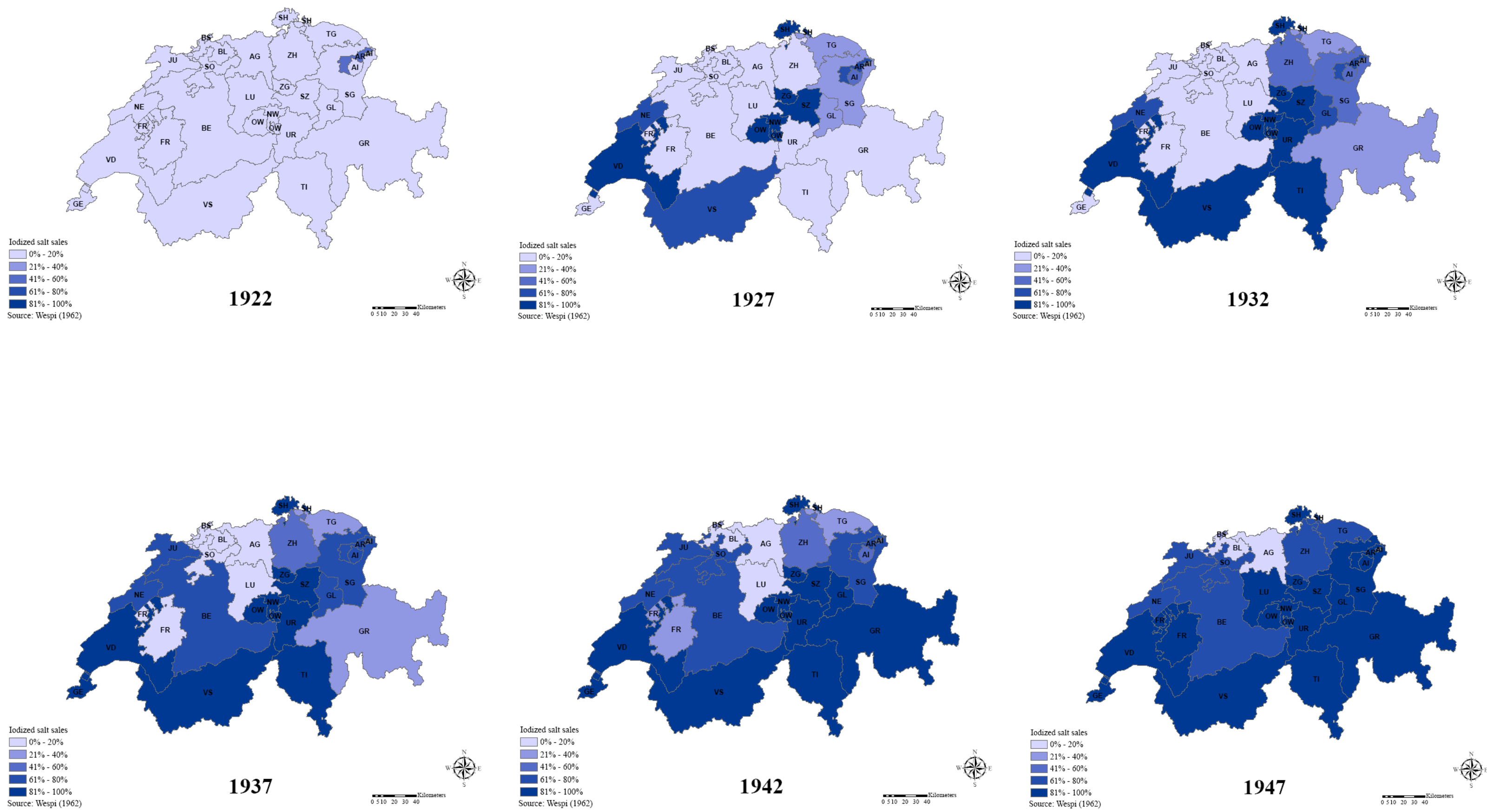


Table 1: Summary statistics, labor force and non-active individuals

	Employed	**Unemployed**	**Non-active**	**Total**
Males	1,143,788	1,742	51,084	1,196,614
Females	477,040	923	749,163	1,227,126
Total	1,620,828	2,665	800,247	2,423,740

Source: 1970 Swiss Census

3.2 The 1970 Swiss Census and Dictionary of Occupational Titles

I identify the effect of iodization on occupational choice using microdata from the 1970 Swiss Census (Federal Statistical Office 1970), which includes detailed information on a person's year and municipality of birth. Switzerland is a federation made up of 26 cantons, 184 districts and 2,896 municipalities. Apart from age and birth location, the Swiss Census records, among other things, detailed information on occupational outcomes (except for earnings), municipality of residence, and municipality of work.

The 1970 Swiss Census records an individual's municipality of birth. This low level of aggregation is particularly important, because endemic iodine deficiency was a very localized phenomenon, and it depended on the iodine content of a population's local sources of food and water. Municipalities within a short distance of each other might have had very different exposure to iodine before iodized salt was introduced, so it is important to know an individual's location of birth in as much geographic detail as possible.

I look at all individuals born in Switzerland from 1905 to 1945 (inclusive) whose occupation is recorded in the Swiss Census. Unfortunately, occupation is only recorded for people actively employed (both part- and full-time) at the time of the Census. This excludes most women in my sample, which is why I focus on males in my econometric analysis. Table 1 shows that less than 39% of females were active in the labor force in 1970. On the contrary, out of 1,196,614 males born in the period 1905-1945, 95.7% were active in 1970. Unemployment in this sample is extremely low, at 0.15%, and most non-active individuals are retired

Table 2: Broad occupational categories

	Occupational Category	Total	Percent
High-paying occupations	1: Legislators, senior officials, managers	83,833	7.34
	2: Professionals	78,508	6.88
	3: Technicians and Associate Professionals	171,644	15.03
	4: Clerks	158,118	13.85
	5: Service, shop and market sales workers	48,612	4.26
	6: Skilled agricultural and fishery workers	115,300	10.10
	7: Craft and related trades workers	312,020	27.33
	8: Plant/machine operators and assemblers	123,306	10.80
	9: Elementary Occupations	50,301	4.41
	Total	1,141,642	100

Source: 1970 Swiss Census

because they have reached legal retirement age. This is reassuring, since I am losing a very small part of the sample by focusing on currently employed individuals, and selection into employment is not a concern in this context.

The 1970 Swiss Census contains detailed information on each individual's occupation, using 4-digit codes according to the International Standard Classification of Occupations (ISCO). Using these data, I group individuals into 9 broad occupation categories, according to the first digit of their ISCO code. Table 2 shows the distribution of these occupational categories in the Swiss population. One of the outcomes that I use in the econometric analysis is an indicator variable for working in one of the top three occupational categories, which correspond to executive and managerial positions, senior officials and legislators, professionals such as physicians, engineers and lawyers, as well as technicians and associate professionals such as police inspectors, trade brokers, and health associates. These occupational categories have earned higher wages historically, compared to the other categories of occupations in the data. For example, in the second trimester of 2007, the annualized median income of full-time workers in these top categories was over 84,000 Swiss Franks (about 68,880 USD) or more, whereas the corresponding number for all other occupation categories was less than

65,000 Swiss Franks (about 53,300 USD).[12] About 29.3% of males are employed in the top tier occupational categories.

Unfortunately, the Swiss Census does not ask any income questions, so I do not have access to individual earnings data. As the next best solution, for the econometric analysis that follows, I assign to each individual in my sample median earnings by broad occupational category (as shown on Table 2), hours of work (full-time or part-time) and type of employment (self-employed, family company worker, paid employee, or apprentice), and use these imputed wages as an outcome variable. The earliest year for which such earnings data are available is 1991, which is 21 years after the Census. While this is not ideal, assuming that someone's line of work did not change drastically between 1970 and 1991, this approach will still give me a sense of the effect of iodization on earnings. This effect, though, will go through observed occupational choice and type of employment, rather than individual latent productivity.

