Salt Iodization and the Enfranchisement of the American Worker*

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Abstract

In 1924, The Morton Salt Company began nationwide distribution of iodine-fortified salt. Access to iodine, a key determinant of cognitive ability, rose sharply. We compare outcomes for cohorts exposed *in utero* to iodized salt with those of slightly older, unexposed cohorts, across states with high versus low iodine deficiency rates prior to salt fortification. Labor force participation rose by 0.6 percentage points, driven by a rise in low-skill employment. Educational attainment declined by 0.09 years, mainly due to decreased primary school completion, consistent with the hypothesis that cognitive ability and schooling are substitutes at low levels of schooling.

Keywords: early life, cognitive ability, iodine, labor force participation, wage distribution
JEL Codes: I12, I15, I18, J24, N32

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1 Introduction

Inadequate access to essential micronutrients such as iron, vitamin A, iodine, and zinc in low-income countries has staggering costs in terms of mortality, poor health, and lost productivity (Black et al., 2013). The short-term health benefits of improving micronutrient availability, especially for young children, are clear (Bhutta et al., 2013), but little is known about impacts in the long run. Moreover, few studies have examined the impacts of large-scale supplementation or eradication campaigns.[1] How long do the effects of improved access to vital micronutrients last? If health effects do persist, do they spill over onto socioeconomic outcomes? Which individuals are most affected by blanket campaigns? These questions are still largely unanswered.

In this study, we draw lessons from the historical experience of the United States, where natural access to iodine, an essential micronutrient, was scarce in many areas of the country until the mid-1920s. Iodine regulates thyroid hormone availability, which determines the density of fetal neural networks (Lamberg, 1991). Medical studies suggest that iodine deficiency affects cognitive function at all ages, but is particularly detrimental during gestation, when even mild deficiency can greatly hamper cognitive development (Cao et al., 1994). Moreover, the effects of fetal iodine deficiency disorder (IDD) are irreversible: an inadequate supply of iodine in the first trimester of gestation permanently reduces intelligence quotients (IQ), regardless of subsequent supplementation (Hetzel and Mano, 1989; Pharoah and Connolly, 1987; Zimmermann et al., 2005).[2]

We study the education, labor force, and income distribution impacts of rapid, large-scale salt iodization in the twentieth century US. The Morton Salt Company, the largest salt producer in the US, initiated nationwide iodized salt distribution shortly after the invention of iodine-fortified salt in the early 1920s. In less than half a decade, the US went from zero to nearly universal availability of iodized salt (Markel, 1987). Iodine deficiency rates plummeted in the following decade, most markedly in areas that were highly iodine deficient prior to the introduction of iodized salt (Brush and Atland, 1952; Hamwi et al., 1952; Schiel and Wepfer, 1976). Feyrer et al. (2013) show that IQ may have risen substantially–up to 15 points–as a result. We ask: what happened to the economic outcomes of those

[1] Notable recent exceptions are Feyrer et al. (2013), Politi (2011b), and Politi (2011a), which we will discuss in detail. Much of the available evidence is from the INCAP longitudinal study (Martorell, 1995), which followed Guatemalan children from 4 small villages over 20 years, some of whom were exposed to a nutrient intervention *in utero* and in early life, and others who were given a placebo.

[2] It bears mention that studies from the medical literature are correlational: causal evidence on the effects of iodine exposure in humans is limited. The study by Feyrer et al. (2013) is important in this sense, because it provides the most rigorous evidence to date of the impact of fetal iodine access on adult cognitive performance.

whose *in utero* access to iodine improved? Did increased IQ affect schooling choices? Were labor supply and wages impacted significantly, and which parts of the income distribution did salt iodization most affect?

We use a simple difference in differences strategy to identify these effects. We compare outcomes for cohorts born just before iodization (1920-1923) to those born during (1924-1927) and after (1928-1931), across areas with varying pre-iodization deficiency rates. For the latter source of variation, we use pre-iodization rates of goiter, the main physical manifestation of IDD (Love and Davenport, 1920; Olesen, 1929). States with low goiter rates pre-iodization are appealing as a control group for the following reason. For normal cognitive functioning to be achieved, fetal iodine levels need to be above a "protective threshold" (Cao et al., 1994; Eltom et al., 1985; Furnee, 1997). Before salt fortification, iodine access was wholly determined through the amount of naturally occurring iodine in food. In areas where access to iodine through food was already adequate, additional iodine through salt fortification should have no *cognitive* effect, since most individuals were already above the protective threshold. We follow these cohorts through their productive lives, from ages 25 to 55, using data from the 1950-1980 censuses. We perform a variety of robustness checks in support of our claim that observed differences in trends are causally related to salt iodization.

We begin with educational attainment. We obtain the surprising result that schooling decreased significantly by nearly .1 years as a result of salt iodization. This impact is driven by primary school and junior high completion, which declined by roughly .6 to .9 percentage points respectively. The effect on high school completion is also negative, though not precisely estimated across most specifications. The impacts on college completion are fairly tightly bound around 0. The negative schooling effects are strongest – nearly twice as large – in states with blue-collar (industrial) economies.

We argue that these impacts are consistent with both the biological mechanism of iodine's *in utero* impact and with the hypothesis that at low levels of schooling, cognitive ability and education are substitutes. Given the threshold-type dose response to iodine, blanket access to iodized salt likely had a very targeted impact–at the bottom of the ability distribution. Those individuals who were previously below the protective threshold were pulled up above it, shifting the left tail of the ability distribution to the right. If cognitive ability endowments and education inputs are substitutes at low levels of schooling, this rightward shift would generate a decrease in the optimal years of schooling for the targeted population. Put another way, the returns to an additional year of education for a low-ability type are likely low. If ability and schooling are substitutes in the determination of, for example, a blue-collar wage, then the low-ability individual whose endowment has increased due to salt iodization may choose less education at the margin.

Results on employment, occupational choice, and income distributions are consistent with this interpretation. Labor force participation rose by .6-.7 percentage points, driven mainly by an increase in low-skill employment. Working in low-wage positions, these labor force joiners swelled the bottom of the income distribution.

Patterns of heterogeneity in these results show that impacts were most pronounced for non-whites and females entering blue-collar jobs. Specifically, the largest increases in labor force participation and entry into blue-collar jobs occurs for females and non-whites; while the decreases in schooling are concentrated in states with the largest blue-collar employment shares. Though a *reduction* in educational attainment at lower levels of schooling and a *rise* in low-wage blue-collar employment as a result of an *increase* in cognitive ability might seem, at first, surprising, these results are both strongly consistent with, and even help to explain in part, existing stylized facts and historical trends identified by previous studies in the literature. Goldin and Margo (1992) report that an increased demand for low-skilled labor and a rise in education and skills among the existing labor force (predominantly white males), lead to a compression in wages across white and blue collar jobs during the 1940s, 50s and 60s. This "Great Compression," which significantly reversed only after the 1960s, incentivized new labor force participants (namely non-whites and females during this time) to forego primary and secondary schooling and enter the labor force earlier, taking up blue-collar jobs.

Goldin (1999) shows, consistent with both our findings of stronger impacts among non-whites and females and the low return to primary and secondary schooling among new workforce entrants during this time, that school enrollments for females aged 5-19 start to fall below that of male counterparts after 1930, despite being nearly identical to male enrollment rates during the first 3 decades of the 20th century. Similarly, Goldin (1999) finds that, although school enrollment rates for non-whites aged 5-19 of both sexes begin to converge to those of whites in the first 2-3 decades of the 20th century, this convergence slows by nearly 50% (from 5 pp/decade to 3 pp/decade) between 1920 and 1950. Finally, similar facts and trends have been identified for labor force participation and income across race and gender during this time period. Killingsworth and Heckman (1987) show that females born in 1930 enter the workforce at an earlier age and stay in the workforce longer than females born in 1920. That is, females born in 1930 are nearly 10 percentage points more likely to be working at ages 20 and 50 than those born in 1920. This of course coincides perfectly with our treatment and also with the largest rise in labor force participation of married women in US history from 1950-1960, a rise of nearly 10 percentage points or 50% from the baseline. Additional analysis presented in Killingsworth and Heckman (1987) shows that a large portion of this increase in labor force participation among women during this period was due to an increase in part-time work in blue-collar manufacturing jobs. Butler and Heckman (1977) show that black women participated in the labor force at a rate 50% higher than white women during the late 1940s and early 1950s and black men participated at the same rate as white men, but both black men and women earned roughly 50% less than their white counterparts, consistent with a higher participation in blue-collar jobs.

Our results add to the growing literature on the long-term effects of early-life conditions.[3] Much of this "fetal origins" work has focused on demonstrating the impacts of traumatic experiences (disease, natural disasters, environmental factors, etc.) in early life. Few studies have estimated the gains to exposure to purposeful and beneficial large-scale distribution of resources. The distinction between the two types of studies is important because the latter "shock" can yield actionable information: policies with demonstrated positive impacts can be advocated for and reproduced. A small set of studies–including Hoynes et al. (2012), Bleakley (2007), Bleakley (2010), Field et al. (2009), Almond et al. (2010), Politi (2011b), Bhalotra and Venkataramani (2012), and Feyrer et al. (2013)–have recently made strides in this direction.[4] We build on this evidence base: the results of these studies and ours offer lessons from historical policy experiments from which present-day policymakers, particularly in developing countries, might profitably draw.

Our findings are particularly related to the recent work by Feyrer et al. (2013) on the cognitive impacts of salt iodization in the US. Using data on the spatial distribution of goiter from enlisted men in WWI, the authors find that army recruits in WWII born in previously highly iodine-deficient regions experience a differential increase post-iodization in the likelihood of being placed in the Air Forces. The authors use this estimated effect, combined with the fact that placement in the Air Forces was partially determined by performance on the Armed Forces Qualifying Test, to approximate the IQ gains from iodization. They estimate sizable gains of nearly 15 IQ points. The line of inquiry in our study is complementary to this result. Does increased cognitive ability generate shifts in educational attainment and labor market participation? It is not obvious which answer we might predict. A larger

[3]See Heckman (2006), Almond and Currie (2011), and Currie and Vogl (2012) for syntheses of this literature.

[4]Our results stand in contrast to Politi (2011b)'s findings on the impacts of salt iodization in Switzerland. She finds that high school and college completion both rose as a result of iodization. This may be because the sectoral composition of the economy made returns to higher education very different in Switzerland.

cognitive endowment might increase or decrease the returns to education and experience, and perhaps differentially so in high- and low-skilled sectors. Given this, it is crucial to estimate impacts on economic outcomes in addition to cognitive ability effects.

We also contribute new empirical evidence to the debate on the shape of the skill production function taking initial endowments and investments as arguments. A recent body of work–including Almond et al. (2009), Cunha et al. (2010), Aizer and Cunha (2012), and Bhalotra and Venkataramani (2012) among others, and reviewed in Almond and Mazumder (2013)–explores the degree to which initial disadvantages can be compensated for with parental investments, and whether the ability to compensate is higher or lower at early verses late stages of development. We find that the improvement in cognitive endowments brought about by salt iodization led to a *reduction* in completed years of schooling, driven mainly by a reduction in primary school and junior high completion. These results are consistent with the notion that, prior to iodization, formal primary schooling was being used in part to compensate for low cognitive endowments. After the rapid scale up of access to iodized salt, primary schooling was apparently less necessary to achieve the level of skill necessary for low-wage employment in agriculture and manufacturing. On the other hand, secondary and post-secondary school completion was largely unaffected by salt iodization, suggesting that higher levels of schooling were not being used to compensate for pre-iodization cognitive disadvantages.

Finally, we add evidence on the long-run effects of micronutrient fortification campaigns, and in particular mass salt iodization as a means of eradicating iodine deficiency. Nearly 2 billion people worldwide–a third of the world's population–do not have adequate access to iodine (Andersson et al., 2010; de Benoist et al., 2004). Recent estimates from the economics literature suggest that the incidence of iodine deficiency, and thus the returns to reducing IDD, may be very large (Feyrer et al., 2013; Field et al., 2009; Politi, 2011b). Policymakers in IDD-endemic countries, as well as the WHO, UNICEF, and other international organizations, have made increasing access to iodine a high priority (WHO, 1992). Mass salt iodization to prevent IDD is, far and away, the preferred policy: iodizing salt is much cheaper than continuous supplementation in populations with iodine-deficient diets, and, taken with other micronutrients such as iron, is highly cost-effective in terms of fetal and infant deaths averted (Center, 2008).

It is important, then, as many low-income countries make decisions about investing in salt fortification and distribution infrastructure, to quantify in rigorous fashion the economic benefits of salt iodization. Clearly, there are many differences–related to infrastructure, centralization of distribution, competing disease risks, labor markets, etc.–between the US in the early- and mid-twentieth century and the low-income countries still suffering from high rates of IDD today. But drawing from the historical experience in the US offers some insight into the promise of salt iodization, in terms of the rate and completeness of adoption and the long-term economic returns that could be achieved.

