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 0.9 percentage points, driven by a rise in low-skill employment. Educational attainment declined by 0.2 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 wage 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 part 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 high and low pre-iodization deficiency rates. To identify the latter difference, we use pre-iodization rates of goiter, the main physical manifestation of IDD (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 about 0.2 years as a result of salt iodization. This impact is driven by primary school completion, which declined by nearly 2 percentage points. The effect on high school completion is also negative, though not precisely estimated across most specifications. The impacts on college enrollment and 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 and wage and income distributions conditional on participation are consistent with this interpretation. Labor force participation rose by nearly 1 percentage point, driven mainly by an increase in low-skill employment. While the income distributions conditional on labor force participation of both high and low deficiency states shifted to the right over birth cohorts, the distribution in high deficiency states shifted less than in low deficiency states, consistent with an influx of low-skilled labor force participants. In summary, as a result of iodization, school completion declined, as more workers joined the blue-collar labor force. Working in low-wage positions, these labor force joiners swelled the bottom of the wage distribution, bringing down the average wage conditional on participation.

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

[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.

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 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 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 be used to compensate for pre-iodization cognitive disadvantages.

Finally, we add evidence on the long-run effects of 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

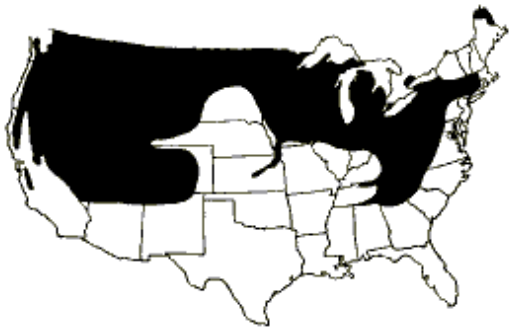
2.1 Iodine Deficiency and its Consequences

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

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

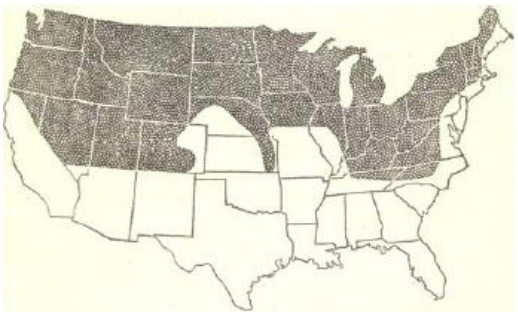
Figure I: Simple Goiter Incidence Among US Drafted Men in World War I and Iodine Content of Drinking Water in the US (1924)



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)

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%-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 I 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 high correlation between the geographic pattern of goiter incidence among WWI

[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.

recruits and the geographic pattern of iodine content of drinking water as reported in 1924 by the then prominent scientist Jesse Francis McClendon (map on the right).

As mentioned above, there is a threshold of iodine intake beyond which more intake brings no additional benefit; it is thus appropriate to depict the relationship between goiter incidence and water iodine content in terms of low content versus high content, rather than in terms of continuous values. More details on this comparison can be found in McClendon and Hathaway (1924) and McClendon (1939).

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. Our paper uses the Olesen goiter rates because they are drawn from a sample more relevant to our focus on *in utero* iodine deficiency, compared to a potentially non-representative sample of adult male recruits.

The Olesen data, summarized in Table A.1, show variation in goiter prevalence across states within regions. 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

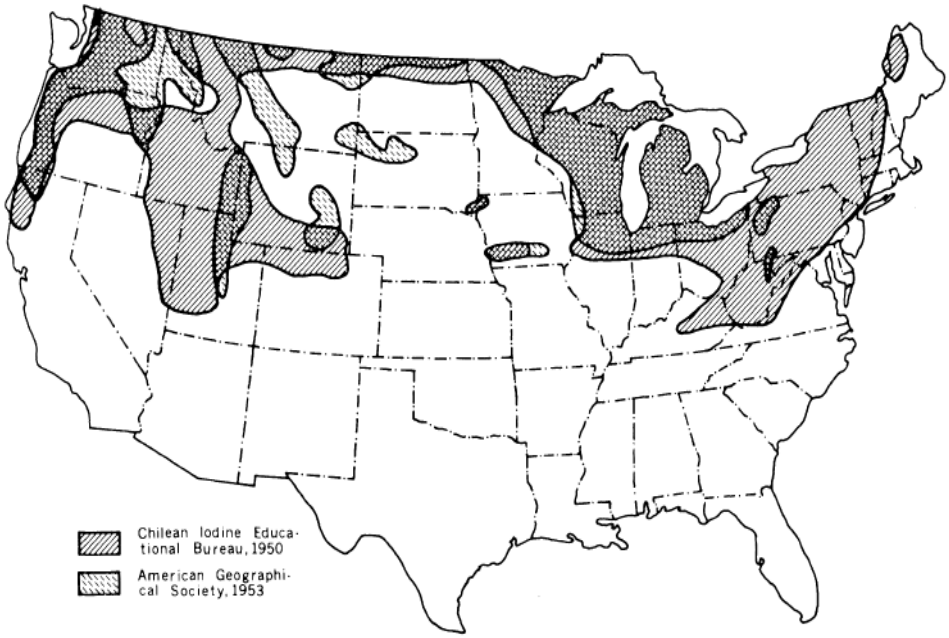
It was not until 1895 when iodine was first found in the thyroid gland by a German chemist Eugen Baumann (Baumann, 1896). Since then experiments were conducted to study the impact of changes in iodine content and the enlargement of the incidence of goiter in different kinds of animals, including dogs, 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. 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 II 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 I) and 1950, and further from 1950 to 1953.

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



Source: Schiel and Wepfer (1976)

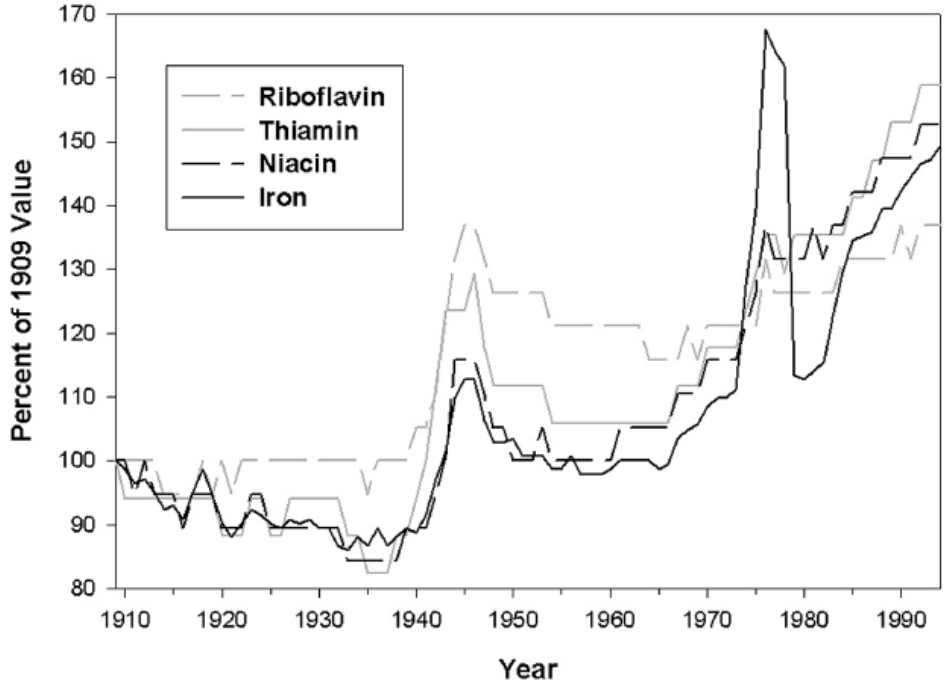
2.4 Goiter and Confounding Factors

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 I shows that goiter incidence was concentrated in the northern states, which were socioeconomically better off compared to the southern states.

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 III shows the change in the per capita riboflavin, iron, niacin, and thiamin contents of Ameri-

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



Source: Backstrand (2002)

can 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 various diseases as well as the interactions of these prevalences 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.

3 Data

3.1 Goiter Data

Our information on the geographic distribution of iodine deficiency prior to salt iodization comes from Olesen (1929), which includes a compiled list of goiter rates among children. 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. Table A.1 lists the remaining 37 states in ascending order of state-level goiter prevalence. The median goiter rate in this sample is 9.1%. For our main specification, all states above the median are classified as high deficiency states, while all states below the median are classified as low deficiency states. See Data Appendix for details on how the state-level averages were calculated.

