Salt Iodization and the Enfranchisement of the American Worker*

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Abstract

In 1924, The Morton Salt Company, the largest salt producer in the United States, began nationwide distribution of iodine-fortified salt. Access to iodine, a key determinant of cognitive ability, rose considerably, leading to increased intelligence quotients particularly in places where deficiency was previously rampant. We compare outcomes for cohorts exposed *in utero* to iodized salt to slightly older, unexposed cohorts, across individuals born in states with previously high versus low iodine deficiency rates. We document substantial impacts of salt iodization. High school completion rose by nearly 6 percentage points, and labor force participation went up by 1 point. Analysis of income transitions by quantile shows that new labor force joiners entered at the bottom of the wage distribution and took up blue collar jobs, pulling down average wage income conditional on employment. Our results inform the ongoing debate on salt iodization in many low-income countries. We show that blanket iodized salt distribution in fact had a very targeted impact, benefiting the worker on the margin of employment, and generating sizeable economic returns at low cost.

Keywords: early-life factors, cognitive ability, iodine deficiency, labor force participation, wage distribution
JEL: I12, I15, N32, O12

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1 Introduction

Nearly a third of the world's population–2 billion people worldwide–does not have adequate access to iodine, a micronutrient vital to cognitive development (de Benoist et al. 2004, Andersson et al. 2010). Iodine deficiency affects cognitive function at all ages, but is particularly detrimental in the gestation period, when even mild deficiency can greatly hamper cognitive development (Cao et al. 1994).[1] 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 (Pharoah and Connolly 1987, Hetzel and Mano 1989, Zimmermann et al. 2005).

Recent estimates suggest the incidence of iodine deficiency, and thus the returns to reducing IDD, may be very large (Field, Robles and Torero 2009, Politi 2011a, Feyrer, Politi and Weil 2013). With these returns in mind, and much progress still to be made, 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. In this study, we draw lessons from the historical experience of the United States, where iodine deficiency was rampant in many areas of the country until the mid-1920s. 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, Van Fossen, Whetstone and Williams 1952, Schiel and Wepfer 1976). Recent evidence suggests that IQ rose nearly 15 points as a result (Feyrer et al. 2013). We ask: what happened to the economic outcomes of those whose *in utero* access to iodine improved? What 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

[1] Iodine regulates thyroid hormone availability, which determines the density of fetal neural networks (Lamberg 1991).

after (1928-1931), across areas with high and low pre-iodization deficiency rates. To identify the latter difference, we use a 1920 (pre-iodization) map of the prevalence of goiter, the main physical manifestation of IDD (Love and Davenport 1920).[2] 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 standard robustness checks that support our claim that observed differences in trends are causally related to salt iodization.

We estimate substantial impacts on employment, education, and wage and income distributions. Labor force participation increased by about 1 percentage point and high school completion went up by 6 points. Surprisingly, average impacts on income and wage earnings were negative. We analyzed changes in the distributions of these outcomes to better understand this result. When we look at transitions across income and wage quantiles over time, we find a shift into the bottom two quintiles and away from the upper three. Paired with the observed increase in labor force participation, we interpret these transitions to imply that labor force joiners, working in low-paying jobs, swelled the bottom of the wage distribution, bringing down the average wage conditional on labor force participation. Reinforcing this interpretation, we find an increase in blue collar labor for exposed cohorts.

Taken as a whole, our findings are remarkably consistent with the hypothesized relationships between fetal iodine access, cognitive ability, and labor activity. If cognitive ability is a positive determinant of labor activity and earnings, labor force changes should be concentrated at the bottom of the IQ distribution, where improved iodine access enabled individuals on the margin of participation to join the labor force. These new labor force joiners took up blue collar jobs with wages at the bottom of the wage distribution, which drew down the average wage conditional on participation.

This study adds to the rapidly growing literature on the long–term effects of early-life conditions.[3] We believe our work is a novel contribution to the ideas in this literature for three reasons. First, the effects of *in utero* iodine deficiency work through the specific channel of cognitive ability. This is different from work that focuses on birth weight (Behrman and Rosenzweig 2004, Black, Devereux and Salvanes 2007, Rosenzweig and Zhang 2009, Bharadwaj, Loken and Neileson Forthcoming) and *in utero* shocks (Currie and Schmieder 2009), both of which may influence later outcomes through many channels.

Second, many papers in the "fetal origins" literature use variation induced by shocks rather

[2]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" (Furnee 1997, Cao et al. 1994, Eltom et al. 1985). 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 the population was already above the protective threshold.

[3]See Almond and Currie (2011) for a nice synthesis of this literature.

than by policy changes.[4] We add to the subset of studies–including Bleakley (2010a), Bleakley (2010b), Field et al. (2009), Politi (2011a), Doyle et al. (2010), Bhalotra and Venkataramani (2012), and Feyrer et al. (2013) –that examine the long-term impacts of policy interventions. The results of these studies and ours offer lessons from historical policy experiments from which present-day policymakers might profitably draw.

Third, we identify distributional impacts often overlooked in other studies. We show that even untargeted (mass) interventions like salt iodization can effectively have targeted impacts on narrowly defined subpopulations.

Finally, we also contribute to the policy debate on tackling iodine deficiency in the developing world. 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 that still suffer from high rates of IDD today. But drawing from the historical experience in the United States should at least offer some insight into the promise of salt iodization, in terms of the economic returns that could be achieved.

The recent study by Feyrer et al. (2013) estimates that Morton Salt Co.'s decision to iodize may have increased IQ by 15 points, accounting for a significant part of the so-called Flynn Effect, the steady rise IQ in the US over the twentieth century. Our estimates, paired with this number, suggest that each IQ point accounts for nearly one tenth of a point increase in labor force participation.

The rest of the paper is divided into the following sections. Section 2 discusses the history of iodine deficiency in the US and Morton Salt Co.'s decision to iodize its salt supply. Section 4 discusses our data sources. Section 3 describes the empirical strategy we use to identify effects of salt iodization on economic outcomes. Section 5 describes the results. Section 6 concludes.

2 Historical 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

[4] For example, studies have traced the long-term impacts of illnesses (Almond 2006), natural disasters like hurricanes (Currie and Rossin-Slater 2013) and earthquakes (Torche 2011), and environmental pollutants (Almond, Edlund and Palme 2009, Sanders 2012).

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

older ages, and 200 μg for pregnant and lactating women (Clar, Wu, Liu and Li 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 IDD's are goiter, hypothyroidism (causing fatigue, lethargy, slow speech and thought), impaired mental function, retarded physical development, and increased susceptibility of the thyroid gland to nuclear radiation (WHO 2004). [6] Although the most detrimental IDD is cretinism due to severe iodine deficiency, less extreme in utero and postnatal deficiency can also be highly damaging and result in a 5%-50% loss of individual productivity depending on severity (Hetzel and Pandav 1996).

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

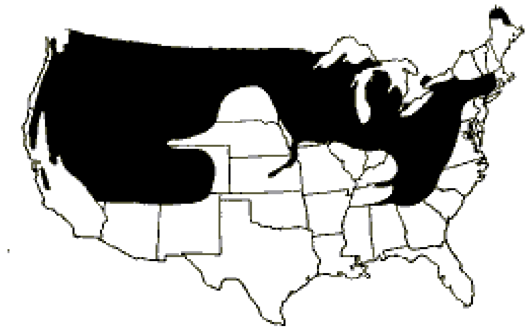
2.2 The Geography of Iodine Deficiency in the US

The map on the left in Figure 1 illustrates the geographic distribution of goiter incidence across the US based on data from the 1917 WWI draft examinations, which is, to our knowledge, the first and only nationwide goiter survey in the US. A "goiter belt" can be seen in the northern parts. The figure also shows a very high correlation between the geographic pattern of goiter incidence among WWI 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). The high correlation between the two patterns suggests that the WWI draft statistics would serve as a good representation of the geographic pattern of iodine deficiency in the general population. Our baseline estimates use the "Defects" data, but we also

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

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

replicate our results using the smaller sample of 32 states in McClendon's water iodine content data. These results are reported in the appendix, and we find remarkably similar coefficients to the "Defects" estimates.

In a publication in the Public Health Reports in 1929, Robert Olesen, a surgeon at the U.S. Public Health Service, gathered data from independent thyroid surveys as well as from direct correspondence with state, county and city health officers across the country to verify the geographic distribution of goiter in the general public against the findings from the WWI draft examinations. Olesen (1929) concludes that the evidence among the young population from elementary school to college confirms the geographic variation in goiter incidence among WWI recruits in those areas where he could collect data. This gives further validity to the use of the WWI draft statistics in this study.

The WWI draft statistics summarized in Table A.1 in the Appendix show substantial variation in goiter prevalence across states within a region. This is consistent with available water iodine content data provided by McClendon and Hathaway (1924) and the survey data collected in Olesen (1929). For example, in Illinois, McClendon and Hathaway (1924) shows locations with 1, 5, 10, 12 and 88 parts of iodine per hundred billion parts of water, and Olesen (1929) shows goiter rates ranging from 4% to 75%, which is summarized in Table A.2. Olesen notes that draft examinations record goiters so large that military collars would not button, which

explains the much higher goiter incidence found among the wide population. This variation is important in allowing 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.