The rest of the paper is organized as follows. Section 2 discusses iodine deficiency and its prevalence in the early twentieth century, as well as the history of salt iodization in the US. Section 3 discusses our data sources. Section 4 describes our empirical strategy. Section 5 describes the results. Section 6 concludes with a discussion of the size of the economic benefits of iodization.

2 Background

2.1 Iodine Deficiency and its Consequences

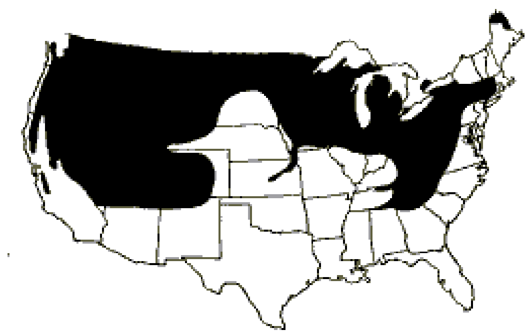
Iodine is crucial to the functioning of every body cell.[5] The thyroid gland in the lower part of the neck uses iodine from foods to produce thyroid hormones, which are released into the blood stream and transported throughout the body to control metabolism (the conversion of oxygen and calories to energy). The highest iodine contents for human consumption are found in some milks, leafy vegetables, and sea foods. The optimal iodine intake as recommended by the WHO is very small: a daily dose of 90 μg for infants of 0-59 months, 120 μg for ages 6 to 12, 150 μg for older ages, and 200 μg for pregnant and lactating women (Clar et al., 2002). (Half a teaspoon of iodized salt contains about 150 μg of iodine). Nevertheless, iodine deficiency can be a risk for many people due to the minute iodine content in most foods, and is most likely in areas far from the sea, especially mountainous areas due to erosion (Hetzel, 1989). When iodine intake is insufficient, the thyroid gland gets enlarged by working extra hard to produce the needed thyroid hormones.

At any stage from the fetal age to adulthood, insufficient iodine intake can cause a number of functional and developmental abnormalities, often referred to as iodine deficiency disorders (IDD). The main IDDs are goiter, hypothyroidism (causing fatigue, lethargy, slow speech and thought), impaired mental function, retarded physical development, and increased susceptibility of the thyroid gland to nuclear radiation (WHO, 2004).[6] Although the most detrimental IDD is cretinism due to severe iodine deficiency, less extreme in utero and postnatal deficiency can also be highly damaging and result in a

[5] http://www.endocrineweb.com/thyfunction.html

[6] Goiter may not be visible if iodine deficiency is minimal. On the other hand, iodine deficiency is the primary, but not exclusive, cause of goiter. Goiter, when sufficiently large, may cause complications such as aspiratory difficulty.

Figure 1: Simple Goiter Incidence Among US Drafted Men in World War I and Iodine Content of Drinking Water in the US



Simple goiter among drafted men in the US in WW I

Black areas: High goiter incidence, i.e. 6 and more goiter cases per 1,000 drafted men
White areas: Low goiter incidence, i.e. 5 and less goiter cases per 1,000 drafted men

Source: McClendon (1939)

Iodine concent in drinking water in the US

Black areas: Iodine-poor, i.e. 22 and less parts of iodine per hundred billion parts of water
White areas: Iodine-rich, i.e. 23 and more parts of iodine per hundred billions parts of water

Source: McClendon and Hathaway (1924)

5%-50% loss of individual productivity depending on severity (Hetzel and Pandav, 1996).

Correlational evidence of the impact of iodine deficiency on human capital among school-age children is abundant. Huda et al. (1999) find that in Bangladesh hypothyroid children performed worse than those with normal thyroid gland function on reading, spelling and cognition, controlling for health and socioeconomics. Even in a developed-country area with very mild iodine deficiency (Jaen, Spain), Santiago-Fernandez et al. (2004) report the risk of having an IQ below 70 to be greater in children with urinary iodine levels less than 100 μg/liter.

2.2 The Geography of Iodine Deficiency in the US

The map on the left in Figure 1 illustrates the geographic distribution of goiter incidence across the US based on data from the 1917 WWI draft examinations, which is, to our knowledge, the first and only nationwide goiter survey in the US. A "goiter belt" can be seen in the northern parts. The figure also shows a very similar geographic pattern in goiter incidence among WWI recruits and in the iodine content of drinking water as reported in 1924 by the then prominent scientist Jesse Francis McClendon (map on the right). The similarity between these two patterns suggests that the WWI draft statistics would serve as a good representation of the geographic pattern of iodine deficiency in the general population. In our estimations, we do not use McClendon's water iodine content data, as the author presents numerical information for only 27 states and many states are presented with data at only one location.

In a publication in the Public Health Reports published in 1929, Robert Olesen, a surgeon at the U.S. Public Health Service, gathered goiter data dating from 1924. He consulted independent thyroid surveys and directly communicated with state, county and city health officers across the country to verify the geographic distribution of goiter in the general public against the findings from the WWI draft examinations. Olesen (1929) concludes that the evidence among the young population from elementary school to college confirms the geographic variation in goiter incidence among WWI recruits in those areas where he could collect data. This gives further validity to the use of the WWI draft statistics in this study. Summarized in column 1 of Table A1, the WWI draft statistics show considerable variation in goiter prevalence across states even within regions defined by the nine Census divisions. This variation is crucial as it allows us to control for region-level time effects to remove any systematic coincidence between the goiter distribution and geographic differences in economic development over time, such as the North-South divide.

2.3 Introduction of Iodized Salt in the US in 1924

It was not until 1895 when iodine was first found in the thyroid gland by a German chemist Eugen Baumann (Baumann, 1896). Since then experiments were conducted to study the impact of changes in iodine content and the enlargement of the incidence of goiter in different kinds of animals, including dogs, cattle, hogs, and fish (Marine and Feiss, 1915; Marine and Lenhart, 1909; Smith, 1917). However, it was only in 1914-1915 that goiter in humans was reported in an organized manner in the US for the first time by Hall (1914) and Olesen (1915), using examination data from 3,339 University of Washington students and from 606 women and 193 men in Chicago, respectively. The experiment of scientist David Marine and colleagues in Ohio in 1917-1919, providing iodated syrup to school girls of grades 5 to 12, was the first known evidence that iodine supplementation could control and prevent goiter in humans (Marine and Kimball, 1917). Two grams of iodated syrup were given twice a year to 2,190 of 4,495 school girls in Akron, Ohio. As the test concluded, only five treated girls developed thyroid enlargement whereas 495 untreated girls did. Among the girls with initial thyroid enlargements, 70% of the treated showed a gland size decrease while only 15% of those not treated showed such a decrease (Marine and Kimball, 1921).

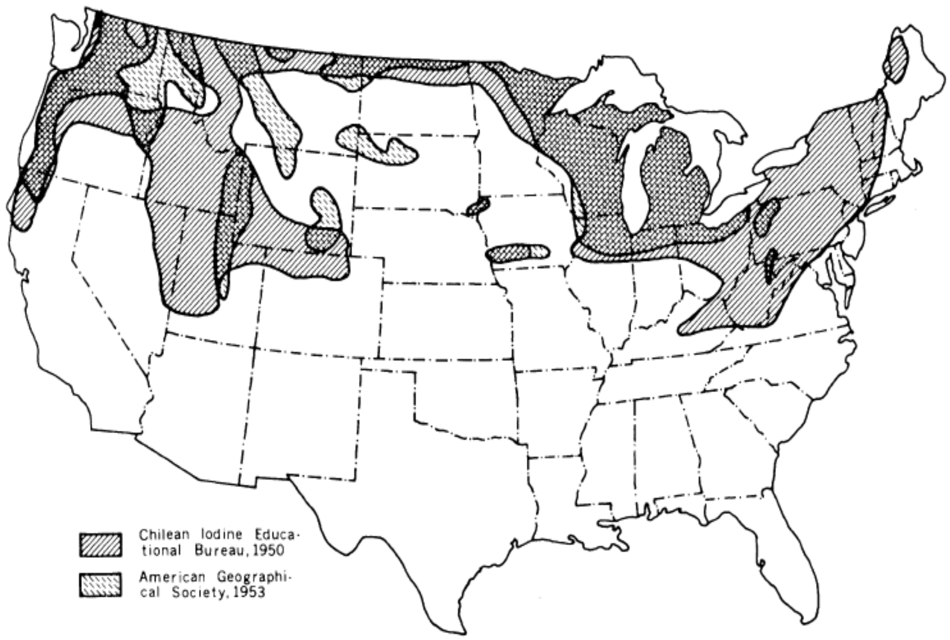
Coincidental with findings from the Ohio experiment, a few other factors put focus on goiter in humans as a health problem in America during the early 1920s (Annegers and Mickelsen, 1973), among them: (a) the decline of other childhood diseases allowed more attention to goiter; (b) McClendon discovered the coincidence between goiter and the iodine content of drinking water; and (c) the WWI draft examinations revealed the nationwide extent of goiter prevalence. The evidence by Marine and colleagues inspired Switzerland to set up prophylactic programs, one of which used salt as an iodization vehicle. The use of salt was adopted enthusiastically by David Cowie of the University of Michigan, who was interested in eliminating widespread simple goiter in his home state and therefore worked with salt companies to convince them to market iodized salt to the public. Iodized salt appeared in Michigan groceries on May 1, 1924, and nationally in the fall of 1924. Although there was no law mandating salt iodization, with the continued educational efforts of the Michigan State Medical Society and zealous advertisements by salt producers, iodized salt rapidly grew popular. By 1930, iodized salt sales were eight times plain salt sales (Markel, 1987).

Many later surveys found marked decreases in thyroid enlargement, especially among continuous users of iodized salts. Interestingly, Schiel and Wepfer (1976) found that, among Michigan school children in 1924-51, there was a decline in goiter rates among non-users. Cowie attributed this to ingestion of iodized salt without realizing it, such as in school canteens and restaurants, which seems plausible given that iodized salt made up 90% of salt sales in Michigan at the time (Markel, 1987). This observation alleviates concerns about self-selection into using iodized salt and supports the approximate universality of the intervention. Figure 2 shows U.S. goiter survey results compiled by the Chilean Iodine Educational Bureau in 1950 and the American Geographical Society in 1953. The size of the endemic goiter areas decreased considerably between the WWI draft era (Figure 1) and 1950, and further from 1950 to 1953.

2.4 Goiter and Confounding Factors

Marine's 1917-19 experiment was the first to inform the US public that iodine supplementation could prevent and treat goiter; hence there is little reason to suspect a *direct* role of iodine in residential selection or selection into iodine-rich diets. Supporting this claim, Figure 1 shows that goiter incidence was concentrated in the northern states, which were socioeconomically better off compared to the southern states.

Figure 2: U.S. goiter distribution in the early 1950s

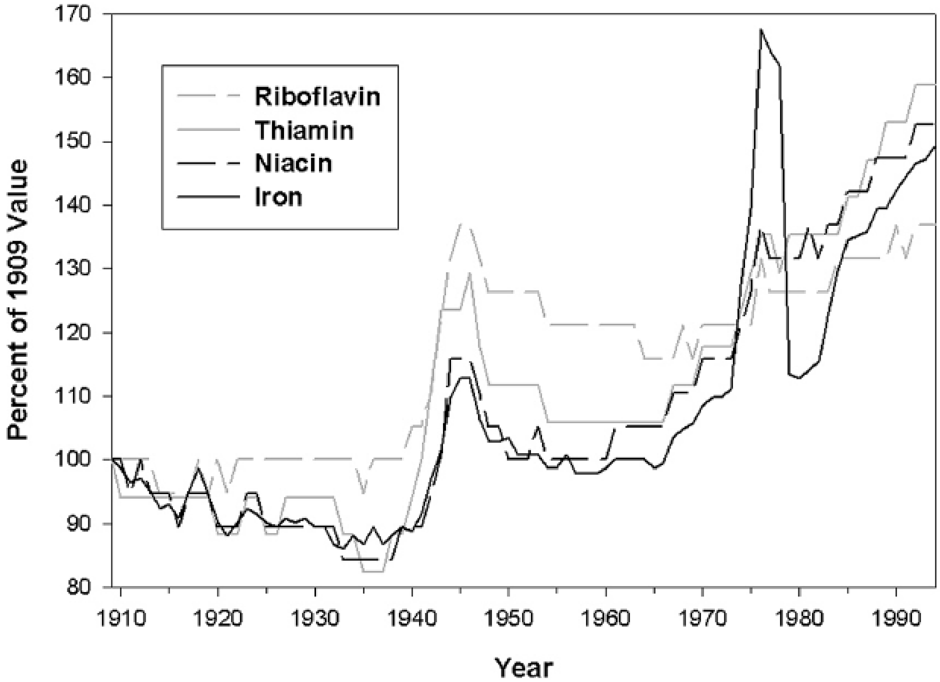


Source: Schiel and Wepfer (1976)

However, one might still suspect that high goiter incidence areas prior to iodization were also more likely to have high incidence of other nutrient deficiencies or other health issues such as malaria or hookworm. Similarly, we might worry that concurrent with the roll out of iodized salt, there may have been other important changes in the U.S. diet or in other health conditions. In fact, food fortification in the US began with salt iodization in 1924, with discoveries of the role of vitamin and mineral deficiencies in many diseases and sicknesses (Backstrand, 2002). However, the knowledge remained mostly in the laboratory until May 1941 when President Roosevelt called a National Nutrition Conference for Defense, due to high malnutrition rates and fears of potential U.S. involvement in war.