In order to confirm that our results are not being driven by the particular set of states reported in Olesen (1929), we also use a second measure of goiter in a robustness check. This measure comes from 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 rates per 1000 men. Table A.3 lists all states recorded in Love and Davenport (1920), in ascending order of goiter prevalence. The goiter rates recorded here are much smaller than the goiter rates from Olesen (1929). This is due to the greater noticeability of goiter among children compared to adults. Since goiter is already an indication of extreme iodine deficiency, the estimates in the Olesen data more closely reflect what we are trying to measure; they are also representative of a wider population than the army recruit data. 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 tighter 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.

Each individual in the sample is identified as having a high or low risk of being born to an iodine deficient mother, depending on whether their state of birth is a high or low goiter state (classified according to the methods described above). 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, high school, and college completion. In terms of labor outcomes, we are interested in the rates at which individuals are participating in the labor force, as well as their wage income and total income. We use log wages and log income (conditional on reporting non-zero values). 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, 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 the individual's state of residence.

We also construct dummy variables to indicate whether an individual is living in a "blue collar" or "goods sector" 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 or a job in the goods-producing sector. States with at- or above-median proportions are categorized as "blue collar" or "goods sector" states. For more details on the construction of variables, see the Data Appendix.

3.3 Region Controls

There are clear regional patterns in the distribution of goiter. This necessitates the inclusion of region by birth year dummies, which we use in all of our specifications. We control for region of birth using the nine Census Bureau divisions, reported in Table A.2. The inclusion of these interaction terms means we are identifying off of within-region variation, essentially comparing the high and low goiter

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)	0.614	0.611	0.617	-0.00543***
	(0.487)	(0.487)	(0.486)	(0.00152)
1(Earned Positive Wage)	0.503	0.517	0.484	0.0325***
	(0.500)	(0.500)	(0.500)	(0.00157)
1(Graduated High School)	0.291	0.322	0.248	0.0742***
	(0.454)	(0.467)	(0.432)	(0.00142)
1(Graduated College)	0.0555	0.0626	0.0457	0.0170***
	(0.229)	(0.242)	(0.209)	(0.000715)
Wage Income	13540.2	15009.9	11399.0	3610.9***
	(10803.5)	(11087.6)	(9996.1)	(47.51)
1(Female)	0.503	0.502	0.505	-0.00361*
	(0.500)	(0.500)	(0.500)	(0.00156)
1(Black)	0.0949	0.0147	0.204	-0.190***
	(0.293)	(0.121)	(0.403)	(0.000869)
Number of Observations	418791	241689	177102	

states 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. Another way we control for regional patterns is by including controls for the average latitude and longitude of individuals' state of birth. These figures were obtained from an online database.[7]

3.3.1 Summary Statistics

Table I 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 the pre-treatment conditions in high and low goiter states. About 60% of the population participated in the labor force, although around half earned a positive wage. High school and college graduation, positive wage earning, and wage income were significantly higher in high goiter states, which is consistent with the Northern states having better socioeconomic conditions prior to the iodization of salt. 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. They also emphasize the importance

[7] MaxMind: $http://dev.maxmind.com/geoip/legacy/codes/state_latlon/$

of our region-by-birth-year interaction dummies.

3.4 Other Diseases

In certain specifications, as robustness checks, we control for the pre-iodization rates of other diseases, including malaria, hookworm, and tuberculosis. In addition to goiter, Love and Davenport (1920) recored rates of various "defects" found in recruits, including tuberculosis. For malaria, we use the malaria mortality rates from the 1890 Census, used in Bleakley (2010). Hookworm rates are also taken from Bleakley (2010). These rates were drawn from around 20,000 recruits in 1917 and 1918, a smaller and separate sample from the recruits tested in Love and Davenport (1920) (Kofoid and Tucker, 1921). As with goiter, the state-level medians of these disease prevalence rates were calculated, and each individual was assigned to either a low or high-prevalence indicator for that particular disease, depending on their state of birth.

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 high v. low 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 Olesen (1929)'s list of goiter rates observed in school children. We assign each individual in the census a goiter rate using their state of birth. We do this 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. This proxy will, of course, not fully reflect actual iodine exposure *in utero*. 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 us to classify individuals generally as having a low v. high exposure to iodine *in utero*.

We interpret differences in trends in economic outcomes across individuals born in high v. low goiter states as being causally related to salt iodization. The particular features of the role of iodine in regulating cognitive ability bolster this interpretation. For normal cognitive functioning, fetal iodine must be above a "protective threshold" (Cao et al., 1994; Eltom et al., 1985; Furnee, 1997). Above this threshold, additional iodine does not yield much of a cognitive benefit; below it, even small changes in access to iodine can generate large shifts in IQ (Dugbartey, 1998; Lavado-Autric et al., 2003; Pop et al., 1999; Sundqvist et al., 1998).

The presence of this protective threshold has strong implications for our empirical strategy. While salt iodization increased iodine intake across the entirety of the US population, additional iodine in low deficiency areas, in which most of the population was already above the protective threshold, likely

had little effect on cognitive abilities. In contrast, in high deficiency areas, in which the risk of falling below the threshold was more pronounced, the same increase in iodine intake likely generated large changes in IQ.[8]

We study the outcomes of three cohorts 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 nation-wide 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 estimates for impacts in these two cohorts are indistinguishable, suggesting that iodized salt did indeed proliferate very quickly.

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 high v. low iodine deficiency areas. In our baseline specification, we split the sample at the median state-level goiter rate, creating a high goiter (above median) v. low goiter (below median) exposure designation assigned by state of birth. We estimate the following base specification, for individual i born in year t in state s (census division r), for outcome o recorded in census year c, where T is a treatment dummy which equals 1 if the individual was born in a high goiter state, D is a dummy for belonging to the "during" cohort, and A is a dummy for belonging to the "after" cohort:

$$o_{ist} = \beta_1 T_s D_t + \beta_2 T_s A_t + (\zeta_r \text{ x } \delta_t) + (\lambda_c \text{ x } \delta_t) + \mu_s + \delta_t + \eta X \varepsilon_{ist}. \quad (1)$$

Here, β_1 and β_2 are the main coefficients of interest, measuring the difference in trends in outcome o across individuals born in high and low goiter states over time. The specification includes state of birth (μ_s) and year of birth fixed effects (δ_t), which absorb the main effects of T_s, D_t, and A_t. We also control for region of birth by birth year interactions (ζ_r x δ_t), defining regions as the 9 Census Bureau divisions. These interaction terms control for any division-specific trends over time that may coincide with the national goiter distribution. The inclusion of these controls means we are comparing outcome

[8] Feyrer et al. (2013)'s back-of-the-envelope calculations suggest that average IQ went up by about 15 points as a result of iodization.

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. $(\lambda_c \times \delta_t)$ 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 average race and average gender (measured in 1920) of the individual's state of residence interacted with the during and after dummies.

We test the robustness of the results to the inclusion of contemporaneous disease eradication programs (namely related to tuberculosis, hookworm, and malaria) as well as compulsory schooling laws and WWII mobilization rates at the state of residence. In addition, we interact the longitude and latitude of the state center with the during and after variables as a way to control for geographic access to iodine and as an additional way to control for regional changes over time. We also show robustness to alternative sources of data, namely the goiter rates of enlisted men used by Feyrer et al. (2013). Finally, to address issues of measurement error in our treatment variable we instrument for goiter rates in the Olesen data with the goiter rate from the data on enlisted men. 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.