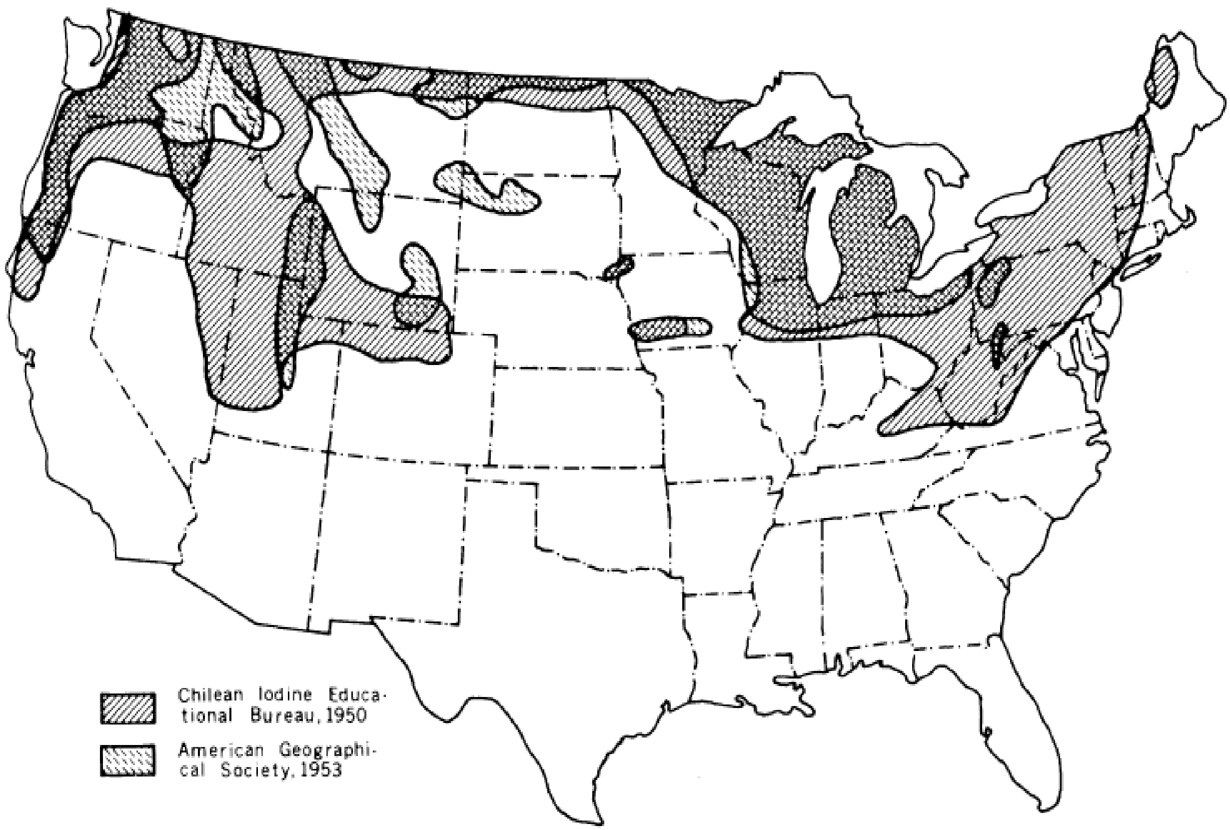
2.3 Introduction of Iodized Salt in the US in 1924

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 Lenhart 1909, Marine and Feiss 1915, 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

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



Source: Schiel and Wepfer (1976)

attributed this to ingestion of iodized salt without realizing it, such as in school canteens and restaurants, which seems plausible given that iodized salt made up 90% of salt sales in Michigan at the time (Markel 1987). This observation alleviates concerns about self-selection into using iodized salt and supports the approximate universality of the intervention. Figure 2 shows U.S. goiter survey results compiled by the Chilean Iodine Educational Bureau in 1950 and the American Geographical Society in 1953. The size of the endemic goiter areas decreased considerably between the WWI draft era (Figure 1) and 1950, and further from 1950 to 1953.

2.4 Goiter and Confounding Factors

Marine's 1917-19 experiment was the first to inform the US public that iodine supplementation could prevent and treat goiter; hence there is little reason to suspect a *direct* role of iodine in

residential selection or selection into iodine-rich diets. Supporting this claim, Figure 1 shows that goiter incidence was concentrated in the northern states, which were socioeconomically better off compared to the southern states.

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

Figure 3 shows the change in the per capita riboflavin, iron, niacin, and thiamin contents of American food between 1909 and 1994, which does not coincide with the timing of salt iodization. In order to address concerns about the contemporaneous eradication of infectious diseases, we check the robustness of our main results to controlling for baseline geographic variation in the prevalence of 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. [7]

3 Empirical Strategy

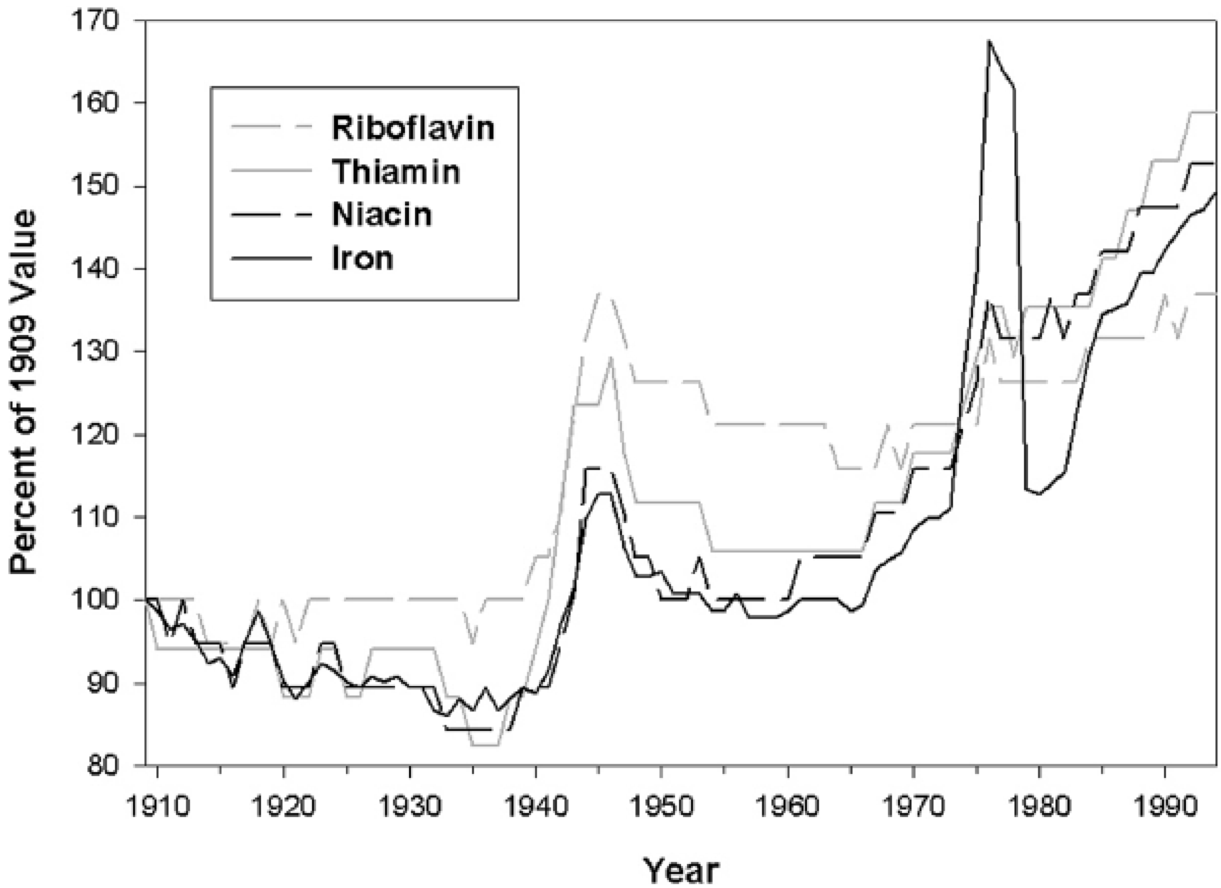
3.1 Overview of strategy

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 (2010b), 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 essentially the same 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 1920 in the continental US to identify differences in

[7] We also examine correlations between state-level goiter rates and state-level changes in total mortality and cause-specific mortality rates between 1930 or 1940 (after the introduction of iodized salt) and 1910 or 1920 (before the introduction of iodized salt) and find that more iodine deficient states experienced smaller decreases in those mortality rates (results available upon request).

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



Source: Backstrand (2002)

pre-iodization deficiency rates. As described in section 4, we use data from Love and Davenport (1920)'s map of goiter rates observed in armed forces recruits. We assign each individual in the census samples 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 actually iodine exposure *in utero*, and may in some instances not exhibit high correlation with the overall population goiter rate, given that the Love and Davenport (1920) data are on male armed forces recruits. 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" (Furnee 1997, Cao et al. 1994, Eltom et al. 1985). 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 (Lavado-Autric et al. 2003, Pop et al. 1999, Dugbartey 1998, 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.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.

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 how long iodization (from 0 to nearly 100 percent availability nationwide) took. 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.

3.2 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.[8] We estimate the following base specification, for individual i born in year t in state s (census region 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:

$$o_{ist} = \beta_1 T_s D_t + \beta_2 T_s A_t + (\zeta_r \text{ x } c) + \mu_s + \delta_t + \varepsilon_{ist}. \tag{1}$$

Here, β_1 and β_2 are the main coefficients of interest, measuring the difference in trends in outcome o across individuals 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, as well as a census region-specific linear trend in the outcome over time. In subsequent refinements to this basic specification, we add individual controls for race and gender, as well as controls for the average race and average gender (measured in 1940) of the individual's state of residence interacted with a post-iodization ($t \geq 1924$) dummy. We also test the robustness of the results to the inclusion of contemporaneous disease eradication programs, namely related to tuberculosis, hookworm, and malaria.

4 Data

4.1 Goiter Data

Our data on the geographic distribution of iodine deficiency before 1924 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. In this paper, we use the state-level prevalence rates, although rates for

[8]In the appendix, we test the robustness of the results to changing the definition of goiter; for these checks, instead of splitting at the median goiter rate, we use continuous goiter rate, a dummy for greater than the 25th percentile in the state-level goiter distribution, and a dummy for greater than 75th percentile of this distribution. We find that the results are generally stable across all these definitions.

smaller regions (collections of counties known as sections) were recorded as well.[9] Using goiter rates as a proxy for iodine deficiency levels, we are able to classify all states (excluding Hawaii) as either high or low deficiency.