Figure 3 shows the change in the per capita riboflavin, iron, niacin, and thiamin contents of American food between 1909 and 1994, which does not coincide with the timing of salt iodization. In order to address concerns about the contemporaneous eradication of infectious diseases, we check the robustness of our main results to controlling for baseline geographic variation in the prevalence of malaria and tuberculosis as well as the interactions of these rates with a post-iodization dummy. The robustness of our results alleviates concerns about the geographic pattern of goiter incidence, and hence of expected benefits from iodized salt, coinciding with the geographic pattern of other health-related improvements.

Figure 3: Change in the per capita riboflavin, iron, niacin, and thiamin content of the U.S. food supply between 1909 and 1994



Source: Backstrand (2002)

3 Data

3.1 Goiter Data

Our information on the geographic distribution of iodine deficiency prior to salt iodization comes from the data used to create the first map in Figure 1, medical examinations of over two and a half million drafted men aged 18 to 30 before World War I. Conducted on a large sample of men from all over the United States within a short period of time between 1917 and 1918, these examinations offer a snapshot of the geographic distribution of various mental and physical defects prior to the iodization of salt. Love and Davenport (1920) documents prevalence rates in this sample for over 200 medical conditions, including goiter. In this paper, we use the state-level prevalence rates, although rates for smaller regions (collections of counties known as sections) were recorded as well.[7] We use goiter rates as a proxy for state-level iodine deficiency rates prior to salt iodization. Column 1 of Table A1 reports for each state the goiter rate recorded in Love and Davenport (1920). The median goiter rate is .214%

[7]Unfortunately, we cannot use the section-level goiter data because we only have state of birth, not county of birth, for the individuals in our sample.

and the maximum is 2.686% .

We also check for robustness to another source of goiter data, a list of goiter rates among children complied by Olesen (1929). Starting in 1924, these rates were calculated by experienced health workers from samples of school children in a varying number of localities in 43 states. 6 out of these 43 states did not report a numerical goiter rate (only qualitative descriptions, like "very little goiter") and were therefore excluded. Column 2 of Table A1 reports the goiter rates from this dataset for the remaining 37 states. Appendix section B.4 contains more details about how state-level averages were calculated for this dataset. The median goiter rate in this sample is 9.1%. Due to the greater noticeability of goiter among children compared to adults and the more stringent requirement for goiter to be recorded in the military records,[8] the Olesen (1929) rates are much higher than the rates from Love and Davenport (1920). The correlation between the two measures of goiter is 0.45.

3.2 Census Data

We also use data from the United States Decennial Census, restricting to individuals born in the twelve-year period spanning 1920 to 1931, which includes the years before, during, and after the nationwide spread of iodized salt. We are interested in education, labor, and income outcomes for this cohort throughout their productive work life, from age 25 to 55. This age restriction is used in order to exclude those still in school or early retirees. As a result, we pool data from the 1950 to 1980 Censuses.

Individuals are assigned to the goiter rate in their state of birth, which proxies for their risk of being born to an iodine deficient mother. Individuals are also grouped according to their birth year. Those born in the years 1920 to 1923 are marked as "pre-iodization," those born from 1924 to 1927 are classified as born "during iodization," and those born from 1928 to 1931 are considered "post-iodization." Iodized salt first appeared in grocery stores in 1924 and was reported to have generated eight times more sales than regular salt by 1930 (Markel, 1987). In creating the "during" category, we allow four years of leeway following the initial introduction of iodized salt to ensure that the after cohort was exposed to an environment with sufficiently widespread iodized salt availability.

3.2.1 Outcome and Control Variables

The education outcomes we study are years of completed schooling and dummies for primary, junior high, high school, and college completion. In terms of labor outcomes, we are interested in indi-

[8]Goiter was recorded in the military recruit data if it was large enough to prevent the buttoning of a uniform collar.

viduals' participation in the labor force as well as the types of occupations they hold. To represent employment, we use two variables: a dummy for labor force participation (which includes job-seekers as participants) and an unconditional dummy for employment (which is set to zero for job-seekers). We also look at the types of occupations: whether individuals are self-employed or in blue-collar jobs. Finally, we also look at total income, which includes income from all sources, including wages and self-employment income. We take the log of unconditional income, setting this equal to zero for those earning no income. We also create dummy variables to identify the income quintile to which each individual belongs. We first calculate log income quintiles from the 1950 census (in 1999 dollars). We then define, for each individual, dummies for inclusion in each income quintile. We apply the same income cutoffs for inclusion in each quintile to later census observations to map how each cohort's income distribution shifted.

Additional variables taken from the Census include gender and race. In addition to including female and black dummy variables as controls, we also control for pre-iodization demographic conditions in the individual's state of residence. This is done by calculating the black and female proportions from the 1920 Census in the individual's state of residence.

We also construct a dummy variable to indicate whether an individual is living in a "blue collar" state to include as a triple interaction in some specifications. This is done by first pooling the 1920 and 1930 Censuses and ranking states according to the proportion of individuals working a blue collar job. States with at- or above-median proportions are categorized as "blue collar" states. Column 4 of Table A1 reports each state's binary classification. For more details on the construction of variables, see the Data Appendix.

3.3 Census Division Controls

There are clear regional patterns in the distribution of goiter. This necessitates the inclusion of Census division by birth year dummies, which we use in all of our specifications. We control for region of birth using the nine Census Bureau divisions, listed in Table A1. The inclusion of these interaction terms means we are identifying off of within-region variation, essentially comparing states across the goiter distribution within each of the nine divisions in terms of their deviations from the division's non-linear trend across birth cohorts in the outcome variable.

Table 1: Summary Statistics for Individuals Aged 25-55, 1940 Census

	(1)	(2)	(3)	(4)
	Whole Sample	*High Goiter States*	*Low Goiter States*	*High-Low Difference*
1(Participated in Labor Force)	0.602	0.615	0.613	-0.0132***
	(0.490)	(0.487)	(0.487)	(0.00178)
1(Employed)	0.562	0.571	0.569	-0.00940***
	(0.496)	(0.495)	(0.495)	(0.00181)
1(Self-Employed)	0.201	0.203	0.203	-0.00196
	(0.401)	(0.402)	(0.402)	(0.00189)
Years of Schooling	9.702	8.900	9.049	0.802***
	(3.038)	(3.518)	(3.448)	(0.0125)
Wage Income	14488.5	12888.1	13182.3	1600.5***
	(10788.6)	(10699.9)	(10734.2)	(56.16)
1(Female)	0.499	0.505	0.503	-0.00596**
	(0.500)	(0.500)	(0.500)	(0.00183)
1(Black)	0.00884	0.129	0.107	-0.120***
	(0.0936)	(0.335)	(0.309)	(0.00111)
Number of Observations	495263	91964	403299	

Notes: *** p<0.01, ** p<0.05, * p<0.1. High Goiter states are those in the top quartile of the Love and Davenport (1920) goiter distribution (See Table A1).

3.3.1 Summary Statistics

Table 1 reports summary statistics for the entire population aged 25-55 in the 1940 Census. As 1940 was the last Census year before the during and after cohorts entered our sample as working adults aged 25 and over, this gives us a snapshot of pre-treatment labor outcomes, educational attainment, and demographic composition.[9] Column 1 displays statistics for the whole sample: about 60% of the sample participated in the labor force, and the majority of these individuals were employed. Self-employed workers made up about 20% of the labor market. On average, individuals attended school until the ninth grade.

We also split the sample into high and low goiter states, using the 75th percentile of the Love and Davenport (1920) goiter distribution as the cut-off between the two groups (see column 3 of Table A1 for a list of the states and their classifications according to this rule.) Although our main specification does not use this arbitrary cutoff, we use it in this descriptive exercise to illustrate pre-treatment con-

[9] Total income and blue collar status are two variables that we use in our analysis but are not available in the 1940 Census. Instead of total income, we report wage income, which is available in the 1940 census but does not include income from sources other than wage work.

ditions for states of different levels of iodine deficiency risk. In 1940, before our treated individuals had entered the workforce, wage income and educational attainment were significantly higher in high goiter states, which is consistent with Northern states having better socioeconomic conditions prior to the iodization of salt. On the other hand, labor force participation and employment rates were lower in high goiter states. These significant differences, while they point to underlying level differences between high and low goiter states prior to the introduction of iodized salt, are accounted for in our difference-in-differences approach, described in the next section. They also emphasize the importance of our Census division by birth-year dummies, which are discussed in more detail in section 4.

3.4 Other Diseases

In certain specifications, as robustness checks, we control for the pre-iodization rates of two other diseases: malaria and tuberculosis. We take tuberculosis rates from the Love and Davenport (1920) data, which also recorded rates of various other "defects" found in recruits. For malaria, we use the malaria mortality rates from the 1890 Census, used in Bleakley (2010).

3.5 Compulsory Schooling and State Mobilization Rates

In another robustness test, we add years of compulsory schooling as a control variable. We obtained this variable from state-level data used in Lleras-Muney (2002), compiled from multiple sources. This data reports the number of years of required schooling (either by compulsory attendance laws or implied by child labor laws) in each state in each year from 1915 to 1939. Using the same strategy as Lleras-Muney (2002), we match each individual to the law in place in their state of birth in the year they turned 14 (the minimum leaving age across all states and years), as this is arguably the most relevant to their schooling continuation choices.

We also include WWII state mobilization rates, obtained from Acemoglu et al. (2004), as a control. Due to timing of the war, if WWII mobilization had any impact on these individuals, it likely affected them during their young adult or adult life: we therefore use mobilization rates in the individual's state of residence rather than their state of birth.

4 Empirical Strategy

4.1 Overview of strategy

In this section, we describe the empirical strategy we use to identify the effects of salt iodization on economic outcomes. As described in section 2, once Morton Salt Co.'s decision to iodize its supply was made, the spread of iodized salt was wide scale and fairly rapid. Since iodization happened nationwide, however, there was no true exclusion from exposure. In the spirit of Bleakley (2010), Hornbeck (2012), and others, our basic strategy is to compare trends in economic outcomes in states with different levels of pre-iodization iodine deficiency rates. Feyrer et al. (2013) use a similar strategy to identify the impacts of iodization on recruits' placement into the Army v. the Air Force.

We use the spatial distribution of goiter in 1924 in the continental US to identify differences in pre-iodization deficiency rates. As described in section 3, we use data from the Love and Davenport (1920) survey of military recruits. We link each individual in the census to a goiter rate using their state of birth. We use state of birth to draw focus to the effects of *in utero* exposure to iodine rather than exposure through one's life.

We interpret the goiter value as a proxy for the extent of iodine deficiency in one's state of birth during early life. This proxy will, of course, not fully reflect actual iodine exposure. Nevertheless, as shown in the previous sections, as well as in Feyrer et al. (2013), the spatial distribution of goiter generally mirrors well the distribution of iodine content in water sources. While admittedly an imperfect proxy, the distribution allows a rough ordering of individuals according to their exposure to iodine *in utero*.

We study the outcomes of three cohorts: those born before (1920-1923), during (1924-1927), and after (1928-1931) salt iodization. We consider this middle ("during") group because, while the proliferation of iodized salt across the US was rapid, we do not have data on the geographic pattern of this nationwide spread. During the proliferation period, it is possible that we find muted effects, if iodized salt had not yet reached some markets. To allow for this, we separate the "during" and "after" iodization period. In practice, the magnitudes of estimates for impacts in these two cohorts are very similar, suggesting that iodized salt did indeed proliferate very quickly.

We interpret differences in trends in economic outcomes across individuals born in states with varying levels of goiter as causally related to salt iodization. Although there does exist a "protective threshold" that fetal iodine must reach in order to ensure normal cognitive functioning, we do not know what this threshold is and how to map it to goiter prevalence rates. We therefore take an agnostic approach and use continuous goiter rates to capture differential cohort trends that vary along the ordering of states by risk of iodine deficiency.