5 Results

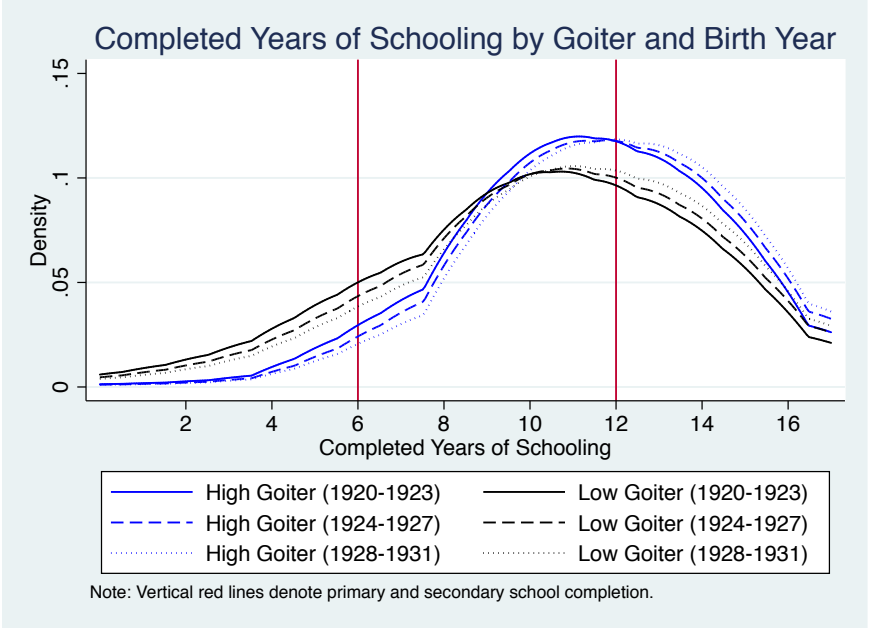
In this section, we present results from the empirical analysis discussed in section 4. In all of the regressions that follow, our coefficients of interest are the "after" by high-goiter interaction and the "during" by high-goiter interaction: these represent the effect of salt iodization on our outcomes of interest.[9]

5.1 Education

We begin by exploring effects of the availability of iodized salt in the year of birth on educational attainment. Theoretical predictions about the direction of the potential shift in educational attainment are ambiguous. Ultimately, the effect of salt iodization on schooling decisions depends on how substitutable or complementary are schooling and cognitive ability. That is, higher cognitive ability might increase the returns to schooling, or actually crowd out returns to schooling in the labor market. Fur-

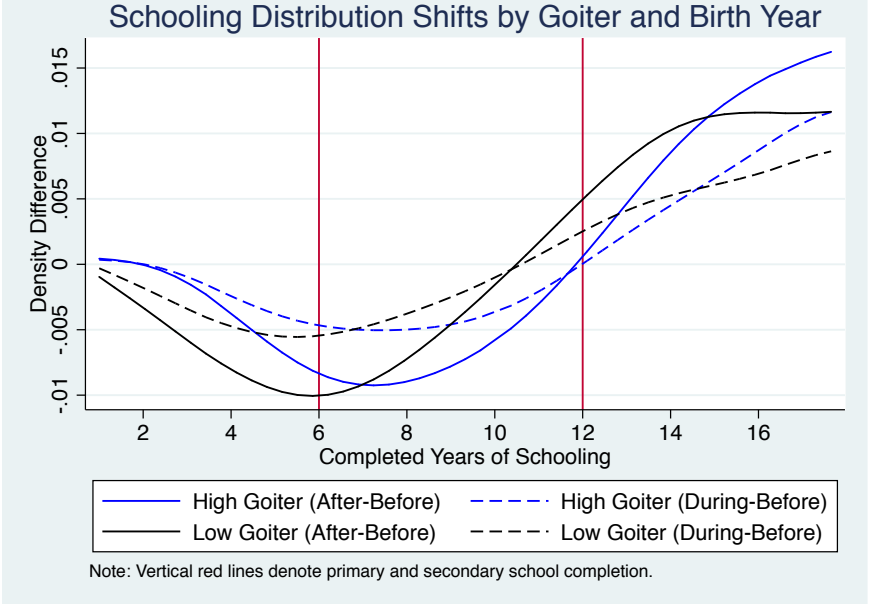
[9]Recall our main specification includes birth year and state of birth fixed effects, year of birth by census year interactions, census division of birth by birth year interactions, a female dummy, a black dummy, and 1920 state-level female and black proportions interacted with the after and during dummies.

Figure IV



Note: Vertical red lines denote primary and secondary school completion.

Figure V



Note: Vertical red lines denote primary and secondary school completion.

thermore, this relationship between cognitive ability and returns to schooling might vary by the level of schooling and/or the specific labor market opportunity in question. For example, for low-skilled occupations, we might suspect that higher cognitive ability is substitutable for primary schooling (i.e., the ability to learn simple skills like reading, writing and arithmetic sufficient for blue-collar employment outside of the classroom is increasing in cognitive endowment). On the other hand, high-skilled occupations (e.g, finance or engineering) likely require a level of skill that must be formally taught in school and is more easily learned by students with higher cognitive ability. Therefore, we might suspect that cognitive ability and schooling are complements at the secondary or post-secondary level.

Figures IV and V depict shifts in the distribution of educational attainment across birth cohorts for states with high and low pre-iodization goiter rates. In Figure IV, we see that states with high pre-iodization goiter rates had higher completed years of schooling on average than states with low pre-iodization goiter rates, both before and after iodization. However, high goiter states showed a slower shift to the right in completed years of schooling across birth cohorts during and after salt iodization than did low goiter states. Figure V shows that this pattern of a slower growth in completed years of schooling in high goiter states as comported to low goiter states is concentrated roughly between primary and secondary school. Of course, though suggestive of a negative impact of salt iodization on grade completion around late elementary and middle school, these naive graphical comparisons do not properly account for state-of-birth and birth year unobservables nor for region-specific non-linear trends in grade completion during these years.

Table II displays results from the regression analogs to the exercise depicted in Figures IV and V, but with the inclusion of birth year and 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.

The first column shows that salt iodization had a significant negative impact on total years of completed schooling. Columns 2 to 4 show us that this result is driven by early years of schooling: salt iodization significantly reduced the probability of primary school completion by almost 2 percentage points for the "after" cohort relative to the "before" cohort and about 1.4 percentage points for the "during" cohort relative to the "before" cohort, but had no significant effect 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.

Table II: Effects of Salt Iodization on Education

	(1)	(2)	(3)	(4)
	Years of Schooling	1(Completed Primary)	1(Completed High School)	1(Completed College)
After x High Goiter	-0.192***	-0.0198***	-0.0126	0.00364
	(0.0660)	(0.00520)	(0.0105)	(0.00641)
During x High Goiter	-0.135**	-0.0140***	-0.00658	0.00233
	(0.0605)	(0.00487)	(0.00889)	(0.00457)
Observations	1322567	1322567	1322567	1322567
Mean of Dependent Variable	11.50	0.965	0.628	0.131

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 and year of birth fixed effects, year of birth x census year dummies, census division of birth x birth year dummies, and demographic controls.

If cognitive ability substitutes for schooling at low but not higher levels of schooling, we might suspect that the education impacts would be concentrated among individuals who are a priori more likely to go into low-skilled jobs. Therefore, we next analyze whether our results in Table II differ by the types of jobs and industries dominating the workforce in an individual's state of residence. Table III augments our original specification with the addition of a third interaction variable. The first three columns report whether the education results differ according to whether an individual lives in a blue collar state, while the last three columns explore heterogeneity by whether the individual's state of residence offers higher employment in goods-producing sectors.

Under the assumption that individuals were either living in their current state of residence during their schooling years or had accurate expectations on what type of state they would end up migrating to, the blue collar and goods sector dummies act as proxies for whether individuals made their schooling decisions with the expectations of low-skilled jobs in the future. With this line of reasoning, we expect those living in blue collar and goods sector states to be the ones driving the substitution results found in Table II, which is exactly what we find. Columns 1 and 4 of Table III show us that the effect of salt iodization on primary school completion is negative overall (as we found in Table II), but significantly more so for those living in a blue collar or goods sector state. Column 2 shows us that this same result holds for high school completion: while the overall effect of salt iodization on high school completion is nil, the effect for individuals living in blue collar states is negative. This suggests

that cognitive ability might act as a substitute for even higher levels of schooling for individuals likely to take up low-skill jobs. Again, in both columns 3 and 6, we see that salt iodization did not seem to affect college completion at all. There was no differential effect among blue collar or goods-sector states, which is consistent with cognitive ability being less substitutable or even complementary 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. Table IV reports regression results for our labor outcomes of interest. Column 1 shows that salt iodization increased labor force participation by 0.9 percentage points for the after cohort, which is consistent with cognitive ability substituting for schooling and allowing individuals to enter the labor force earlier. Columns 2 and 3 report results for log wage and log income, conditional on employment: these regressions are only run on the sample of individuals with positve wage or total earnings. Here, the negative significant effect of salt iodization on income reflects both the effect on selection into employment as well as changes in the distribution of incomes conditional on employment. In order to parse out these effects, we next look more closely