The median goiter rate is .2205% and the maximum is 2.686% . 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. [10] Table A.1 lists all states recorded in Love and Davenport (1920), in ascending order of goiter prevalence.

There are some regional patterns in this distribution due to the geographic factors contributing to natural iodine levels in the soil (for instance, most east coast states are below the median because soil in coastal areas tends to be richer in iodine (Fuge 2007)). However, there are several other factors that contribute to the natural level of iodine available to a particular area, including the type of soil (specifically, its ability to retain added iodine), and availability of seafood and other iodine-rich foods (Fuge 2007).

In order to confirm that our results are not being driven by the specific population from which our goiter measures were drawn, we also use a second measure of goiter as a robustness check. This data was collected by Olesen (1929) and reported for 32 states in McClendon (1939). These goiter measurements were collected from school children in a varying number of localities in each of the 32 states. The data includes overall rates (including boys and girls) as well as rates among girls only. For our analysis, we use the overall rates. Table A.2 lists all states reported in McClendon (1939) in ascending order of state-level goiter prevalence, calculated as the simple average of all rates listed for that state. As discussed in Section 2, the goiter rates recorded here are up to 50 times larger than the goiter rates from the draft examinations. This is due to the greater noticeability of goiter among children compared to adults as well as the fact that the Draft Board only recorded goiters that were large enough to interfere with buttoning up a military collar. Using this goiter variable, we construct the high and low iodine deficiency indicators in the exact same way described for the army goiter rates.

4.2 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 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

[9] Note that section-level goiter data is not being used because the Census lacks information on county of birth. Although county of residence is recorded in the restricted-use Census, this was deemed an unsuitable proxy for county of birth given that almost 40% of the sample currently lives outside their state of birth

[10] See appendix for analysis using different percentiles as cutoffs

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.

4.2.1 Outcome and Control Variables

In terms of labor outcomes, we are interested in the rates at which individuals are participating in the labor force, earning positive wages, and graduating from high school. The income outcomes we look at include wage income, total income, and occupation type (specifically, blue collar employment). For all outcomes except high school graduation, we focus on individuals aged 25 to 55. For high school graduation, we focus only on those aged 25 to 35 because we are interested strictly in people who graduated high school and not individuals who received the GED later on in life (who look identical to high school graduates in the Census). There were sharp increases in GED test-taking during our sample years; in order to purge our analysis of these potentially confounding influences, we restrict to a younger cohort.

Additional variables taken from the Census include gender and race. In some specifications, 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 by calculating the black and female proportions from the 1920 Census in the the individual's state of residence. For more details on the construction of variables, see the Data Appendix.

4.2.2 Industry Variables

To analyze industry trends associated with the iodization of salt, we calculate labor shares by industrial category and state of residence in each Census year. We use the industry classification system used by the Census Bureau and categorize each worker into one of two supersectors: either service-providing or goods-manufacturing. We then break down the goods-producing sector into three smaller groups: agriculture, manufacturing, and construction. For more details on the construction of these industry categories, see the Data Appendix.

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

	(1)	(2)	(3)	(4)
	Whole Sample	*High Goiter States*	*Low Goiter States*	*High-Low Difference*
1(Participated in Labor Force)	0.613	0.604	0.621	-0.0165***
	(0.487)	(0.489)	(0.485)	(0.00138)
1(Earned Positive Wage)	0.495	0.493	0.497	-0.00376**
	(0.500)	(0.500)	(0.500)	(0.00143)
1(Graduated High School)*	0.355	0.410	0.305	0.105***
	(0.478)	(0.492)	(0.460)	(0.00203)
Wage Income	13182.3	14187.4	12238.6	1948.8***
	(10734.2)	(10707.3)	(10673.6)	(43.42)
1(Worked a Blue Collar Job)	0.564	0.556	0.572	-0.0159***
	(0.496)	(0.497)	(0.495)	(0.00181)
1(Female)	0.503	0.501	0.505	-0.00403**
	(0.500)	(0.500)	(0.500)	(0.00142)
1(Black)	0.107	0.0310	0.178	-0.147***
	(0.309)	(0.173)	(0.383)	(0.000852)
Number of Observations	495263	240658	254605	

*Notes: Statistics for 1(Graduated High School) are calculated for the population aged 25-35 only.

4.2.3 Summary Statistics

Table 1 reports summary statistics for the entire population aged 25-55 in the 1940 Census. As 1940 was the last Census year before the during and after cohorts entered our sample as working adults aged 25 and over, this gives us a snapshot of the pre-treatment conditions in high and low goiter states. About 60% of the population participated in the labor force, although slightly less than half earned a positive wage. Both of these rates were significantly higher in low goiter states. Possibly because these higher rates of participation meant the inclusion of more low-skilled workers, average wage income (conditional on earning a positive wage) was significantly lower in low-goiter states. Consistent with this observation, low goiter states also had a higher proportion of the population working in blue collar jobs. High school graduation rates were also slightly lower in low goiter states. These significant differences, while they point to underlying differences between high and low goiter states prior to the introduction of iodized salt, are accounted for in our difference-in-differences approach.

4.3 Other Diseases

In certain specifications, as falsification checks, we control for the pre-iodization rates of other diseases, including malaria, hookworm, and tuberculosis. For malaria, we use the malaria mor-

tality rates from the 1890 Census, used in Bleakley (2010b). Hookworm rates are also taken from Bleakley (2010b). 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.

5 Results

In this section, we present results from the empirical analysis discussed in section 3.

5.1 Labor Supply and Education

We begin by exploring effects of the availability of iodized salt in the year of birth on labor supply decisions and educational attainment. As discussed in section 3 above, the analysis rests fundamentally on a comparison of outcomes across cohorts born before and after the availability of iodized salt in states with above and below median goiter incidence prior to salt iodization. Figure 4 depicts comparisons in mean labor force participation and positive wage earning across four groups: those born just before and after 1924, in states with above and below median goiter incidence.

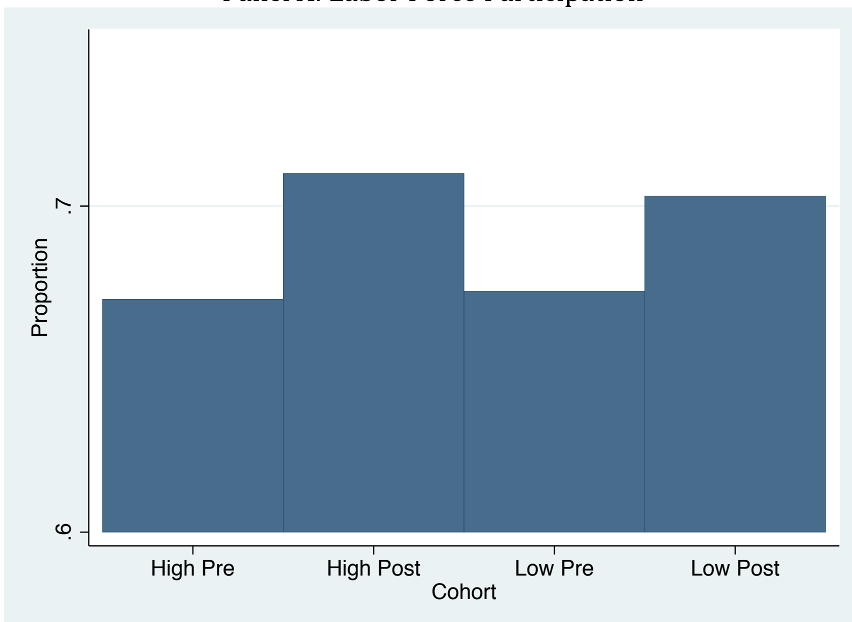
In Panel A, we see that cohorts born between 1920 and 1923 in states with above median goiter incidence had slightly lower labor force percentage than cohorts born in the same years in states with below median goiter incidence. However, cohorts born between 1924 and 1931 in high goiter states have *higher* labor force participation than cohorts born in the same years in low goiter states. It is, therefore, clear that contemporaneous to the rise in the availability of iodized salt in the US there was a larger increase in labor force participation among cohorts born in high goiter states than among those born in low goiter states.

In Panel B, we check the same patterns for the percentage of positive wage earners in the cohort. This outcome corrects for any individuals reporting employment without positive pay as well as includes individuals not actively seeking employment as non-wage-earners. The patterns are qualitatively very similar, though the percentage of positive wage earners is of course lower than the percentage of labor force participants for each cohort. Also, in the percentage of positive wage earners, the difference in pre-iodization percentages across high and low goiter states is larger than the post-iodization gap, in contrast to labor force participation percentages. This suggests that the availability of iodized salt *in utero* lead primarily to a rise in employment-seeking, rather than an improvement in employment rates among job-seekers.

