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A bit of salt, a trace of life: Gender norms and the impact of a salt iodization program on human capital formation of school aged children[☆]

Zichen Deng[a,*], Maarten Lindeboom[b]

[a] NHH Norwegian School of Economics, Norway
[b] Vrije Universiteit Amsterdam, The Netherlands; Centre for for Health Economics, Monash University, Australia; Tinbergen Institute, The Netherlands; IZA Bonn, Germany

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A B S T R A C T

This paper evaluates the effect of a national salt iodization program on the cognition of school-aged children in China. We focus on the role of gender preferences. Linking pre-eradication iodine deficiency rates with household survey data, we find a strong positive impact of prenatal exposure to the program on cognition and schooling for girls. For boys, we find no effect. Child preferences play an important role in parental investment decisions and impact program effects. We find that parents invest more in girls with a high initial endowment. For boys, this is different. Parents invest in boys, irrespective of their initial endowment. The nationally implemented program may therefore primarily benefit low endowment girls. We then exploit village-level variation in gender attitudes and find that gender attitudes are related to parental investment behavior and that the program's impact is stronger for girls born to parents with strong preferences for boys.

1. Introduction

Iodine deficiency early in pregnancy can have significant, irreversible effects on fetal brain development and can have important consequences for human capital formation and subsequent socioeconomic outcomes. This has been established in the medical literature (see Zimmermann, 2011, for a systematic literature review) and in economic papers (Adhvaryu et al., 2020; Araujo et al., 2021; Feyrer et al., 2017; Field et al., 2009, see, for instance).

This paper evaluates the effect of a nationally implemented salt iodization program on the cognition of school-aged children in China. We focus on the role of parental gender preferences, how these may shape parental investment decisions and how this may lead to gender differences in the impact of the program. Gender preferences are deeply rooted in gender norms, which are important in East and South-East Asia, the Middle East, and North Africa, and may be important in the western world. Gender norms may already impact children very early in life and may in part explain heterogeneous gender effects found in the literature on the long-run effects

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* Corresponding author.
E-mail addresses: zichen.deng@nhh.no (Z. Deng), m.lindeboom@vu.nl (M. Lindeboom).

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of early life shocks (Adhvaryu, Bednar, Molina, Nguyen and Nyshadham, 2020; Field, Robles and Torero, 2009; Maccini and Yang, 2009). Understanding the mechanisms underlying program effects is crucial for designing future interventions.

To fight iodine deficiency-related diseases, the Chinese government implemented a national program requiring salt to contain iodine in October 1994. At the same time, the government introduced biennial province-based monitoring to record the use and iodine content of household salt, along with urinary iodine concentrations among schoolchildren. After introducing the program, the percentage of children who had goiter dropped rapidly.[1] Given the importance of iodine during the gestational period for brain development (Cao et al., 1994; Zimmermann, 2011), we focus on the potential impact of this policy on cognitive ability and school attainment for children who are affected in utero.

We link iodine deficiency information across locations collected at the start of the intervention to nationally representative rural samples drawn from the *China Family Panel Studies* (CFPS). A unique aspect of the CFPS survey is that math and vocabulary ability from standardized tests were collected alongside schooling information. Similar to Shah and Steinberg (2017), our human capital measurements in the CFPS have the advantage that the same tests were given to each individual in the survey, regardless of whether s/he is currently enrolled in school.

To identify the long-term benefits of the salt iodizing policy, we use the national salt iodizing program as a quasi-experiment and exploit geographic variation in goiter prevalence before the intervention. We essentially compare improvements in math and vocabulary ability and years of schooling for cohorts conceived before and after the salt iodization in areas with varying pre-intervention goiter prevalence. Additionally, we make sure that we are comparing outcome variable trends (by birth cohort) across high and low goiter province of birth in their deviation from each region's average trend. We also include an extensive set of controls, such as pre-treatment province characteristics interacted with cohort dummies to flexibly control for confounding factors at the province level that might affect cohorts differently.

Baseline results from a difference-in-differences (DiD) analysis show that the salt iodization policy has substantial and significant effects on cognition for girls. A one standard deviation (11.24%) decrease in the pre-intervention regional goiter rate is associated with a 0.1–0.15 standard deviation increase in a math and vocabulary test scores. We also see significant increases in years of schooling (about 0.4 years). For boys, we find very small and insignificant effects. A simple calculation shows that the improvement in human capital for girls translates to a 6% increase in income in adulthood.[2]

We consider the role of parental investments as one potential way to rationalize our findings.[3] Following the suggestion of Adhvaryu et al. (2019); Adhvaryu and Nyshadham (2016), we perform supplemental analyses that examine whether parental investment in young children is related to birth endowments. Specifically, we find a strong positive association between an index for parental time investments in children and birth weight. This suggests that parents make reinforcing investments in their children (i.e., they invest more in children with a high initial endowment). However, the association varies by gender and suggests that parents always invest in boys, irrespective of their initial endowment. For girls this is different, parents invest most in girls with a high initial endowment. The nationally implemented program reduces the negative cognition effects of iodine deficiency for both genders and this may primarily benefit low endowment girls.

To make sure that gender differences in the program effects are driven by parental preferences and not by inherent biological differences between males and females, we turn to *within* gender comparisons. Similar to Dahl et al. (2017); Dhar et al. (2018); Dossi et al. (2019), we proxy gender preferences by gender attitudes. Specifically, we exploit attitude information in the survey about the appropriate roles and rights for women and girls to proxy gender preferences. We find that parents invest less in girls in areas with attitudes favoring boys. Next, in a triple DiD framework, we find that the program effects are largest in communities with the strongest son preferences. A concern may be that gender attitudes are not randomly allocated across communities. We therefore also estimate models that include community characteristics interacted with cohort dummies. This does not alter the results. As an alternative proxy for gender preferences, we use pre-program county-level sex-ratios. These estimates are very similar to our estimates from the main (triple DiD) model. Taken together, the evidence from our models suggests that gender preferences are an indispensable factor in explaining the gender difference in program effects.

Our study contributes to at least three strands in the literature. First, we add to the literature on the long-term effects of early-life conditions. Much early "fetal origins" work (see, among others, Almond, 2006; Van den Berg et al., 2006) has focused on demonstrating the impact of extreme, traumatic experiences (disease outbreak, recessions, famines, severe environmental shocks, etc.) in early life. Recent studies (see Adhvaryu et al., 2020; Brown et al., 2018; Feyrer et al., 2017; Hoynes et al., 2016; Niemesh, 2015) have focused on estimating gains from exposure to a purposeful large-scale distribution of resources. The nationally implemented intervention in China started just after the launch of the 1993 WHO campaign. It is also a common, moderate intervention and has relevant external validity, so our results will help policymakers optimize similar policies in the future. Furthermore, while there are many studies that look at the impact of in utero exposure to the quantity of food (see Lumey et al., 2011, for an excellent review of the famine literature), only a few studies (e.g. Adhvaryu et al., 2020; Feyrer et al., 2017; Field et al., 2009) have looked at the long-run effects of food quality or nutrient intake.

[1] Iodine is an essential component of hormones produced by the thyroid gland. Iodine deficiency can lead to goiter, an enlarged thyroid gland located at the base of the neck.

[2] For this we use Wang (2013) who finds that one year of additional schooling raises income by 15% in China. See also Section 4.

[3] Another possibility is that female fetuses are more sensitive to maternal thyroid deficiency than male fetuses. In Section 5 we argue that this channel is of secondary importance.

Second, we contribute to the discussion on intermediate proxy indicators of long-term outcomes. Adhvaryu et al. (2020); Feyrer et al. (2017) examine the long-term effect of a salt iodization program, promoted by a private firm, on lifetime income. Adhvaryu et al. (2020) find that exposure to the iodine program increases incomes by about 10%. We look at the effect of a public program on childhood cognition and education and find substantial effects. Our study thus sheds light on how early-life disadvantage unfolds over time. We use measurements of human capital that include standardized numeracy tests for all children, unlike most other studies that look at school enrollment. A few recent studies, such as (Almond et al., 2015; Bharadwaj et al., 2017; Figlio et al., 2014; Shah and Steinberg, 2017), take a similar approach by examining the effects of events in early childhood on cognitive test outcomes for school-aged children. However, since most of these studies use administrative data from developed countries, the standardized tests only cover children in schools. In developing countries, however, a substantial share of children are already out of school at a young age, so examining program effects on children in school will only give a partial picture of the effectiveness of the intervention. Moreover, most human capital measurements are self-reported performance measures, which makes them difficult to compare across individuals. Our work complements the literature with evidence from a vast developing country and uses a data set where the results of standardized math and verbal tests are collected for all children, in and out of school.