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

	(1)	(2)	(3)	(4)	(5)	(6)
	1(Completed Primary)	1(Completed High School)	1(Completed College)	1(Completed Primary)	1(Completed High School)	1(Completed College)
State Industry Variable	1(Blue Collar State)			1(Goods Sector State)		
After x High Goiter x State Type	-0.0203***	-0.0435**	0.00275	-0.0260***	-0.00881	0.00966
	(0.00483)	(0.0179)	(0.0102)	(0.00526)	(0.0198)	(0.0116)
During x High Goiter x State Type	-0.0154***	-0.0297*	-0.00384	-0.0213***	0.00965	0.0110
	(0.00496)	(0.0175)	(0.0104)	(0.00553)	(0.0150)	(0.00994)
After x High Goiter	-0.00874***	0.00167	-0.000470	-0.00902***	-0.00581	0.00107
	(0.00303)	(0.00900)	(0.00449)	(0.00299)	(0.0101)	(0.00429)
During x High Goiter	-0.00450*	0.00307	0.000998	-0.00443*	-0.00490	-0.000614
	(0.00257)	(0.00718)	(0.00348)	(0.00249)	(0.00742)	(0.00261)
After x State Type	0.0220***	-0.00920	-0.0228*	0.0252***	-0.00412	-0.0200
	(0.00539)	(0.0173)	(0.0114)	(0.00523)	(0.0193)	(0.0139)
During x State Type	0.0205***	-0.00939	-0.0192*	0.0217***	-0.0145	-0.0158
	(0.00555)	(0.0158)	(0.0105)	(0.00587)	(0.0147)	(0.0120)
High goiter x State Type	0.0497***	0.132***	0.0547***	0.0486***	0.0692***	0.0197*
	(0.00759)	(0.0224)	(0.0153)	(0.00861)	(0.0191)	(0.00996)
State Industry	-0.0506***	-0.0593**	-0.0104	-0.0510***	-0.0635***	-0.00692
	(0.00772)	(0.0224)	(0.00912)	(0.00866)	(0.0208)	(0.00845)
Observations	1322567	1322567	1322567	1322567	1322567	1322567
Mean of Dependent Variable	0.965	0.628	0.131	0.965	0.628	0.131

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 and year of birth fixed effects, year of birth x census year dummies, census division of birth x birth year dummies, and demographic controls.

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

	(1)	(2)	(3)
	1(Participated in the Labor Force)	Log Wage Income	Log Total Income
After x High Goiter	0.00887***	-0.0561***	-0.0325*
	(0.00315)	(0.0205)	(0.0174)
During x High Goiter	0.00491	-0.0591***	-0.0358**
	(0.00342)	(0.0199)	(0.0176)
Observations	1427788	894550	1059916
Mean of Dependent Variable	0.699	10.03	9.980

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 and year of birth fixed effects, year of birth x census year dummies, census division of birth x birth year dummies, and demographic controls.

at how salt iodization changed the distribution of income.

5.3 Income Distribution

Figures VI and VIII plot wage and total income distributions, respectively, for high and low goiter states before, during, and after salt iodization. Figures VII and IX plot the shifts in wage and total income distributions across birth cohorts for high and low goiter states. Figures VI and VIII show that high goiter states had higher density in the right tail of the income distributions and less density in the center and left tails than did low goiter states, both before and after salt iodization. However, Figures VII and IX show that high goiter states experienced less of a decline in the density of the left tails of the distributions (particularly over values representing the first and second quintiles of the 1950 income distribution) than did the low goiter states, and less of an increase in the density in the right tail of the wage and total income distributions.

We next run quantile dummy regressions to validate the graphical patterns depicted in Figures VI through IX. We run separately regressions of five dummies on the regressors represented in equation 1, one corresponding to inclusion in each of the quintiles of the 1950 census distributions, as described in section 3.2.1. Results are reported in Table V. Panel A reports effects on wage income quintiles, while Panel B reports effects on total income quintiles.

In Panel A, columns 1 through 3 show positive effects of access to iodized salt on the probability of being in the lower wage income quintiles. Specifically, the likelihood of being in the first to third wage

Figure VI

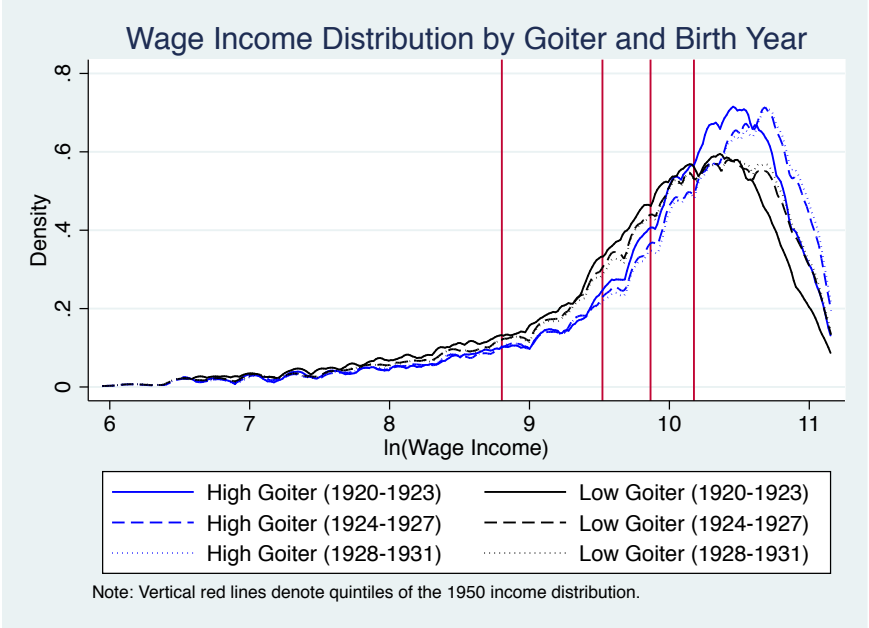


Figure VII

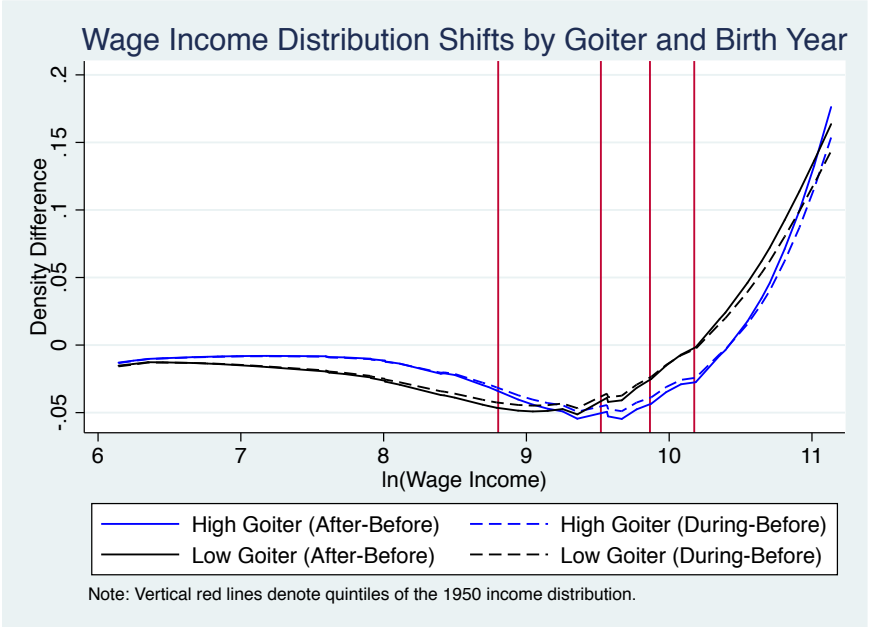
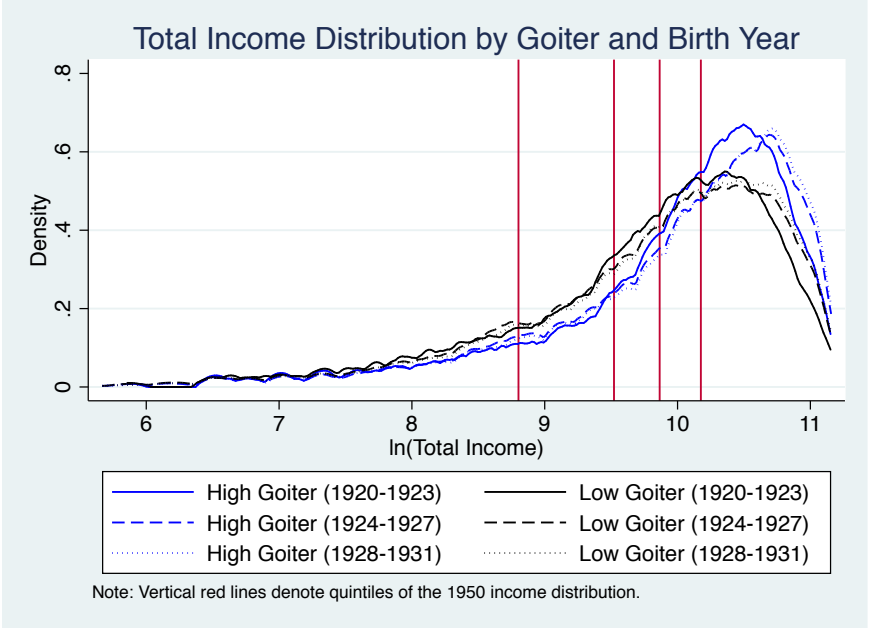
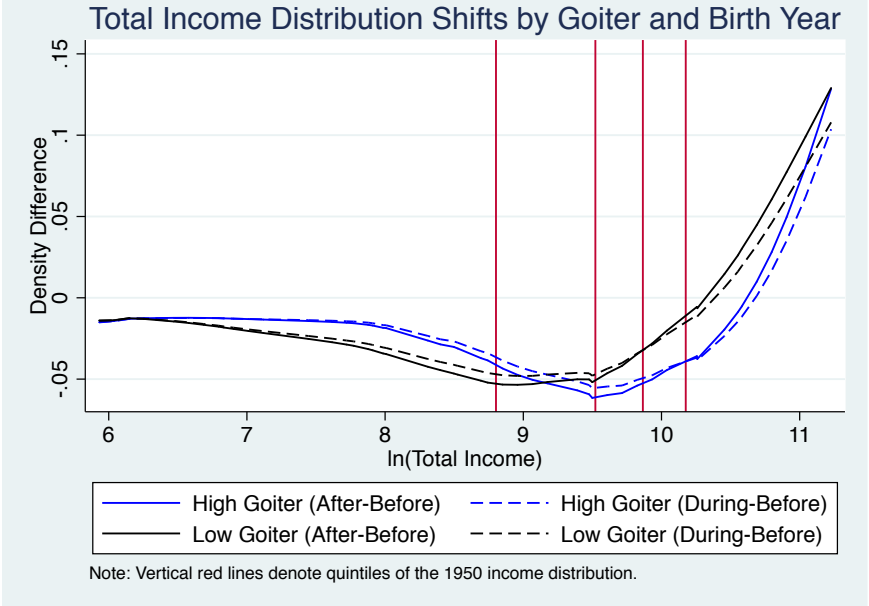