Table 2 presents results from the analogous difference-in-difference analysis to the compar-

Figure 4: Proportion of Labor Force Participants and Positive Wage Earners in Each Cohort

Panel A: Labor Force Participation



Panel B: Positive Wage Earners

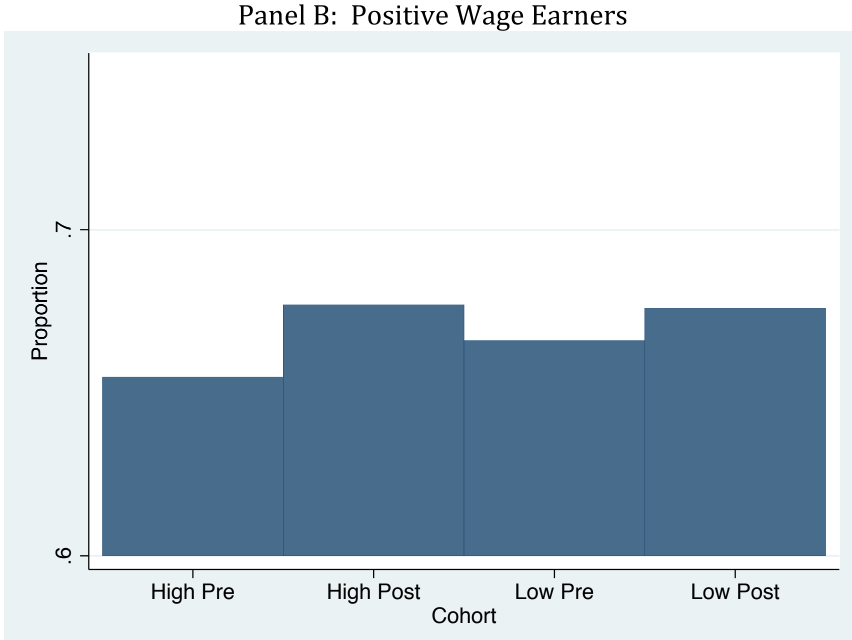


Table 2
Labor Supply and Education Differences

Panel A: 1(Participated in Labor Force)

	(1) Pre-Iodization	(2) Post-Iodization	(3) Post-Pre Difference
Born in a Low Goiter State	0.674	0.703	0.0292***
	(0.469)	(0.457)	(0.00117)
Born in a High Goiter State	0.671	0.710	0.0386***
	(0.470)	(0.454)	(0.00121)
High-Low Difference	-0.00245	0.00693***	0.00938***
	(0.00153)	(0.000772)	(0.00168)

Panel B: 1(Earned Positive Wage)

	(1) Pre-Iodization	(2) Post-Iodization	(3) Post-Pre Difference
Born in a Low Goiter State	0.666	0.676	0.0100***
	(0.472)	(0.468)	(0.00133)
Born in a High Goiter State	0.655	0.677	0.0219***
	(0.475)	(0.468)	(0.00137)
High-Low Difference	-0.0108***	0.00110	0.0119***
	(0.00175)	(0.000804)	(0.00191)

Panel C: 1(Graduated High School)

	(1) Pre-Iodization	(2) Post-Iodization	(3) Post-Pre Difference
Born in a Low Goiter State	0.110	0.415	0.305***
	(0.313)	(0.493)	(0.00221)
Born in a High Goiter State	0.154	0.521	0.367***
	(0.361)	(0.500)	(0.00243)
High-Low Difference	0.0442***	0.106***	0.0615***
	(0.00201)	(0.00210)	(0.00328)

isons in Figure 4. Panel A reports means and differences for labor force participation; while Panel B presents means and differences for positive wage earning. Indeed, the pre-iodization difference across high and low goiter states is larger than the post-iodization difference for positive wage earning; while the opposite is true for labor force participation. High goiter states experienced a rise in labor force participation after salt iodization that was roughly .94 percentage points larger than that in low goiter states. Similarly, high goiter states experienced a rise in positive wage earning after salt iodization that was roughly 1.2 percentage points larger than that in low goiter states.

Lastly, Panel C of Table 2 presents the difference-in-difference results for high school graduation rate. We find that the high school completion rate in high goiter states prior to salt iodization was already roughly 4.4 percentage points higher than that in low goiter states. This is potentially due to a low demand for low quality, unskilled labor in these states or a need to invest in upgrading the quality of unskilled labor. Nevertheless, post-iodization the difference in high school completion grows to over 10 percentage points. High goiter states experienced a rise in high school completion after salt iodization that was roughly 6.1 percentage points larger than that in low goiter states.

Next, we run regressions analogous to the difference-in-differences analysis but with the inclusion of additional controls. Specifically, as discussed in section 3 above, we include state of birth and year of birth fixed effects as well as state-of-residence time trends in all specifications. Table 3 presents the results of this regression analysis. The results reported in columns 1 through 6 correspond to specifications including a linear state-of-residence time trend, while the results reported in columns 7 through 9 correspond to specifications including state-of-residence by census year dummies to allow for non-linear state time trends. Specifications in columns 4 through 9 also include other demographic controls such as gender and race as well as pre-iodization state means for these variables and interactions of these state means with post-iodization dummies.

Lastly, the specifications from Table 3 divide the post-iodization period into "during" iodization and "after." That is, we include a dummy for being born between 1924 and 1927 ("during" roll out of iodized salt) and a dummy for being born between 1928 and 1931 ("after" availability of iodized salt peaked), as well as the interactions of these dummies with the dummy for above median state goiter incidence. These cohorts are compared to cohorts born between 1920 and 1923 ("before" salt iodization).

The results across all columns of Table 3 are remarkably stable and consistent with the estimates from the simple difference-in-differences analysis reported in Table 3. Comparing after iodization cohorts to before iodization, estimates of the effects of the availability of iodized salt on labor force participation range from 1.15 percentage points in column 1 to just under .85 percentage points in column 4. Similarly, estimates of effects on positive wage earning range from

Table 3

Effects of Salt Iodization on Labor Supply and Education

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	1(Participated in Labor Force)	1(Earned a Positive Wage)	1(Graduated High School)	1(Participated in Labor Force)	1(Earned a Positive Wage)	1(Graduated High School)	1(Participated in Labor Force)	1(Earned a Positive Wage)	1(Graduated High School)
After x High Goiter	0.0115***	0.0116***	0.0759***	0.00851***	0.0108***	0.0605***	0.0107***	0.0129***	0.0802***
	(0.00314)	(0.00369)	(0.0179)	(0.00307)	(0.00378)	(0.0160)	(0.00267)	(0.00326)	(0.0164)
During x High Goiter	0.0106***	0.0118***	0.0461***	0.00961**	0.0117***	0.0351***	0.0117***	0.0137***	0.0475***
	(0.00374)	(0.00362)	(0.0104)	(0.00377)	(0.00406)	(0.0101)	(0.00329)	(0.00346)	(0.0100)
Fixed Effects		State of Birth, Year of Birth			State of Birth, Year of Birth			State of Birth, Year of Birth	
State Time Trends		Linear			Linear			Non-Linear (State x Year Dummies)	
Demographic Controls		No			Yes			Yes	
Observations	1,678,661	1,553,941	337,454	1,678,661	1,553,941	337,454	1,678,661	1,553,941	337,454
Mean of Dependent Variable	0.699	0.674	0.354	0.699	0.674	0.354	0.699	0.674	0.354

Notes: Robust standard errors in parentheses (*** p<0.01, ** p<0.05, * p<0.1).

nearly 1.3 percentage points to 1.08 percentage points; while estimates of effects on high school graduation range from over 8 percentage points to roughly 6 percentage points.

Notably, comparing cohorts born during roll out of iodized salt to cohorts born before salt iodization yield nearly identical (even at times *larger*) estimates to those from "after" cohort comparisons for labor force participation and positive wage earning; estimates range from just under 1 to 1.17 percentage points and 1.17 to 1.37 percentage points, respectively. This seems to suggest that roll out of iodized salt occurred quickly, affecting post-iodization cohorts almost immediately. On the other hand, comparisons of before to during cohorts yield smaller (though still fairly large and significant) estimates than comparisons of before to after cohorts for high school completion. "During" estimates of effects on high school completion range from 3.5 to 4.75 percentage points.

5.2 Income and Job Type

Having established effects of salt iodization on labor supply and educational attainment, we next explore whether incomes responded to salt iodization as well. In Table 4, we present results from the difference-in-difference analysis on wage income, total income, and the percent employed in blue collar jobs. Note that all of these outcomes are conditional on employment. That is, effects on incomes and type of employment will reflect a composite of the effect on selection into employment as well as changes in the distribution of incomes and job type conditional on employment.

Panels A and B of Table 4 report means and differences in wage incomes and total incomes, respectively; while Panel C reports means and differences in the percent employed in blue collar jobs. The means and differences reported in column 1 of all three panels indicate that high goiter states had, on average, higher incomes and more skilled employees. This pattern is consistent with high goiter states having limited labor force participation and lower quality workers among low skilled residents. In column 2, we see that these gaps close measurably post iodization, though high goiter states continue to have slightly less low-skilled, low income workers.

Column 3 reports that high goiter states experienced a rise in blue collar jobs (relative to white collar) of more than 1 percentage point larger than that in low goiter states. This influx of blue collar laborers drove down the average wage income in high goiter states post iodization by nearly $402 (in 1999 dollars). Mean total income shows a similar pattern, but fell insignificantly in high goiter states by only $179. This attenuation is possibly due to farm income offsetting the inability of low-skilled, low income laborers to find wage work in high goiter states pre-iodization.