I combine the occupational data of the 1970 Swiss Census with data on occupational characteristics compiled by Paula England and Barbara Kilbourne from the Dictionary of Occupational Titles for 1980 US Census Detailed Occupations (England and Kilbourne 1988).[13] These data contain scores on a variety of characteristics for all occupational codes used in the 1980 US Census. For example, occupations get scores according to verbal, numerical, as well as physical demands associated with each occupation. In order to match occupational characteristics to occupations listed in the 1970 Census, I first match occupational codes from the 1980 US Census with ISCO codes, which is the classification used in the Swiss Census. For many four-digit ISCO categories there were either no entries or no direct correspondence with US Occupational codes, so I aggregate ISCO codes to three-digit categories, and compute the average value of each characteristic in each category. I end up with 108 distinct occupations, and there are eight characteristics matched to each occupation.

[12] Source: Communication from the Swiss Federal Statistical Office.

[13] The dataset is available in electronic format and freely distributed by the Inter-university Consortium for Political and Social Research (ICPSR).

Table 3: Eight job characteristics: means and standard deviations for each occupational category

ISCO category	**Manual Dexterity**	**Motor Coordination**	**Physical Demands**	**Strength**	**Spatial Aptitude**	**Numerical Aptitude**	**Verbal Aptitude**	**Intelligence**
1	2.21	2.19	0.75	1.70	2.33	3.15	3.74	2.84
	(0.07)	(0.06)	(0.23)	(0.13)	(0.10)	(0.07)	(0.08)	(0.09)
2	2.53	2.41	1.04	1.75	3.15	3.74	4.35	3.43
	(0.54)	(0.31)	(0.63)	(0.31)	(0.70)	(0.47)	(0.21)	(0.24)
3	2.55	2.59	1.36	1.86	2.69	3.15	3.50	2.61
	(0.46)	(0.40)	(0.70)	(0.33)	(0.59)	(0.37)	(0.31)	(0.26)
4	2.68	3.10	1.77	1.50	2.25	2.70	3.15	2.18
	(0.10)	(0.44)	(0.21)	(0.42)	(0.13)	(0.13)	(0.09)	(0.07)
5	2.56	2.51	1.44	2.26	2.32	2.63	2.88	1.94
	(0.17)	(0.28)	(0.36)	(0.27)	(0.25)	(0.35)	(0.23)	(0.21)
6	2.51	2.28	3.07	3.47	3.04	2.62	2.75	2.29
	(0.07)	(0.06)	(0.16)	(0.08)	(0.12)	(0.10)	(0.06)	(0.13)
7	3.21	2.87	2.68	2.84	3.11	2.63	2.74	1.99
	(0.21)	(0.08)	(0.55)	(0.39)	(0.31)	(0.20)	(0.15)	(0.10)
8	2.84	2.75	2.04	2.69	2.62	2.30	2.53	1.78
	(0.09)	(0.14)	(0.17)	(0.24)	(0.19)	(0.21)	(0.20)	(0.21)
9	2.90	2.47	2.33	3.16	2.43	2.13	2.33	1.53
	(0.06)	(0.13)	(0.29)	(0.30)	(0.09)	(0.17)	(0.11)	(0.10)
Total	2.76	2.68	2.01	2.38	2.70	2.74	3.02	2.21
	(0.38)	(0.80)	(0.74)	(0.74)	(0.49)	(0.45)	(0.53)	(0.47)

Notes: Source: 1970 Swiss Census, and England and Kilbourne (1988)

I look into occupational characteristics which broadly correspond to various physical and cognitive demands of occupations (following the methodology of Case and Paxson (2006)). The variables corresponding to physical requirements are manual dexterity, motor coordination, physical demands (such as climbing, kneeling, and reaching), and strength. The variables related to the cognitive requirements of a given occupation are spatial, verbal, and numerical aptitude, as well as intelligence. Following Case and Paxson (2006), in some cases I reverse-coded some of these variables, so that a higher value always corresponds to higher requirements for a given characteristic in an occupation. Values for each characteristic typically range from 1 to 5, except for physical demands, where values range from 0 to 4, and motor coordination and intelligence, where values range from 1 to 4.

Cognitive requirements such as verbal and numerical aptitude tend to have higher values for occupations in upper ISCO categories (1, 2, 3), whereas the opposite is true for physical requirements such as manual dexterity and strength. Table 3 lists average scores and standard deviations for each job characteristic for each broad ISCO category in the Swiss Census. For example, legal professionals (a sub-category of ISCO category 2, which includes lawyers and judges) have really high scores for numerical and verbal aptitude (4.2 and 4.4 respectively). On the contrary, this occupational category only has a score of 0.4 for physical demands, and 1.2 for strength. On the other hand, agricultural laborers (part of ISCO category 9) have scores of 2 and 2.2 for numerical and verbal aptitude, whereas they have scores of 2.9 and 3.5 for physical demands and strength.

These occupational characteristics are, as one would expect, highly correlated with each other. Instead of using all of them in my econometric analysis, I conduct factor analysis on them, in order to capture the main underlying dimensions over which occupations differ from each other. This exercise delivers two factors with eigenvalues higher than 1.[14] These first two factors correspond to two indices for each occupation, and they are linear combinations of the occupational characteristics listed above. The two indices summarize the cognitive

[14]According to the Kaiser criterion in factor analysis, factors with eigenvalues equal or higher to 1 should be retained.

Table 4: Factor Analysis on Occupational Characteristics: Factor Loadings

Characteristic	**Factor 1: Cognitive Demands**	**Factor 2: Physical Demands**	**Uniqueness**
Intelligence	0.9561	-0.0646	0.0816
Verbal Aptitude	0.9541	-0.1672	0.0617
Numerical Aptitude	0.9431	0.0400	0.1090
Spatial Aptitude	0.4227	0.8067	0.1706
Strength	-0.7662	0.3412	0.2966
Physical Demands	-0.5658	0.7050	0.1829
Motor Coordination	-0.1063	0.7664	0.4014
Manual Dexterity	-0.4334	0.8027	0.1678

Source: England and Kilbourne (1988)

and physical demands for each occupation.

Tables 4 and 5 show the results of the factor analysis. I use principal components factoring and rotate the factor loadings so that, by construction, the two factors are not correlated with each other. The two factors together capture 81.6% of the total variance observed across 108 occupational categories in eight occupational characteristics. Table 4 shows the correlation of each characteristic with each of the two factors, as well as the idiosyncratic variance of each characteristic, which is not shared with the other variables (uniqueness). Factor 1 is defined by characteristics such as intelligence and verbal aptitude, whereas it is negatively correlated with characteristics such as strength and physical demands. As such, it captures the cognitive demands of an occupation. I call this factor "Cognitive Demands of Occupation" and use it as an outcome variable in my econometric analysis.

On the contrary, Factor 2 is more heavily defined by characteristics pertaining to physical demands and is negatively correlated with intelligence and verbal aptitude. Spatial aptitude also plays a significant role for Factor 2. I refer to Factor 2 as "Physical Demands of Occupation", and I used it as an outcome variable in a robustness check.

Table 5 shows how each characteristic is used to create the two indices, one for the

Table 5: Factor Analysis on Occupational Characteristics: Scoring Coefficients

Characteristic	Factor 1: Cognitive Demands	Factor 2: Physical Demands
Intelligence	0.25506	0.06846
Verbal Aptitude	0.24417	0.02389
Numerical Aptitude	0.26202	0.11235
Spatial Aptitude	0.19697	0.39150
Strength	-0.17521	0.07031
Physical Demands	-0.08371	0.24785
Motor coordination	0.04819	0.32073
Manual Dexterity	-0.03764	0.30347

Source: England and Kilbourne (1988)

Table 6: Cognitive and Physical Demands Indices by Occupational Category: means and standard deviations

ISCO category	Cognitive Demands	Physical Demands
1	0.8000	-1.2448
	(0.1104)	(0.2855)
2	1.8331	0.2608
	(0.4169)	(1.5166)
3	0.8009	0.0000
	(0.3247)	(1.4090)
4	0.0893	-0.0185
	(0.1954)	(0.5601)
5	-0.2681	-0.3399
	(0.3878)	(0.5827)
6	-0.4313	0.4060
	(0.1487)	(0.1130)
7	-0.3214	1.4322
	(0.2937)	(0.5050)
8	-0.6242	0.3037
	(0.2382)	(0.3160)
9	-1.2139	-0.0268
	(0.2581)	(0.2090)
Total	0.0172	0.4382
	(0.7780)	(1.0518)

Sources: 1970 Swiss Census, and England and Kilbourne (1988) cognitive and one for the physical demands of each occupation. Each occupation gets a "score" for each factor, which is a linear combination of the occupational characteristics, each multiplied by the coefficients shown in Table 5. The cognitive index, as expected, places a big weight on cognitive characteristics, while it weighs physical demands negatively. The physical index, on the contrary, gives relatively bigger emphasis on characteristics focusing on physical demands.