Figure VIII



Note: Vertical red lines denote quintiles of the 1950 income distribution.

Figure IX



Note: Vertical red lines denote quintiles of the 1950 income distribution.

Table V: Effects of Salt Iodization on Income by Quintile

Panel A: Wage Income

	(1)	(2)	(3)	(4)	(5)
	1st Quintile	2nd Quintile	3rd Quintile	4th Quintile	5th Quintile
After x High Goiter	0.00875**	0.0114***	0.00641**	-0.00108	-0.0225***
	(0.00366)	(0.00207)	(0.00270)	(0.00311)	(0.00735)
During x High Goiter	0.0109***	0.00833***	0.00541**	-0.000697	-0.0215***
	(0.00344)	(0.00189)	(0.00239)	(0.00308)	(0.00730)
Observations	1322567	1322567	1322567	1322567	1322567
Mean of Dependent Variable	0.0739	0.0682	0.0728	0.0880	0.373

Panel B: Total Income

	(1)	(2)	(3)	(4)	(5)
	1st Quintile	2nd Quintile	3rd Quintile	4th Quintile	5th Quintile
After x High Goiter	0.00406	0.00914***	0.00284	-0.00234	-0.0167**
	(0.00353)	(0.00271)	(0.00333)	(0.00350)	(0.00727)
During x High Goiter	0.00674*	0.00559	0.00398	-0.00286	-0.0149**
	(0.00386)	(0.00346)	(0.00276)	(0.00348)	(0.00697)
Observations	1319342	1319342	1319342	1319342	1319342
Mean of Dependent Variable	0.101	0.0922	0.0841	0.0971	0.429

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 and year of birth fixed effects, year of birth x census year dummies, census division of birth x birth year dummies, and demographic controls.

income quintile as defined by the 1950 census rose between 0.5 and 1.1 percentage points more during and after the roll out of iodized salt in high goiter states than in low goiter states. On the other hand, as presented in column 5, the likelihood of being in the 5th income quintile significantly declined.

The pattern in the results presented in Panel B are quite similar to those in Panel A, with the estimates a bit smaller and less precisely estimated. The likelihood of being in the 2nd quintile of total income rises in high goiter states by .9 percentage points more after the roll out of iodized salt, while the probability of being in the highest quintile significantly fell.

The coefficients from these five regressions are graphed in Figure X. Consistent with our previous education results, these income results emphasize that salt iodization had its biggest impact on the left tail of the skill distribution, leading to influx of new labor force participants into the left tail 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 impaired cognitive functioning otherwise, not those who would have already achieved normal cognitive functioning. Salt iodization appears to have primarily benefited the left tail of the skill distribution, allowing them to enter the labor force (even with less schooling) and take up low-paying jobs.

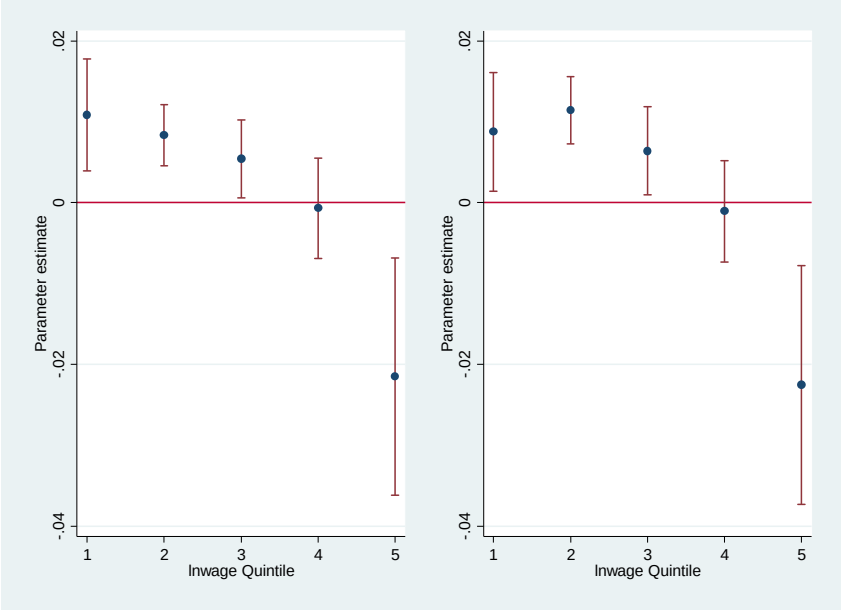
5.4 Robustness

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 many infections diseases, which occurred roughly contemporaneously to the roll out of iodized salt, might be driving the results. The correlation between early 1900's goiter rates and prevalence of diseases like tuberculosis, malaria, and hookworm are weak and negative (-0.3, -0.36, and -0.35, respectively) and thus unlikely to be driving our results. We validate this, however, by running the main regressions controlling additionally for dummies for above median incidence of tuberculosis, hookworm, and malaria and the interaction of these dummies with the during and after dummies. These results are reported in Table VI. The pattern of results is overwhelmingly preserved: substitution for lower years of schooling and movement into the labor force at the left tail of the income distribution.