Third, we shed light on the literature about child gender preferences. Gender biases favoring males, particularly in education, are most relevant in developing countries like China and India. Females in those countries often receive fewer investments from parents (see, for example, Barcellos et al., 2014; Bharadwaj and Lakdawala, 2013; Jayachandran and Kuziemko, 2011; Oster, 2009) and are unlikely to reach their full potential in education, health, and personal autonomy. Our results point at positive (possibly unintended) spillovers to females from a general program. Our study, therefore, also speaks to the relevance of early life conditions in explaining gender differences in socioeconomic outcomes later in life.[4]

Our results point towards three observations that are relevant for policy and the literature referred to above: parental investment responses are relevant when interpreting empirical estimates of the effects of (adverse) shocks early in life; child gender preferences can be important for these investment decisions; and large scale programs can have positive and possible unintended effects on gender equality in societies where boy preferences are important.

The rest of the paper is organized as follows. Section 2 provides a brief overview of Iodine Deficiency Disorders (IDD), the Universal Salt Iodization (USI) program, and related literature. Section 3 describes the data we use in our analysis. Section 4 outlines our empirical model and baseline results and relates our findings with earlier findings from the literature. We presents a simple model where gender preferences may induce different parental investment in girls and boys in Section 5 and introduce gender attitudes as a proxy for gender preferences. Section 6 summarizes our findings, places these findings into context and concludes.

2. Background

Iodine is an essential component of the hormones produced by the thyroid gland and is therefore essential for human life (Zimmermann, 2011). Insufficient iodine intake causes many disorders from the fetal stage to adulthood, the most common of which is an enlargement of the thyroid gland. Although this enlargement, called goiter, is the most visible symptom of iodine deficiency, it has no severe consequences. However, fetal exposure to iodine deficiency may lead to impaired neurodevelopment. The brain damage caused by severe iodine deficiency at this stage in life is often irreversible.

Doctors have known that iodine can help prevent goiter since the mid-1800's (Zimmermann, 2008). Iodine was not discovered in the thyroid gland until 1895 (Baumann, 1896). Switzerland was the first country to introduce iodized salt in 1922. The United States introduced iodized salt in 1924 after the executive Council of the Michigan State Medical Society officially endorsed iodized salt. In 1993, the World Health Organization (WHO) proposed a worldwide campaign to eradicate Iodine Deficiency Disorders (IDD). The primary intervention strategy for IDD control is Universal Salt Iodization (USI), a simple, universally effective, and cheap policy. The World Bank reports that USI only costs $0.05 per child per year.

Historically, endemic goiter was common in the mountain regions in China. In the 1940s, more than 20% of the residents of Kunming, the capital of the province of Yunnan, had goiter (Simoons, 1990). The Chinese Academy of Preventive Medicine estimated that about 450 million people lived in iodine-deficient areas in the 1990s, with more than 30% of the population considered at risk of IDD (see Chen and Wu, 1998). The iodine deficiency disorders problem was acknowledged as a public health threat, and in 1993 the State Council of China announced a Universal Salt Iodization (USI) policy to eliminate IDD by 2000.

Universal Salt Iodization was a national strategy. USI requires that all edible salt, including salt for food processing and household use, is iodized. Accordingly, all counties throughout China were required to supply iodized salt (except for very few (about 1%) officially approved counties). The goal of the policy was to increase salt iodine levels enough to bring the median urinary iodine concentration of children into the 100–199 μg/L range and maintain optimal urinary iodine concentration (MUIC) levels for pregnant women (150–249 μg/L). To reach the desired intake of iodine, the State Council enacted national regulation on salt iodization in October 1994. The required level of salt iodization during the manufacturing process was set at 50 mg/kg in 1994.

Between 1993 and 1995, a national monitoring system was built to track trends in goiter prevalence among school children aged 8–10. The monitoring program collected data between March and June 1995. In our empirical analyses (see Section 4), we use the outcome of this monitoring exercise as the pre-policy distribution of iodine deficiency levels across provinces. Note that this period is a few months after the implementation of the Salt Iodization Program. Therefore, the cross-province variation in goiter rates may

[4] See Almond and Currie (2011), who call for work that integrates work on son preference with work on fetal origins.

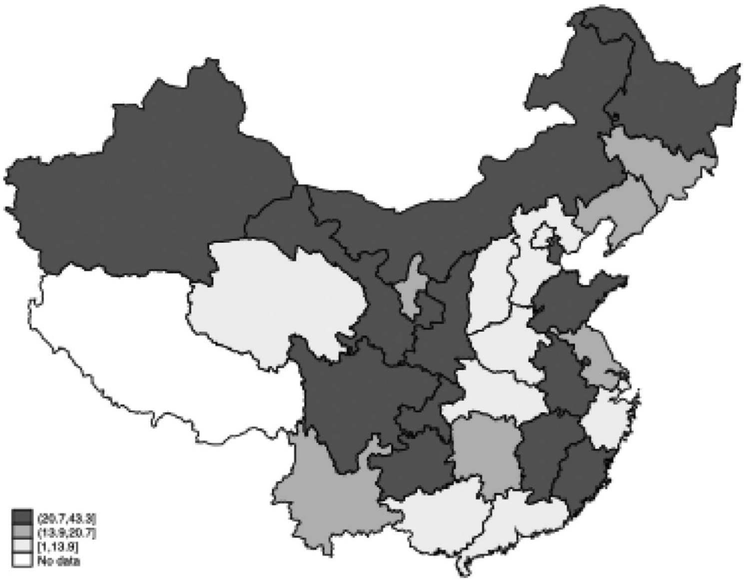


Fig. 1. Goiter distribution at the start of 1995.
Notes: Fig. 1 reports goiter rates (%) (among schoolchildren aged 8–10) in 1995. Darker areas represent higher goiter rates.

not reflect the pre-policy distribution of iodine deficiency rates. It is important to stress that the literature has documented lags of at least one year before goiter rates normalize after iodine depletion (Jooste et al., 2000; Pardede et al., 1998; Zimmermann et al., 2003).[5]

Fig. 1 shows the pre-policy spatial distribution of iodine deficiency levels for schoolchildren aged 8–10. Pre-policy (1995) goiter rates among children under ten years old do not differ significantly by gender Sun (2018). The dark areas (mostly western and northern provinces) indicate high prevalence rates (up to 43.3%), while the light areas (southeast) indicate low prevalence rates. For our empirical analyses, it is important to know whether the Universal Salt Iodization policy was effective in increasing the urinary iodine concentration levels in the population. We turn to this question in the next section.

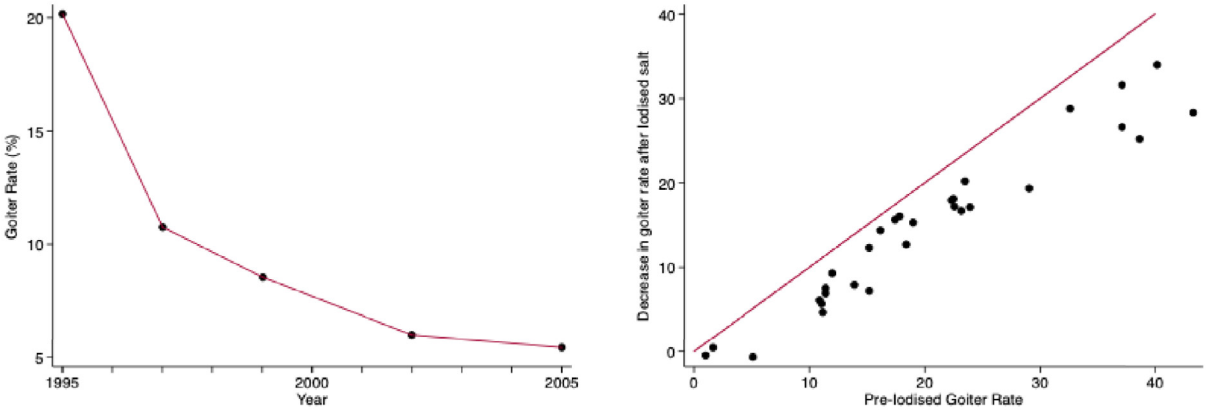
3. Data

3.1. Goiter Data

The base, pre-policy geographic distribution of goiter prevalence before the salt iodization policy (see Fig. 1) comes from the 1995 National Iodine Survey on goiter rates among schoolchildren. The county served as the primary sampling unit, and in each province 30 counties (clusters) were selected from a county population list. In each selected county, a school was sampled at random. Children aged 8 to 10 years at the time of the survey served as the index population. For each cluster, 40 children were selected at random from the enrollment list. All children were examined for thyroid size by palpation. Therefore it includes goiter rates Class I (can only be determined by palpation) and Class II (can be detected by palpation and can be seen in normal posture). Class II constitutes less than 2% of the total number of cases (Sun, 2018). The sample size for each province ranged from 1200 to 2400 (mean, 1,259). Our goiter data has an important advantage over goiter measures used in some recent studies like Adhvaryu et al. (2020); Feyrer et al. (2017), who use goiter prevalence among military recruits. Their index population consists of young and healthy adults and may not be a representative measure of local iodine deficiency rates.