After I construct the two indices, I combine the data with the Swiss Census, so that each individual who is active in the labor force is matched with an index measuring the cognitive demands of his occupation, and another index measuring the physical demands. Table 6 shows means and standard deviations for the two occupational indices by broad occupational category in my sample. The two indices vary quite a bit within each singe-digit occupational category, taking values ranging from -2.4 to 2.7.

In addition to occupational outcomes, in my econometric analysis I also look at individual migration choices, and in particular urban-rural migration for work. I take advantage of the rich information on location of birth, work and residence (all at the municipality level) available in the Swiss Census to construct an indicator variable switching on for those individuals working in a capital municipality, conditional on not being born in one. About a quarter of those not born in a capital city end up working in one in my sample.

Section 4, which follows, outlines my identification strategy.

4 Identification strategy

I identify the effect of iodization on long-term outcomes by relying on two sources of variation. First, there was pre-existing variation in the prevalence of iodine deficiency for exogenous reasons related to each location's geological history. By using Bircher's data on goiter in recruits I am able to focus on districts that were heavily affected by iodine deficiency disorders, and thus stood to benefit the greatest from the generalized use of iodized salt. On the contrary, I do not expect less deficient districts to benefit as much from iodization.

The second source of variation that I use in my identification strategy comes from the fact that the adoption of iodized salt did not happen simultaneously across Switzerland. Contrary to the USA, where a national iodization campaign and heavy marketing by salt manufacturers made iodized salt available quickly around the country, in Switzerland it was up to every canton to allow the sale of iodized salt within its jurisdiction. Table A.2 in the Appendix contains Wespi's iodine circulation data. As described in section 3.1, there was not much variation in terms of the change in the legislative framework, allowing the sale of iodized salt. Actual consumption of iodized salt differed greatly from canton to canton, though. This variation in consumption of iodized salt gives me a proxy of iodine treatment for each cohort in each canton.

The outcomes that I look at focus on occupational choice, and its link with cognitive ability. First, I look at the probability of selecting into a top tier occupational category. Using the 9 broadly-defined categories outlined in section 3.2, I create an indicator variable switching on for individuals employed in the top three occupational categories, comprised of managerial, professional, and technical professions. Consistent with the predictions of Roy's model of occupational choice (Roy 1951), I expect treated individuals to be more likely to sort into occupations with higher cognitive demands, which traditionally have higher remuneration.

Second, I look at the whole range of occupations, and their cognitive demands. As described in section 3.2, I assign each occupation (using 3-digit ISCO classifications) an index of its cognitive demands, which comes from Factor Analysis of eight occupational characteristics. I expect treated individuals' occupations to have higher cognitive demands, since their comparative advantage increased in that direction post-iodization.

Third, I use imputed wages to measure the effect of iodization on earnings. I use median earnings data aggregated according to an individual's broad occupational category (9 classifications as described in section 3.2), hours worked (full-time or part-time), and type of employment (self-employed, family company, or paid employed). In most specifications I focus on full-time workers. I expect earnings to increase for treated individuals, because of their sorting into higher-paying occupations.

Finally, I look for evidence of increased spatial mobility of treated individuals towards destinations with higher earnings potential. In particular, I examine whether individuals work in a capital city, conditional on not being born in one. If capital cities have a higher concentration of high-earnings, high-ability jobs, and they offer more or better labor market opportunities for individuals with higher levels of human capital, I expect treated individuals to be more likely to migrate to capital cities for work. Indeed, wages in my sample are about 8% higher for individuals who work in a capital city.[15]

My sample consists of all Swiss-born males, born between 1905 and 1945 (inclusive) and interviewed in the 1970 Swiss Census. I focus on males since, as described in section 3.2, most females in 1970 were not active in the labor force. For occupational choice outcomes I only use those individuals that were employed in 1970, because occupational data were recorded only for them. My results are thus conditional on being active in the labor market. However, as described in section 3.2, selection into employment is not an issue in this particular context. The unemployment rate in my sample is 0.15%, and most non-active individuals are retired due to age (the retirement age is 65).[16]

In order to estimate the in utero effect of iodization, I regress individual outcomes on iodized salt sales as a percentage of total salt sales one year prior to birth in one's canton of birth. In particular, I estimate the following model for an individual i born in canton c in district d in year t:

$$outcome_{icdt} = \alpha + \beta \cdot SALT_{ct} + \gamma \cdot HGSALT_{cdt} + controls_{cdt} + \epsilon_{icdt} \tag{1}$$

[15] I also constructed the variable at the district level, limiting the sample to those not born in a district containing a capital municipality, and generating an indicator variable which switches on for those who end up working in such a district. The estimation results are very similar.

[16] Assuming that severely deficient individuals opted out of the labor force prior to iodization, selection into employment would introduce downwards bias to my estimates.

where:

$SALT_{ct}$ is the percentage of iodized salt sales in canton of birth, one year prior to birth.

$HGSALT_{cdt} = SALT_{ct} \cdot I(\text{High goiter})_d$ is the percentage of iodized salt sales interacted with a high goiter district indicator variable.

$controls_{cdt}$ are:

ζ_t: Cohort of birth fixed effects.

δ_c: Canton of birth fixed effects.

$HG_{cd} = \delta_c \cdot I(\text{High goiter})_d$: Canton-specific fixed effects for high goiter districts.

$\theta_{ct} = \delta_c \cdot (\text{Year of birth})_t$: Canton-specific time trends.

I cluster standard errors at the birth canton level to control for within-canton serial correlation.

The coefficient on $SALT_{ct}$ gives the effect of iodization for low goiter districts. It measures the effect of iodized salt sales going from 0 to 100% of total salt sales in these districts. The coefficient on $HGSALT_{cdt}$ gives the difference in the effect of iodization between low- and high-goiter districts. The sum of the coefficients on $SALT_{ct}$ and $HGSALT_{cdt}$ gives the total effect of iodization in high-goiter districts. Cohort of birth fixed effects control for cohort-specific shocks that equally affect everyone born in Switzerland in the same year. Canton of birth fixed effects control for permanent canton characteristics, and I allow these characteristics to be different for high-goiter districts within a canton. In addition, I add canton-specific linear trends to control for gradual changes in outcomes, that are not related to the impact of iodization.

The model in equation 1 controls for many confounding factors that might be biasing the estimated effect of iodization. One might worry that the timing of adoption of iodized salt by each canton was correlated with the health environment in each canton. My identification strategy is immune to permanent regional differences in the demand and supply of health; canton fixed effects deal with this concern. My identification strategy is also immune to nationwide changes in the demand or supply of health, to the extent that those are absorbed by cohort fixed effects. I also control for gradual changes at the canton level that could impact labor market outcomes, by including canton-specific trends.

The identifying assumption is that, within the window of time when iodized salt started circulating widely, there were no other changes in health conditions at the canton level, which affected highly deficient districts differentially from non-deficient districts. In order to make sure that this identifying assumption is satisfied, I next focus on the small window of time when iodized salt became widely used in each canton. By focusing on these canton-specific iodization events I get "cleaner" identification. I am able to estimate the causal effect of salt iodization by comparing outcomes shortly before and shortly after the iodization event in each canton.