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

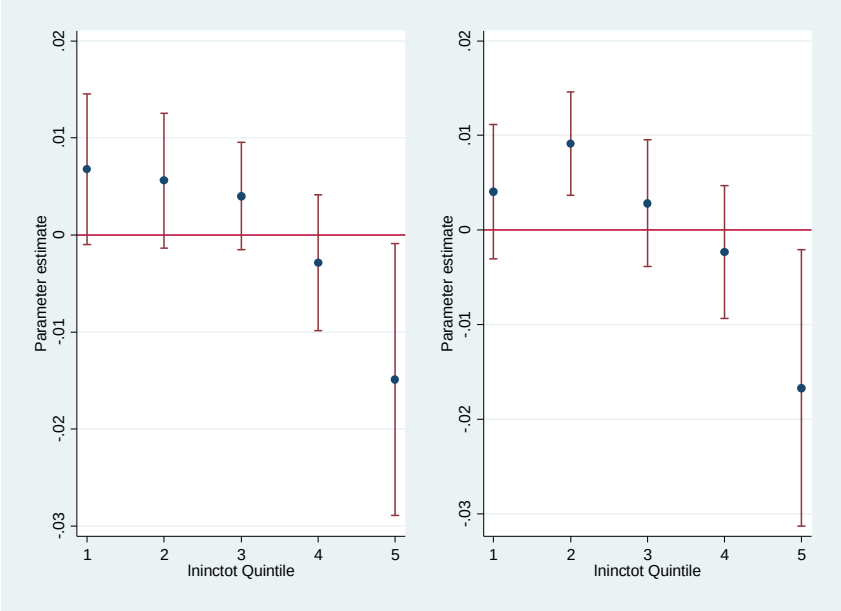
Figure X: Income Quintile Regression Coefficients

Panel A: Wage Income



During After

Panel B: Total Income



During After

Table VI: Robustness to Contemporaneous Disease Eradication

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	1(Completed Primary)	1(Completed High School)	1(Completed College)	1(Participated in Labor Force)	1st Wage Quintile	2nd Wage Quintile	3rd Wage Quintile	4th Wage Quintile	5th Wage Quintile
After x High Goiter	-0.0174***	0.00706	0.00632	0.00895**	0.0105**	0.0111***	0.00508*	-0.00325	-0.0182**
	(0.00579)	(0.00970)	(0.00660)	(0.00391)	(0.00400)	(0.00237)	(0.00258)	(0.00291)	(0.00718)
During x High Goiter	-0.0128**	0.00107	0.00425	0.00423	0.0119***	0.00908***	0.00427	-0.00221	-0.0194**
	(0.00523)	(0.00777)	(0.00474)	(0.00382)	(0.00372)	(0.00204)	(0.00268)	(0.00315)	(0.00751)
After x High Tuberculosis	0.00267	0.0323***	0.00332	-0.00145	0.00429	0.000102	-0.00479*	-0.00519*	0.00508
	(0.00530)	(0.0100)	(0.00544)	(0.00397)	(0.00434)	(0.00290)	(0.00242)	(0.00263)	(0.00470)
During x High Tuberculosis	0.0000399	0.000605***	0.0000978	-0.00000696	0.000183	0.000124	-0.000209**	-0.000165	0.000173
	(0.000152)	(0.000210)	(0.000124)	(0.000127)	(0.000146)	(0.000116)	(0.0000903)	(0.000114)	(0.000192)
After x High Hookworm	0.00917**	-0.0199*	-0.00755*	-0.00201	-0.00605**	-0.00248	-0.00549**	0.000910	0.0117**
	(0.00359)	(0.0108)	(0.00443)	(0.00309)	(0.00234)	(0.00211)	(0.00230)	(0.00234)	(0.00479)
During x High Hookworm	0.00594**	-0.0159**	-0.00470	-0.00286	-0.00406*	-0.00370*	-0.00711***	-0.000492	0.0138**
	(0.00271)	(0.00717)	(0.00307)	(0.00285)	(0.00230)	(0.00198)	(0.00198)	(0.00219)	(0.00533)
After x High Malaria	0.00782**	0.00199	-0.000315	0.00176	-0.00398*	-0.00220	0.000737	0.00170	0.0114***
	(0.00296)	(0.00888)	(0.00585)	(0.00269)	(0.00212)	(0.00229)	(0.00209)	(0.00206)	(0.00415)
During x High Malaria	0.00566**	0.00101	0.00139	-0.00329	-0.00350*	-0.00264	-0.00149	-0.000716	0.00862**
	(0.00227)	(0.00597)	(0.00386)	(0.00275)	(0.00198)	(0.00186)	(0.00172)	(0.00212)	(0.00428)
Observations	1322567	1322567	1322567	1427788	1322567	1322567	1322567	1322567	1322567
Mean of Dependent Variable	0.965	0.628	0.131	0.699	0.0739	0.0682	0.0728	0.0880	0.373

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 and year of birth fixed effects, year of birth x census year dummies, census division of birth x birth year dummies, and demographic controls.

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 and thus probably also incomes of individuals, particularly 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 VII shows that our main results are robust to the inclusion of all of these controls; our coefficients of interest remain virtually unchanged.

Our next robustness check addresses concerns associated with the clear geographic pattern to the goiter distribution, particularly along the lines of the North-South divide. The region of birth by birth year controls are included to control for any systematic relationships between the goiter distribution and regional trends, but because many Census divisions include both Northern and Southern states, these Census divisions may not be controlling for the regional trends we care most about. In order to address this issue, we replace the Census division interactions with latitude and longitude controls: specifically, average state latitude interacted with the during and after dummies, as well as average state longitude interacted with the during and after dummies. Table VIII shows us that our major results remain intact with this new method of controling for regional differences.

Our final set of robustness tables are aimed at addressing potential problems with the goiter data we use. First of all, while it is known that there is a "protective threshold" for fetal iodine levels, above which normal cognitive functioning is achieved, we do not know what this threshold is. Table A.1 shows that using the median goiter rate as a cutoff means that we group states with goiter levels as low as 9% with states that have goiter rates of up to 76%. In an attempt to avoid such drastic heterogeneity in goiter rates within our high goiter group, we therefore check robustness to the use of

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

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	1(Completed Primary)	1(Completed High School)	1(Completed College)	1(Participated in Labor Force)	1st Wage Quintile	2nd Wage Quintile	3rd Wage Quintile	4th Wage Quintile	5th Wage Quintile
After x High Goiter	-0.0150***	-0.00144	0.00411	0.00831**	0.00651*	0.0103***	0.00669**	0.000437	-0.0192**
	(0.00378)	(0.00977)	(0.00579)	(0.00358)	(0.00334)	(0.00230)	(0.00302)	(0.00312)	(0.00731)
During x High Goiter	-0.0100***	0.00224	0.00326	0.00427	0.00884***	0.00757***	0.00462*	0.00109	-0.0179**
	(0.00346)	(0.00872)	(0.00394)	(0.00335)	(0.00301)	(0.00195)	(0.00270)	(0.00319)	(0.00710)
After x Compulsory Schooling	-0.00354***	-0.0101***	-0.00206	0.000777	0.00133	0.00196***	0.000270	0.000332	-0.00380**
	(0.00128)	(0.00309)	(0.00225)	(0.00117)	(0.000919)	(0.000716)	(0.00123)	(0.000844)	(0.00169)
During x Compulsory Schooling	-0.00237**	-0.00691***	-0.00199	0.000866	0.00147	0.00131*	0.00148	-0.000287	-0.00417**
	(0.00112)	(0.00231)	(0.00144)	(0.000932)	(0.000955)	(0.000711)	(0.00127)	(0.000728)	(0.00180)
WWII Mobilization Rate	0.216***	0.455**	0.0315	0.00172	-0.0930**	0.0123	0.0144	0.125***	0.0339
	(0.0415)	(0.209)	(0.184)	(0.0678)	(0.0406)	(0.0323)	(0.0423)	(0.0360)	(0.182)
Observations	1322567	1322567	1322567	1427788	1322567	1322567	1322567	1322567	1322567
Mean of Dependent Variable	0.965	0.628	0.131	0.699	0.0739	0.0682	0.0728	0.0880	0.373

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 and year of birth fixed effects, year of birth x census year dummies, census division of birth x birth year dummies, and demographic controls.

Table VIII: Robustness to Inclusion of Latitude and Longitude Controls

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	1(Completed Primary)	1(Completed High School)	1(Completed College)	1(Participated in Labor Force)	1st Wage Quintile	2nd Wage Quintile	3rd Wage Quintile	4th Wage Quintile	5th Wage Quintile
After x High Goiter	-0.0104**	0.00897	0.00769	0.00563	0.00553**	0.00850***	0.00270	-0.00300	-0.00891*
	(0.00400)	(0.0105)	(0.00734)	(0.00365)	(0.00232)	(0.00177)	(0.00264)	(0.00235)	(0.00451)
During x High Goiter	-0.00791**	0.00656	0.00446	0.00643*	0.00724***	0.00724***	0.00240	-0.00337	-0.00660
	(0.00329)	(0.00851)	(0.00614)	(0.00325)	(0.00258)	(0.00174)	(0.00218)	(0.00216)	(0.00462)
After x Latitude	-0.00473***	-0.00223	0.00316***	0.000633	0.00325***	0.00185***	0.000938**	-0.000666	-0.00476***
	(0.000817)	(0.00155)	(0.00114)	(0.000494)	(0.000757)	(0.000374)	(0.000363)	(0.000436)	(0.00103)
After x Longitude	0.000485**	0.00243***	0.000328	-0.000422**	0.0000228	-0.000409***	-0.000371**	-0.0000714	0.000564
	(0.000227)	(0.000548)	(0.000272)	(0.000172)	(0.000203)	(0.000131)	(0.0000779)	(0.000103)	(0.000457)
During x Latitude	-0.00350***	-0.00107	0.00290***	0.000744	0.00291***	0.00167***	0.000979***	-0.000236	-0.00490***
	(0.000780)	(0.00128)	(0.000894)	(0.000591)	(0.000738)	(0.000361)	(0.000331)	(0.000433)	(0.00107)
During x Longitude	0.000408**	0.00181***	0.000278	-0.000413**	-0.0000251	-0.000335***	-0.000265**	-0.000214**	0.000497
	(0.000178)	(0.000454)	(0.000231)	(0.000187)	(0.000165)	(0.000118)	(0.0000776)	(0.0000968)	(0.000420)
Observations	1322567	1322567	1322567	1427788	1322567	1322567	1322567	1322567	1322567
Mean of Dependent Variable	0.965	0.628	0.131	0.699	0.0739	0.0682	0.0728	0.0880	0.373

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 and year of birth fixed effects, year of birth x census year dummies, and demographic controls.

