Iodine deficiency and schooling attainment in Tanzania[†]

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1 Introduction

An estimated one billion people globally are at risk of iodine deficiency disorder (IDD) due to insufficient consumption of foods rich in iodine, the only micronutrient deficiency known to have significant, non-reversible effects on cognitive development.[1] Based on studies indicating that IDD frequently results in irreversible brain damage in the fetus (Cao et al., 1994; Hetzel and Mano, 1989; Pharoah and Connolly, 1987), the World Health Organization has labeled IDD "the most common cause of preventable mental retardation (WHO, 1992)." If true, the resulting loss in cognitive capacity could have important consequences for aggregate human capital accumulation in afflicted settings, leading to a lower fraction of children enrolling in or attending school, slower rates of grade attainment for age, and fewer students progressing to institutions of higher education. Yet despite increased attention in the development literature to the consequences of micronutrient deficiencies on health and productivity, there has to date been no assessment of the influence of iodine deficiency on schooling.

This research evaluates the impact of reductions in fetal IDD on child schooling attainment in Tanzania that resulted from an intensive distribution of iodized oil capsules (IOC) in several districts of the country between 1986 and 1994. Since iodine is thought to matter most before a child is born, we look for evidence of improvements in cognitive ability attributable to the intervention by assessing whether children who benefited from iodine supplements in utero exhibit higher rates of grade progression at ages 10 to 13. Of particular interest is the possible role of iodine deficiency in explaining gender differences in schooling outcomes, in light of scientific evidence of biological differences between males and females in iodine sensitivity in utero.

The question has potentially important implications for understanding cross-country differences in human capital investment, rates of return to schooling and labor productivity. In this sense, our analysis contributes to the growing literature on the effects of malnutrition and low-level health problems on growth and development. Unlike short-term variation in nutrition or health, fetal IDD is believed to limit the intellectual ability of an individual for life, so the impact on schooling is likely to be particularly acute. Understanding the role of physiological determinants of schooling informs a fundamental debate in the literature on barriers to schooling attainment in developing countries surrounding the importance of supply-driven explanations for low levels of human capital investment versus differences across settings in returns to education. It is also possible that equilibrium schooling levels to some degree reflect biological differences in the ability to progress through school, which could vary widely across settings if micronutrient deficiencies are an important determinant of cognitive capacity.

Furthermore, if girls are particularly susceptible to IDD in utero, gender differentials in schooling attainment might in part be explained by physiologically-driven sex differences in rates of learning disability that result from widespread fetal IDD. This is a particularly compelling explanation for gender differences in schooling patterns in Tanzania, where lower female attainment is almost entirely accounted for by the abysmal rate at which girls achieve passing grades on the national secondary school qualifying exam. Alarmingly, although in 2001 roughly the same numbers of boys and girls completed primary school and sat for the national exam required for entrance to secondary school, boys were 69% more likely to pass the test.

Although many countries undertook intensive iodine supplementation programs during the 1990s, there are two important advantages to studying the case of Tanzania. First, Tanzania was one of the largest and most intensive iodine supplementation programs, ultimately reaching approximately 25% of the population for an average of 4.2 years. As a result, approximately 1.9 million babies born during and immediately after the program were fully protected from fetal IDD.[2] The breadth of the program and well-defined target population enable follow-up studies of these cohorts based solely on year and district of birth. Second, Tanzania was one of the earliest countries to distribute iodine supplements. Hence, evaluation of this program's initial effect on children born during the intervention provides a first glimpse of the long-run patterns that can be expected to emerge over the coming decade in a number of other countries.

The long-run effect of fetal iodine intake is of particular interest in light of recent worldwide progress in reducing IDD through universal salt iodization (USI) legislation passed in much of the world during the 1990s. Between 1980 and 2000, at least 28 countries – half of them on the African continent – reduced TGR by more than 20% through national salt iodization, and several others that lack data are believed to have made similarly important gains. Because children born after these changes are only now reaching school age in the most affected regions, there has been little opportunity to evaluate the impact of these reforms on health and well-being or to determine whether resulting reductions in IDD will alter the global pattern of schooling attainment in the near future.

A related policy issue is determining the value of devoting further resources necessary to fully eradicate IDD. Although USI is arguably the most successful micronutrient intervention in world history, legal regulations on salt production are rarely sufficient to guarantee dietary change among the neediest rural populations who consume mainly subsistence food products. In

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[1] Epidemiological criteria for assessing sufficient iodine intake is 100 μ/I or above.

[2] Estimation is based on 1988-1994 population and (crude) birth rate data from the World Bank's World Development Indicators.

some West African countries less than 30% of households presently consume iodized salt despite universal legislation (UNICEF, 2005). Furthermore, iodized salt may be insufficient to reduce IDD in populations whose diets contain sufficient amounts of iodine-depleting foods. To eliminate deficiencies among remote and severely affected populations, more costly interventions such as ongoing IOC would be required.