A quick look at the data on Table A.2 reveals that, although iodized salt consumption for the country as a whole increased gradually, at the canton level mass consumption of iodized salt occurred within a short window of time, usually spanning two or three years (though this window occurs at different times across cantons). I use these sudden iodization events in order to identify the effect of iodization. I define the iodization event in each canton as the first year in which iodized salt sales exceeded 50% of total salt sales. In almost all cantons this year corresponds to the best-fitting structural break in the time series of iodized salt sales. I describe the details of picking the year of the iodization event in section A.2 of the Appendix. These iodization events are, on average, associated with a rise in iodized salt sales from 20% to around 65% of total salt sales within a couple of years (see Figure 3).

I employ a Comparative Interrupted Time Series Design (CITSD) to estimate the effect of the iodization event on outcomes. This is similar to a Differences-in-Differences approach, but I am able to also control for canton-specific trends. In particular, I estimate the following model for an individual i born in canton c in district d in year t:

$$outcome_{icdt} = \alpha + \beta \cdot HGTREATED_{cdt} + \gamma \cdot TREATED_{ct} + controls_{cdt} + \epsilon_{icdt} \quad (2)$$

where:

$HGTREATED_{cdt} = I(\text{High goiter})_d \cdot I(\text{Born after iodization event})_{ct}$ is an indicator variable for being born after iodization event in a high goiter district.

$TREATED_{ct} = I(\text{Born after iodization event})_{ct}$ is an indicator variable for being born after iodization event in canton of birth.

$controls_{cdt}$ are same as before: ζ_t (cohort fixed effects), δ_c (canton fixed effects), HG_{cd} (canton fixed effects for high goiter districts), and θ_{ct} (canton-specific time trends).

As before, I cluster standard errors at the birth canton level to control for within-canton serial correlation.

Equation 2 identifies the effect of the iodization event within each canton, and focuses on high-goiter districts. As mentioned above, iodization events are, on average, associated with an increase in iodized salt sales of about 45 percentage points, from 20% to 65%. In order to back out the full effect of iodization, I employ an Instrumental Variables approach, instrumenting treatment (iodized salt sales one year prior to birth in canton of birth) with assignment to treatment (indicator variable switching on for those cohorts born after the iodization event in each canton). This approach normalizes the reduced form effect estimated by the model in equation 2 by dividing it with the first stage estimates of the impact of the iodization event on iodized salt sales. For this estimation strategy I redefine one's age relative to the iodization event in each canton, and I then allow for pre-iodization and post-iodization trends to differ. In more detail, I use Two Stage Least Squares to estimate the following model for an individual i born in canton c in district d in year t:

$$outcome_{icdt} = \alpha + \beta \cdot SALT_{ct} + \gamma \cdot HGSALT_{cdt} + controls_{cdt} + \epsilon_{icdt} \tag{3}$$

where, as before:

$SALT_{ct}$ is the percentage of iodized salt sales in canton of birth, one year prior to birth.

$HGSALT_{cdt} = SALT_{ct} \cdot I(\text{High goiter})_d$ is the percentage of iodized salt sales interacted with a high goiter district indicator variable.

$SALT_{ct}$ and $HGSALT_{cdt}$ are the treatment variables, and they instrumented by variables defining assignment to treatment:

$TREATED_{ct} = I(\text{Born after iodization event})_{ct}$, and

$HGTREATED_{cdt} = I(\text{High goiter})_d \cdot I(\text{Born after iodization event})_{ct}$

$controls_{cdt}$ are: ζ_t (cohort fixed effects), δ_c (canton fixed effects), HG_{cd} (canton fixed effects for high goiter districts), as well as:

$\lambda_{ct} = (\text{Year of birth})_t - (\text{Year of iodization event})_c$: Age relative to iodization event in canton of birth. This controls for a linear pre-iodization trend.

$\kappa_{ct} = TREATED_{ct} \cdot \lambda_{ct}$: Age relative to iodization event for those born post-iodization. This allows for a different linear trend post-iodization.

Standard errors, as before, are clustered at the birth canton level to control for within-canton serial correlation. I also estimate specifications with quadratic trends, where I include λ_{ct}^2 and κ_{ct}^2 as additional controls.

The model in equation 3 identifies the total effect of iodization in high goiter districts using the iodization event in each canton. As in equation 1, the total effect of iodization for high goiter districts is the sum of the coefficients on $SALT_{ct}$ and $HGSALT_{cdt}$. The exclusion restriction imposes that the variables $TREATED_{ct}$ and $HGTREATED_{cdt}$ are not correlated with the error term in equation 3, and only affect the outcomes because they predict treatment. Equation 3 already includes canton and cohort fixed effects, as well as trends, as controls. In other words, the identifying assumption is that, within the short window of time when iodized salt was adopted in each canton, nothing else changed discontinuously in such a way that high goiter districts benefited more than low-goiter districts within a given canton.

In order to alleviate any remaining concerns that adoption of iodized salt was correlated with *changes* in the health environment, in a way that somehow impacted highly deficient areas more than the rest of the country, I have also collected canton-level historical data on health, in order to show that changes in various measures of demand and supply of health do not predict the date of iodization for each canton. The historical data on canton-level health provision that I have been able to find are the following: mortality from six infectious diseases (smallpox, scarlet fever, measles, typhoid fever, diphtheria, whooping cough), infant mortality, infant mortality from intestinal disease, births per midwife, residents per doctor, and residents per dentist.[17] I use two different measures of adoption of iodized salt: the first year when iodized salt circulated in a canton, and the first year in which sales of iodized salt exceeded 50% of total salt sales. I find no evidence that changes in mortality and medical personnel can predict the timing of adoption of iodized salt.[18] The exact timing of adoption of iodized salt thus appears to be idiosyncratic and unrelated to changes in other variables that might have affected the health environment in utero.

5 Results

Table 7 shows the estimates of linear regressions of individual outcomes on iodized salt in one's canton of birth one year prior to one's birth. In high goiter districts iodization increased the probability of sorting into a top tier occupational category by 3.10 percentage points. About 29% of individuals in my sample are employed in such occupations, so this is a significant increase of more than 10%. When iodized salt sales go from 0 to 100% of total salt sales, the index of cognitive demands of occupations increases by about 0.06 points, and this effect is statistically significant. The cognitive demands index ranges from -2.14 to 2.53, with an average of 0.0177 and a median value of -0.12. The estimate impact of iodization on this index corresponds to about 8% of a standard deviation. The impact on gross earnings is also

[17] These historical data are available from the Swiss Federal Statistical Office.

[18] Results are available from the author upon request. Only measures of infant mortality weakly predict early adoption of iodized salt. In particular, a decrease in infant mortality over the 1920s is weakly correlated (at the 10% significance level) with earlier take-up of iodized salt (take-up is defined as the first year in which sales of iodized salt exceeded 50% of total salt sales). This is not a surprising result, and it is consistent with the medical literature linking iodine deficiency to stillbirths. Thus, this correlation is consistent with the hypothesis that iodization improved the intrauterine environment, resulting in fewer stillbirths and lower neonatal mortality.

Table 7: The effect of iodized salt on long-term outcomes: OLS

	TOP TIER OCCUPATION (1)	COGNITIVE DEMANDS (2)	WAGE (3)	MIGRATION (4)
Effect of iodized salt in high goiter districts	3.10***	0.0552***	798***	2.28**
	[0.862]	[0.0161]	[269.8]	[1.06]
High goiter X Iodized salt	2.93***	0.0542***	763.3**	2.42***
	[0.700]	[0.0145]	[316.7]	[0.741]
Iodized salt	0.169	0.00102	34.70	-0.132
	[0.443]	[0.00656]	[147.2]	[0.888]
Outcome sample average	29.28	0.0177	58,156	24.8
Cohort FE	YES	YES	YES	YES
Canton FE	YES	YES	YES	YES
Canton FE X High goiter FE	YES	YES	YES	YES
Canton Trends	YES	YES	YES	NO
Observations	1,137,706	1,073,964	1,137,706	886,404
R-squared	0.026	0.042	0.031	0.018

Notes: *** p<0.01, ** p<0.05, * p<0.1; Top tier occupations include managers, professionals, technicians and associate professionals. Columns (1) and (4) correspond to percentage point changes. Iodized salt is the percentage of iodized salt sales over total salt sales in canton of birth one year prior to birth. High-goiter districts are those at the top 25% of the population-weighted goiter distribution. In column (3), the median wage is 55,200 Swiss Francs. Clustered standard errors in brackets, robust to within-canton serial correlation.

statistically significant, and estimated at 798 Swiss francs (1991 values), which is 5.7% of a standard deviation, or 1.38% of the average wage (or 1.44% of the median). Taken together, these results suggest that iodization had a significant impact on occupational outcomes on individuals born in previously deficient districts, through its effect on cognitive ability and the health environment in utero.