Table IX: Robustness to 75th Percentile High Goiter Variable

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	1(Completed Primary)	1(Completed High School)	1(Completed College)	1(Participated in Labor Force)	1st Wage Quintile	2nd Wage Quintile	3rd Wage Quintile	4th Wage Quintile	5th Wage Quintile
After x High Goiter	-0.00755***	-0.0288***	-0.00845*	0.00338	0.00231	0.00593***	0.00153	0.00108	-0.0112***
	(0.00194)	(0.0104)	(0.00454)	(0.00245)	(0.00205)	(0.00190)	(0.00285)	(0.00224)	(0.00392)
During x High Goiter	-0.00503***	-0.0115	-0.00501	0.00293	0.00299*	0.00411**	-0.000423	0.00278	-0.00674
	(0.00170)	(0.00853)	(0.00313)	(0.00299)	(0.00163)	(0.00167)	(0.00231)	(0.00202)	(0.00409)
Observations	1427788	1322567	1322567	1322567	1322567	1322567	1322567	1322567	1322567
Mean of Dependent Variable	0.699	0.676	0.965	0.628	0.0739	0.0682	0.0728	0.0880	0.373

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 and year of birth fixed effects, year of birth x census year dummies, census division of birth x birth year dummies, and demographic controls.

the 75th percentile of the goiter distribution as an alternative high goiter cutoff.[10] Table IX replicates our main outcomes using this new goiter variable, and our major conclusions remain: we see that salt iodization led to lower primary school completion and movement into the lower wage quintiles. Since the use of a different cutoff changes the regions within which we have variation in our goiter variable, this naturally alters some of our results: for instance, there is some evidence of substitutability at higher levels of schooling for the after cohort and the positive coefficients in the labor force regressions are no longer significant. However, the robustness of our major conclusions to this alternate definition of "high goiter" affirms that our results are not driven by some arbitrarily defined cutoff. In fact, our results are also robust to the use of the continuous goiter rate rather than a binary dummy, although the interpretation of the coefficients in those regressions is less straightforward (results not shown here but available upon request).

As a second check to ensure that our results are driven by actual differences in the pre-iodization goiter distribution rather than by features of our data (such as the 13 states for which we have no goiter data), we also check robustness to Love and Davenport (1920) data, which includes goiter rates for the entire continental United States. For these specifications, we use the 75th percentile as a cutoff to create the high goiter dummy.[11] Table X shows that our results are remarkably robust to the use of this goiter variable. Interestingly, in addition to substitution at lower levels of schooling (in column 1), we also see some evidence of substitution at higher levels of schooling (in columns 2 and 3). We still see positive impacts on labor force participation, which seems to have led to movement into the first

[10] This is the cutoff rule used Feyrer et al. (2013).

[11] This follows Feyrer et al. (2013), who use this data in their paper.

Table X: Robustness to Love and Davenport Data

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	1(Completed Primary)	1(Completed High School)	1(Completed College)	1(Participated in Labor Force)	1st Wage Quintile	2nd Wage Quintile	3rd Wage Quintile	4th Wage Quintile	5th Wage Quintile
After x High Goiter	-0.00877**	-0.0239**	-0.0188**	0.00485	0.00604*	0.00207	0.00209	-0.00719***	-0.00550
	(0.00397)	(0.00923)	(0.00850)	(0.00348)	(0.00356)	(0.00260)	(0.00298)	(0.00262)	(0.00738)
During x High Goiter	-0.00616**	-0.0215***	-0.0121**	0.00456	0.00474	0.00380	0.00145	-0.00497*	-0.00531
	(0.00300)	(0.00634)	(0.00551)	(0.00306)	(0.00339)	(0.00274)	(0.00282)	(0.00265)	(0.00651)
Observations	1678661	1553941	1553941	1553941	1553941	1553941	1553941	1553941	1553941
Mean of Dependent Variable	0.698	0.674	0.960	0.620	0.0758	0.0696	0.0743	0.0883	0.366

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 and year of birth fixed effects, year of birth x census year dummies, census division of birth x birth year dummies, and demographic controls.

three and out of the fourth quintiles. Although the labor force participation and income distribution results are smaller and less precisely estimated than our main results, the consistency of the overall picture emphasizes that data issues are not driving our results.

Our final robustness check addresses potential biases introduced by measurement error. Given that we do not have the information to population-weight our state-level averages of goiter rates, it is possible that we are over or underweighting areas non-randomly by taking simple averages across various localities. Fortunately, we have a second source of goiter data and can use this to instrument for our above-median goiter dummy, provided that the measurement error in Love and Davenport (1920) is uncorrelated with the measurement error in Olesen (1929). Given the drastically different contexts and methods of data collection, we find this to be a reasonable assumption. Using the continuous goiter rates from Love and Davenport (1920), interacted with the during and after dummies, as instruments for our high goiter by "after" and high goiter by "during" interactions, we run our main regressions in an instrumental variables specification and report the results in Table XI. Although less precisely estimated, the instrumental variables estimates are very similar to the OLS estimates, suggesting that measurement error was not generating spurious results.

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

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

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	1(Completed Primary)	1(Completed High School)	1(Completed College)	1(Participated in Labor Force)	1st Wage Quintile	2nd Wage Quintile	3rd Wage Quintile	4th Wage Quintile	5th Wage Quintile
After x High Goiter	-0.0185***	-0.0171	-0.0153	0.0147**	0.00695	0.0108***	0.0107**	-0.00666	-0.0162
	(0.00465)	(0.0146)	(0.0156)	(0.00591)	(0.00651)	(0.00399)	(0.00514)	(0.00442)	(0.0101)
During x High Goiter	-0.0116***	-0.0192	-0.00559	0.0122*	0.00575	0.00921**	0.00821	-0.00428	-0.0154*
	(0.00362)	(0.0133)	(0.0112)	(0.00676)	(0.00463)	(0.00352)	(0.00501)	(0.00433)	(0.00867)
Observations	1322567	1322567	1322567	1427788	1322567	1322567	1322567	1322567	1322567
Mean of Dependent Variable	0.965	0.628	0.131	0.699	0.0739	0.0682	0.0728	0.0880	0.373

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 and year of birth fixed effects, year of birth x census year dummies, census division of birth x birth year dummies, and demographic controls. Instruments used were After x Goiter Rate from Love and Davenport (1920) and During x Goiter Rate from Lovea nd Davenport (1920).

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 larger than 1 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 nearly 2 billion USD in additional wage income using, conservatively, the mean of first income quintile (62 million x 0.01 x 3200 USD = 1.984 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.

Table A.1 Goiter Prevalence by State, from Olesen

Low Goiter States		High Goiter States	
California	0.023	New Jersey	9.100
Alabama	0.067	Oklahoma	10.410
Arizona	0.080	New York	12.050
New Mexico	0.100	Wyoming	15.000
New Hampshire	0.200	Pennsylvania	15.470
North Carolina	0.200	Washington	17.642
Mississippi	0.310	Connecticut	18.200
Georgia	0.800	Michigan	19.577
Rhode Island	0.860	Illinois	20.377
Massachusetts	1.600	Montana	20.400
Missouri	3.000	Oregon	22.500
North Dakota	3.967	Minnesota	23.635
Tennessee	5.217	Maine	24.800
Louisiana	5.525	Ohio	28.435
Maryland	6.150	Colorado	35.413
Kentucky	6.890	West Virginia	43.943
Kansas	8.371	Utah	44.900
Virginia	8.955	Wisconsin	46.632
		Indiana	76.000

Notes: All prevalence rates are in percentage points.