4.2 Specification

The basic difference in differences strategy, then, is to compare the outcomes of cohorts born before to those born during and after iodization, across individuals born in states of varying levels of iodine deficiency. In our baseline specification, we use the continuous goiter rate (but in robustness checks, we split the sample at the 75th percentile, creating a high goiter v. low goiter designation as in Feyrer et al. (2013)). We estimate the following specification, for individual i born in year t in state s (census division d), for outcome o recorded in census year c, where G is the continuous goiter rate, D is a dummy for belonging to the "during" cohort, and A is a dummy for belonging to the "after" cohort:

$$o_{ist} = \beta_1 G_s D_t + \beta_2 G_s A_t + \mu_s + (\zeta_d \text{ x } \delta_t) + (\lambda_c \text{ x } \delta_t) + \eta X_{ist} + \varepsilon_{ist}. \tag{1}$$

Here, β_1 and β_2 are the main coefficients of interest, measuring the difference in trends in outcome o across individuals exposed to different levels of iodine deficiency over time. The specification includes state of birth (μ_s) and year of birth fixed effects (δ_t, which are interacted with census years as well as divisions), which absorb the main effects of G_s, D_t, and A_t. The census division of birth by birth year interactions (ζ_d x δ_t) are crucial because they control for any division-specific trends over time that may coincide with the national goiter distribution. In particular, division-by-birth-year fixed effects should alleviate concerns about differential trends for Northern and Southern states because we are comparing outcome variable trends (by birth cohorts) across high and low goiter states of birth in their deviations from each Census division's mean non-linear trend. (λ_c x δ_t) are census year by birth year interactions, included to account for differential trends in the outcome variables as the cohorts age. Included in X are individual controls for race and gender, as well as controls for the proportion of the population that is female and that is black (measured in 1920) in the individual's state of residence, interacted with the during and after dummies. Standard errors are clustered at the state of residence level to allow for arbitrary correlation of the errors for individuals residing in the same state.

We test the robustness of our results to the inclusion of contemporaneous disease eradication programs (namely related to tuberculosis and malaria) as well as compulsory schooling laws and WWII mobilization rates at the state of residence. We also show robustness to the use of a discrete cutoff instead of continuous goiter rates and to an alternative source of data, the goiter rates among school children collected by Olesen (1929). Finally, to address issues of measurement error in our treatment variable we instrument for goiter rates in the military recruit data with the goiter rate from Olesen (1929).

5 Results

In this section, we discuss the results of our empirical strategy described in section 4. We begin first with a graphical illustration of our main results. Again, for this descriptive analysis, we use the 75th percentile of the goiter distribution to classify states as high or low goiter, but do not rely on this arbitrary cutoff for our regression analysis.

Figure 4: Trends in the High Goiter-Low Goiter Schooling Differential

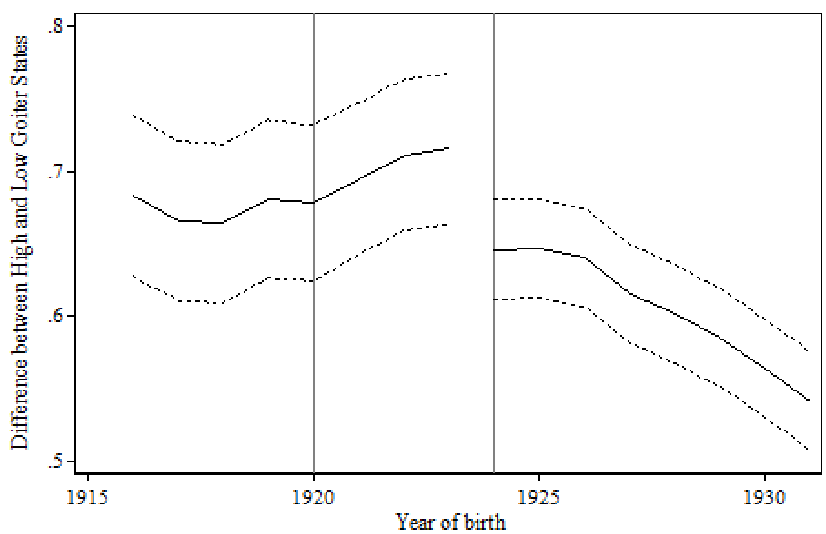
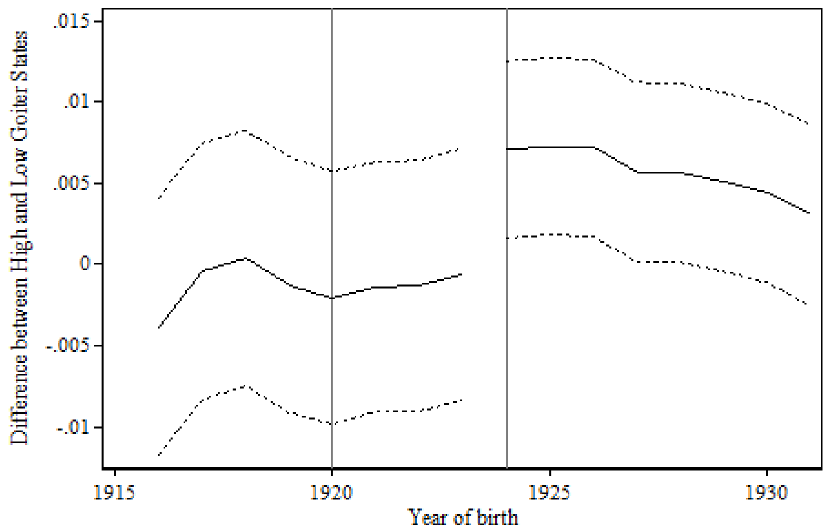


Figure 4 plots the lowess-smoothed difference in educational attainment between individuals born in high and low-goiter states, by birth year, from 1916 to 1931. Figure 5 depicts the analogous graph for employment rates. 95% confidence intervals are denoted by the dotted lines. The first vertical line indicates the beginning of our "before" cohort, and the second vertical line marks the beginning of our iodine-exposed ("during" and "after") cohorts. We include the four birth years prior to the those included in our sample in order to show that high and low goiter states exhibited similar pre-trends, an important validity check for our difference-in-differences strategy.

Figure 5: Trends in the High Goiter-Low Goiter Employment Rate Differential



During the pre-iodization period (1916 to 1923), Figure 4 shows that the gap in completed years of schooling between high and low goiter states is relatively flat. After 1925, however, the difference shifts downward and continues to decline for the younger birth cohorts up until 1931.

In Figure 5, it is also clear that the difference between individuals in high and low goiter states remained fairly constant between 1916 and 1924. In the year after the introduction of iodized salt, however, there is a sharp shift upward, implying that individuals born in high goiter states saw larger increases in employment rates than those born in low goiter states. Although the difference in employment rates hovered around or slightly less than zero throughout the entire pre-iodization period, this figure jumps up to just over half a percentage point in 1925 and remains positive for the remainder of the sample period.

Both of these graphs show the year of the introduction of iodized salt coinciding with breaks in the relative education and employment trends. Of course, though suggestive of a negative impact of salt iodization on grade completion and a positive impact on employment, these naive graphical comparisons do not properly account for state-of-birth and birth year unobservables nor for region-specific non-linear trends during these years.

5.1 Education

We therefore move on to the regression analogs to the exercise depicted in the figures above, beginning with our education outcomes. In all of the regressions that follow, our coefficients of interest are the after-by-goiter rate interaction and the during-by-goiter rate interaction: these represent the effect of salt iodization on our outcomes of interest. Our specification includes state of birth fixed effects, year of birth by census year interactions, census division of birth by birth year interactions, a female dummy, a black dummy, and 1920 state-level female and black proportions interacted with the after and during dummies. Table 2 displays results on education outcomes. In all of the regressions that involve a continuous goiter rate, we multiply each relevant coefficient by the inter-quartile range of the goiter distribution (0.713) to obtain a value that can be interpreted as the effect of moving from a relatively low goiter state (at the 25th percentile) to a high goiter state (at the 75th percentile).

Table 2: Effects of Salt Iodization on Education

	(1)	(2)	(3)	(4)	(5)
	Years of Schooling	1(Completed Primary)	1(Completed Junior High)	1(Completed High School)	1(Completed College)
After x Goiter Rate	-0.0897***	-0.00624***	-0.00940***	-0.00657	-0.00487
	(0.0256)	(0.00158)	(0.00262)	(0.00487)	(0.00344)
During x Goiter Rate	-0.0578**	-0.00409***	-0.00704***	-0.00653	-0.00185
	(0.0216)	(0.00128)	(0.00203)	(0.00420)	(0.00280)
Observations	1553941	1553941	1553941	1553941	1553941
Mean of Dependent Variable	11.43	0.960	0.907	0.620	0.129

Notes: Standard errors, clustered by state of residence, in parentheses (*** p<0.01, ** p<0.05, * p<0.1). *Goiter Rate* is the goiter rate in the individual's state of birth from Love and Davenport (1920), scaled by the difference between the 75th and 25th percentile of the goiter distribution (0.71). *After* is a dummy equal to 1 for those born 1928-1931. *During* is a dummy equal to 1 for those born 1924-1927. These regressions restrict to indivduals born in 1920-1931 aged 25 to 55. All regressions include state of birth fixed effects, year of birth x census year dummies, census division of birth x birth year dummies, gender, race, and 1920 state-level female and black proportions interacted with During and After dummies.

The first column shows that salt iodization significantly reduced total years of completed schooling by about 0.09 years. Columns 2 to 5 show that this result is driven by early years of schooling: salt iodization significantly reduced the probability of primary and junior high completion but had no significant impact on high school or college completion. For the individuals in our sample, the improvements in cognitive ability brought on by salt iodization acted as a substitute for low levels of schooling, perhaps because parents deemed schooling less necessary for children with sufficiently high cognitive ability endowment.

If cognitive ability substitutes for schooling at low but not higher levels of schooling, we would expect education impacts to be concentrated among individuals who were a priori more likely to go into low-skilled jobs. Therefore, we next analyze whether our results in Table 2 differ by the types of jobs and industries dominating the workforce in an individual's environment. Table 3 augments our original specification with the addition of a third interaction variable: an indicator for whether an individual lives in a blue collar state, defined by the prevalence of blue collar jobs in their state of residence during the 1920 and 1930 censuses (see section 3).

Under the assumption that individuals made schooling decisions while in the same state as their current state of residence or had accurate expectations about the type of state they would reside in as an adult, the blue collar dummy acts as a proxy for whether individuals made their schooling decisions with the expectation of taking low-skilled jobs in the future. We therefore expect those living in blue collar states to be the ones driving the substitution results found in Table 2, which is exactly what we find. Column 1 of Table 3 shows us that the effect of salt iodization on primary school completion is negative overall (as we found in Table 2), but significantly more so for those living in a blue collar state. For junior high school completion, the effect is only negative and significant for blue collar states. Again, in both columns 3 and 4, we see that salt iodization did not seem to affect completion of higher levels of schooling in any type of state, blue collar or not, which is consistent with cognitive ability being less substitutable for higher levels of schooling.

These results are broadly consistent with those of other recent studies in the literature. For example, Cunha et al. (2010) find that the elasticity of substitution between investments and initial skill stock is higher in earlier stages of investment than in later stages. That is, they find that it is easier to compensate for initial disadvantages (particularly, in cognitive skills) with early investments than with late investments. Similarly, we find evidence of stronger substitutability between cognitive endowments and primary schooling than between cognitive endowments and secondary or post-secondary schooling. It should be noted that in their empirical exercise, Cunha et al. (2010) consider ages 0-6 as the "early" stage and ages 6-14 as the "late" stage of investment; while we find evidence of substitutability through primary school (ages 12-13), and weakening of this relationship by the end of high school (ages 17-18). However, these differences are likely, at most, empirical nuances due to varying sample characteristics. Particularly, our sample is drawn from cohorts born more than a half century before those in the sample studied in Cunha et al. (2010). Accordingly, the longer and later stages of development might reflect the naturally less complex natures of the school curricula, as well as the ultimate job tasks represented in the labor market opportunities of the time.

5.2 Labor Supply and Income

Having shown that salt iodization acted as a substitute for low levels of schooling, we next ask how this impacted the labor outcomes of these individuals. Interestingly, despite reducing the average number of years of schooling, salt iodization does not appear to have hindered employment outcomes in any way, as shown in Table 4, which summarizes the regression results for our labor outcomes of interest. In fact, effects on labor force participation (column 1) and the probability of being employed (column 2) are both positive and significant, with effect sizes ranging from 0.4 to 0.7 percentage points. As column 3 shows, these employment effects seem driven primarily by movement into self-employed rather than wage work. Finally, salt iodization does not appear to have significantly impacted occupation types or total incomes, on average. These results suggest that salt iodization allowed people to earn the same amount of income with less schooling.