The survey was held every two or three years, enabling us to track the effectiveness of the Universal Salt Iodization program over time. The program was very effective. By 2002, provinces converged to low child goiter rates, so provinces with high pre-eradication levels of goiter experienced the largest reductions. This decline in goiter rates is illustrated in Fig. 2a, which shows average goiter rates (%) across China over 1995–2002. The average goiter rate decreased from 20% in 1995 to around 5% in 2005. Fig. 2b shows the post-campaign decline in goiter rate versus pre-campaign levels. This figure shows that the policy was effective in bringing down goiter rates for *all* provinces.

[5] Pardede et al. (1998) and Jooste et al. (2000) documented non-significant reductions in the size of the thyroid gland among children age 12 in South Africa one year after the introduction of iodized salt. Zimmermann et al. (2003) found only an eight percent reduction in the goiter rates in children aged 8–9 in Cote d'Ivoire even two years after the salt intervention.



(a) Goiter Rates Decline (b) Before and After the Intervention

Fig. 2. Goiter prevalence before and after the intervention.
Notes: Fig. 2a reports time-series data on mean goiter rate (among schoolchildren aged 8–10) across country from 1995 to 2005. Fig. 2b shows the post-intervention decline in goiter rate versus pre-intervention levels across China.

3.2. The sample, outcome variables and control variables

3.2.1. The sample

The micro-level data used in this study come from the *China Family Panel Studies* (CFPS). The CFPS is a large-scale nationally representative panel survey conducted by the Social Science Survey Institute at Peking University. Three waves of the survey were published before 2017. The CFPS baseline wave (hereafter CFPS-2010) selected a total of 14,798 households, containing 33,600 adults and 8990 children. This baseline survey includes a standard math and verbal test.

The data include birth information, such as year and month of birth, place of birth, and whether individuals were born in a rural area. We restrict ourselves to those born in rural areas (81% of the total population). The intervention is likely to be 'cleaner' for those born in a rural area, since those in urban areas had better access to micronutrient food supplements.[6] The survey also collected respondents' migration history. Migration at young ages is very low (less than 3%). The Salt Iodization policy was implemented in October 1994 and we therefore include cohorts born between July 1991 and June 1999. In CFPS-2010 these individuals were between 11 and 19 years old. This leaves us with 3237 children (1641 boys and 1596 girls) for which we have all the key information on test scores and education.

3.2.2. Variables

In the regression analyses we use two outcome measures: schooling (defined as the number of years in school) and a test score. The test score is based on a math test and a verbal test designed by the CFPS team. Both tests were presented to the students irrespective of their age. The math test was designed to test for primary and secondary school math knowledge and consists of twenty-four math problems. Questions were sorted in order of increasing difficulty, and each question counted for one point. Similarly, the verbal test consists of thirty-four Chinese characters based on language textbooks. Characters, which counts for one point each, are sorted in order of increasing difficulty. Full scores of the math and language test are 24 and 34, respectively. We construct our main cognitive measure (Test Score) by taking the first principal component from a principal components analysis (PCA) on the math and verbal test. This variable captures 75% of the total variance of the two tests.

The sample also includes basic socio-demographic variables, such as gender, parental education. At this point we should note that families in rural areas were regularly exempted from the one-child policy. For example, rural married couples were allowed to have a second child if the first child was female (Zhang, 2017). Indeed, the sex-ratio in our sample of rural born children is about 1.07, which is lower than 1.12 (the sex-ratio at birth in the 1990s documented in Jayachandran (2015)). In our empirical strategy it is important to control for possible mean reversion. Therefore, we supplement the set of individual controls with a series of province-level pre-policy characteristics. All these variables are listed in Appendix A, where we also describe how we constructed each variable.

Table 1 reports summary statistics for socio-demographic variables by gender for provinces with high initial (pre-policy) goiter rates (goiter rates above the median of 17%) and low initial goiter rates (goiter rate prevalence less than 17%) for cohorts born before the implementation of the program (1991–1994).[7] Parental education is higher in regions with low initial goiter rates, and female

[6] In addition, the use of such supplements is likely to vary by parental Socio-Economic Status (SES), which correlates strongly with our cognitive and educational outcomes measures.

[7] In the Appendix, we provide summary statistics for the cohorts born after the implementation of the salt iodization policy (Table A2).

Table 1
Summary statistics.

	High Goiter Provinces		Low Goiter Provinces	
	Female	Male	Female	Male
Outcomes				
Schooling	8.88	8.98	9.46	9.29
	(2.70)	(2.34)	(1.99)	(2.08)
Math Test Scores	14.7	15.1	16.0	15.4
	(5.65)	(5.43)	(4.82)	(5.09)
Verbal Test Scores	25.3	25.0	26.7	25.0
	(7.62)	(7.12)	(5.95)	(7.17)
1st Principal Component	0.084	0.26	0.48	0.31
	(1.85)	(1.22)	(1.03)	(1.08)
Demographics				
Age	16.8	16.8	17.0	17.0
	(1.24)	(1.25)	(1.26)	(1.28)
Father's Educational Attainment	2.31	2.29	2.55	2.53
	(0.95)	(0.96)	(0.89)	(0.89)
Mother's Educational Attainment	1.69	1.78	2.13	2.05
	(0.86)	(0.88)	(0.94)	(0.90)
Number of observations	370	370	347	394

Notes: Author's tabulations of CFPS-2010. Sample consists of individuals born in rural area between July 1991 and June 1995. We label a province as high/low goiter if its goiter rate is above/below 17% (median).

outcomes on test scores and education are slightly better than the outcomes for males. However, the differences in schooling and test scores between high and low goiter regions are larger for girls than for boys.

4. Empirical strategy and average program effects

China rolled out nationwide salt iodization in October 1994. Therefore, we cannot use any province as a pure control group. As a proxy for pre-policy iodine deficiency rates, we use province goiter rates among 8–10 year old children at the start of 1995 (see Fig. 1). Like Adhvaryu et al. (2020); Bleakley (2010), we use a difference-in-differences (DiD) design. We compare trends in various outcome measures in provinces with different levels of iodine deficiency before the salt iodization program.

We define someone as treated if their entire gestation period is after the implementation of the salt iodization program.[8] All others are considered controls. We consider alternative definitions of treatment and control groups in Appendix B. In contrast to the 1924 salt iodization policy in the U.S., the Chinese iodized salt campaign was implemented rapidly across the entire country. Soon after the start of the program, more than 80% of families had access to iodized salt. Two years later, this had increased to 95%.

We focus on the impact of the salt iodization policy on cognitive ability and schooling of children by running the following baseline regression:

$$Y_{ipt} = \beta_0 + \beta_1 Post_{it} \times Goiter_p + X_{ipt}\rho + \delta_p + \gamma_t + \epsilon_{ipt}, \tag{1}$$

where outcome Y_{ipt} is the first component of a Principal Component Analysis (PCA) of the cognitive test scores and years of schooling for individual i, born in province p, in year t. $Post_{it}$ is a dummie variable that equals 1 if the individual was conceived after the introduction of iodized salt. $Goiter_p$ is a measure of pre-eradication iodine deficiency rates in individual i's province of birth. We use standardized goiter rates from the National Iodine Survey held at the start of 1995. The vector X_{ipt} includes individual characteristics. δ_p and γ_t are province and birth cohort fixed effects. Note that the birth cohort fixed effects are important because our outcome variables are measured at fixed points in time (2010), which implies that those exposed to iodized salt are younger than the controls. We also control for region-specific linear trends.[9] We additionally estimate models where we replace the region-specific linear trends by region of birth and birth year interactions.

Our primary interest is the continuous treatment variable $Post_{it} \times Goiter_p$, which proxies potential iodine exposure. Recall from Fig. 2b that the salt iodization policy was very effective in reducing goiter rates in all provinces. So while the parameter β_1 is the intention-to-treat effect, the high compliance rates make it very close to the treatment effect. Table 2 reports the regression results from our baseline model (Eq. 1). Panel A reports the results for females, Panel B for males. Although the table only reports the coefficient of interest, in all specifications, we include controls for province and year of birth fixed effects and region-specific linear trends (Columns 1 and 2). In Columns 3 and 4, besides parental education controls, we also add (mean-reversion) controls: provincial average educational attainment in Census 1990 interacted with the dummy for treated cohorts, hospitals per capita in 1991, hospital beds per capita in 1991, and the sex-ratio in Census 1990, number of schools per capita in 1991, and poverty rates in 1993 all

[8] We use a nine-month gestation period, which is standard in the literature.
[9] The regions consist of several provinces. See Table A1 of the Appendix A for precise definitions.

Table 2
Iodine exposure and human capital attainment, by gender.