A Additional Tables

In Table A.1, we present the states ordered by goiter prevalence calculated from Olesen (1929). In the left column are the states with goiter rates below the median and in the right column are states with goiter rates above the median.

Table A.2 lists all states by Census region, and identifies which states fall into our goiter belt classification.

In Table A.3, we present the states ordered by goiter prevalence calculated from Love and Davenport (1920). In the left column are the states with goiter rates below the median and in the right column are states with goiter rates above the median.

B Data Appendix

B.1 State-Level Goiter Rates

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

Table A.2 Regional Classification of States

Census Region	State	Above Median Olesen	Above p75 Olesen	Above p75 Love & Davenport
New England Division	Connecticut	1	0	0
New England Division	Maine	1	1	0
New England Division	Massachusetts	0	0	0
New England Division	New Hampshire	0	0	0
New England Division	Rhode Island	0	0	0
New England Division	Vermont			0
Middle Atlantic Division	New Jersey	1	0	0
Middle Atlantic Division	New York	1	0	0
Middle Atlantic Division	Pennsylvania	1	0	0
East North Central Div.	Illinois	1	0	1
East North Central Div.	Indiana	1	1	0
East North Central Div.	Michigan	1	0	1
East North Central Div.	Ohio	1	1	0
East North Central Div.	Wisconsin	1	1	1
West North Central Div.	Iowa			0
West North Central Div.	Kansas	0	0	0
West North Central Div.	Minnesota	1	1	1
West North Central Div.	Missouri	0	0	0
West North Central Div.	Nebraska			0
West North Central Div.	North Dakota	0	0	1
West North Central Div.	South Dakota			0
South Atlantic Division	Delaware			0
South Atlantic Division	District of Columbia			0
South Atlantic Division	Florida			0
South Atlantic Division	Georgia	0	0	0
South Atlantic Division	Maryland	0	0	0
South Atlantic Division	North Carolina	0	0	0
South Atlantic Division	South Carolina			0
South Atlantic Division	Virginia	0	0	0
South Atlantic Division	West Virginia	1	1	1
East South Central Div.	Alabama	0	0	0
East South Central Div.	Kentucky	0	0	0
East South Central Div.	Mississippi	0	0	0
East South Central Div.	Tennessee	0	0	0
West South Central Div.	Arkansas			0
West South Central Div.	Louisiana	0	0	0
West South Central Div.	Oklahoma	1	0	0
West South Central Div.	Texas			0
Mountain Division	Arizona	0	0	0
Mountain Division	Colorado	1	1	0
Mountain Division	Idaho			1
Mountain Division	Montana	1	1	1
Mountain Division	Nevada			0
Mountain Division	New Mexico	0	0	0
Mountain Division	Utah	1	1	1
Mountain Division	Wyoming	1	0	1
Pacific Division	Alaska			1
Pacific Division	California	0	0	0
Pacific Division	Oregon	1	1	1
Pacific Division	Washington	1	0	1

Table A.3 Goiter Prevalence by State, from Love and Davenport

Low Goiter States		High Goiter States	
Florida	0.021	Nebraska	0.227
Texas	0.027	Virginia	0.333
Massachusetts	0.030	South Dakota	0.384
Arkansas	0.043	Missouri	0.398
New Jersey	0.043	Pennsylvania	0.410
Georgia	0.050	California	0.438
Rhode Island	0.055	District of Columbia	0.447
Maine	0.056	Colorado	0.530
Alabama	0.057	Ohio	0.568
Mississippi	0.057	Nevada	0.638
Delaware	0.059	Indiana	0.642
Louisiana	0.063	Iowa	0.661
Oklahoma	0.067	Illinois	0.780
New Hampshire	0.072	West Virginia	0.790
South Carolina	0.087	Minnesota	0.793
Connecticut	0.091	North Dakota	0.884
Maryland	0.094	Michigan	1.130
New Mexico	0.101	Alaska	1.314
Arizona	0.110	Wisconsin	1.384
New York	0.118	Wyoming	1.538
Kansas	0.124	Utah	1.562
Kentucky	0.142	Montana	2.097
North Carolina	0.170	Washington	2.325
Tennessee	0.190	Oregon	2.402
Vermont	0.214	Idaho	2.686

Notes: All prevalence rates are in percentage points.

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.

B.2 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
- *High Goiter*=1 if individual was born in a state with a goiter rate at or above median according to Olesen (1929); *High Goiter*=0 if individual was born in a state with below-median goiter rates according to Olesen (1929). This variable is missing for individuals born in states without goiter measurements recorded in Olesen (1929).

Because the Census gives us a snapshot of the population every 10 years, each group only appears in our dataset at specific ages. For example, members of the "before" group are aged 27-30 in the 1950 Census, 37-40 in the 1960 Census, and so on. Meanwhile, the "during" individuals were aged 23-26 in the 1950 Census and ten years older each subsequent Census, while the "after" individuals were aged 19-22 in the 1950 Census and ten years older each following Census. We never see "before" individuals aged 31-36, for example, or "during" individuals aged 27-32. It is for this reason that we do not include age fixed effects with birth year fixed effects in our specification. This means that when we compare across cohorts, we are always comparing groups of different ages; however, our underlying assumption is that the differences between these cohorts is fixed across high and low goiter states in the absence of iodization.

B.3 Outcome Variables

B.3.1 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 chool)=0 if the individual completed less than 6 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;
  1(Participated in Labor Force)=0 if the individual did not participate in the labor force
- *Log Wage Income*: This is the log of the annual wage and salary income earned by the individual (for those earning positive wages/salary). This variable is missing for individuals recorded as having zero wage/salary income. 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). All values are adjusted to 1999 prices using to Census-provided multipliers. Logs were taken after all of the adjustments were made.
- *Log Total Income*: This is the log of the annual total income earned by the individual (for those earning positive total income). This variable is missing for individuals recording as earning zero total income. 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). All values are adjusted to 1999 prices according to Census-provided multipliers. Logs were taken after all of the adjustments were made.

B.3.2 Income Quintile Analysis

1(Total Income Quintile 1) to *1(Total Income Quintile 5)* and *1(Wage Income Quintile 1)* to *1(Wage Income Quintile 5)* were constructed as follows. Using the entire population aged 25-55 from the

1950 Census, the 20th, 40th, 60th, and 80th percentiles were calculated for log income and log wage. These were used as the baseline quintiles to construct the following variables:

- *1(Total Income Quintile 1)*=1 if the individual's log income fell into the first quintile of *Total Income* ; *1(Total Income Quintile 1)*=0 if the individual's log income falls outside of this first quintile. This variable is missing for those with missing total income in the Census. Analogous variables were constructed for the second, third, fourth, and fifth quintiles. For each individual, only one of these five variables is set equal to one.

- *1(Wage Income Quintile 1)*=1 if the individual's log wage income fell into the first quintile of *Wage Income* ; *1(Wage Income Quintile 1)*=0 if the individual's log wage falls outside of this first quintile. This variable is missing for those with missing wage income in the Census. Analogous variables were constructed for the second, third, fourth, and fifth quintiles. For each individual, only one of these five variables is set equal to one.

B.4 Variables used as Controls and for Robustness Checks

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

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

- *femaleprop1920*: This measures the state-level proportion of the population that was female in the individual's state of residence (as reported in the 1920 Census).

- *blackprop1920*: This measures 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.

- *1(Goods Sector 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 in the goods-producing super-sector

1(Goods Sector State)=0 if individual resides in a state that had a below-median proportion of individuals working in the goods-producing super-sector (according to the 1920 and 1930 Censuses). Goods industry jobs were identified using the *ind1950* industry codes from the Census.

- *High Tuberculosis*=1 if individual was born in a state with a tuberculosis rate at or above median according to Love and Davenport (1920); *High Tuberulosis*=0 if individual was born in a state with below-median tuberculosis rates according to Love and Davenport (1920).
- *High Hookworm*=1 if individual was born in a state with a hookworm rate at or above median according to Bleakley (2010); *High Hookworm*=0 if individual was born in a state with below-median hookworm rates according to Bleakley (2010).
- *High Malaria*=1 if individual was born in a state with a malaria rate at or above median according to Bleakley (2010); *High Malaria*=0 if individual was born in a state with below-median malaria rates 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
- *Latitude*: Average latitude for the individual's state of birth
- *Longitude*: Average longitude for the individual's state of birth

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