Although we see no effects of salt iodization on income on average, it is possible that salt iodization changed the distribution of income. We run quantile dummy regressions to investigate this in more detail. We separately run our main specification on five dummy variables, one corresponding to inclusion in each of the quintiles of the 1950 Census distribution, as described in section 3.2.1. The coefficients from these five regressions are graphed in Figure 6, along with their 95% confidence intervals. The left panel depicts the scaled during-by-goiter coefficients, and the right panel the after-by-goiter coefficients. In both figures, there is a similar pattern of results: positive coefficients for the 2nd and 3rd quintiles, but negative coefficients for the 4th and 5th quintiles. Appendix Table A2 reports the regressions corresponding to this figure. The after-by-goiter coefficient and the during-by-goiter coefficients are positive and significant at the 10% level. Consistent with the previous education results, these distributional income results emphasize that the positive impact of salt iodization was concentrated at the left tail of the skill distribution, leading to the influx of new labor force participants in the second and third quintiles of the income distribution. This fits in well with the idea of a "protective threshold," which suggests that improvements in fetal iodine levels should affect those who would have had low

Table 3: Effects of Salt Iodization on Education, by State Industry Type

	(1)	(2)	(3)	(4)
	1(Completed Primary)	1(Completed Junior High)	1(Completed High School)	1(Completed College)
After x Goiter Rate x 1(Blue Collar State)	-0.0128***	-0.0209***	-0.00959	0.00137
	(0.00354)	(0.00642)	(0.0111)	(0.00473)
During x Goiter Rate x 1(Blue Collar State)	-0.0120***	-0.0222***	-0.0102	0.000971
	(0.00324)	(0.00602)	(0.00922)	(0.00489)
After x Goiter Rate	-0.00226**	-0.00290	-0.00386	-0.00557
	(0.000940)	(0.00194)	(0.00518)	(0.00430)
During x Goiter Rate	-0.000320	-0.000267	-0.00364	-0.00242
	(0.000934)	(0.00177)	(0.00482)	(0.00371)
After x 1(Blue Collar State)	0.0210***	0.0290***	-0.00916	-0.0152*
	(0.00502)	(0.00902)	(0.0190)	(0.00883)
During x 1(Blue Collar State)	0.0231***	0.0353***	-0.00604	-0.0152*
	(0.00508)	(0.00886)	(0.0173)	(0.00794)
Goiter Rate x 1(Blue Collar State)	0.0211***	0.0351***	0.0266**	0.00407
	(0.00481)	(0.00767)	(0.0124)	(0.00717)
1(Blue Collar State)	-0.0390***	-0.0604***	-0.0169	0.0130
	(0.00724)	(0.0116)	(0.0186)	(0.00933)
Observations	1553941	1553941	1553941	1553941
Mean of Dependent Variable	0.960	0.907	0.620	0.129

Notes: Standard errors, clustered by state of residence, in parentheses (*** p<0.01, ** p<0.05, * p<0.1). *Goiter Rate* is the goiter rate in the individual's state of birth from Love and Davenport (1920), scaled by the difference between the 75th and 25th percentile of the goiter distribution (0.71). *After* is a dummy equal to 1 for those born 1928-1931. *During* is a dummy equal to 1 for those born 1924-1927. These regressions restrict to indivduals born in 1920-1931 aged 25 to 55. All regressions include state of birth fixed effects, year of birth x census year dummies, census division of birth x birth year dummies, gender, race, and 1920 state-level female and black proportions interacted with During and After dummies.

Table 4: Effects of Salt Iodization on Labor and Income Outcomes

	(1)	(2)	(3)	(4)	(5)
	1(Participated in the Labor Force)	1(Employed)	1(Self-Employed)	1(Blue Collar Worker)	Log Total Income
After x Goiter Rate	0.00619***	0.00710***	0.00317	0.00686	0.00568
	(0.00186)	(0.00197)	(0.00197)	(0.00458)	(0.0198)
During x Goiter Rate	0.00413*	0.00451*	0.00473**	0.00448	-0.00882
	(0.00223)	(0.00242)	(0.00186)	(0.00392)	(0.0165)
Observations	1678661	1678661	1338838	1168224	1549843
Mean of Dependent Variable	0.698	0.672	0.106	0.394	8.007

Notes: Standard errors, clustered by state of residence, in parentheses (*** p<0.01, ** p<0.05, * p<0.1). *Goiter Rate* is the goiter rate in the individual's state of birth from Love and Davenport (1920), scaled by the difference between the 75th and 25th percentile of the goiter distribution (0.71). *After* is a dummy equal to 1 for those born 1928-1931. *During* is a dummy equal to 1 for those born 1924-1927. These regressions restrict to indivduals born in 1920-1931 aged 25 to 55. All regressions include state of birth fixed effects, year of birth x census year dummies, census division of birth x birth year dummies, gender, race, and 1920 state-level female and black proportions interacted with During and After dummies.

cognitive functioning otherwise, not those who would have already achieved high cognitive functioning. Salt iodization appears to have primarily benefited the left tail of the skill distribution, allowing people to enter the labor force (even with less schooling) and take up low-paying jobs.[10] .

5.3 Heterogeneous Impacts

We now analyze how these labor impacts differ for various sub-groups of the population, for whom labor market opportunities were very different. In particular, we run the same regressions separately by race and gender.

In Table 5, we report our regression results for females in Panel A and for males in Panel B. Here, it is clear that the labor force participation and employment results are being primarily driven by females. Labor force participation and employment both rose by about 1 percentage point more for high goiter states in the after cohort (relative to the before cohort), while this same coefficient is less than half a percentage point for males and insignificant. Interestingly, however, the movement into self-employment appears to be driven by males, who saw a significant increase in the probability of being self-employed: about 0.6 percentage points (for both the during and after cohorts). There is also strong evidence of heterogeneity in the dimension of occupation type. Although we see no significant

[10]It should be noted that these quintile dummies are created using the 1950 income distribution, which means that movement into the 2nd and 3rd quintiles involve below-median incomes.

Table 5: Effects of Salt Iodization on Income Outcomes by Gender

	(1)	(2)	(3)	(4)	(5)
	1(Participated in the Labor Force)	1(Employed)	1(Self-Employed)	1(Blue Collar Worker)	Log Total Income
Panel A: Female					
After x Goiter Rate	0.00968**	0.0101**	-0.000418	0.0114**	0.0182
	(0.00395)	(0.00388)	(0.00195)	(0.00519)	(0.0316)
During x Goiter Rate	0.00592	0.00477	0.00264	0.0129**	-0.0128
	(0.00408)	(0.00388)	(0.00187)	(0.00488)	(0.0261)
Observations	868739	868739	562697	429374	801048
Mean of Dependent Variable	0.496	0.475	0.0497	0.189	5.974
Panel B: Male					
After x Goiter Rate	0.00208	0.00358	0.00599*	0.00662	-0.0107
	(0.00193)	(0.00232)	(0.00301)	(0.00562)	(0.0105)
During x Goiter Rate	0.00157	0.00365	0.00639**	0.00163	-0.00934
	(0.00224)	(0.00286)	(0.00279)	(0.00447)	(0.0126)
Observations	809922	809922	776141	738850	748795
Mean of Dependent Variable	0.916	0.884	0.147	0.513	10.18

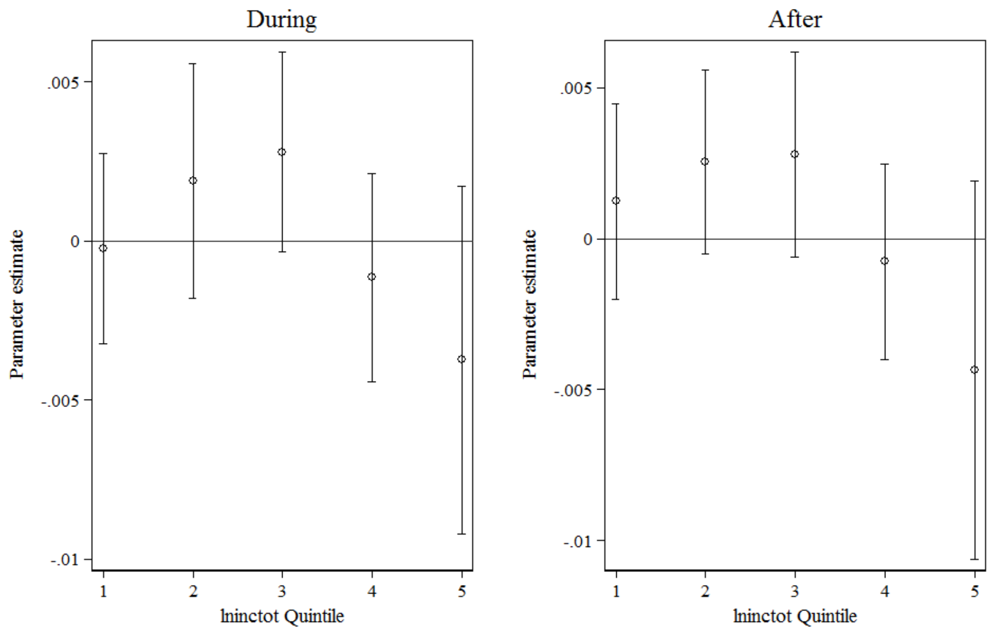
Notes: Standard errors, clustered by state of residence, in parentheses (*** p<0.01, ** p<0.05, * p<0.1). *Goiter Rate* is the goiter rate in the individual's state of birth from Love and Davenport (1920), scaled by the difference between the 75th and 25th percentile of the goiter distribution (0.71). *After* is a dummy equal to 1 for those born 1928-1931. *During* is a dummy equal to 1 for those born 1924-1927. These regressions restrict to indivduals born in 1920-1931 aged 25 to 55. All regressions include state of birth fixed effects, year of birth x census year dummies, census division of birth x birth year dummies, and 1920 state-level female and black proportions interacted with During and After dummies.

Table 6: Effects of Salt Iodization on Income Outcomes by Race

	(1)	(2)	(3)	(4)	(5)
	1(Participated in the Labor Force)	1(Employed)	1(Self-Employed)	1(Blue Collar Worker)	Log Total Income
Panel A: Minorities					
After x Goiter Rate	0.0118	0.0163*	0.0113	0.0369**	0.00335
	(0.00963)	(0.00943)	(0.00962)	(0.0145)	(0.0952)
During x Goiter Rate	0.0173**	0.0190**	0.0126	0.0371***	0.0306
	(0.00829)	(0.00890)	(0.0102)	(0.0136)	(0.0934)
Observations	184901	184901	144800	124917	167928
Mean of Dependent Variable	0.680	0.638	0.0510	0.459	7.990
Panel B: White					
After x Goiter Rate	0.00421**	0.00477**	0.00135	0.00495	0.00871
	(0.00186)	(0.00205)	(0.00194)	(0.00490)	(0.0219)
During x Goiter Rate	0.00186	0.00230	0.00341*	0.00304	-0.0102
	(0.00231)	(0.00257)	(0.00184)	(0.00421)	(0.0181)
Observations	1493760	1493760	1194038	1043307	1381915
Mean of Dependent Variable	0.701	0.677	0.113	0.386	8.009

Notes: Standard errors, clustered by state of residence, in parentheses (*** p<0.01, ** p<0.05, * p<0.1). *Goiter Rate* is the goiter rate in the individual's state of birth from Love and Davenport (1920), scaled by the difference between the 75th and 25th percentile of the goiter distribution (0.71). *After* is a dummy equal to 1 for those born 1928-1931. *During* is a dummy equal to 1 for those born 1924-1927. These regressions restrict to indivduals born in 1920-1931 aged 25 to 55. All regressions include state of birth fixed effects, year of birth x census year dummies, census division of birth x birth year dummies, and 1920 state-level female and black proportions interacted with During and After dummies.

Figure 6: Total Income Quintile Regression Coefficients



effects on blue collar employment for the whole sample, salt iodization appears to have significantly increased blue collar employment for females by about 1 percentage point. No effects are found for men.

Table 6 summarizes the results of this same sub-group analysis for race, separately reporting regression results for minorities in Panel A and white individuals in Panel B. Although positive and significant labor force effects are present in both groups, the effects are almost twice the size among minorities. For instance, the after-by-goiter interaction shows that salt iodization increased the probability of employment by over 1 percentage point for minorities but less than half a percentage point for whites. Column 4 shows that for the minority subset of the population, like for females, the probability of working in a blue collar job increased – by almost 0.4 percentage points. Heterogeneity in the impacts of iodization on self-employment is slightly less clear: the effects on whites are smaller in magnitude but significant at the 10% level for the during-by-goiter interaction, while the effects on minorities are insignificant but much larger in magnitude.

These heterogeneous impact results are consistent with many stylized facts documented in the literature. Demand for low-skilled labor soared in the 1940s, coinciding with the time that individuals affected by salt iodization would join the formal labor market (Goldin and Margo, 1992). A "Great

Compression" of the wage structure decreased the return to low levels of education and provided a strong incentive for new labor force participation among females and non-whites. Goldin (1999) shows that school enrollment rates began to diverge for males and females starting around 1930, as females began to lag behind males. While the enrollment gap between whites and non-whites narrowed dramatically during the 20th century, the convergence slowed from 1920-1950.