The effect of iodization on the probability of migrating for work is statistically significant and estimated at 2.28 percentage points, but only if canton trends are not included in the model. Including canton trends absorbs the effect of iodization, so this result is not robust to the most demanding specification.

Next, Table 8 displays the estimation results of model 2, employing a Comparative Interrupted Time Series Design for different cohort ranges. As Figure 3 shows, the iodization event corresponds to an average increase in iodized salt consumption from 20% to about 65%. Comparing the entire period before and after the iodization event, iodized salt sales increase by 55 percentage points (see Table 9). Given that the model in equation 2 estimates the effect of a smaller increase in iodized salt consumption, I expect the point estimates in Table 8 to be lower than the estimates in Table 7. I also note that, given that iodized salt continues to increase after the iodization event, I expect the point estimates to be higher when more cohorts enter the regression, compared to the estimates than only use a restricted range of cohorts around the timing of the iodization event. This is because the estimator in equation 2 compares average outcomes of cohorts born before and after iodization, so the post-iodization average increases when cohorts exposed to higher levels of iodized salt are included in the sample.

Table 8 confirms that iodization events significantly affected cohorts born in high goiter districts. As expected, the point estimates in Table 8 are smaller in magnitude than the estimates in Table 7, and they generally increase when the age range increases. Panel A of Table 8 shows that the probability of sorting into a top tier occupation increases by 1.82 percentage points if one is born after iodization in a high goiter district. The point estimate increases by progressively increasing the range of cohorts from 5 to 20 years around the iodization event, from 1.11 to 1.76 percentage points. Panel B shows qualitatively similar results for the cognitive demands index. For individuals born after iodization in high goiter districts, the index of cognitive demands associated with their occupation increases by 0.0344, and this is a statistically significant increase. Panel C of Table 8 shows results for wages. I limit the sample to full-time workers.[19] Annual gross wages increase by 582 Swiss francs (1991) for those born in high goiter districts after iodization. Panel D of Table 8 shows that labor migration was not affected by iodization. The estimated effects, displayed in percentage point changes, are practically zero, and even turn negative (though insignificant)

[19] There are 34,940 part-time workers and 288 apprentices in the data, corresponding to 3.1% of the sample. Most of the individuals in these categories are either in the beginning or in the end of their professional lives (younger than 30 or older than 55 years old). Results are similar when I include these workers in the sample.

for some cohort ranges.

Table 8: Comparative Interrupted Time Series Design

	All cohorts (1)	Born +/-5 yrs from event (2)	Born +/-10 yrs from event (3)	Born +/-15 yrs from event (4)	Born +/-20 yrs from event (5)
PANEL A: TOP TIER OCCUPATIONAL CATEGORY					
High goiter X Treated	1.82***	1.11**	1.14***	1.59***	1.76***
	[0.487]	[0.400]	[0.359]	[0.344]	[0.378]
Treated	-0.188	0.168	0.121	0.0616	-0.191
	[0.401]	[0.340]	[0.247]	[0.280]	[0.301]
Cohort FE	YES	YES	YES	YES	YES
Canton FE	YES	YES	YES	YES	YES
Canton X High goiter FE	YES	YES	YES	YES	YES
Canton trends	YES	YES	YES	YES	YES
Observations	1,141,642	263,312	501,007	703,607	868,020
R-squared	0.026	0.023	0.022	0.022	0.023
PANEL B: COGNITIVE DEMANDS OF OCCUPATION					
High goiter X Treated	0.0344***	0.0318***	0.0251***	0.0326***	0.0334***
	[0.00931]	[0.00752]	[0.00506]	[0.00451]	[0.00560]
Treated	-0.00363	0.00533	0.00391	-0.00101	-0.00515
	[0.00543]	[0.00615]	[0.00433]	[0.00410]	[0.00407]
Cohort FE	YES	YES	YES	YES	YES
Canton FE	YES	YES	YES	YES	YES
Canton X High goiter FE	YES	YES	YES	YES	YES
Canton trends	YES	YES	YES	YES	YES
Observations	1,077,720	248,116	472,815	664,552	819,861
R-squared	0.042	0.033	0.034	0.036	0.037

Continued on next page

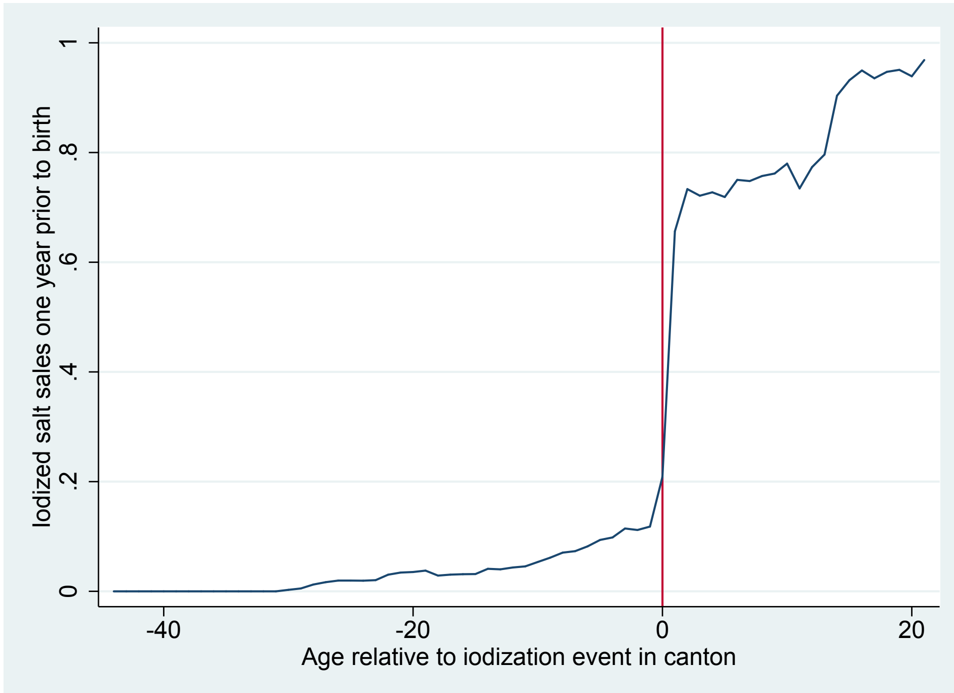
Table 8 – *Continued from previous page*

	All cohorts (1)	Born +/-5 yrs from event (2)	Born +/-10 yrs from event (3)	Born +/-15 yrs from event (4)	Born +/-20 yrs from event (5)
PANEL C: WAGE					
High goiter X Treated	582.4***	364.8***	350.6**	501.1***	533.9***
	[187.2]	[54.35]	[146.7]	[174.4]	[179.9]
Treated	-107.1	66.30	-27.97	-75.24	-106.1
	[131.0]	[70.11]	[72.50]	[92.86]	[103.2]
Cohort FE	YES	YES	YES	YES	YES
Canton FE	YES	YES	YES	YES	YES
Canton X High goiter FE	YES	YES	YES	YES	YES
Canton trends	YES	YES	YES	YES	YES
Observations	1,106,432	258,266	490,481	687,449	845,860
R-squared	0.027	0.027	0.025	0.023	0.023
PANEL D: MIGRATION FOR WORK INTO CAPITAL CITY					
High goiter X Treated	0.677	0.168	-0.345	-0.259	0.0476
	[0.676]	[0.636]	[0.254]	[0.201]	[0.397]
Treated	-0.00325	-0.115	-0.0337	0.0752	-0.0559
	[0.287]	[0.335]	[0.270]	[0.253]	[0.257]
Cohort FE	YES	YES	YES	YES	YES
Canton FE	YES	YES	YES	YES	YES
Canton X High goiter FE	YES	YES	YES	YES	YES
Canton trends	YES	YES	YES	YES	YES
Observations	889,754	204,423	388,266	544,315	674,166
R-squared	0.018	0.015	0.016	0.017	0.017

Notes: *** p<0.01, ** p<0.05, * p<0.1; Coefficients in Panels A and D correspond to changes in percentage points.; Panel C includes full-time workers only. Clustered standard errors in brackets, robust to within-canton serial correlation.