Table 5 presents results from the analogous regression analysis. Specifications corresponding to results reported across columns 1 through 9 are identical to those from Table 3. Specifically, columns 1 through 3 include a state-of-residence linear time trend; columns 4 through 6 include

Table 4
Income and Job Type Differences

Panel A: Wage Income

	(1) Pre-Iodization	(2) Post-Iodization	(3) Post-Pre Difference
Born in a Low Goiter State	26858.8	30147.9	3289.0***
	(18292.5)	(19723.5)	(67.76)
Born in a High Goiter State	30189.4	33076.2	2886.8***
	(18904.8)	(20368.7)	(72.47)
High-Low Difference	3330.6***	2928.4***	-402.2***
	(84.58)	(41.89)	(99.10)

Panel B: Total Income

	(1) Pre-Iodization	(2) Post-Iodization	(3) Post-Pre Difference
Born in a Low Goiter State	27192.9	29736.9	2544.0***
	(19316.3)	(20688.1)	(65.92)
Born in a High Goiter State	30639.2	33004.6	2365.4***
	(19965.2)	(21332.2)	(70.37)
High-Low Difference	3446.3***	3267.7***	-178.6
	(82.90)	(40.18)	(96.31)

Panel C: 1(Worked a Blue Collar Job)

	(1) Pre-Iodization	(2) Post-Iodization	(3) Post-Pre Difference
Born in a Low Goiter State	0.478	0.386	-0.0928***
	(0.500)	(0.487)	(0.00152)
Born in a High Goiter State	0.457	0.374	-0.0823***
	(0.498)	(0.484)	(0.00157)
High-Low Difference	-0.0217***	-0.0111***	0.0105***
	(0.00199)	(0.000980)	(0.00218)

Table 5

Effects of Salt Iodization on Income and Job Type

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Wage Income	Total Income	1(Worked a Blue Collar Job)	Wage Income	Total Income	1(Worked a Blue Collar Job)	Wage Income	Total Income	1(Worked a Blue Collar Job)
After x High Goiter	-491.2***	-302.9	0.0135***	-366.4*	-171.9	0.0121**	-470.1***	-245.2	0.00673
	(182.8)	(192.9)	(0.00488)	(206.4)	(202.4)	(0.00501)	(160.9)	(179.3)	(0.00555)
During x High Goiter	-470.2***	-226.7	0.00780**	-267.5	-15.43	0.00819**	-352.1**	-75.57	0.00354
	(169.8)	(162.1)	(0.00328)	(185.1)	(176.5)	(0.00352)	(140.0)	(144.2)	(0.00401)
Fixed Effects		State of Birth, Year of Birth			State of Birth, Year of Birth			State of Birth, Year of Birth	
State Time Trends		Linear			Linear			Non-Linear (State x Year Dummies)	
Demographic Controls		No			Yes			Yes	
Observations	1,047,359	1,245,396	1,168,224	1,047,359	1,245,396	1,168,224	1,047,359	1,245,396	1,168,224
Mean of Dependent Variable	31024	30891	0.398	31024	30891	0.398	31024	30891	0.398

Notes: Robust standard errors in parentheses (*** p<0.01, ** p<0.05, * p<0.1).

this linear time trend as well as demographic controls; and columns 7 through 9 include demographic controls and state-of-residence by census year dummies as non-linear state time trends.

Regression estimates of the effects of salt-iodization on incomes are quantitatively similar to the difference-in-difference estimates across specifications and generally significant at conventional levels for wage income. Point estimates of effects on wage incomes range (across both “after” and “during” comparisons) from -$268 to -$491 as compared to mean wage income of roughly $31,000. Point estimates of effects on total incomes range from -$15 to -$303, but none of the estimates are significant at conventional levels.

Comparisons of percent working blue collar jobs for cohorts born “during” the roll out of iodized salt to cohorts born before provide estimates of effects ranging from .35 percentage points (column 9) to .82 percentage points (column 6). Comparisons for cohorts born “after” to cohorts born before yield estimates of the effect of salt iodization on percent working blue collar jobs of between .67 percentage points (column 9) and 1.35 percentage points (column 3). These estimates should be compared to a mean of just under 40 percent, and with the exception of those from column 9 are significant at the 5 percent level.

5.3 Income Distribution

The results presented thus far have been consistent with the interpretation that access to iodized salt lead to an enfranchisement of the lowest skilled, lowest quality workers and an influx into the left tail of the income distribution. We now explicitly investigate distributional effects of access to iodized salt on income. Figure 5 plots income distributions for high and low goiter states before and after salt iodization. Panel A shows wage income distributions; while Panel B shows total income distributions. The left half of each panel plots the distributions for all 4 cohort groups; while the right half of each panel plots the post-pre-iodization difference for high and low goiter states.

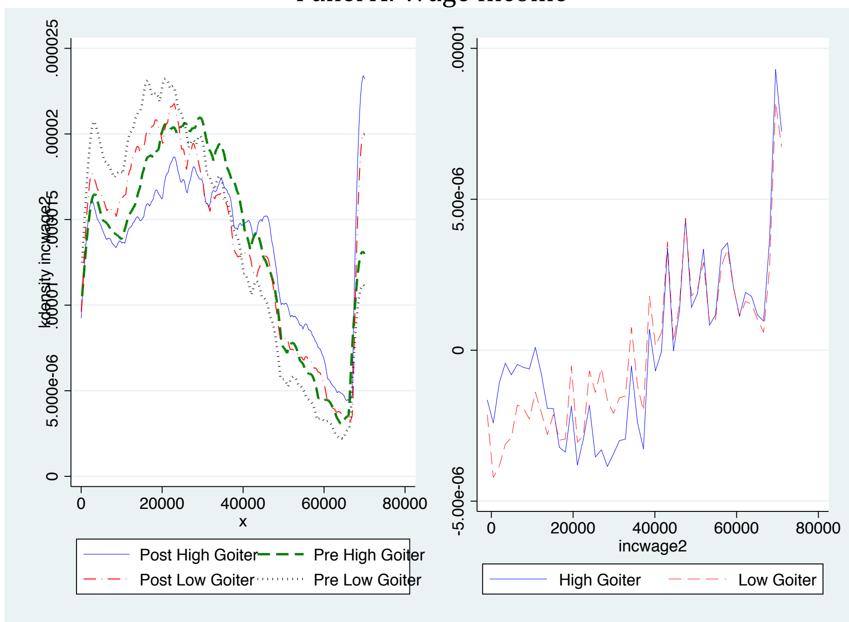
It is clear that the effects of access to iodized salt were concentrated in the lowest income quantile. That is, the highest income quantiles (roughly above $45,000 per year in 1999 dollars) appear to have shifted nearly identically across high and low goiter states. On the other hand, the lowest quantile of income grew faster in high goiter states than in low goiter states; while the middle income quantile (roughly between $20,000 and $45,000) grew faster in low goiter states.

We next run quantile dummy regressions to validate these graphical patterns. We define dummies for inclusion in each income quintile using the 1940 census. We then apply the same income cutoffs for inclusion in each quintile to later census observations to map how each cohort’s income distribution shifted. The results from these regression reported in Table 6. 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 the lower wage income quantiles. Specifically, the likelihood of being in the first

Figure 5: Income Distributions of Each Cohort

Panel A: Wage Income



Panel B: Total Income

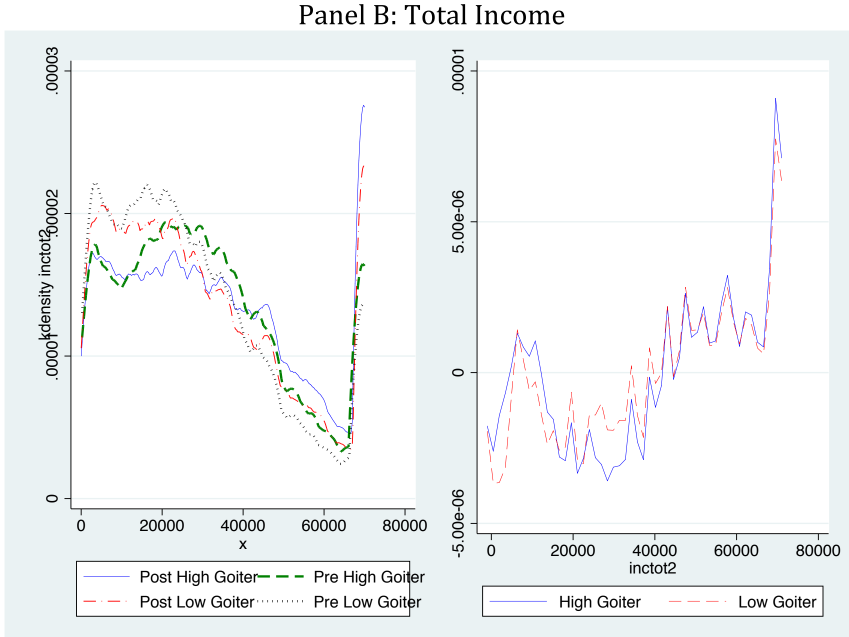


Table 6
Effects of Salt Iodization on Income by Quintile

Panel A: Wage Income

	(1)	(2)	(3)	(4)	(5)
	1st Quintile	2nd Quintile	3rd Quintile	4th Quintile	5th Quintile
After x High Goiter	0.0134***	0.00798***	0.00112	-0.00383	-0.00705*
	(0.00381)	(0.00184)	(0.00237)	(0.00245)	(0.00396)
During x High Goiter	0.0125***	0.00748***	0.00129	-0.000713	-0.00875**
	(0.00337)	(0.00189)	(0.00198)	(0.00200)	(0.00342)
Fixed Effects			State of Birth, Year of Birth		
State Time Trends			Linear		
Demographic Controls			No		
Observations	1,553,941	1,553,941	1,553,941	1,553,941	1,553,941
Mean of Dependent Variable	0.0766	0.0695	0.0753	0.0718	0.380

Panel B: Total Income

	(1)	(2)	(3)	(4)	(5)
	1st Quintile	2nd Quintile	3rd Quintile	4th Quintile	5th Quintile
After x High Goiter	0.00978**	0.00625**	-0.000832	-0.00698**	-0.00593
	(0.00387)	(0.00256)	(0.00227)	(0.00297)	(0.00404)
During x High Goiter	0.00582*	0.00538**	0.000539	-0.00279	-0.00699**
	(0.00293)	(0.00224)	(0.00181)	(0.00261)	(0.00326)
Fixed Effects			State of Birth, Year of Birth		
State Time Trends			Linear		
Demographic Controls			No		
Observations	1,549,843	1,549,843	1,549,843	1,549,843	1,549,843
Mean of Dependent Variable	0.104	0.0938	0.0870	0.0982	0.420

Notes: Robust standard errors in parentheses (*** p<0.01, ** p<0.05, * p<0.1).

wage income quantile as defined by the 1950 census rose by 1.25 to 1.34 percentage points more during and after the roll out of iodized salt than in low goiter states. The likelihood of being in the second wage income quantile rose by nearly .8 percentage points both during and after; while the likelihood of being in the third income quintile rose (insignificantly) by only .11 to .13 percentage points more in high goiter states. These effects are significant at the 1 percent level. On the other hand, as presented in columns 4 and 5, the likelihood of being in the 4th was not significantly affected, and the likelihood of being in the 5th wage income quintiles dropped by between .7 and and .88 percentage points. The estimates in column are 5 are significant at between the 5 and 10 percent level.