Killingsworth and Heckman (1987) show that women born just after salt iodization were more likely to be working at ages 20 and 50 than those born just before salt iodization. Many of these women held blue-collar manufacturing or part-time jobs, which aligns with our results presented above. Finally, Butler and Heckman (1977) document the rise in relative wages of blacks to whites that occurred as a result of civil rights legislation. Their analysis extends back to the late forties. They find that throughout the forties and fifties, blacks were at least as likely to participate in the labor force as whites, but their wages were roughly half as large as those of whites. While civil rights legislation explains much of the increase in relative wages during the 1960s, part of the initial difference can be attributed to blacks having a greater participation in blue-collar jobs.

5.4 Robustness

We run additional regressions to check the robustness of our main results to additional controls and alternate explanations for the patterns observed. We might be concerned that other contemporaneous health improvements, such as the eradication of diseases or development of new treatments, which occurred roughly contemporaneously to the roll out of iodized salt, might be driving the results. In particular, malaria eradication programs, concentrated in the South, took place in the 1920's (Bleakley, 2010). The 1940's, on the other hand, saw strides in the treatment and prevention of tuberculosis, which could have had contemporaneous effects on the labor market outcomes of our sample cohorts.[11] The correlation between early 1900's goiter rates and prevalence of tuberculosis and malaria are weak and negative (-0.3 and -0.36, respectively) and thus unlikely to be driving our results. We validate this, however, by running the main regressions controlling additionally for pre-iodization prevalence rates of tuberculosis and malaria and the interaction of these dummies with the during and after dummies. These results are reported in Table 7. The pattern of results is overwhelmingly preserved: substitution for lower years of schooling and movement into the labor force.

[11] Though first discovered several decades prior, the BCG vaccine began to gain acceptance in the United States after World War II (Comstock, 1994). Moreover, the first antibiotic and first bacterial agent effective against tuberculosis were discovered

Table 7: Robustness to Contemporaneous Disease Eradication

	(1)	(2)	(3)	(4)	(5)
	1(Completed Primary)	1(Completed High School)	1(Completed College)	1(Participated in Labor Force)	1(Employed)
After x Goiter Rate	-0.00483*	0.00579	-0.00293	0.00616***	0.00727***
	(0.00252)	(0.00573)	(0.00439)	(0.00220)	(0.00251)
During x Goiter Rate	-0.00277	0.000845	0.000246	0.00447*	0.00443*
	(0.00226)	(0.00463)	(0.00341)	(0.00250)	(0.00255)
After x Tuberculosis Rate	-0.00150	0.0109***	0.00215	0.000665	0.000908
	(0.00227)	(0.00391)	(0.00246)	(0.00130)	(0.00156)
During x Tuberculosis Rate	-0.000792	0.00701***	0.00254	0.00113	0.000640
	(0.00208)	(0.00247)	(0.00152)	(0.00117)	(0.00125)
After x Malaria Rate	0.0129***	0.0127**	0.000210	-0.00258	-0.00260
	(0.00389)	(0.00564)	(0.00385)	(0.00305)	(0.00296)
During x Malaria Rate	0.00948***	0.00573	-0.000523	-0.00269	-0.00260
	(0.00338)	(0.00482)	(0.00346)	(0.00438)	(0.00440)
Observations	1553264	1553264	1553264	1677969	1677969
Mean of Dependent Variable	0.960	0.620	0.129	0.698	0.672

Notes: Standard errors, clustered by state of residence, in parentheses (*** p<0.01, ** p<0.05, * p<0.1). *Goiter Rate* is the goiter rate in the individual's state of birth from Love and Davenport (1920), scaled by the difference between the 75th and 25th percentile of the goiter distribution (0.71). *After* is a dummy equal to 1 for those born 1928-1931. *During* is a dummy equal to 1 for those born 1924-1927. These regressions restrict to indivduals born in 1920-1931 aged 25 to 55. All regressions include state of birth fixed effects, year of birth x census year dummies, census division of birth x birth year dummies, gender, race, and 1920 state-level female and black proportions interacted with During and After dummies.

We also address the possibility that changes in compulsory schooling laws, implemented at different times across states, may be driving part of the differential changes in labor outcomes that we attribute to introduction of iodized salt. We use data collected by Lleras-Muney (2002), which records the minimum years of schooling required by law in each state from 1915 to 1939. Like Lleras-Muney (2002), we match each individual to the compulsory schooling laws in place at their state of birth when they turn 14 (lowest minimum leaving age across all states). For the analysis discussed here, we use the number of years of school required according to compulsory attendance laws, although the results are similar when we use the number of years required according to child labor laws. Since we already include state of birth fixed effects in our regressions, our concern is not with the main effect of these compulsory schooling laws but instead, their interaction with our during and after dummies.

Just as compulsory schooling laws could have driven schooling decisions for our cohorts of interest, it is also known that state mobilization rates for WWII affected labor force participation, particularly for females during this period (Acemoglu et al., 2004). Since mobilization rates were not uniform across states, we run our main specification including state of residence mobilization rates as a control, along with years of compulsory schooling interacted with the during and after dummies. Table 8 shows that our main results are robust to the inclusion of all of these controls; our coefficients of interest remain virtually unchanged.

Our final set of robustness tables are aimed at addressing various issues related to the particular goiter data and variable we use. First of all, although we use continuous goiter as our proxy for iodine deficiency risk, it is not clear that a linear relationship is the most appropriate. In fact, it is known that there is a "protective threshold" for fetal iodine levels, above which normal cognitive functioning is achieved. In order to test for robustness to other representations of our goiter variable that capture this biological feature of fetal iodine, we run our regressions using a discrete indicator for high goiter states. Like Feyrer et al. (2013), we define states as high goiter if they are in the top quartile of the goiter distribution (see Table A1). Table 9 reports regression results for our main outcomes using this discrete goiter variable, and our major conclusions remain unchanged: salt iodization led to lower primary school completion and increased employment and labor force participation. It should be noted that switching to a discrete cutoff eliminates any variation in the goiter variable within four of the nine Census divisions, which (due to our inclusion of division fixed effects) changes the source of identification for our coefficients of interest. This naturally alters some of our results: for instance, the effects

in 1944 (Daniel, 2006).

Table 8: Robustness to Inclusion of Compulsory Schooling Laws and WWII Mobilization Rates

	(1)	(2)	(3)	(4)	(5)
	1(Completed Primary)	1(Completed High School)	1(Completed College)	1(Participated in Labor Force)	1(Employed)
After x Goiter Rate	-0.00599***	-0.00686	-0.00528	0.00648***	0.00708***
	(0.00166)	(0.00448)	(0.00354)	(0.00201)	(0.00216)
During x Goiter Rate	-0.00362***	-0.00624	-0.00192	0.00441*	0.00449*
	(0.00132)	(0.00393)	(0.00286)	(0.00227)	(0.00247)
After x Compulsory Schooling	-0.00366**	-0.00878***	-0.00147	0.00132	0.00249*
	(0.00147)	(0.00323)	(0.00225)	(0.00105)	(0.00129)
During x Compulsory Schooling	-0.00228*	-0.00456**	-0.00138	0.00149*	0.00241**
	(0.00121)	(0.00186)	(0.00131)	(0.000838)	(0.000975)
WWII Mobilization Rate	0.240***	0.500**	0.103	-0.00302	-0.0663
	(0.0411)	(0.190)	(0.166)	(0.0652)	(0.0758)
Observations	1540845	1540845	1540845	1664620	1664620
Mean of Dependent Variable	0.960	0.619	0.128	0.698	0.672

Notes: Standard errors, clustered by state of residence, in parentheses (*** p<0.01, ** p<0.05, * p<0.1). *Goiter Rate* is the goiter rate in the individual's state of birth from Love and Davenport (1920), scaled by the difference between the 75th and 25th percentile of the goiter distribution (0.71). *After* is a dummy equal to 1 for those born 1928-1931. *During* is a dummy equal to 1 for those born 1924-1927. These regressions restrict to indivduals born in 1920-1931 aged 25 to 55. All regressions include state of birth fixed effects, year of birth x census year dummies, census division of birth x birth year dummies, gender, race, and 1920 state-level female and black proportions interacted with During and After dummies.

on high school and college completion are now positive (and, for the during coefficient in the college completion regression, significant). Rather than contradict our previous results, this actutally strengthens our argument about the targeted nature of our intervention and the substitutability of schooling and cognitive ability only at low levels of skill. Salt iodization decreased schooling completion only for those at low levels of schooling and appear to have had very different effects on higher levels, where cognitive ability and schooling are likely not substitutable.

Table 9: Robustness to 75th Percentile High Goiter Variable

	(1)	(2)	(3)	(4)	(5)
	1(Completed Primary)	1(Completed High School)	1(Completed College)	1(Participated in Labor Force)	1(Employed)
After x High Goiter	-0.00886***	0.0114	0.00451	0.00546*	0.00613*
	(0.00186)	(0.0104)	(0.00406)	(0.00312)	(0.00322)
During x High Goiter	-0.00621***	0.00629	0.00525**	0.00538**	0.00590*
	(0.00144)	(0.00826)	(0.00246)	(0.00267)	(0.00329)
Observations	1553941	1553941	1553941	1678661	1678661
Mean of Dependent Variable	0.960	0.620	0.129	0.698	0.672

Notes: Standard errors, clustered by state of residence, in parentheses (*** p<0.01, ** p<0.05, * p<0.1). *High Goiter* is equal to 1 if the goiter rate from the individual's state of birth from Love and Davenport (1920) is in the top quartile of the goiter distribution. *After* is a dummy equal to 1 for those born 1928-1931. *During* is a dummy equal to 1 for those born 1924-1927. These regressions restrict to indivduals born in 1920- 1931 aged 25 to 55. All regressions include state of birth fixed effects, year of birth x census year dummies, census division of birth x birth year dummies, gender, race, and 1920 state-level female and black proportions interacted with During and After dummies.

To ensure that our results are not being driven by particular features of the Love and Davenport (1920) data (for instance, the sample of adult men which may not be very representative of the whole population, or the fact that only extreme cases of goiter were recorded), we also check for robustness to the use of the Olesen (1929) goiter data, which calculated rates from both young boys and girls and recorded even minor cases of goiter. Table 10 shows that our results are remarkably robust to the use of this goiter variable. As with our Love and Davenport (1920) results, the coefficients are scaled by the inter-quartile range (in this case, 18.8 percentage points), which results in effect sizes slightly smaller than in our main specification.

Another way to address this issue is to use the Olesen (1929) data to instrument for our Love and

Table 10: Robustness to Olesen Data

	(1)	(2)	(3)	(4)	(5)
	1(Completed Primary)	1(Completed High School)	1(Completed College)	1(Participated in Labor Force)	1(Employed)
After x Goiter Rate	-0.00575**	-0.0119**	-0.00189	0.00204*	0.00283*
	(0.00245)	(0.00534)	(0.00270)	(0.00120)	(0.00148)
During x Goiter Rate	-0.00390**	-0.00240	-0.000335	0.00152	0.00220
	(0.00190)	(0.00408)	(0.00203)	(0.00152)	(0.00172)
Observations	1322567	1322567	1322567	1427788	1427788
Mean of Dependent Variable	0.965	0.628	0.131	0.699	0.672

Notes: Standard errors, clustered by state of residence, in parentheses (*** p<0.01, ** p<0.05, * p<0.1). *Goiter Rate* is the goiter rate in the individual's state of birth from Olesen (1929), scaled by the difference between the 75th and 25th percentile of the goiter distribution (18.8). *After* is a dummy equal to 1 for those born 1928-1931. *During* is a dummy equal to 1 for those born 1924-1927. These regressions restrict to indivduals born in 1920-1931 aged 25 to 55. All regressions include state of birth fixed effects, year of birth x census year dummies, census division of birth x birth year dummies, gender, race, and 1920 state-level female and black proportions interacted with During and After dummies.

Davenport (1920) data. Provided that the measurement error in Love and Davenport (1920) is uncorrelated with that of Olesen (1929), this would deal with any measurement error issues related to the methods of data collection or non-representative nature of the sample. Given the drastically different contexts and methods of data collection, we find it reasonable to assume uncorrelated errors across the two datasets. Using a discrete above-median high goiter dummy from Olesen (1929) (interacted with during and after dummies) as instruments for the continuous Love and Davenport (1920) goiter rate (also interacted with those cohort dummies),[12] we run our main regressions in an instrumental variables specification and report the results in Table 11. The instrumental variables estimates are very similar though slightly larger than the OLS estimates. Measurement error was not generating spurious results and if anything, may have been attenuating our results. The effect on primary schooling completion is around 1 to 2 percentage points, while the employment and labor force effects range from half a percentage point to just over a full percentage point. First stage results are reported in the Appendix (Table A3).