Finally, I employ an Instrumental Variables approach in order to estimate the full effect of iodization, as outlined in section 4 (equation 3). Table 8 showed the reduced form effect of iodization events across Swiss cantons. Figure 3 illustrates the first stage relationship and Table 9 shows related estimation results. It is no surprise that assignment to treatment is a very strong predictor of treatment. For individuals born right after the iodization event, iodized salt sales are on average 45 percentage points higher compared to individuals born

Figure 3: Iodized salt sales before and after iodization event



in the same canton in the previous year. Iodized salt sales post iodization are, on average, 55 percentage points higher than before iodization.

Table 10 displays results from Two Stage Least Squares estimation. The effect of iodization is identified off the sudden increase in iodized salt intake marking each canton's transition into its generalized use. The coefficients correspond to the effect of iodized salt going from 0 to 100% of total salt sales. I allow for different trends before and after the iodization event, and I employ both linear and quadratic trend specifications. Quadratic trends increase the point estimate of iodized salt, which estimates the impact of iodization in less deficient districts, but they don't change the estimate on the interaction of iodized salt and the high goiter district indicator variable, which measures the difference in the effect of iodization between high goiter districts and the rest of the country. The estimated effect of iodized salt in high goiter districts is statistically similar to the OLS estimates of Table 7, though the specifications employing quadratic trends generally produce higher point estimates.

It is clear from Table 10 that salt iodization had a statistically significant and quanti-

Table 9: First stage estimates: Effect of iodization event on iodized salt sales one year prior to birth

	(1) All districts	(2) High goiter only
Treated	0.548***	0.567***
	[0.000359]	[0.000608]
Constant	0.198***	0.187***
	[0.00121]	[0.000710]
Cohort FE	YES	YES
Canton FE	YES	YES
Trends	Linear	Linear
Observations	1,192,628	298,442
R-squared	0.935	0.952
F-statistic	254697	125296

Notes: Notes: *** p<0.01, ** p<0.05, * p<0.1; Clustered standard errors in brackets, robust to within-canton serial correlation.

tatively big impact on occupational outcomes in the most deficient districts. Looking at the effects for occupational outcomes in specifications with quadratic trends (columns (2), (4), and (6) of Table 10), salt iodization increased the probability of selecting into a top tier occupational category by 4.27 percentage points. Given that the baseline probability of entering these occupations in my sample is around 29%, this is a big effect of almost 15%. The cognitive demands index in high goiter districts also increased by 0.08 points, or 10% of a standard deviation, as a result of iodization. Gross annual earnings (for full-time workers) increase by 1,070 Swiss francs (in 1991 values), which is about 1.9% of annual median earnings for full-time workers. Taken together, these results suggest that salt iodization had a big impact on occupational outcomes of treated cohorts through its effect on cognitive ability and the health environment in utero.

Table 10: The effect of iodized salt on long-term outcomes: Two-stage Least Squares

	TOP TIER OCCUPATION		COGNITIVE DEMANDS		WAGE		MIGRATION	
	Linear Trends (1)	Quadratic Trends (2)	Linear Trends (3)	Quadratic Trends (4)	Linear Trends (5)	Quadratic Trends (6)	Linear Trends (7)	Quadratic Trends (8)
Effect of iodized salt in high goiter district	2.75***	4.27***	0.0458***	0.0787***	880.6***	1,070***	1.16	1.75*
	[0.756]	[0.774]	[0.0129]	[0.0150]	[277.5]	[371.5]	[1.26]	[1.00]
High goiter X Iodized salt	3.08***	3.18***	0.0610***	0.0633***	1,114***	1,120***	2.30***	2.36***
	[0.437]	[0.513]	[0.00984]	[0.0112]	[276.6]	[262.0]	[0.832]	[0.802]
Iodized salt	-0.332	1.09**	-0.0153	0.0155	-233.7	-50.80	-1.14	-0.606
	[0.625]	[0.510]	[0.00936]	[0.00988]	[220.3]	[175.8]	[0.726]	[0.776]
Cohort FE	YES	YES	YES	YES	YES	YES	YES	YES
Canton FE	YES	YES	YES	YES	YES	YES	YES	YES
Canton FE X High goiter FE	YES	YES	YES	YES	YES	YES	YES	YES
Observations	1,137,706	1,137,706	1,073,964	1,073,964	1,102,553	1,102,553	886,404	886,404
R-squared	0.026	0.026	0.042	0.042	0.026	0.026	0.018	0.018

Notes: *** $p<0.01$, ** $p<0.05$, * $p<0.1$; Top tier occupations include managers, professionals, technicians and associate professionals. Coefficients for top tier occupation and migration correspond to percentage point changes. Iodized salt is the percentage of iodized salt sales over total salt sales in canton of birth one year prior to birth. High-goiter districts are those at the top 25% of the population-weighted goiter distribution. Columns (5) and (6) include full-time workers only. Clustered standard errors in brackets, robust to within-canton serial correlation.

Migration into a capital city (for the subsample of individuals not born in one) seems to have been affected differently in high goiter areas compared to the rest of the country, suggesting a possible impact of iodization on urban-rural migration patterns. However, these coefficients are not robust when the sample is restricted to smaller cohort ranges around the iodization events, contrary to the other outcomes.[20]

In the next section I present two robustness checks: first, I estimate the effect of iodization on Factor 2 of the Factor Analysis on occupational characteristics (see section 3.2 for a description of Factor 2). Then, I use an alternative measure of iodine deficiency, the iodine content of water, which is a measure available for a limited set of municipalities. In section 7 I interpret and discuss the findings from the main econometric analysis of this section.

6 Robustness checks

6.1 Physical Demands of Occupations

As described in section 3.2, Factor Analysis on occupational characteristics results in two Factors. Factor 1 is defined by cognitive demands such as intelligence and verbal and numerical aptitude, it is negatively correlated with physical demands such as strength, and it is used in the main analysis to identify the causal effect of iodization on occupational outcomes. Factor 2, which I call Physical Demands, is more mixed, and it is positively correlated with physical demands of occupations. I do not expect this index of occupational characteristics to be affected by iodization.

I conduct the same econometric analysis as the one described in section 4, and, as expected, I find no evidence of an effect of iodization on this index. Table 11 presents estimation results. Column (1) displays the OLS estimates of the effect of iodized salt. Column (2) presents estimates of the Comparative Interrupted Time Series Design, which identifies the effect of iodization events. Columns (3) and (4) present Two Stage Least Squares estimates

[20] These extended results are available upon request from the author.