	(1) Test Scores (PCA)	(2) Schooling (Years)	(3) Test Scores (PCA)	(4) Schooling (Years)
Panel A: Female				
Post × Goiter	0.23	0.31	0.22	0.40
	(0.074)***	(0.088)***	(0.065)***	(0.079)***
	[0.080]***	[0.094]***	[0.070]***	[0.082]***
Mean of Dep. Var.	0.014	7.66	0.014	7.66
Observations	1596	1596	1596	1596
Panel B: Male				
Post × Goiter	–0.0046	0.0036	0.072	0.034
	(0.10)	(0.14)	(0.11)	(0.10)
	[0.11]	[0.15]	[0.11]	[0.11]
Mean of Dep. Var.	–0.014	7.66	–0.014	7.66
Observations	1641	1641	1641	1641
Panel C: Female-male difference				
Post × Goiter	0.23	0.30	0.15	0.37
P-value	(0.048)**	(0.036)**	(0.095)*	(0.000)***
Additional Controls	No	No	Yes	Yes

Notes: Each coefficient is from a separate regression. All regressions control for fixed effects specific to birth province and birth year, region-specific linear trends. Additional controls include parental education, provincial average educational attainment in Census 1990 interacted with the dummy for treated cohorts (mean-reversion control), hospitals per capita in 1991, hospital beds per capita in 1991, and the sex-ratio in Census1990, number of schools per capita in 1991, and poverty rates in 1993 all interacted with cohort dummies. Standard errors clustered by province appear in parenthesis. Standard errors based on wild-bootstrap approach (Cameron et al., 2008) with 999 replications appear in square brackets. *, **, *** indicates significance at the 10%, 5% and 1% level.

interacted with cohort dummies.[10] These additional controls should alleviate concerns about the possible confounding influence of other coincident changes. Standard errors (in parentheses) are clustered at the province-of-birth level to allow for arbitrary correlation of the errors for individuals born in the same province. Wild-bootstrapped standard errors Cameron et al. (2008) are reported in square brackets.

Table 2 shows significant and sizable effects for females. For females, a one standard deviation (11.24%) decrease in the pre-intervention goiter rate is associated with a 0.4 year increase in schooling and a 0.2 (SD) increase in test scores. The 0.4 year increase in schooling translates into an income increase of about 6%.[11] For males, the coefficients are substantially smaller and not significant. In panel C we report estimates of the female-male difference. For test-scores the effects are significantly different at the 10% level (p-value of 9%). The associated p-value for a different schooling effect is less than 1%. The estimated effect on schooling for females in Table 2 is in line with Field et al. (2009), who find that the iodine supplement program increased schooling by 0.30–0.56 years.

Since our estimates use the cross-province convergence in goiter rates created by the introduction of iodized salt (Fig. 2a and 2b), convergent pre-trends across high and low-base goiter rate provinces prior to 1995 are a concern. Therefore, we also use an event study design to formally test for the common pre-trends assumption. Specifically, we run the regression

$$Y_{ipt} = \beta_0 + \sum_{t=1991}^{1998} \beta_t \times Birth_{it} \times Goiter_p + X_{ipt}\rho + \delta_p + \gamma_t + \epsilon_{ipt}, \tag{2}$$

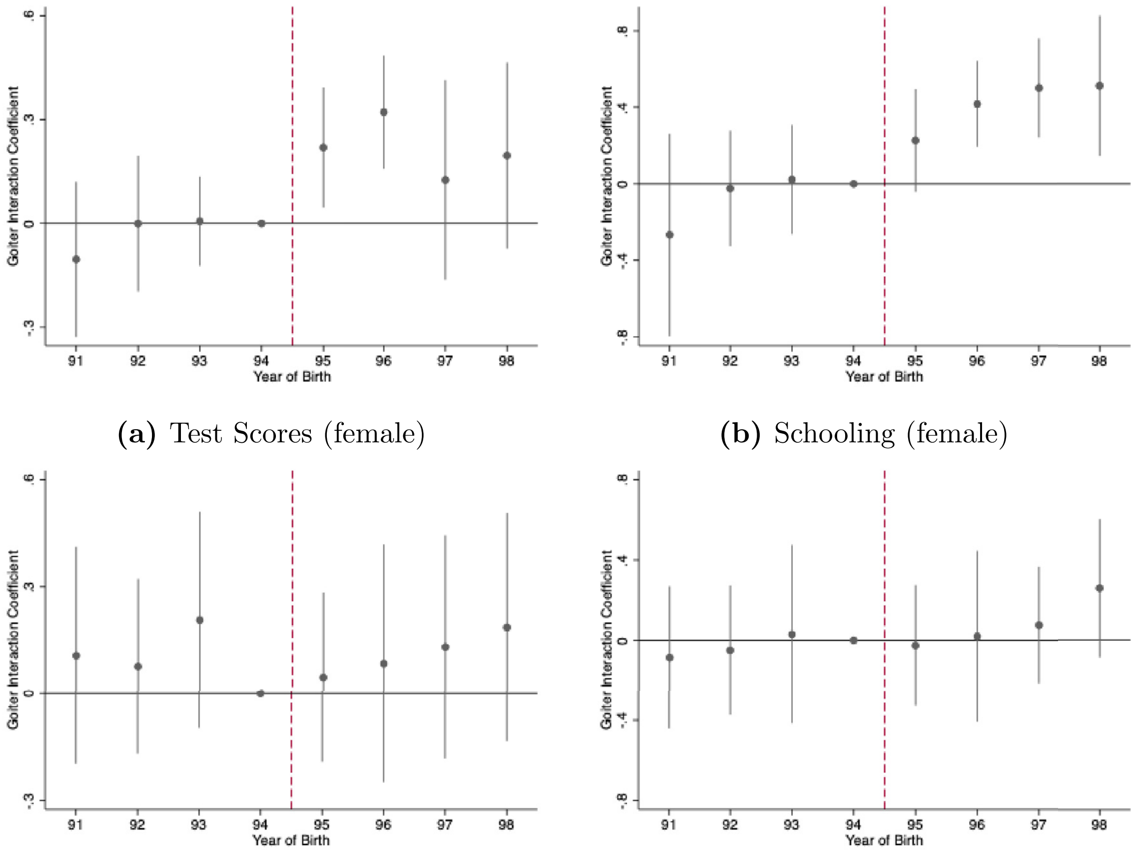
with $Birth_{it}$ the year of birth. β_t gives the cohort-specific relationship between pre-eradication iodine deficiency rates and later-childhood outcomes.[12] Fig. 3 plots the estimated coefficients (β_t) and shows that we cannot reject the common trend assumption for both genders.

In Table 3 below we present the results of a placebo test where we use parental education as the outcome variable. The idea of this test is that parental education should not be affected by future exposure to iodized salt. If we do find an effect, it may suggest that our results are driven by parental background. Unfortunately, there are too many missing observations on the years of schooling for the parents. We therefore use the educational attainment for the father and the mother. The results for the parents are reported

[10] Provincial poverty rates in 1993 are from Woo et al. (2004).

[11] For this we used the result from Wang (2013) who finds that one year of additional schooling in China raises income by 15%. For the females in our study the income increase is about 0.4×0.15 which is about 6%.

[12] In practice, β_{1994} represents estimates of individuals born between July 1994 and June 1995, and β_{1995} for the cohort born between July 1995 and June 1996, etc. We made these adjustments because individuals born after July 1995 were conceived after the implementation of the salt iodization policy. Similarly, the 1993 cohort are those born between July 1993 and June 1994.



(a) Test Scores (female) **(b)** Schooling (female)

(c) Test Scores (male) **(d)** Schooling (male)

Fig. 3. Event study by gender.
Notes: Each point reflects the coefficient estimated on an interaction term between the birth year (compared to 1994) and the pre-intervention (base) level of the goiter rate in the birth-province. Capped spikes represent 95 percent confidence intervals. All models condition upon birth province and birth year fixed effects, and region-specific linear trends.

in Columns 1 and 2 of Table 3. In Column 3, we report the result for educational attainment of the child.[13] We find small and insignificant effects of the program for the educational attainment of the parents. This contrasts with the significant effect for their child.

In Appendix B, we explore additional robustness checks such as excluding the partially exposed and using the drop in the goiter rates between 1995 and 2005, instead of the goiter rate in 1995 (Table B1). We also present separate results for the Math and Verbal test scores (Table B2) and perform a falsification test where we randomly assign the treatment (Fig. B1. All these analyses confirm the baseline outcomes of Table 2.

Other economics studies also have found differential effects by gender. Adhvaryu et al. (2020); Feyrer et al. (2017) exploit a nationwide salt-iodization program initiated by the public health authorities in Michigan in 1924. Feyrer et al. (2017) find strong effects for males: iodized salt in utero leads to a 15 point increase in I.Q. Interestingly, Adhvaryu et al. (2020), using census data, find no effects for males, but strong increases in income (11%), labor force participation (0.68%) and full-time work (0.9%) for females. Araujo et al. (2021) examine the effect of a large scale Iodization program in Tanzania. They find schooling increases for both genders and find larger effects for females (although the differences in coefficients are not significant). Field et al. (2009) also using data from Tanzania find stronger effects for girls. Earlier epidemiological studies (Bautista et al., 1982; Bleichrodt and Born, 1996) also find stronger cognitive improvements in girls. Larger effects of iodine in utero for females are also consistent with the medical literature. This literature posits that female fetuses are more sensitive to maternal thyroid deficiency than male fe-

[13] Note that the youngest cohort in our sample (all born after 1995) are young and very likely to be still in school. Therefore estimated program effects for the child are likely to be downward biased.