[12] We use this particular discrete variable instead of continuous goiter because it generated the strongest first-stage F-statistic, but the magnitudes of second-stage coefficients were relatively similar across different variations of the Olesen instruments.

Table 11: Instrumental Variables Estimates of the Effects of Salt Iodization

	(1)	(2)	(3)	(4)	(5)
	1(Completed Primary)	1(Completed High School)	1(Completed College)	1(Participated in Labor Force)	1(Employed)
After x Goiter Rate	-0.0229***	-0.0145	0.00421	0.0103***	0.0145***
	(0.00837)	(0.0110)	(0.00772)	(0.00395)	(0.00485)
During x Goiter Rate	-0.0163**	-0.00765	0.00271	0.00577	0.00927*
	(0.00725)	(0.00954)	(0.00547)	(0.00401)	(0.00506)
Observations	1322567	1322567	1322567	1427788	1427788
Mean of Dependent Variable	0.965	0.628	0.131	0.699	0.672

Notes: Standard errors, clustered by state of residence, in parentheses (*** p<0.01, ** p<0.05, * p<0.1). *Goiter Rate* is the goiter rate in the individual's state of birth from Love and Davenport (1920), scaled by the difference between the 75th and 25th percentile of the goiter distribution (0.71). *After* is a dummy equal to 1 for those born 1928-1931. *During* is a dummy equal to 1 for those born 1924-1927. These regressions restrict to indivduals born in 1920-1931 aged 25 to 55. All regressions include state of birth fixed effects, year of birth x census year dummies, census division of birth x birth year dummies, gender, race, and 1920 state-level female and black proportions interacted with During and After dummies. Instruments used were After x High Goiter (above median) and During x High Goiter (above median) from Olesen (1929).

6 Conclusion

In this study, we document the effects of the rapid nationwide iodization of salt in the United States. We estimate substantial impacts on educational attainment and labor force participation. Impacts on educational attainment are concentrated at lower grade levels and amongst residents of states with higher proportions of blue and goods sector employment. These education results are consistent with the improved cognitive ability brought about through salt iodization being a substitute for educational attainment at lower grade levels. Correspondingly, most of the new labor force participants appear to have entered the left tails of the wage and total income distribution.

Our results contribute to several strands of literature and current policy debates. This study contributes to the growing literature on the long-term effects of early-life conditions, particularly the smaller set of recent work estimating gains to purposeful and beneficial large-scale policy interventions like fortification schemes. These results differ from earlier studies of early-life "shocks" in that they validate the impacts of actionable policies which can then be reproduced elsewhere. In this way, the study of historic successes, and failures for that matter, in US and other developed settings, can potentially provide important predictions for academic researchers and policy-makers faced with similar issues in developing countries today.

Our study also contributes evidence to a recent body of work investigating the degree to which cognitive ability and formal schooling can substitute for or complement one another at various stages of development. We find that an increase in cognitive ability at the lower end of the skill distribution crowded out primary school completion and drove up labor force participation in low-wage jobs. On the other hand, we find little evidence of an impact of salt iodization on secondary or post-secondary school completion, suggesting that pre-iodization cognitive disadvantages were being compensated for with primary but not higher levels of schooling.

Additionally, our study provides evidence of the magnitude of benefits from eradication of deficiencies in essential micronutrients such as iodine. Many developing country populations face myriad nutritional constraints which have long-lasting impacts on health, economic livelihoods, and general welfare. Our estimates show that salt iodization led to a roughly .6 percentage point rise in labor force participation, particularly in the first and second income quintiles. From a base labor force of 62 million in 1940, this amounts to over 1 billion USD in additional wage income using, conservatively, the mean of first income quintile (62 million x 0.006 x 3200 USD = 1.190 billion USD).

Lastly, it should be noted that the “intervention” cost the taxpayer nothing, in that the roll-out of iodized salt was completely undertaken by the private sector. That is, the cost of salt iodization was fully borne by the salt producer, while the cognitive benefit was realized by the general population. We conjecture that the rapid rise in both supply and demand (as evidenced by the negligible difference between the “during” and “after” coefficients) might be attributable to the efficiency and underlying profit motive of the private firm that undertook the intervention.

A Additional Tables

In Table A1, we list all states (excluding Hawaii) by Census division, along with their corresponding goiter rates from Love and Davenport (1920) (in column 1) and Olesen (1929) (in column 2). We also include their corresponding high-goiter classification using the 75th percentile of the Love and Davenport (1920) distribution as a cutoff in column 3, as well as their classification a blue collar state in column 4.

Table A2 reports coefficients from the quantile dummy regressions that are graphically illustrated in Figure 6. Note that the means of the dependent variables do not sum to one because individuals earning no income were assigned a zero for all five dummies (See section B for details on the construction of these variables.)

Table A3 reports the first-stage regressions for the instrumental variables specification reported in Table 11, which uses a discrete above-median high goiter variable from the Olesen (1929) data (interacted with during and after dummies) to instrument for the continuous goiter rate from Love and Davenport (1920) (also interacted with the cohort dummies).

Table A1: Regional Classification of States

		(1)	(2)	(3)	(4)
Census Division	State	Love and Davenport (1920) Goiter Rate	Olesen (1929) Goiter Rate	Above p75 Love and Davenport (1920)	1(Blue Collar State)
New England	Connecticut	0.091	18.2	0	0
New England	Maine	0.056	24.8	0	1
New England	Massachusetts	0.030	1.6	0	0
New England	New Hampshire	0.072	0.2	0	1
New England	Rhode Island	0.055	0.9	0	0
New England	Vermont	0.214	.	0	1
Middle Atlantic	New Jersey	0.043	9.1	0	0
Middle Atlantic	New York	0.118	12.1	0	0
Middle Atlantic	Pennsylvania	0.410	15.5	0	0
East North Central	Illinois	0.780	20.4	1	0
East North Central	Indiana	0.642	76.0	0	1
East North Central	Michigan	1.130	19.6	1	0
East North Central	Ohio	0.568	28.4	0	0
East North Central	Wisconsin	1.384	46.6	1	0
West North Central	Iowa	0.661	.	0	0
West North Central	Kansas	0.124	8.4	0	0
West North Central	Minnesota	0.793	23.6	1	0
West North Central	Missouri	0.398	3.0	0	1
West North Central	Nebraska	0.227	.	0	0
West North Central	North Dakota	0.884	4.0	1	0
West North Central	South Dakota	0.384	.	0	0
South Atlantic	Delaware	0.059	.	0	0
South Atlantic	District of Columbia	0.447	.	0	0
South Atlantic	Florida	0.021	.	0	1
South Atlantic	Georgia	0.050	0.8	0	1
South Atlantic	Maryland	0.094	6.2	0	1
South Atlantic	North Carolina	0.170	0.2	0	1
South Atlantic	South Carolina	0.087	.	0	1
South Atlantic	Virginia	0.333	9.0	0	1
South Atlantic	West Virginia	0.790	43.9	1	1
East South Central	Alabama	0.057	0.1	0	1
East South Central	Kentucky	0.142	6.9	0	1
East South Central	Mississippi	0.057	0.3	0	1
East South Central	Tennessee	0.190	5.2	0	1
West South Central	Arkansas	0.043	.	0	1
West South Central	Louisiana	0.063	5.5	0	1
West South Central	Oklahoma	0.067	10.4	0	0
West South Central	Texas	0.027	.	0	1
Mountain	Arizona	0.110	0.1	0	0
Mountain	Colorado	0.530	35.4	0	0
Mountain	Idaho	2.686	.	1	0
Mountain	Montana	2.097	20.4	1	1
Mountain	Nevada	0.638	.	0	1
Mountain	New Mexico	0.101	0.1	0	1
Mountain	Utah	1.562	44.9	1	0
Mountain	Wyoming	1.538	15.0	1	1
Pacific	Alaska	1.314	.	1	1
Pacific	California	0.438	0.0	0	0
Pacific	Oregon	2.402	22.5	1	1
Pacific	Washington	2.325	17.6	1	0

Table A2: Effects of Salt Iodization on Income by Quintile

	(1)	(2)	(3)	(4)	(5)
	1st Income Quintile	2nd Income Quintile	3rd Income Quintile	4th Income Quintile	5th Income Quintile
After x Goiter Rate	0.00124	0.00254*	0.00278	-0.000757	-0.00435
	(0.00161)	(0.00151)	(0.00169)	(0.00161)	(0.00312)
During x Goiter Rate	-0.000243	0.00188	0.00279*	-0.00115	-0.00374
	(0.00148)	(0.00183)	(0.00156)	(0.00163)	(0.00272)
Observations	1549843	1549843	1549843	1549843	1549843
Mean of Dependent Variable	0.103	0.0942	0.0860	0.0980	0.422

Notes: Standard errors, clustered by state of residence, in parentheses (*** p<0.01, ** p<0.05, * p<0.1). *Goiter Rate* is the goiter rate in the individual's state of birth from Love and Davenport (1920), scaled by the difference between the 75th and 25th percentile of the goiter distribution (0.71). *After* is a dummy equal to 1 for those born 1928-1931. *During* is a dummy equal to 1 for those born 1924-1927. These regressions restrict to indivduals born in 1920-1931 aged 25 to 55. All regressions include state of birth fixed effects, year of birth x census year dummies, census division of birth x birth year dummies, gender, race, and 1920 state-level female and black proportions interacted with During and After dummies.

Table A3: First Stage Results for Instrumental Variables Estimates of the Effects of Salt Iodization

	(1)	(2)	(3)	(4)
	Education Outcomes		Labor Outcomes	
	After x Goiter Rate	During x Goiter Rate	After x Goiter Rate	During x Goiter Rate
After x High Goiter (Olesen Data)	0.868***	-0.00597	0.866***	-0.00907
	(0.170)	(0.0103)	(0.169)	(0.00929)
During x High Goiter (Olesen Data)	-0.00119	0.862***	-0.00343	0.858***
	(0.00892)	(0.170)	(0.00804)	(0.169)
Observations	1322567	1322567	1427788	1427788
Mean of Dependent Variable	0.249	0.255	0.230	0.250
F-statistic for excluded instruments	13.204	13.314	13.1	13.117

Notes: Standard errors, clustered by state of residence, in parentheses (*** p<0.01, ** p<0.05, * p<0.1). All regressions include state of birth fixed effects, year of birth x census year dummies, census division of birth x birth year dummies, gender, race, and 1920 state-level female and black proportions interacted with During and After dummies. High Goiter (Olesen Data) is equal to 1 for individuals born in states in the top half of the goiter distribution from Olesen (1929).

B Data Appendix

B.1 Independent Indicator Variables

- *Before*=1 if individual was born in 1920-1924; *Before*=0 otherwise
- *During*=1 if individual was born in 1924-1927; *During*=0 otherwise
- *After*=1 if individual was born in 1928-1931; *After*=0 otherwise

B.2 Outcome Variables

B.2.1 Basic Outcomes

- *Years of Schooling*: Years of schooling completed by the individual.
- *1(Completed Primary School)*=1 if the individual completed 6 or more years of schooling.
  1(Completed Primary School)=0 if the individual completed less than 6 years of schooling.
- *1(Completed Junior High)*=1 if the individual completed 8 or more years of schooling.
  1(Completed Junior High)=0 if the individual completed less than 8 years of schooling.
- *1(Graduated High School)*=1 if the individual graduated high school. This includes those who completed the GED but not those who went to vocational school ;
  1(Graduated High School)=0 if the individual did not complete high school.
- *1(Graduated College)*=1 if the individual graduated from college;
  1(Graduated College)=0 if the individual did not complete college.
- *1(Participated in Labor Force)*=1 if the individual participated in the labor force (by either working or looking for work);
  1(Participated in Labor Force)=0 if the individual did not participate in the labor force.
- *1(Employed)*=1 if the individual was employed;
  1(Employed)=0 if the individual did not work, irrespective of whether the individual looked for a job.
- *1(Self-Employed)*=1 if the individual was self-employed;
  1(Self-Employed)=0 if the individual worked for wages as an employee.

- *1(Blue Collar)*=1 if the individual was in the labor force and fell into one of the following blue-collar occupation type categories (according to the Census Bureau's 1950 occupation classification system): farmers, craftsmen, operatives, farm laborers, and laborers;
  1(Blue Collar)=0 if the individual was in the labor force but fell into some other occupation category. This variable is missing for those not in the labor force.

- *Log Total Income*: This is the log of the total annual income earned by the individual (for those earning positive total income) and zero for those who earned zero income. All values are adjusted to 1999 prices according to Census-provided multipliers. Although this variable is top-coded differently across Census years, we applied the top-coding from the 1950 Census to all years (setting the maximum income to $70,000). Logs were taken after all of the adjustments were made.