Table 11: Robustness Check: Physical demands of occupations

			2SLS	
	OLS	CITSD	Linear Trends	Quadratic Trends
	(1)	(2)	(3)	(4)
Effect of iodized salt in high goiter districts	-0.00798	-	-0.0259	-0.00620
	[0.0149]		[0.0188]	[0.0195]
High goiter X Iodized salt	-0.00269	-	-0.0140	-0.0125
	[0.0132]		[0.0112]	[0.0101]
Iodized salt	-0.00529	-	-0.0119	0.00631
	[0.0111]		[0.0130]	[0.0147]
High goiter X Treated	-	0.00135	-	-
		[0.00880]		
Treated	-	-0.00342	-	-
		[0.00701]		
Cohort FE	YES	YES	YES	YES
Canton FE	YES	YES	YES	YES
Canton FE X High goiter FE	YES	YES	YES	YES
Canton Trends	YES	YES	-	-
Observations	1,073,964	1,077,720	1,073,964	1,073,964
R-squared	0.009	0.009	0.008	0.008

Notes: *** $p<0.01$, ** $p<0.05$, * $p<0.1$; Iodized salt is the percentage of iodized salt sales over total salt sales in canton of birth one year prior to birth. High-goiter districts are those belonging to the top 25% of the population-weighted goiter distribution. Low-goiter districts are those belonging to the bottom 25% of the population-weighted goiter distribution. Clustered standard errors in brackets, robust to within-canton serial correlation.

of the effect of iodized salt on the Physical Demands index of occupations. Consistent with the hypothesis, there is no evidence of an effect of iodization on this index. If anything, the point estimates are negative, though they are not statistically significant.

6.2 Iodine Content of Water

Bircher's dataset on goiter rates in recruits, which I use in my main econometric analysis, is the most comprehensive and consistent source of information on iodine deficiency and its spatial variation across Switzerland prior to iodization. In this section I use a different source

Table 12: Iodine content of water and goiter rates

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).

of variation, the iodine content of water, as recorded in von Fellenberg (1926).

Von Fellenberg's article, published in 1926, contains a lot of information on the iodine content of different rocks, soil, locally grown foods, and water across different localities in Switzerland. It is hard to use in its entirety, because comparisons of the iodine content of different types of rock, soil, and foods are hard, and it is not as comprehensive as Bircher's monograph. However, there is information on the iodine content of drinking water from six municipalities across Switzerland. Table 12 presents the data, along with the corresponding goiter figures in the same municipality and the relevant district from Bicher's monograph, for comparison purposes. Municipalities where the iodine content of water is higher are also those where there is little goiter.

I use the data on the iodine content of water and run similar specifications to those described in Sections 4 and 5. I first regress outcomes on the amount of iodized salt one year prior to birth, as well as the interaction of iodized salt one year prior to birth and the iodine content of water in the municipality of birth. Then I focus on the major iodization event in each canton, and, in similar fashion, I check whether the iodine content of water

Table 13: Robustness check: Iodine content of water

	TOP TIER OCCUPATION (1)	COGNITIVE DEMANDS (2)	WAGE (3)	MIGRATION (4)
<u>PANEL A: OLS</u>				
Iodine content of water X Iodized salt	-7.646***	-0.172**	-1,722*	-6.963
	[0.008]	[0.032]	[0.088]	[0.252]
Iodized salt	12.59***	0.213***	1,852	6.591
	[0]	[0]	[0.24]	[0.536]
Cohort FE	YES	YES	YES	YES
Municipality FE	YES	YES	YES	YES
Observations	38,141	35,217	38,141	8,811
R-squared	0.021	0.034	0.021	0.010
<u>PANEL B: CITSD</u>				
Iodine content of water X Treated	-5.138**	-0.118*	-1,196*	-5.320
	[0.044]	[0.052]	[0.064]	[0.164]
Treated	7.891***	0.136***	1,199	4.710
	[0.004]	[0.004]	[0.16]	[0.408]
Cohort FE	YES	YES	YES	YES
Municipality FE	YES	YES	YES	YES
Observations	38,141	35,217	38,141	8,811
R-squared	0.021	0.034	0.021	0.010

Notes: *** p<0.01, ** p<0.05, * p<0.1; Clustered p-values in brackets, computed using the 6-point wild cluster bootstrap proposed by Webb (2013) to allow for within-municipality serial correlation. Top tier occupations include managers, professionals, technicians and associate professionals. Columns (1) and (4) correspond to percentage point changes.

affected the impact of iodization on treated cohorts. I expect areas where the iodine content of water was higher to be *less* affected by iodization. I add cohort and municipality of birth fixed effects in all specifications. There are only six municipalities in this analysis, so there are very few clusters in the data. For this reason I use the 6-point wild cluster bootstrap, as recommended by Cameron and Miller (2015) and described in Webb (2013), to allow for within-municipality serial correlation. Table 13 displays the results. Consistent with the hypothesis and with the results of the main analysis, the higher is the iodine content of water in a municipality, the less it benefited from iodized salt.

7 Interpretation and discussion of findings

The results presented in section 5 imply that the in utero effects of iodization on cognitive ability were substantial. This section discusses my main findings.

Table 14 displays some summary statistics on the proportion of individuals sorting into top tier occupations and the average value for the cognitive demands index before and after iodization events, for high goiter districts and the rest of the country. For individuals born in high goiter districts, the proportion selecting into top tier occupations increased by 5.46 percentage points. Looking at the estimates in Table 8, almost a third (31.5%) of this change can be explained by increased consumption of iodized salt. Similarly, increased consumption of iodized salt explains almost a fifth of the change in the cognitive demands index over this period.

The estimated effects on wages are quantitatively very large. One must remember that the numbers correspond to imputed wages rather than earnings data recorded at the individual level. Thus, the main sources of wage variation in my data are an individual's occupational choice and type of employment (self-employed, family company employee, apprentice, or paid employee). Still, the results on wages are useful if one wants to put a monetary value related to increased productivity due to iodization. The estimates for wages in Table 3 place the effect of iodization in the order of 2% of Swiss GDP per capita in 1991 (the year that the earnings data were collected).[21] This number corresponds to increased earnings for a quarter of the Swiss population in a single year. The present value of increased earnings over the duration of one's working life is a much bigger value.

It is worth noting that the estimates in section 5 only refer to the effect of iodization in utero. This is when cognitive ability and foetus development are compromised if there is iodine deficiency. However, there are other conditions arising from iodine deficiency that occur at other points in life, and which can be reversible. For example, young children

[21] According to data from the Swiss Federal Statistical Office, Swiss GDP in 1991 in current prices was 54,687 Swiss francs.

Table 14: Change in occupational choice and characteristics after iodization

	High goiter districts		**Rest of Switzerland**	
	Born before iodization	**Born after iodization**	**Born before iodization**	**Born after iodization**
Proportion going into top tier occupations	0.2582	0.3128	0.2890	0.3291
	(0.4376)	(0.4636)	(0.4533)	(0.4699)
Cognitive Demands	-0.0626	0.1011	0.0007	0.1141
	(0.7566)	(0.8021)	(0.7692)	(0.8013)

Notes: Standard deviations in parentheses. Source: 1970 Swiss Census, England and Kilbourne (1988), and Wespi (1962)

Table 15: Effect of iodization on cohort size

	OLS		CITSD	
	(1) Cohort size	(2) Log of cohort size	(3) Cohort size	(4) Log of cohort size
Effect of iodized salt in high goiter districts	22.09	0.0217	-	-
	[54.24]	[0.0735]		
High goiter X iodized salt	14.45	0.0220		
	[52.40]	[0.0576]	-	-
Iodized salt	7.642	-0.000288		
	[11.68]	[0.0309]		
High goiter X Treated	-	-	9.304	0.0323
			[34.66]	[0.0266]
Treated	-	-	4.027	0.00203
			[8.974]	[0.0196]
Cohort FE	YES	YES	YES	YES
Canton FE	YES	YES	YES	YES
Canton*HG FE	YES	YES	YES	YES
Canton trends	YES	YES	YES	YES
Observations	7,561	7,561	7,585	7,585
R-squared	0.356	0.395	0.355	0.391

Notes: *** p<0.01, ** p<0.05, * p<0.1; Iodized salt is the percentage of iodized salt sales over total salt sales in canton of birth one year prior to birth. High-goiter districts are those belonging to the top 25% of the population-weighted goiter distribution. Low-goiter districts are those belonging to the bottom 25% of the population-weighted goiter distribution. Clustered standard errors in brackets, robust to within-canton serial correlation.

that were born before iodization but were treated with iodine would have seen their goiters disappear or decrease in size. In fact, iodized salt was promoted in order to tackle the prevalence of goiters, not in order to fight mental deficiencies. The continuum of IQ loss associated with iodine deficiency was not established by the scientific community at that time. To the extent that iodine treatment, administered after birth, further improved productivity, decreased medical bills, etc, I am underestimating the full effect of iodization by focusing on the cognitive channel.