Table 3
Iodine exposure and educational attainment, additional results.

Educational Attainment	(1) Father's	(2) Mother's	(3) Child
Panel A: Female			
Post × Goiter	0.0093	–0.017	0.072
	(0.051)	(0.054)	(0.026)**
	[0.055]	[0.058]	[0.028]**
Mean of Dep. Var.	2.37	1.91	2.16
Observations	1596	1596	1596
Panel B: Male			
Post × Goiter	–0.0091	–0.051	–0.0084
	(0.047)	(0.038)	(0.031)
	[0.056]	[0.039]	[0.033]
Mean of Dep. Var.	2.38	1.92	2.14
Observations	1641	1641	1641

Notes: Each coefficient is from a separate regression. Educational attainment is an ordered categorical variable ranging from one to four (illiterate, graduated from primary school, middle school and high school). All regressions control for fixed effects specific to birth province and birth year, region-specific linear trends. Standard errors clustered by province appear in parenthesis. Standard errors based on wild-bootstrap approach (Cameron et al., 2008) with 999 replications appear in square brackets. *, **, *** indicates significance at the 10%, 5% and 1% level.

tuses Zimmermann (2011). However, this does not imply that there are no effects for males; see for instance the findings of Feyrer et al. (2017) and Field et al. (2009).

5. More on gender differences

In developing countries, gender differences in socio-economic outcomes are bigger than in developed countries, and cultural gender norms may contribute to these gender differences. Cultural gender norms may be particularly important in East and South-East Asia and might be an important factor underlying heterogeneous gender effects found for girls in the literature on the long-run effects of negative early life shocks in Asia (see for instance Dinkelman (2017) for Asia, Maccini and Yang (2009) for Indonesia and Pathania (2007) for India).

To better understand how early life iodine deficiency may influence individuals' life trajectories and how this may depend on gender norms, we follow the framework proposed by Cunha et al. (2006, 2010). We split the life-cycle into two childhood periods (1 and 2) and adulthood. The production technologies for a child's skills in period 2 can be written as

$$\theta_2 = f(\theta_1, I(\theta_1, e), X, \omega), \tag{3}$$

where θ represents cognitive skills, I is parental investments in cognitive skills, X are parental and child characteristics, and ω are unobserved determinants of skills.[14] Following Almond et al. (2018); Yi et al. (2015), the total effect of a shock early in life (e) on cognition can be decomposed into two parts:

$$\underbrace{\frac{\mathrm{d}\theta_2}{\mathrm{d}e}}_{A} = \underbrace{\frac{\partial\theta_2}{\partial e}}_{B} + \underbrace{\frac{\partial\theta_2}{\partial I}}_{C} \times \underbrace{\frac{\partial I}{\partial e}}_{D}. \tag{4}$$

The term (A) on the left-hand side of (4) is the total effect of an early-life shock and corresponds to the usual reduced form estimates in the empirical literature. In our study, before the salt-iodization policy, (A) would be the effect of iodine deficiency, i.e., the pre-intervention cognitive outcomes in late childhood due to geographical variation in iodine levels. The first term on the right-hand side (B) is the biological effect that directly operates through the production function. The second term ($C \times D$) is a behavioral effect from the parental investment response, where (C) is the productivity effect of the investment (the marginal efficiency of investment) and (D) is the resource allocation effect.

[14] In Cunha et al. (2006) θ is a vector of cognitive and non-cognitive skills. Eq. (3) looks at the child's outcome in the second period, i.e. when the child is older. Cunha et al. (2006) consider the child's outcome as an adult, (θ_3).

We have several reasons to believe that the biological channel (B) can not fully explain our empirical findings. First, if the biological mechanism is important in explaining gender differences in the program effect, then we would also observe gender differences in pre-program goiter rates among school-age children. Sun (2018) shows that goiter rates among children under ten years old do not differ significantly by gender.[15] Second, we find a null effect for males, but there are studies such as Feyrer et al. (2017) that find improvements in IQ for males from a similar iodization policy. Finally, recent work by Adhvaryu et al. (2020) and Molina (2020) finds that gender differences in the long-run impact of early life shocks are primarily driven by market-related channels, rather than pure biological channels. Taken together, this evidence suggests that the childhood environment may shape the long-run impact of an iodization policy.

Another way to explain gender differences in the policy impact is to think about parental investment responses in their children (i.e., the term $C \times D$). Parents' investment strategies are jointly determined by parental preferences, the shape of the production function, and the resource constraints parents face (Almond et al., 2018). The empirical literature that tries to examine the direction of parental investments is recent and the evidence is sparse. Adhvaryu and Nyshadham (2016) estimate the effects of shifts in childhood endowments on health investments in children. They consider a large scale iodine supplementation program in Tanzania and find that children with higher program exposure were more likely to receive necessary investments from their parents. This points at reinforcing parental investments. Using survey data from Ghana, Adhvaryu et al. (2019) study the long-run impact of early life circumstances caused by fluctuations in cocoa prices. They find that parents invest more in children with a high initial endowment (i.e., children born in a period of high cocoa prices).[16] With reinforcing investments, the total reduced form effect A will be larger than the biological effect (B).

Following Adhvaryu and Nyshadham (2016), we could directly examine whether observed parental investment responses are related to initial endowments. The CFPS includes information about parental time investments in young children (younger than 6 years old at the time of the survey in 2010). Unfortunately, this information is not available for the cohorts in our sample who were older at the time of the survey. The findings from the analysis below should therefore be considered supplemental evidence about parental investment responses and how these are related to the child's initial endowment. Like Bharadwaj et al. (2018, 2017), we use the child's birth weight as a proxy for their initial endowment. For parental investment we use an unweighted average of the z-score of 3 variables in the CFPS: how often the parent read to their child; how often the parent buys books for their child; and how often they travel with their child (see C.1 for more detail). All three questions are very close to what has been used in the literature Agostinelli and Wiswall (2016); Cunha et al. (2010). We plot birth weight quartiles against the investment index in Fig. C1 of Appendix C.1. Table C1 of Appendix C.1 shows the results of a regression of the investment index on birth weight, gender, and an interaction between birth weight and gender. Both Fig. C1 and Table C1 show that birth weight is strongly associated with parental investments in children, suggesting that parents make reinforcing investments. Interestingly, the large positive constant for males suggests that on average parents invest more in boys, regardless of the initial endowment. The negative sign of the interaction term shows that the gradient is much smaller and insignificant for boys.[17] Our findings are in line with Yi et al. (2015) who use twin data to look at reinforcing and compensating responses in health and educational investments following a health shock. They find that parents compensate in health investments and reinforce educational investments across their children.

Parents invest in their children and the evidence above suggests that reinforcing investments are relevant. Parents invest more in boys no matter their initial endowment. For girls this is different, parents invest most in girls with high initial endowments. The salt iodization policy neutralizes geographically determined iodine deficiency rates. It reduces the negative cognition effects of iodine deficiency for both genders. This primarily benefits low endowment girls. This suggests that the program effects for girls are driven by girls with low initial endowments.

5.1. Exploiting gender attitude information

We find evidence of gender differences in parental investments and can use this to rationalize gender differences in the effects of the iodization policy. This reasoning is, however, not sufficient to rule out that the biological effect B drives most if not all of the gender differences in the program effects (Table 2), nor have we provided direct evidence that gender preferences play an important role.[18] In this section, we turn to $within-gender$ analyses of program effects, which exploit plausibly exogenous variation in gender preferences. Assuming that for a $given$ gender the biological effect (B) is independent of parental preferences, the total reduced form

[15] At this point it is important to note that Sun (2018) uses Class I goiter information. Class I goiter cannot be see in normal posture and can only be found by palpation.

[16] As Heckman (2007) and Almond et al. (2018) show, this finding can also be rationalized if the child health production exhibits complementarities of investments across different childhood periods.

[17] Specifically, for boys the slope equals 0.266 ($0.95 - 0.684$), s.e. 0.202 for boys.

[18] The biological effect B may vary, for instance, due to differences in the human capital production function or if boys and girls are placed on different segments of the human capital production function. For example, Friedhoff et al. (2000) finds (in rats) that females fetuses are more sensitive to maternal thyroid deficiency than male fetuses. Further, even if production functions are similar across genders, initial endowment levels may have been different for boys and girls. For instance, if boys have higher initial endowments, then with declining marginal productivity the iodization policy will result in smaller policy effects for boys. Within gender analyses (see the remainder of this section) that exploit differences in preferences rule this mechanism out.

effect (A) will not vary with parental preferences if there are no behavioral effects. On the other hand, reduced form estimates that vary with gender preferences hint at preferences driving behavioral responses of parents.