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 significant. The likelihood of being in the 1st quintile of total income rises in high goiter states by .58 percentage points more during the roll out of iodized salt and by .98 percentage points more after salt iodization than in low goiter states. The likelihood of being in the 2nd quintile rose by .54 percentage points and nearly .63 percentage points more during and after the roll out of iodized salt, respectively. On the other hand, the likelihood of being in the 4th quantile of total income *fell* by .28 and .7 percentage points more in high goiter states during and after the roll out of iodized salt, respectively. Overall, these effects are generally significant at the 5 percent level.

The patterns of effects on wage and total income distributions are summarized in Figure 6.

5.4 Industry Growth Trends

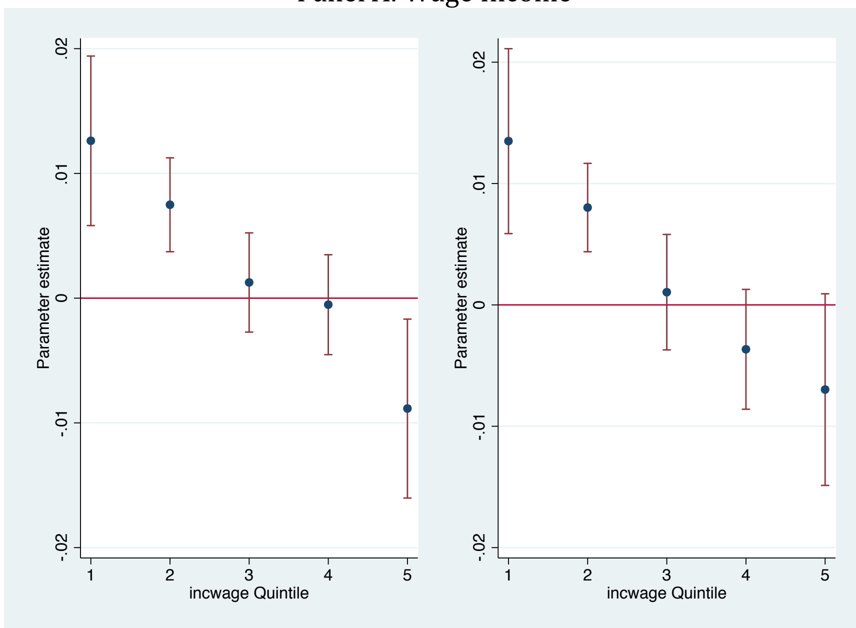
The empirical findings discussed thus far are broadly consistent with the roll out of iodize salt leading to the enfranchisement of low-skilled labor in high goiter states. High goiter states show signs, pre-iodization, of a thin supply of low-skilled labor and/or low-quality labor in the left tail of the income distribution. An influx of low-skilled labor (or alternatively, higher quality low-skilled labor) would not only change the shape of the income distribution, but a shift in the relative size of factor endowments (i.e. low-skilled labor vs. high-skilled labor) should affect the sector growth trajectory of high goiter states post-iodization.

Specifically, we hypothesize that a rise in the endowment of low-skilled labor of high goiter states post-iodization should lead to a higher growth rate (or less negative, more precisely) in low-skilled-labor-intensive sectors (e.g. goods production) perhaps in place of growth in high-skilled industries (e.g. services). We provide suggestive graphical evidence in support of this hypothesis in Figures 7 and 8. Figure 7 plots sector growth rates from 1950 to 1990 against the pre-iodization state goiter incidence level; while Figure 8 plots the employment percentage of the goods and services sectors in each census year for both high and low goiter states.

Panel A of Figure 7 depicts the relationship between pre-iodization state goiter incidence and the growth rate of the goods sector over the second half of the 20th century. It is clear that

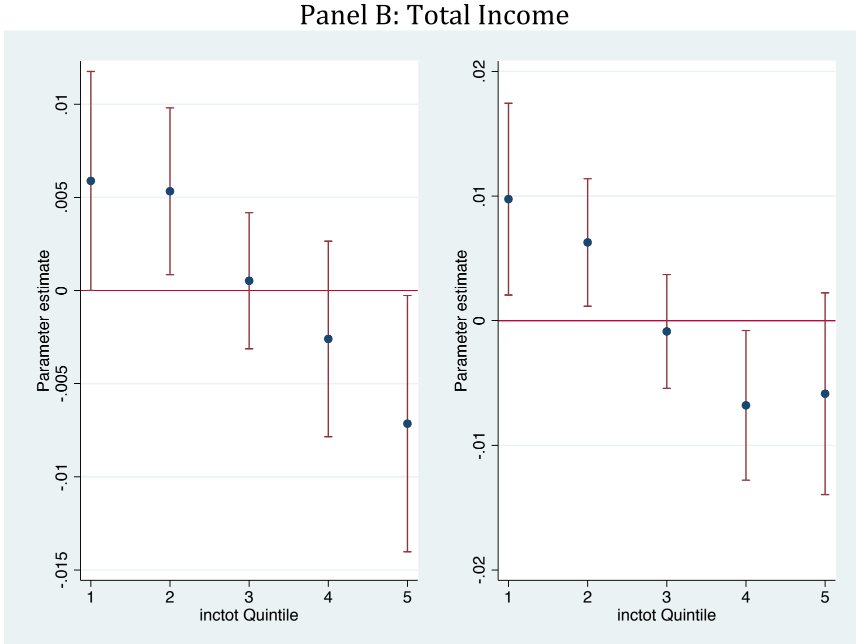
Figure 6: Income Quintile Regression Coefficients

Panel A: Wage Income



During After

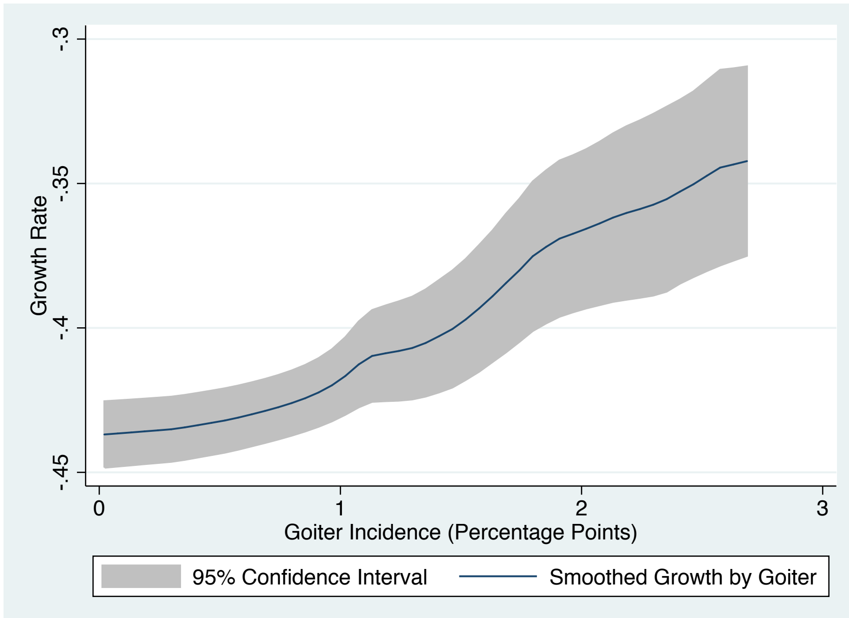
Panel B: Total Income



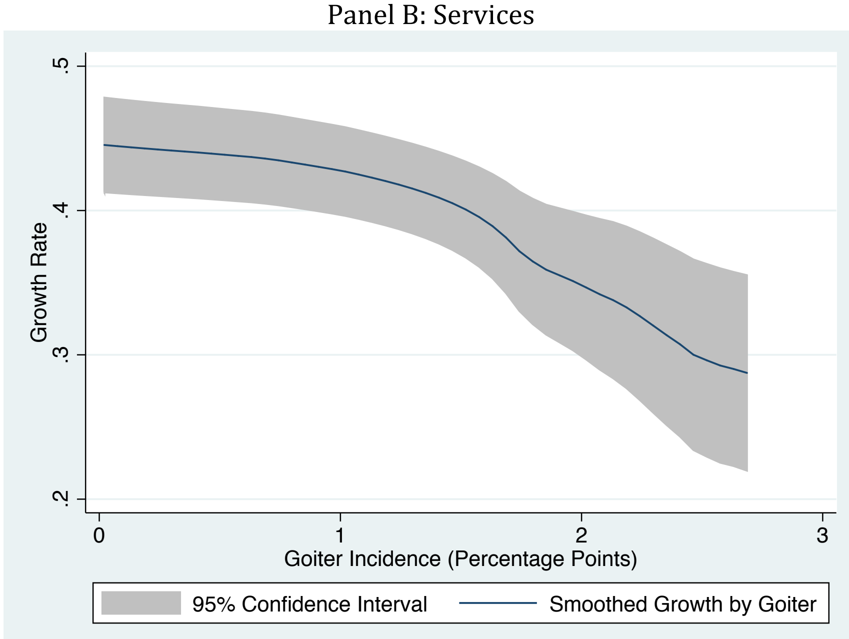
During After

Figure 7: Sector Employment Growth Rates by 1920 Goiter Level

Panel A: Goods



Panel B: Services



a high pre-iodization goiter incidence predicts a slower decline in employment in the goods sector at the state level. Panel B of Figure 4 depicts the relationship between goiter and services sector growth rates. Here we see that a high pre-iodization goiter incidence is associated with a lower growth rate in states' services sector growth.