B.2.2 Income Quintile Analysis

1(Total Income Quintile 1) to *1(Total Income Quintile 5)* were constructed as follows. Using the entire population aged 25-55 from the 1950 Census, we calculate the 20th, 40th, 60th, and 80th percentiles for log income. These were used as the baseline quintiles to construct the following variables:

- *1(Total Income Quintile 1)*=1 if the individual's log income was greater than zero and fell into the first quintile of *Total Income* from the 1950 Census ; *1(Total Income Quintile 1)*=0 if the individual's log income fell outside of this first quintile or was equal to zero. This variable is missing for those with missing total income in the Census. Analogous variables are constructed for the second, third, fourth, and fifth quintiles. For each individual, at most only one of these five variables is set equal to one. For those with zero income, all of the dummies are set equal to zero.

B.3 Other Variables

- *female*=1 for females; *female*=0 for males

- *black*=1 for black individuals; *black*=0 for all other races

- *white*=1 for white individuals; *white*=0 for all other races; this is the minority group in Panel A of Table 6

- *femaleprop1920*: The state-level proportion of the population that was female in the individual's state of residence (as reported in the 1920 Census).
- *blackprop1920*: The state-level proportion of the population that was black in the individual's state of residence (as reported in the 1920 Census).
- *1(Blue Collar State)*=1 if individual resides in a state that, according to the 1920 and 1930 Censuses, had an at- or above-median proportion of individuals working at a blue-collar job
  1(Blue Collar State)=0 if individual resides in a state that had a below-median proportion of individuals working at a blue-collar job (according to the 1920 and 1930 Censuses). Blue collar jobs were identified using the *occ1950* occuptation codes from the Census.
- *Tuberculosis*: Pre-iodization tuberculosis rate in state of birth according to Love and Davenport (1920)
- *Malaria*: Pre-iodization malaria rate in state of birth according to Bleakley (2010)
- *Compulsory Schooling*: Number of years of schooling required by compulsory attendance laws in the individual's state of birth in the year they turned 14 (which is the minimum leaving age across all states and years)
- *Mobilization Rate*: WWII mobilization rate for individual's state of residence

B.4 State-Level Goiter Rates from Olesen (1929)

Olesen (1929) reports goiter rates in various localities for 37 states. For each of these localities, there is a column for boys, a column for girls, as well as a column for boys and girls. For each of these columns, he reports the percent found with goiter and in some cases, also the number of children examined. Because the number of children examined is missing for over 400 localities, and also because weighting by this number would be artificial (since we do not have locality populations, which would be the ideal), we calculate the simple mean of the percentages across all localities within a state for each column. Our goiter rate of interest is the state-level goiter rate in the boys and girls column. For states which have no percentages reported in the boys and girls column, we take the average across the boys column and the girls column. For those that only have a boys column or a girls column, we use the state average of the non-missing column.

References

Acemoglu, D., Lyle, D., et al. (2004). Women, war, and wages: The effect of female labor supply on the wage structure at midcentury. *Journal of Political Economy*, 112(3):497–551.

Aizer, A. and Cunha, F. (2012). The production of human capital: endowments, investments and fertility. Technical report, National Bureau of Economic Research.

Almond, D. and Currie, J. (2011). Killing me softly: The fetal origins hypothesis. *Journal of Economic Perspectives*, 25(3):153–172.

Almond, D., Doyle, J., Kowalski, A., and Williams, H. (2010). Estimating marginal returns to medical care: Evidence from at-risk newborns. *Quarterly Journal of Economics*, 125(2):591634.

Almond, D., Edlund, L., and Palme, M. (2009). Chernobyls subclinical legacy: Prenatal exposure to radioactive fallout and school outcomes in sweden. *Quarterly Journal of Economics*, 124(4):1729–1772.

Almond, D. and Mazumder, B. (2013). Fetal origins and parental responses. *Annu. Rev. Econ.*, 5(1):37–56.

Andersson, M., de Benoist, B., and Rogers, L. (2010). Epidemiology of iodine deficiency: Salt iodisation and iodine status. *Best Practice and Research Clinical Endocrinology and Metabolism*, 24:1–11.

Annegers, J. and Mickelsen, O. (1973). Goiter and iodized salt, a historical review and examination of the present role of iodized salt. Unpublished Manuscript.

Backstrand, J. (2002). The history and future of food fortification in the united states: A public health perspective. *Nutrition Reviews*, 60:15–26.

Baumann, F. (1896). Ueber das normale vorkommen von jod im thierkorper. *Physiol Chem*, 21:319–330.

Bhalotra, S. and Venkataramani, A. (2012). Shadows of the captain of the men of death: Early life health interventions, human capital investments, and institutions. working paper.

Bhutta, Z., Das, J., Rizvi, A., et al. (2013). The lancet nutrition interventions review group, and the maternal and child nutrition study group. evidence-based interventions for improvement of maternal and child nutrition: what can be done and at what cost. *Lancet*, pages 60996–4.

Black, R. E., Victora, C. G., Walker, S. P., Bhutta, Z. A., Christian, P., de Onis, M., Ezzati, M., Grantham-McGregor, S., Katz, J., Martorell, R., et al. (2013). Maternal and child undernutrition and overweight in low-income and middle-income countries. *The Lancet*.

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

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

Brush, B. E. and Atland, J. (1952). Goiter prevention with iodized salt: Results of a thirty-year study. *The Journal of Clinical Endocrinology And Metabolism*, 12(10):1380–1388.

Butler, R. J. and Heckman, J. J. (1977). The government's impact on the labor market status of black americans: A critical review. *NBER Working Paper*, (w0183).

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

Center, C. C. (2008). Copenhagen consensus 2008. *Fredriksberg, Denmark: Copenhagen Consensus Center*.

Clar, C., Wu, T., Liu, G., and Li, P. (2002). Iodized salt for iodine deficiency disorders: A systematic review. *Endocrinology and Metabolism Clinics of North America*, 31:681–698.

Comstock, G. W. (1994). The international tuberculosis campaign: a pioneering venture in mass vaccination and research. *Clinical infectious diseases*, 19(3):528–540.

Cunha, F., Heckman, J. J., and Schennach, S. M. (2010). Estimating the technology of cognitive and noncognitive skill formation. *Econometrica*, 78(3):883–931.

Currie, J. and Vogl, T. (2012). Early-life health and adult circumstance in developing countries. Technical report, National Bureau of Economic Research.

Daniel, T. M. (2006). The history of tuberculosis. *Respiratory medicine*, 100(11):1862–1870.

de Benoist, B., Andersson, M., Egli, I., Takkouche, B., and Allen, H. (2004). Iodine status worldwide: Who global database on iodine deficiency. World Health Organization.

Eltom, M., Karlsson, F. A., Kamal, A. M., Boström, H., and Dahlberg, P. A. (1985). The effectiveness of oral iodized oil in the treatment and prophylaxis of endemic goiter. *Journal of Clinical Endocrinology and Metabolism,*, 61(6):1112–1117.

Feyrer, J., Politi, D., and Weil, D. N. (2013). The economic effects of micronutrient deficiency: Evidence from salt iodization in the united states. NBER Working Paper No. 19233.

Field, E., Robles, O., and Torero, M. (2009). Iodine deficiency and schooling attainment in tanzania. *American Economic Journal: Applied Microeconomics*, 1(4):140–169.

Furnee, C. A. (1997). Prevention and control of iodine deficiency: A review of a study on the effectiveness of oral iodized oil in malawi. *European Journal of Clinical Nutrition*, 51(4):S9–10.

Goldin, C. (1999). A brief history of education in the united states. *NBER Working Paper*, (h0119).

Goldin, C. and Margo, R. A. (1992). The great compression: The wage structure in the united states at mid-century. *The Quarterly Journal of Economics*, pages 1–34.

Hall, D. (1914). The prevalence of goiter in the northwest, based on the examinations of 3,339 students entering the university of washington. *Northwest Medicine*, 6:189–391.

Hamwi, G. J., Van Fossen, A. W., Whetstone, R. E., and Williams, I. (1952). Endemic goiter in ohio school children. *American Journal of Public Health*, 45(10):1344–1348.

Heckman, J. J. (2006). Skill formation and the economics of investing in disadvantaged children. *Science*, 312(5782):1900–1902.

Hetzel, B. and Pandav, C. (1996). *S.O.S for a Billion: The Conquest of Iodine Deficiency Disorders*. Oxford University Press.

Hetzel, B. S. (1989). *The Story of Iodine Deficiency: An International Challenge in Nutrition*, chapter The Biology of Iodine. Oxford University Press.

Hetzel, B. S. and Mano, M. T. (1989). A review of experimental studies of iodine deficiency during fetal development. *Journal of Nutrition*, 119(2):145–151.

Hornbeck, R. (2012). The enduring impact of the american dust bowl: Short- and long-run adjustments to environmental catastrophe. *American Economic Review*, 102(4):1477–1507.

Hoynes, H. W., Schanzenbach, D. W., and Almond, D. (2012). Long run impacts of childhood access to the safety net. Technical report, National Bureau of Economic Research.

Huda, S., Grantham-McGregor, S., Rahman, K., and Tomkins, A. (1999). Biochemical hypothyroidism secondary to iodine deficiency is associated with poor school achievement and cognition in bangladeshi children. *Journal of Nutrition*, 129:980–987.

Killingsworth, M. R. and Heckman, J. J. (1987). Female labor supply: A survey. *Handbook of Labor Economics*, 1:103–204.

Lamberg, B.-A. (1991). Endemic goitreiodine deficiency disorders. *Annals of Medicine*, 23(4):367–372.

Lleras-Muney, A. (2002). Were compulsory attendance and child labor laws effective? an analysis from 1915 to 1939. *Journal of Law and Economics*, 45(2):401–435.

Love, A. G. and Davenport, C. B. (1920). *Defects Found in Drafted Men. Statistical Information Compiled from the Draft Records Showing the Physical Conditions of the Men Registered and Examined in Pursuance of the Requirements of the Selective-Service Act.* Washington DC: Government Printing Office.

Marine, D. and Feiss, H. (1915). The absorption of potassium iodid by perfused thyroid glands and some of the factors modifying it. *Journal of Pharmacology and Experimental Therapeutics*, 7:557–576.

Marine, D. and Kimball, O. (1917). The prevention of simple goiter in man. *Journal of Laboratory and Clinical Medicine*, 3:40–48.

Marine, D. and Kimball, O. (1921). The prevention of simple goiter in man. *Journal of the American Medical Association*, 77:1068–1070.

Marine, D. and Lenhart, C. (1909). Effects of the administration or withholding of iodin-containing compounds in normal, colloid, or actively hyperplastic thyroids of dogs. *Archives of Internal Medicine*, 4:253–270.

Markel, H. (1987). When it rains it pours: Endemic goiter, iodized salt and david murray cowie, md. *American Journal of Public Health*, 77(2):219–229.

Martorell, R. (1995). Results and implications of the incap follow-up study. *The Journal of nutrition*, 125(4 Suppl):1127S–1138S.

Olesen, R. (1915). Goiter, its prevalence in chicago, as shown by the examination of 800 individuals. *Illinois Medical Journal*, 27:16.

Olesen, R. (1929). Distribution of endemic goiter in the united states as shown by thyroid surveys. *Public Health Reports*, 44:1463–87.

Pharoah, P. and Connolly, K. (1987). A controlled trial of iodinated oil for the prevention of endemic cretinism: A long-term follow-up. *International Journal of Epidemiology*, 16(1):68–73.

Politi, D. (2011a). The effects of the generalized use of iodized salt on occupational patterns in switzerland. Working Paper.

Politi, D. (2011b). The impact of iodine deficiency eradication on schooling: Evidence from the introduction of iodized salt in switzerland. Working Paper.

Santiago-Fernandez, P., Torres-Barahona, R., Muela-Martinez, A., Rojo-Martinez, G., Garcia-Fuentes, E., M., G., Leon, A., and Soriguer, F. (2004). Intelligence quotient and iodine intake: A cross-sectional study in children. *The Journal of Clinical Endocrinology & Metabolism*, 89:3851–57.

Schiel, J. B. J. and Wepfer, A. J. (1976). Distributional aspects of endemic goiter in the united states. *Economic Geography*, 52(2):116–126.

Smith, G. (1917). Fetal athyreosis. *Journal of Biological Chemistry*, 29:215–225.

WHO (1992). National strategies for overcoming micronutrient malnutrition. Unpublished.

WHO (2004). Iodine status worldwide. global database on iodine deficiency.

Zimmermann, M. B., Aeberli, I., Torresani, T., and Bürgi, H. (2005). Increasing the iodine concentration in the swiss iodized salt program markedly improved iodine status in pregnant women and children: A 5-y prospective national study. *American Journal of Clinical Nutrition*, 82(2):388–392.