The assumption that gender preferences play no role in the biological effect requires more discussion. With the introduction of ultrasound techniques, parents could respond before birth, either with selective abortion or with increased antenatal investments when the gender of the fetus is revealed (see Bharadwaj and Lakdawala, 2013, for evidence of antenatal investments in India). Upon the child's birth parents may respond after the birth weight and cognition of the child is revealed. We take the position that antenatal investments are included in parental investment decisions. Further, with the availability of ultrasound techniques, parents may resort to sex-selection and parental motives to prefer boys over girls may be related to goiter prevalence rates. This may imply that the marginal girl born in a high goiter area is different from the marginal girl born in a low goiter area, with consequences for the interpretation of our findings. To rule out this potentially confounding difference, we use Census 2000 data to test whether provincial sex-ratios are associated with pre-policy goiter prevalence rates and whether this changes after 1994. These analyses show that there is no association between provincial sex-ratios and provincial iodine deficiency rates. We refer to Fig. C2 and the text in Appendix C.2 for more detail.

Similar to Dahl et al. (2017); Dhar et al. (2018); Dossi et al. (2019) we proxy gender preferences by gender attitudes. The CFPS-2014 wave includes a module with several questions on gender equity attitudes.[19] This module covers topics on gender roles within the household and in public life, and asked respondents whether they agree with six statements phrased against gender equality and women's empowerment. The response categories ranged from 1 "Strongly disagree" to 5 "Strongly agree". We use the attitude information from respondents born between 1951 and 1986 (about the same age of the parents of our target sample.[20] See Table C4 of Appendix C.3 for the statements and average responses for adult males and females. The gender attitude index in the two bottom rows are the mean and normalized mean of the individual responses for the six statements. A lower gender index means more gender-equitable views.

Ideally, we would like to have gender attitudes measured 10 to 20 years before the survey so that they coincide with the period during which parental investments were made. Unfortunately, this information is not available. Gender attitude is measured in 2014 and therefore we have to assume that these gender attitudes are relatively stable over time. Previous work provides evidence to support this assumption. For example, Attané (2012) found that the percentage of women(men) who agree with "Men are turned toward society" (50.4%) and "women devote themselves to their family" (53.7%) only marginally changed between 2000 and 2010. The stable percentages over time reveal the deep-seated internalization of gender roles in some societies. Additionally, Abrevaya (2009); Almond and Edlund (2008) find that son preferences in Asian immigrants to the U.S. persist over time, despite the change in socio-economic environment. Still, it could be the case that the program alters the gender attitudes of the parents, for instance because parents observe that girls benefit from the program. To check this we used the Difference-in-Difference specification 1 to regress parental attitudes on the treatment variable $Post_{it} \times Goiter_p$. The results, reported in Table C3 of Appendix C.3, show that there is no effect of the program on parental gender attitudes.

Assuming that the biological effect does not depend on gender attitudes, we hypothesize that systematic variation of the reduced form estimate (A) with gender attitudes hints at an important role for parental gender preferences in human capital investments in children. To check for this we use the following triple-DiD model that we estimate by gender:

$$Y_{ijpt} = \beta_0 + \beta_1 P_{it} \times G_p \times GA_j + \beta_2 P_{it} \times G_p + \beta_3 P_{it} \times GA_j + \beta_4 GA_j + X_{ipt}\rho + \delta_p + \gamma_t + \epsilon_{ipt}. \tag{5}$$

Y_{ijpt} is the human capital outcome for child i, living in village/community j of province p at time t. $P_{it}(Post_{it})$, $G_p(Goiter_p)$ and X_{ipt} are defined as before. GA_j is the mean of the response to the gender attitude in village/community j that child i resides in.[21] To simplify the interpretation of our results and to reduce the role of measurement error, we construct a dummy variable GA_j indicating whether gender preferences in village j are above the provincial median, i.e. whether village level gender attitudes favor boys. As in the main analyses, we condition on province fixed effects (δ_p). Therefore, our empirical specification absorbs differences in child human capital across provinces and solely relies on within province community/village level variation in gender preferences. By conditioning on birth cohort fixed effects (γ_t), we aim to absorb all variation across age groups.

The main coefficient of interest is β_1. Since we estimate the model separately by gender, this coefficient measures the within gender differential effect of the iodine fortification program across families with varying levels of son preferences. Mapping β_1 to the decomposition (4), it will pick up variation in ($C \times D$), assuming B does not vary within gender.[22]

Table 4 reports the results by gender for cognitive outcomes. We report estimates of β_1 in the first row of panel A (for females) and B (for males). In all specifications, we include controls for province and year of birth fixed effects and region-specific linear trends (Columns 1 and 2). In columns 3 and 4 we also add controls: provincial average educational attainment in Census 1990 interacted with the dummy for treated cohorts (mean-reversion control), hospitals per capita in 1991, hospital beds per capita in 1991, and the sex-ratio in Census 1990, number of schools per capita in 1991, and poverty rates in 1993 all interacted with cohort dummies. There

[19] An alternative proxy could be the sex-ratio (see Edlund et al., 2013, for instance). Selective abortion may be higher in regions where preferences for boys are stronger than in other regions. We therefore also use sex-ratio as a proxy in robustness checks.

[20] This resulted in 20,525 adult respondents, from 528 villages, for whom we have the gender attitude scores.

[21] We rely on a village/community level proxy to avoid endogeneity of a proxy based on the response of the individual's parent. In additional analyses we also used the village level gender attitude variable leaving out the individual response from the parent.

[22] We expect preferences to primarily have a role via D, the parental investment response to the salt-iodization program, but we cannot exclude the possibility that gender preferences also affect the efficiency of investment C.

Table 4
The impact of iodine exposure by gender attitudes (GA).

	(1) Test Scores (PCA)	(2) Schooling (Years)	(3) Test Scores (PCA)	(4) Schooling (Years)
Panel A: Female				
Post × Goiter	0.0032	0.025	0.019	0.022
	(0.099)	(0.092)	(0.11)	(0.11)
	[0.099]	[0.092]	[0.11]	[0.11]
Post × High GA	–0.50	–0.030	–0.39	–0.38
	(0.30)	(0.35)	(0.26)*	(0.49)
	[0.31]	[0.37]	[0.28]	[0.49]
Post × Goiter × High GA	0.39	0.45	0.32	0.49
	(0.21)*	(0.18)**	(0.14)**	(0.16)***
	[0.21]*	[0.18]**	[0.16]*	[0.16]***
Mean of Dep. Var.	0.014	7.66	0.014	7.66
Observations	1596	1596	1596	1596
Panel B: Male				
Post × Goiter	0.012	–0.072	0.10	0.065
	(0.053)	(0.10)	(0.073)	(0.18)
	[0.072]	[0.16]	[0.097]	[0.21]
Post × High GA	–0.22	–0.12	–0.079	0.34
	(0.19)	(0.40)	(0.22)	(0.41)
	[0.19]	[0.40]	[0.23]	[0.54]
Post × Goiter × High GA	-0.021	0.095	-0.0011	-0.028
	(0.12)	(0.24)	(0.17)	(0.22)
	[0.13]	[0.28]	[0.17]	[0.28]
Mean of Dep. Var.	–0.014	7.66	–0.014	7.66
Observations	1641	1641	1641	1641
Additional controls	No	No	Yes	Yes

Notes: All regressions control for fixed effects specific to birth province and birth year, region-specific linear trends. Additional controls include parental education, provincial average educational attainment in Census 1990 interacted with the dummy for treated cohorts (mean-reversion control), hospitals per capita in 1991, hospital beds per capita in 1991, and the sex-ratio in Census 1990, number of schools per capita in 1991, poverty rates in 1993, and communities' pre-policy characteristics all interacted with cohort dummies. The above controls were further interacted with $Post_{it} \times Goiter_p$. Standard errors clustered by province appear in parenthesis. Standard errors based on wild-bootstrap approach (Cameron et al., 2008) with 999 replications appear in square brackets. *, **, *** indicates significance at the 10%, 5% and 1% level.

may be a concern that the interactive effect (β_1) is driven by other factors related to gender attitudes. To mitigate these concerns, we also include interactions of the $Post_{it} \times Goiter_p$ variable interacted with the other (additional) controls.

The estimates of β_1 show large positive and significant effects for females. Girls residing in villages/communities with strong preferences for boys benefit more from the universal salt iodization program than otherwise similar girls in communities/villages with weaker preferences for boys. The effects for boys are much smaller, sometimes have the opposite sign, and are never significant at standard levels. The third row presents estimates of β_2 and reflects the general effect of the iodization policy. We find sizable general policy effects on girls for schooling.

The supplemental analyses in the previous subsection suggest that parents invest in boys, no matter their initial endowment. For girls this is different, investments in girls are primarily aimed at girls with a high initial endowment. Can we square this finding with the gender attitude results above? In Appendix C.3 we relate the parental investment index to gender attitudes. The results are reported in Table C2 and show that investments in girls are lower, notably in areas with attitudes favoring boys. Table 4 shows that the iodization policy is most effective for girls growing up in areas where attitudes towards boys are strong. This does not only imply that parental preferences play an important role in the effectiveness of the salt iodization program on cognitive outcomes, but it also shows that national policies can have positive and unintended effects on gender equality in societies where gender preferences are important.