In Figure 8, Panel A shows that goods sector employment in high goiter states was slower to contract, particularly post-1970. Panel B shows that employment in the services sectors of high goiter states was slower to rise after 1970. While the convergence in sector employment levels across high and low goiter states appears strongest nearly 50 years after salt-iodization, it is reasonable to expect sectoral response to factor endowments to be slow. Nevertheless, we take the patterns in Figures 7 and 8 to be merely suggestive.

5.5 Robustness

Finally, we run additional regressions to check the robustness of our main results to additional controls and alternate explanation for the patterns observed. Specifically, 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. Specifically, if high goiter states also had higher incidence of these diseases (e.g. tuberculosis, hookworm, or malaria), then the eradication of these diseases during the first quarter of the 20th century might be driving the relative change in labor supply, education, and incomes in these states.

In order to check for this possibility, we rerun the main results additionally controlling for a dummy for above median incidence of tuberculosis, hookworm, and malaria and the interaction of these dummies with the post-iodization dummy. These results are reported in Tables 7 and 8. The pattern of results is overwhelmingly preserved.

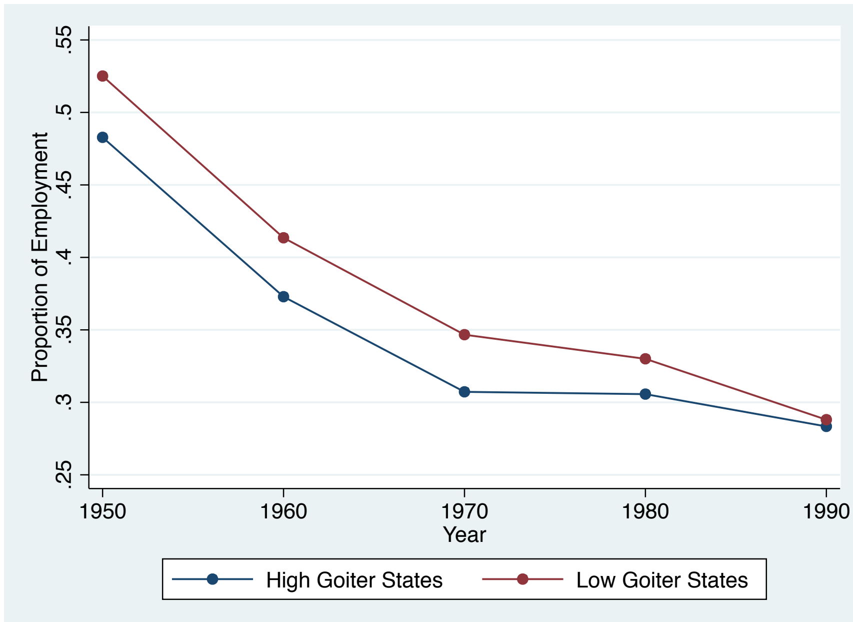
6 Conclusion

In this study, we document the effects of the rapid nationwide iodization of salt in United States. We estimate substantial impacts on high school completion and labor force participation. Most of these labor force joiners took up blue collar jobs and earned wages at the bottom of the wage distribution. Blanket intervention with iodized salt, interestingly, had a very targeted effect, concentrated on individuals at the margin of employment.

The historical experience in the US may hold lessons for the many low-income countries currently deciding whether and how much to invest in iodization. The returns to iodization might be very different in these places, given differences in industry shares, competing risks, the level of consolidation of the salt industry, geographical barriers to salt transport infrastructure,

Figure 8: Sector Employment Trends for High and Low Goiter States

Panel A: Goods



Panel B: Services

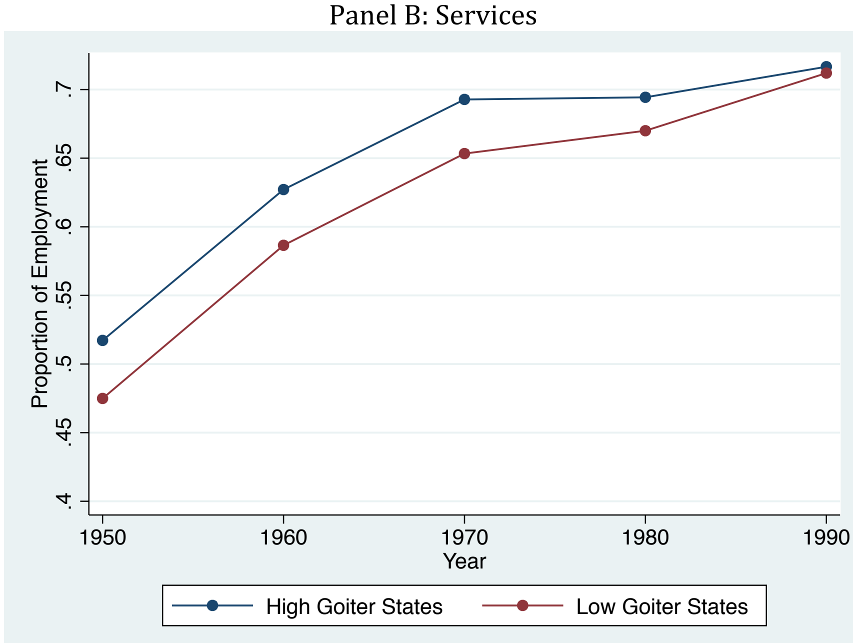


Table 7
Robustness to Contemporaneous Disease Eradication (Labor Supply, Education, Income and Job Type)

	(1)	(2)	(3)	(4)	(5)	(6)
	1(Participated in Labor Force)	1(Earned a Positive Wage)	1(Gradauted High School)	Wage Income	Total Income	1(Worked a Blue Collar Job)
After x High Goiter	0.00923**	0.00983**	0.0271**	-157.8	-99.12	0.0175***
	(0.00352)	(0.00370)	(0.0117)	(176.6)	(194.9)	(0.00468)
During x High Goiter	0.00497*	0.00756**	0.0241***	-194.3	-69.74	0.00971***
	(0.00286)	(0.00317)	(0.00747)	(177.0)	(152.3)	(0.00303)
After x High Tuberculosis	-0.00113	-0.00202	-0.0135*	71.26	-102.8	-0.00272
	(0.00281)	(0.00231)	(0.00719)	(95.83)	(114.4)	(0.00288)
During x High Tuberculosis	-7.80e-05	4.51e-05	0.000252	10.26**	3.775	-9.33e-05
	(8.30e-05)	(8.71e-05)	(0.000183)	(4.939)	(4.468)	(0.000149)
After x High Hookworm	-0.00535*	-0.00632	-0.0816***	545.4***	379.3**	0.0147***
	(0.00309)	(0.00395)	(0.0130)	(131.8)	(149.5)	(0.00386)
During x High Hookworm	-0.0125***	-0.00968**	-0.0379***	410.4***	152.8	0.00714*
	(0.00389)	(0.00419)	(0.00709)	(145.8)	(154.7)	(0.00357)
After x High Malaria	2.16e-06	0.00302	-0.0412***	436.1***	371.8**	0.000558
	(0.00333)	(0.00363)	(0.0123)	(134.7)	(156.1)	(0.00514)
During x High Malaria	-0.00381	-0.00336	-0.0240***	460.0***	344.3**	-0.00108
	(0.00391)	(0.00358)	(0.00792)	(163.2)	(170.1)	(0.00393)
Fixed Effects		State of Birth, Year of Birth			State of Birth, Year of Birth	
State Time Trends		Linear			Linear	
Demographic Controls		No			No	
Observations	1,677,969	1,553,264	337,363	1,046,915	1,244,861	1,167,822
Mean of Dependent Variable	0.699	0.674	0.354	31024	30891	0.398

Notes: Robust standard errors in parentheses (*** p<0.01, ** p<0.05, * p<0.1).

Table 8
Robustness to Contemporaneous Disease Eradications (Income Quintiles)

Panel A: Wage Income

	(1)	(2)	(3)	(4)	(5)
	1st Quintile	2nd Quintile	3rd Quintile	4th Quintile	5th Quintile
After x High Goiter	0.00445***	0.00336**	0.00153	0.00199	0.00280
	(0.00133)	(0.00154)	(0.00190)	(0.00157)	(0.00312)
During x High Goiter	0.00454***	0.00297**	0.000759	0.00415***	-0.00160
	(0.00115)	(0.00140)	(0.00202)	(0.00126)	(0.00268)
After x High Tuberculosis	0.000632	0.000344	-0.00106	-0.00147*	0.00140
	(0.000890)	(0.00126)	(0.00111)	(0.000818)	(0.00177)
During x High Tuberculosis	-2.99e-05	9.96e-05**	-7.97e-05*	-7.74e-06	0.000150
	(5.83e-05)	(4.73e-05)	(4.19e-05)	(4.72e-05)	(0.000113)
After x High Hookworm	-0.00533***	-0.000461	-0.000534	0.00298	0.00709**
	(0.00147)	(0.00178)	(0.00236)	(0.00181)	(0.00304)
During x High Hookworm	-0.00360***	-0.00106	-0.00198	0.00166	0.00455
	(0.00107)	(0.00157)	(0.00213)	(0.00154)	(0.00340)
After x High Malaria	-0.00373**	-0.00294*	5.27e-05	0.00132	0.0125***
	(0.00157)	(0.00171)	(0.00190)	(0.00130)	(0.00325)
During x High Malaria	-0.00353***	-0.00243	-0.00111	0.000658	0.00734*
	(0.00114)	(0.00160)	(0.00209)	(0.00137)	(0.00370)
Fixed Effects			State of Birth, Year of Birth		
State Time Trends			Linear		
Demographic Controls			No		
Observations	1,553,264	1,553,264	1,553,264	1,553,264	1,553,264
Mean of Dependent Variable	0.0766	0.0695	0.0753	0.0718	0.380