A potential issue is selection into my sample. In particular, in the medical literature iodine deficiency has been linked to stillbirths, though the medical evidence relies on observational data. If cohort size increased after iodization, it will introduce downwards bias to my estimates, as the pre-iodization sample is positively selected on survival. I check whether cohort size at the district level is affected by iodization. In particular, I run similar specifications to those employed in my main econometric analysis to check whether iodization affected cohort size in high goiter districts. Table 15 displays the results, both for absolute cohort size, as well as for the log of cohort size in a district. Similar to the main econometric analysis, I present results from an OLS regression of cohort size on iodized salt circulation, but I also employ a Comparative Interrupted Time Series Design to focus on the effect of abrupt iodization events. Although the point estimates for high goiter districts are higher than for the rest of the country, suggesting a positive effect of iodization on cohort size, they are not statistically significant.

In terms of internal validity, my identification relies on the assumption that there were no other within-canton changes that occurred at the same time window as iodization and affected high goiter areas differently than the rest of the country. The evidence from historical data on changes in mortality and health provision suggests that the timing of the iodization events cannot be predicted, which is reassuring. In addition, assignment to treatment is based entirely one's canton and cohort of birth. Given that iodized salt did not circulate in order to enhance cognitive ability, it is not likely that births were timed with the iodization event in mind. From the point of view of individuals born around that time, assignment to treatment is plausibly exogenous.

I am identifying the effect of iodization off an event that increases sales from around 20% to around 65%. This means that the individuals that are born before the event do get some iodine, just not as much as the cohorts born post-iodization. If the effect of iodization is non-linear, and small quantities of iodine have larger effects initially, then I am underestimating the effect of iodization.

One potential issue with the sample is that cantons with a high concentration of high goiter districts tended to adopt iodized salt later than most other cantons. This is not a threat for my identification strategy, since the latter is immune to permanent cross-canton differences (such as risk aversion of the medical community towards the new salt, for example). However, it does mean that, for high goiter districts, there are not as many cohorts born after the iodization event as for the rest of the country. This decreases power, and it makes it harder to identify a statistically significant effect.

As to the external validity of the results, my estimates come from a national nutritional supplementation policy intervention, rather than an isolated, rare historical incident, or a small-scale event. In addition, Switzerland experienced rates of iodine deficiency that are comparable to those encountered in deficient areas of Latin America, Eastern Europe and Asia today (see Kelly and Snedden (1960) for the worldwide distribution of iodine deficiency in the 1960s, as well as UNICEF (2008) for a more recent account). This is reassuring in terms of both relevance and external validity. My estimates speak directly to ongoing efforts to combat iodine deficiency disorders in many parts of the world today.

8 Concluding remarks

The Swiss Iodization Campaign was the first nationally-coordinated nutritional supplementation program. Indeed, salt iodization preceded all other large-scale supplementation programs, such as the addition of vitamins A and D to milk, or the addition of niacin in flour, which began in the 1930s (Bishai and Nalubola 2002). Iron-fortified baby formula and calcium-fortified juice came much later. Salt iodization started in 1922 in Switzerland, followed very closely by the USA in 1924. Yet the impact of salt iodization on long-term outcomes has not been studied before.

My econometric analysis shows that iodization had sizeable effects for the treated populations. The cost-effectiveness of providing universal prophylaxis with iodized salt is indisputable, even if one only takes into account the lower hospitalization costs of people with thyroid disorders. The biggest boost from iodization, however, comes from its substantial impact on the economy resulting from improved cognition and increased productivity.

My analysis speaks directly to policymakers who are involved in ongoing efforts to eradicate iodine deficiency today. Rates of iodine deficiency in Switzerland were comparable to those in other deficient regions around the world, many of which are still affected by iodine deficiency disorders. Apart from evaluating the impact of a policy and informing current supplementation efforts, though, the Swiss Iodization Campaign serves as a rare glimpse of the impact of a plausibly exogenous increase in cognitive ability. In that light, iodine deficiency eradication was an “injection of IQ” for the Swiss population.

In related work (Politi 2014) I show that iodization improved schooling outcomes mainly for females, whereas estimated effects for males are less robust. This is also in line with related literature on the effects of a more recent iodine supplementation program in Tanzania (Field et al. 2009), where the effect on years of schooling for females is higher than for males. Taking into consideration this paper’s findings, I conclude that, even though there is little evidence that iodization greatly affected male schooling, it had a significant impact on longer-term, post-schooling outcomes, such as occupational choice. Females, on the contrary, and in the particular historical context of Switzerland, did not capitalize increased schooling into improved occupational outcomes; most women did not enter the labor force during the period of examination. These remarks raise interesting questions regarding, for example, women's selection into employment over time (see, for example, Mulligan and Rubinstein (2008)), or whether, historically and in specific socio-economic contexts, females benefited from improved cognition and more schooling in other ways, such as better matching in the marriage market.

The fight against iodine deficiency has made tremendous steps in the past 20 years, but there are ongoing efforts for the eradication of iodine deficiency disorders worldwide. Given the obvious cost-effectiveness of universal salt iodization, and the findings of this paper on its long-term economic impact, the obvious conclusion is that eradicating iodine deficiency is a low-hanging fruit, which should be a priority for governments and health-promoting organizations working in iodine deficient regions of the world.

Appendix

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 municipality/district 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 municipality/district. 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 municipality/district. This number is then divided by the total population in that municipality/district in 1880, and then multiplied by 100 to provide a percentage. The formula for computing the prevalence of goiter in a municipality/district (locality) is therefore:

$$\text{goiter in locality} = \frac{\text{number of goitrous recruits in locality} \times 100 \times 100}{6 \times \text{population in locality}}.$$

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%.

Note that, other than dividing the raw goiter data by the district population, the rest of the transformation does not affect the ordering of districts according to their goiter prevalence, and is not necessary for the econometric analysis in the main text.

Table A.1 presents summary statistics on the goiter rate and the population in each canton, as well as the proportion of each canton's population that was born in a high-goiter district. 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.

A.2 Iodization events

I define an "iodization event" in a canton 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. Table A.2 shows panel data on iodized salt circulation, taken from Wespi (1962). For each canton, the iodization event is shown in bold. Iodized salt sales in Basel-Stadt, Basel-Land and Aargau did exceed regular salt sales until 1954, 1950, and 1952 respectively, so all cohorts born in those cantons are considered untreated.

The cantons for which the iodization event 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 year of the iodization event, when iodized salt sales went from 46% to 67% of total salt sales. In Valais, I treat 1925 as the year of iodization, 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.

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

Canton	Goiter rate in canton (weighted by 1970 population)	Male canton population	Proportion in high-goiter districts
Zürich	8.72	153,846	0.06
Berne	14.35	203,766	0.60
Luzern	13.32	65,809	0.88
Uri	1.97	9,415	0
Schwyz	4.64	21,704	0
Obwalden	4.24	7,000	0
Nidwalden	4.87	6,218	0
Glarus	4.87	9,971	0
Zug	9.71	10,653	0
Fribourg	20.13	54,062	0.94
Solothurn	7.37	48,211	0.15
Basel-Stadt	7.45	36,948	0
Basel-Landschaft	5.31	28,497	0
Schaffhausen	3.04	14,597	0
Ap. Ausserrhoden	5.35	14,494	0
Ap. Innerrhoden	3.37	5,208	0
St. Gallen	5.77	89,087	0
Graubünden	3.58	39,801	0
Aargau	13.87	85,266	0.64
Thurgau	2.43	39,321	0
Ticino	1.16	42,076	0
Vaud	1.98	83,518	0
Valais	5.72	49,494	0
Neuchâtel	5.28	29,510	0
Genève	1.50	29,881	0
Jura	2.96	18,261	0
Total Switzerland	8.50	1,196,614	0.25

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

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).

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