5.2. Robustness analyses

In this section, we explore some additional specifications. One concern with our triple-DiD strategy is the potential endogeneity of the gender attitude variable, i.e., gender norms may not be randomly allocated across communities. To address this concern, we first estimate the model with additional controls on communities' characteristics interacted with cohort dummies. For this analysis

Table 5
The impact of iodine exposure by sex ratio (SR).

	(1) Test Scores (PCA)	(2) Schooling (Years)	(3) Educational Attainment
Panel A: Female			
Post × Goiter	0.047	0.15	-.0026
	(0.076)	(0.080)*	(0.032)
	[0.081]	[0.11]	[0.022]
Post × High SR	–0.47	0.031	–0.11
	(0.22)**	(0.41)	(0.045)**
	[0.23]**	[0.53]	[0.052]**
Post × Goiter × High SR	0.29	0.32	0.22
	(0.080)***	(0.13)**	(0.093)**
	[0.081]***	[0.13]**	[0.11]**
Mean of Dep. Var.	0.014	7.66	2.06
Observations	1596	1596	60,746
Panel B: Male			
Post × Goiter	0.033	0.11	–0.014
	(0.10)	(0.15)	(0.032)
	[0.11]	[0.12]	[0.12]
Post × High SR	–0.29	0.50	–0.062
	(0.27)	(0.45)	(0.046)
	[0.26]	[0.41]	[0.052]
Post × Goiter × High SR	0.11	-0.15	0.068
	(0.12)	(0.19)	(0.038)
	[0.12]	[0.25]	[0.042]
Mean of Dep. Var.	–0.014	7.66	2.04
Observations	1641	1641	68,329
Data	CFPS-2010		Census-2010

Notes: All regressions control for fixed effects specific to birth province and birth year, region-specific linear trends. The census 2010 does not have information on years of schooling. We therefore report results for educational attainment in column 3. Standard errors clustered by province appear in parenthesis. Standard errors based on wild-bootstrap approach (Cameron et al., 2008) with 999 replications appear in square brackets. *, **, *** indicates significance at the 10%, 5% and 1% level.

we construct 15 pre-policy characteristics from the village module of the CFPS-2010.[23] Estimates controlling for communities' characteristics by cohort do not alter our results (see Columns 3 and 4 of Table 4). Additionally, we construct the pre-policy sex-ratio as an alternative proxy for gender preference.[24] We use the Census 1990 to calculate male-to-female sex-ratios for children under 4 years old. Unfortunately, we do not have sex-ratio information at the village level and therefore calculate it at the unit of the county (the next level of spatial aggregation).[25] Similar to the gender attitude variable, we construct a dummy variable indicating whether the sex-ratio for a counties is above the provincial median. We report results from triple-DiD regressions using the sex-ratio indicator in Table 5. The estimates based on the CFPS sample (columns 1 and 2) show again significant effects for girls and insignificant effects for boys. The sample is quite small and therefore we also used Census 2010 data to improve statistical inference and confirm whether the null effect for males is really a null effect or an artifact of the small sample sizes in the CFPS. The results of this exercise are reported in column 3 and confirm the results based on the CFPS sample.

Another concern for our triple-difference results in Table 4 is that gender selection could also drive these results. With boy biased gender preferences, parents could selectively abort female fetuses and this selective abortion could vary with gender preferences at the village/community level. In this case, the marginal girl born in a village/community with strong boy preferences may differ from the marginal girl in a gender-neutral village. We link the sex ratio data at the county level to county level gender attitudes to address this potential endogenous sex selection. We relate county level sex-ratios to gender attitudes by year, controlling for province fixed effects. The results of this event study are depicted in Fig. C3 of Appendix C.3. The figure shows that there is no association between gender attitudes and sex-ratios. This finding suggests that sex selection is not a likely driver of our findings in Table 4.

[23] The information in the village module was collected from a knowledgeable individual who has access to statistical materials in the village, such as the director or the accountant of the community committee.

[24] We prefer gender attitudes over sex-ratio as the main proxy for gender preferences because sex-ratio is not a measure of son preference *per se*, but rather the realization of the family's son preference combined with the preferences over the family size (Jayachandran, 2015).

[25] In our data there are 128 counties, each consisting of on average four communities/villages.

6. Conclusion

The medical literature has documented that iodine deficiency in pregnant mothers can lead to neuro-developmental problems for their offspring. This can reduce children's cognitive skills and, consequently, lead to adverse labor market outcomes later in life. Globally about 2 billion people suffer from iodine deficiency. To address iodine deficiency, some countries have implemented salt iodization programs or are planning to do so. This paper evaluates the effect of a nationally implemented salt iodization program on the cognition of school-aged children in China. It differs from previous work since we explicitly focus on the role of gender preferences. Parental preferences play an important role in parental investment decisions and may therefore also affect program outcomes. Gender preferences may also explain gender differences in the empirical literature on the long-run effects of adverse conditions early in life. In our difference-in-differences analyses we find that the iodization program had strong positive effects for girls. The iodization program increases (standardized) test scores by about 0.2 of a standard deviation. The iodization program increases years of schooling for females by about 0.4 years. We infer that this increase translates into income increases of about 6%. However, we do not find any effects for boys. These findings are robust against alternative specifications and falsification tests.

Our findings thus support the effectiveness of low cost public health interventions. Compared to other interventions to increase education, the cost of salt iodization is extremely low. The costs associated with the intervention are about 0.05$ per person per year (WHO, 2005). This contrasts sharply with other interventions, such as class size reductions, costing over $5,000 (2010 dollars) per student per year (Chetty et al., 2011).

Gender norms play an important role in China. Cultural or other contextual factors that favor boys also hold for other countries in South-East Asia, the Middle East, and North Africa, and may also play a role in the western world. Gender preferences may lead parents to have different investment responses for boys and girls. Following Adhvaryu et al. (2019), we first examine whether parental time investment is related to the child's initial endowment (measured by birth weight). These analyses show that parents make reinforcing investments, i.e. that they invest more in children with a better initial endowment. We find this to differ by gender: Parents invest in more in boys and this is independent of the initial endowment. This differs for girls, parents primarily invest in girls with a high initial endowment. The differential investment may explain the findings from our Differences-in-Differences (DiD) analyses. The salt iodization program neutralizes geographically determined iodine deficiency rates and therefore reduces the adverse effects of iodine deficiency for both genders. This primarily benefits girls with a low initial endowment. This suggest that the program effect is largely driven by girls with a low initial endowment.

To make sure that our findings are not driven by inherent biological differences between males and females, we turn to within gender comparisons. We use survey information about community/village level gender attitudes of parents to proxy gender preferences, and then use this measure in separate triple DiD models for males and females. Girls' program effects on cognition are stronger in communities/villages where preferences favoring boys are stronger. We do not find program effects for boys. Our findings suggest that large-scale programs may reduce gender inequalities and contribute to gender convergence in countries where gender preferences are important.

Preferences favoring boys may lead to unequal investments in girls and justify policies that aim to reduce the consequences of such preferences. Also, improved economic circumstances may reduce gender preferences, but earlier work has shown that gender biases persist even with improved economic circumstances (Abrevaya, 2009; Almond and Edlund, 2008). These persistent gender preferences highlight the role for policies such as increasing mandatory schooling for both genders and other public programs that affect all, such as the public health campaign in this paper.

Supplementary materials

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.jhealeco.2022.102614.

CRediT authorship contribution statement

Zichen Deng: Conceptualization, Formal analysis, Methodology, Validation, Visualization, Writing – original draft, Writing – review & editing. **Maarten Lindeboom:** Conceptualization, Formal analysis, Methodology, Validation, Writing – original draft, Writing – review & editing.

References

Abrevaya, J., 2009. Are there missing girls in the united states? evidence from birth data. American Economic Journal: Applied Economics 1 (2), 1–34.

Adhvaryu, A., Bednar, S., Molina, T., Nguyen, Q., Nyshadham, A., 2020. When it rains it pours: the long-run economic impacts of salt iodization in the united states. Rev Econ Stat 102 (2), 395–407. doi:10.1162/rest_a_00822.

Adhvaryu, A., Fenske, J., Nyshadham, A., 2019. Early life circumstance and adult mental health. Journal of Political Economy 127 (4), 1516–1549. doi:10.1086/701606.

Adhvaryu, A., Nyshadham, A., 2016. Endowments at birth and parents' investments in children. The Economic Journal 126 (593), 781–820.

Agostinelli, F., Wiswall, M., 2016. Estimating the technology of children's skill formation. Working Paper.

Almond, D., 2006. Is the 1918 influenza pandemic over? long-term effects of in utero influenza exposure in the post-1940 u.s. population. Journal of Political Economy 114 (4), 672–712.

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

Almond, D., Currie, J., Duque, V., 2018. Childhood circumstances and adult outcomes: act II. J Econ Lit 56 (4), 1360–1446.

Almond, D., Edlund, L., 2008. Son-biased sex ratios in the 2000 united states census. Proceedings of the National Academy of Sciences 105 (15), 5681–5682.