Panel B: Total Income

	(1)	(2)	(3)	(4)	(5)
	1st Quintile	2nd Quintile	3rd Quintile	4th Quintile	5th Quintile
After x High Goiter	0.00319*	0.00222	-0.000234	0.000125	0.00192
	(0.00174)	(0.00174)	(0.00196)	(0.00212)	(0.00358)
During x High Goiter	0.000871	0.00273	-1.96e-05	0.00326*	-0.00252
	(0.00129)	(0.00170)	(0.00158)	(0.00179)	(0.00264)
After x High Tuberculosis	0.00243**	0.000767	-2.78e-05	-0.00136	0.00130
	(0.00106)	(0.00131)	(0.00110)	(0.00103)	(0.00236)
During x High Tuberculosis	-2.18e-05	3.48e-05	-1.64e-05	1.89e-06	6.49e-05
	(9.41e-05)	(5.50e-05)	(4.39e-05)	(5.23e-05)	(6.99e-05)
After x High Hookworm	-0.00312*	-0.000492	-0.00172	0.00302	0.00753**
	(0.00168)	(0.00210)	(0.00219)	(0.00187)	(0.00290)
During x High Hookworm	0.00106	0.000709	-0.00105	0.00152	0.00147
	(0.00135)	(0.00191)	(0.00188)	(0.00173)	(0.00315)
After x High Malaria	-0.00526***	-0.00194	0.00106	0.00170	0.00972***
	(0.00136)	(0.00193)	(0.00188)	(0.00156)	(0.00313)
During x High Malaria	-0.00340**	0.000914	-0.00189	0.00147	0.00607*
	(0.00135)	(0.00188)	(0.00188)	(0.00180)	(0.00350)
Fixed Effects			State of Birth, Year of Birth		
State Time Trends			Linear		
Demographic Controls			No		
Observations	1,549,166	1,549,166	1,549,166	1,549,166	1,549,166
Mean of Dependent Variable	0.104	0.0938	0.0870	0.0982	0.420

Notes: Robust standard errors in parentheses (*** p<0.01, ** p<0.05, * p<0.1).

etc. Nevertheless, what we learn from the US is, at least, that labor activity increases significantly, particularly for individuals who were not in the labor force previously. Thus iodizing salt could function mainly as a pro-poor policy, but could potentially generate spillovers affecting the whole labor force. More evidence on the (partial) iodization experiences of countries like India should be explored to examine the extent to which the US experience was common.

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Table A.1
Goiter Prevalence by State from Love and Davenport (1929)

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.

A Additional Tables

Tables - report replications of the main results on labor force participation, schooling, wage and income distributions, and blue collar labor using the McLendon (1939) data from 32 states in place of the "Defects" data. We find remarkably consistent estimates for all the main results.

B Data Appendix

B.1 Independent Indicator Variables

- $before$=1 if individual was born before 1924; $before$=0 if individual was born in or after 1924
- $during$=1 if individual was born during1924-1927; $during$=0 if individual was born before 1924 or after 1927

Table A.2
Goiter Prevalence by State from McClendon (1939)

Low Goiter States		High Goiter States	
Alabama	0.067	Kansas	8.371
Arizona	0.080	Virginia	8.955
New Mexico	0.100	Oklahoma	10.410
Mississippi	0.310	New York	12.933
Georgia	0.800	Wyoming	15.000
Rhode Island	0.860	Illinois	19.727
Massachusetts	1.600	Montana	20.800
Pennsylvania	2.500	Oregon	24.817
California	3.356	Washington	26.725
New Jersey	3.500	Michigan	28.064
North Dakota	3.967	Ohio	29.214
Louisiana	5.525	West Virginia	42.938
Missouri	6.667	Utah	45.883
Tennessee	6.775	Wisconsin	49.805
Kentucky	6.890	Minnesota	51.483
Maryland	7.799	Indiana	76.000

Notes: All prevalence rates are in percentage points.

Table A.3
Robustness to Alternative Goiter Measurement (Labor Supply, Education, Income and Job Type)

	(1)	(2)	(3)	(4)	(5)	(6)
	1(Participated in Labor Force)	1(Earned a Positive Wage)	1(Gradauted High School)	Wage Income	Total Income	1(Worked a Blue Collar Job)
After x High Goiter	0.00961***	0.0112***	0.0751***	-498.7***	-204.6	0.0101*
	(0.00317)	(0.00392)	(0.0176)	(177.7)	(209.6)	(0.00528)
During x High Goiter	0.0106***	0.0112***	0.0507***	-482.0***	-205.9	0.00765**
	(0.00307)	(0.00326)	(0.00952)	(148.2)	(169.8)	(0.00352)
Fixed Effects		State of Birth, Year of Birth			State of Birth, Year of Birth	
State Time Trends		Linear			Linear	
Demographic Controls		No			No	
Observations	1,319,596	1,222,636	264,037	825,157	977,561	917,229
Mean of Dependent Variable	0.699	0.674	0.354	31024	30891	0.398

Notes: Robust standard errors in parentheses (*** p<0.01, ** p<0.05, * p<0.1).

Table A.4

Robustness to Alternative Goiter Measurement (Income Quintiles)

Panel A: Wage Income

	(1)	(2)	(3)	(4)	(5)
	1st Quintile	2nd Quintile	3rd Quintile	4th Quintile	5th Quintile
After x High Goiter	0.00445***	0.00336**	0.00153	0.00199	0.00280
	(0.00133)	(0.00154)	(0.00190)	(0.00157)	(0.00312)
During x High Goiter	0.00454***	0.00297**	0.000759	0.00415***	-0.00160
Fixed Effects			State of Birth, Year of Birth		
State Time Trends			Linear		
Demographic Controls			No		
Observations	1,553,264	1,553,264	1,553,264	1,553,264	1,553,264
Mean of Dependent Variable	0.0766	0.0695	0.0753	0.0718	0.380

Panel B: Total Income

	(1)	(2)	(3)	(4)	(5)
	1st Quintile	2nd Quintile	3rd Quintile	4th Quintile	5th Quintile
After x High Goiter	0.00319*	0.00222	-0.000234	0.000125	0.00192
	(0.00174)	(0.00174)	(0.00196)	(0.00212)	(0.00358)
During x High Goiter	0.000871	0.00273	-1.96e-05	0.00326*	-0.00252
	(0.00129)	(0.00170)	(0.00158)	(0.00179)	(0.00264)
Fixed Effects			State of Birth, Year of Birth		
State Time Trends			Linear		
Demographic Controls			No		
Observations	1,549,166	1,549,166	1,549,166	1,549,166	1,549,166
Mean of Dependent Variable	0.104	0.0938	0.0870	0.0982	0.420

Notes: Robust standard errors in parentheses (*** p<0.01, ** p<0.05, * p<0.1).

- $after$=1 if individual was born in or after 1928; $after$=0 if individual was born before 1928

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.2 Control Variables

- $female$=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).

B.3 Outcome Variables

B.3.1 Basic Outcomes

- $1(GraduatedHighSchool)$=1 if the individual graduated high school. This includes those who completed the GED but not those who went to vocational school ;
  $1(GraduatedHighSchool)$=0 if the individual did not complete high school.
- $1(ParticipatedinLaborForce)$=1 if the individual participated in the labor force;
  $1(ParticipatedinLaborForce)$=0 if the individual did not participate in the labor force
- $1(WorkedaBlueCollarJob)$=1 if the individual is in the labor force and falls into one of the following blue-collar occupation type categories (according to the Census Bureau's 1950 occupation classification system): farmers, craftsmen, operatives, farm laborers, and laborers; $1(WorkedaBlueCollarJob)$=0 if the individual is in the labor force but falls into some other occupation category. This variable is missing for those not in the labor force.

- $WageIncome$: This is 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.

- $TotalIncome$: This is 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.

B.3.2 Income Quintile Analysis

$1(TotalIncomeQuintile1)$ to $1(TotalIncomeQuintile5)$ and $1(WageIncomeQuintile1)$ to $1(WageIncomeQuintile5)$ 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 total income and total wage. These were used as the baseline quintiles to construct the following variables:

- $1(TotalIncomeQuintile1)$=1 if the individual's total income fell into the first quintile of $TotalIncome$; $1(TotalIncomeQuintile1)$=0 if the individual's total 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.

- $1(WageIncomeQuintile1)$=1 if the individual's total income fell into the first quintile of $WageIncome$; $1(WageIncomeQuintile1)$=0 if the individual's wage income 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 Industry Variables

Although the Census reorganizes this classification system almost every Census year, they also report industry codes using the 1950 occupational scheme in every Census. For consistency, we use these 1950 codes.

- $Goods$=1 if the individual was classified into a goods-producing industry (which includes industries in the agriculture, manufacturing, and construction sectors); $Goods$=0 if the in-

dividual was classified into a service-producing industry. These supersectors are mutually exclusive.

- $Service$=1 if the individual was classified into a service-providing industry (which includes wholesale/retail trade, business services, personal services, entertainment and recreation services, etc); $Service$=0 if the individual was classified into a goods-producing industry.

- $Manufacturing$=1 if the individual was classified into a manufacturing industry; $Manufacturing$=0 if the individual was classified into an industry other than manufacturing.

- $Agriculture$=1 if the individual was classified into an agricultural industry; $Agriculture$=0 if the individual was classified into an industry other than agriculture.

- $Construction$=1 if the individual was classified into a construction industry; $Construction$=0 if the individual was classified into an industry other than construction.

Note that $Goods$=$Agriculture$+$Construction$+$Manufacturing$.