Almond, D., Mazumder, B., van Ewijk, R., 2015. In utero ramadan exposure and children's academic performance. Economic Journal 125 (589), 1501–1533. doi:10.1111/ecoj.12168.
Araujo, D., Carrillo, B., Sampaio, B., 2021. The long-run economic consequences of iodine supplementation. J Health Econ 79.
Attané, I., 2012. Being a woman in china today: a demography of gender. China perspectives 2012 (2012/4), 5–15.
Barcellos, S.H., Carvalho, L.S., Lleras-Muney, A., 2014. Child gender and parental investments in india: are boys and girls treated differently? American Economic Journal: Applied Economics 6 (1), 157–189.
Baumann, E., 1896. Ueber das normale Vorkommen von Jod im Thierkörper.(I. Mittheilung). Hoppe-Seyler's Zeitschrift für physiologische Chemie 21 (4), 319–330.
Bautista, A., Barker, P.A., Dunn, J.T., Sanchez, M., Kaiser, D.L., 1982. The effects of oral iodized oil on intelligence, thyroid status, and somatic growth in school-age children from an area of endemic goiter. Am. J. Clin. Nutr. 35 (1), 127–134.
Van den Berg, G.J., Lindeboom, M., Portrait, F., 2006. Economic conditions early in life and individual mortality. American Economic Review 96 (1), 290–302.
Bharadwaj, P., Eberhard, J.P., Neilson, C.A., 2018. Health at birth, parental investments, and academic outcomes. J Labor Econ 36 (2), 349–394. doi:10.1086/695616.
Bharadwaj, P., Lakdawala, L.K., 2013. Discrimination begins in the womb: evidence of sex-selective prenatal investments. Journal of Human Resources 48 (1), 71–113.
Bharadwaj, P., Lundborg, P., Rooth, D.-O., 2017. Birth weight in the long run. Journal of Human Resources 0715–7235.
Bleakley, H., 2010. Malaria eradication in the americas: a retrospective analysis of childhood exposure. American Economic Journal: Applied Economics 2 (2), 1–45.
Bleichrodt, N., Born, M.P., 1996. A metaanalysis of research on iodine and its relationship to cognitive development. Cognizant Communication Corporation.
Brown, D., Kowalski, A., Lurie, I., 2018. Long-term impacts of childhood medicaid expansions on outcomes in adulthood. Working Paper.
Cameron, A.C., Gelbach, J.B., Miller, D.L., 2008. Bootstrap-based improvements for inference with clustered errors. Rev Econ Stat 90 (3), 414–427.
Cao, X.-Y., Jiang, X.-M., Dou, Z.-H., Rakeman, M.A., Zhang, M.-L., O'donnell, K., Ma, T., Amette, K., DeLong, N., DeLong, G.R., 1994. Timing of vulnerability of the brain to iodine deficiency in endemic cretinism. N top N. Engl. J. Med. 331 (26), 1739–1744.
Chen, J., Wu, H., 1998. Fortification of salt with iodine. Food Nutr Bull 19.
Chetty, R., Friedman, J.N., Hilger, N., Saez, E., Schanzenbach, D.W., Yagan, D., 2011. How does your kindergarten classroom affect your earnings? evidence from project STAR. Q J Econ 126 (4), 1593–1660.
Cunha, F., Heckman, J.J., Lochner, L., Masterov, D.V., 2006. Interpreting the evidence on life cycle skill formation. Handbook of the Economics of Education 1, 697–812.
Cunha, F., Heckman, J.J., Schennach, S.M., 2010. Estimating the technology of cognitive and noncognitive skill formation. Econometrica 78 (3), 883–931.
Dahl, G.B., Kotsadam, A., Rooth, D.-O., 2017. Does integration change gender attitudes? Working Paper.
Dhar, D., Jain, T., Jayachandran, S., 2018. Reshaping adolescents' gender attitudes: evidence from a school-based experiment in india. Working Paper.
Dinkelman, T., 2017. Longrun health repercussions of drought shocks: evidence from south african homelands. The Economic Journal 127 (604), 1906–1939. doi:10.1111/ecoj.12361.
Dossi, G., Figlio, D.N., Giuliano, P., Sapienza, P., 2019. Born in the family: preferences for boys and the gender gap in math. Working Paper doi:10.3386/w25535.
Edlund, L., Li, H., Yi, J., Zhang, J., 2013. Sex ratios and crime: evidence from china. Review of Economics and Statistics 95 (5), 1520–1534.
Feyrer, J., Politi, D., Weil, D.N., 2017. The cognitive effects of micronutrient deficiency: evidence from salt iodization in the united states. J Eur Econ Assoc 15 (2), 355–387.
Field, E., Robles, O., Torero, M., 2009. Iodine deficiency and schooling attainment in tanzania. American Economic Journal: Applied Economics 1 (4), 140–169.
Figlio, D., Guryan, J., Karbownik, K., Roth, J., 2014. The effects of poor neonatal health on children's cognitive development. American Economic Review 104 (12), 3921–3955.
Friedhoff, A.J., Miller, J.C., Armour, M., Schweitzer, J.W., Mohan, S., 2000. Role of maternal biochemistry in fetal brain development: effect of maternal thyroidectomy on behaviour and biogenic amine metabolism in rat progeny. Int. J. Neuropsychopharmacol. 3 (2), 89–97.
Heckman, J.J., 2007. The economics, technology, and neuroscience of human capability formation. Proceedings of the National Academy of Sciences 104 (33), 13250–13255.
Hoynes, H., Schanzenbach, D.W., Almond, D., 2016. Long-run impacts of childhood access to the safety net. American Economic Review 106 (4), 903–934. doi:10.1257/aer.20130375.
Jayachandran, S., 2015. The roots of gender inequality in developing countries. Annu Rev Econom 7 (1), 63–88.
Jayachandran, S., Kuziemko, I., 2011. Why do mothers breastfeed girls less than boys? evidence and implications for child health in india. Q J Econ 126 (3), 1485–1538.
Jooste, P.L., Weight, M.J., Lombard, C.J., 2000. Short-term effectiveness of mandatory iodization of table salt, at an elevated iodine concentration, on the iodine and goiter status of schoolchildren with endemic goiter. Am. J. Clin. Nutr. 71 (1), 75–80.
Lumey, L.H., Stein, A.D., Susser, E., 2011. Prenatal famine and adult health. Annu Rev Public Health 32 (1), 237–262. doi:10.1146/annurev-publhealth-031210-101230.
Maccini, S., Yang, D., 2009. Under the weather: health, schooling, and economic consequences of early-life rainfall. American Economic Review 99 (3), 1006–1026. doi:10.1257/aer.99.3.1006.
Molina, T., 2020. Pollution, ability, and gender-specific investment responses to shocks. J Eur Econ Assoc.
Niemesh, G.T., 2015. Ironing out deficiencies: evidence from the United States on the economic effects of iron deficiency. Journal of Human Resources 50 (4), 910–958.
Oster, E., 2009. Does increased access increase equality? gender and child health investments in india. J Dev Econ 89 (1), 62–76.
Pardede, L.V.H., Hardjowasito, W., Gross, R., Dillon, D.H.S., Totoprajogo, O.S., Yosoprawoto, M., Waskito, L., Untoro, J., 1998. Urinary iodine excretion is the most appropriate outcome indicator for iodine deficiency at field conditions at district level. J. Nutr. 128 (7), 1122–1126.
Pathania, V., 2007. The long run impact of drought at birth on height of women in rural india. Working Paper.
Shah, M., Steinberg, B.M., 2017. Drought of opportunities: contemporaneous and long-term impacts of rainfall shocks on human capital. Journal of Political Economy 125 (2), 527–561. doi:10.1086/690828.
Simoons, F.J., 1990. Food in China: A Cultural and Historical Inquiry. CRC Press.
Sun, D., 2018. Endemic disease in china. Springer.
Wang, L., 2013. Estimating returns to education when the IV sample is selective. Labour Econ 21, 74–85. doi:10.1016/j.labeco.2012.12.007.
Woo, W.T., Li, S., Yue, X., Wu, H.X., Xu, X., 2004. The poverty challenge for china in the new millennium. The Millennium Development Goals Project of the United Nations.
Yi, J., Heckman, J.J., Zhang, J., Conti, G., 2015. Early health shocks, intra-household resource allocation and child outcomes. The Economic Journal 125 (588), F347–F371.
Zhang, J., 2017. The evolution of China's one-child policy and its effects on family outcomes. Journal of Economic Perspectives 31 (1), 141–160. doi:10.1257/jep.31.1.141.
Zimmermann, M.B., 2008. Research on iodine deficiency and goiter in the 19th and early 20th centuries. J. Nutr. 138 (11), 2060–2063.
Zimmermann, M.B., 2011. The role of iodine in human growth and development. In: Seminars in Cell & Developmental Biology, Vol. 22. Elsevier, pp. 645–652.
Zimmermann, M.B., Hess, S.Y., Adou, P., Toresanni, T., Wegmüller, R., Hurrell, R.F., 2003. Thyroid size and goiter prevalence after introduction of iodized salt: a 5-y prospective study in schoolchildren in côte d'ivoire. Am. J. Clin. Nutr. 77 (3), 663–667.