Our findings suggest that reducing fetal IDD has significant benefits for children's cognitive capacity as evidenced by its effect on schooling attainment: Children who receive iodine in utero receive an average of 0.36 years of education above siblings and older and younger children in their district. Furthermore, the effects appear to be larger for girls, indicating a potentially important role of micronutrient deficiencies in gender differences in schooling attainment. The results are robust to a number of alternative empirical specifications, including household and district fixed effects models and observed variation in estimated effects is consistent with predictions regarding relative vulnerability of specific subpopulations to IDD.

2 Background

2.1 Nutrition and productivity

Lack of proper nutrition limits the body's ability to properly develop, protect and work at its capacity. As a result, malnutrition at all stages has been linked to several physical and cognitive impediments throughout a person's life, which has important implications for productivity and growth in impoverished nations. The report of the Commission for Macroeconomics and Health estimated the return on health investment to be in the magnitude of 500% based on cross-country regressions (CMH, 2001). Although impairments may develop at various points in life, those that arise in utero and early childhood are widely believed to be the most damaging (Barker et al., 1989).

The relationship between macro-nutrients (energy and protein intake) and education has been examined through various food ration and subsidized school meal programs. For instance, subsidized school meals in Western Kenya and child nutritional supplements in Guatemala were associated with increased school participation and test scores (Vermeersch, 2003; Behrman et al, 2003). While little attention has been paid to the influence of specific *micro*nutrients on schooling, a number of studies have examined the benefits of micronutrient supplements on health and labor productivity. Research suggests that anemia resulting from iron deficiency, which reduces the body's ability to exert energy, in turn reduces work capacity and in some cases work output. A number of studies in Indonesia found that iron supplementation increased labor force participation, earnings, and work productivity of males and females (Thomas et al, 2003; Basta et al, 1979; Husain et al, 1981). Vitamin A is thought to improve the body's defense against infection, and its deficiency has been found in many studies to be associated with increased mortality and morbidity from respiratory and gastrointestinal disease and blindness (Sommer et al., 1986; Sommer et al., 1981; West et al., 1995; Glasizou et al, 1993; Beaton et al, 1992).

2.2 Effects of Iodine Deficiency in Utero

Iodine is needed for the biosynthesis of thyroid hormones, which are essential for physical and mental development. Development of the central nervous system for normal intellectual functioning depends on an adequate supply of thyroid hormones without which the developing brain does not establish as dense a network of interconnections among the brain cells (Lamberg, 1991).[3] Endemic cretinism is the most severe manifestation of the lack of maternal and fetal thyroid hormone arising from severe dietary iodine deficiency. IDD has also been associated with physical impairments other than fetal brain damage such as congenital anomalies, increased perinatal mortality and deaf mutism in the fetus as well as retarded physical development in childhood and adolescence, however the limited evidence suggests that non-cognitive outcomes occur only under extreme deprivation (WHO; Zimmerman, 2005). Furthermore, studies indicate the brain is particularly sensitive to iodine deficiency during its formation in early fetal life, prior to mid-gestation, whereas physical growth and psychomotor development are believed to be most severely affected in childhood (Cao et al., 1994a).

Although endemic goiter and cretinism associated with iodine deficiency have been depicted for centuries, only during the past decade has IDD been recognized as a leading cause of intellectual impairment worldwide (Merke, 1984; Delange, 2000; Haddow, 1999). Though cretinism is relatively rare, severely affected populations may have rates as high as 3 to 15 percent, imposing a major social and economic burden on the community (Boyages et al., 1988; Halpern et al., 1991; Pandav et al., 1982). More importantly, the effect of IDD on mental development is no longer believed to lead directly to severe mental retardation. Recent evidence from laboratory studies in rats indicates a continuous process by which brain development is sensitive to minor adjustments in thyroid hormone (Sundqvist et al, 1998; Dugbarty, 1998; Pop et al, 1999). Based on this evidence, even mild maternal iodine deficiency is now hypothesized to reduce intelligence quotients by a noticeable margin.

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[3] The recommended daily iodine intake begins at 50 mg for infants under 12 months of age and rises to a level of 150 mg for adults and 200 mg for pregnant and lactating women (WHO, 1996).

While there have been no experimental or large-scale observational studies of the cognitive effects of moderate IDD in humans, there is suggestive evidence from community-based assessments of iodine intervention trials that supplementation can improve performance on cognitive tests (Bleichrodt et al., 1994). One oft-cited study of a community-based intervention in Ecuador found that iodine prophylaxis given before or during pregnancy resulted in improved cognitive functioning in 50 offspring examined two to three years later. The difference corresponded to a 10-15 point improvement in IQ relative to children not included in the study (Shrethsa, 1994). To our knowledge, the long-term impact of increased iodine intake during pregnancy on children's human capital has not been measured in any setting.

2.3 Gender Differences in Iodine Deficiency

Evidence from multiple sources indicates gender differences in the importance of iodine supplementation. In the community-based study mentioned above, cognitive improvements were only found among girls in the study, although the finding is merely suggestive given the limited number of study participants. Similarly, a number of practitioners have noted that IDD is systematically higher among female relative to male adolescents (Allen et al, 2001). A relatively consistent global pattern is that females are more likely to develop goiter than men and goitrous females are more likely to suffer from severe goiter when compared to goitrous men (Simon, 1990). One central limitation of observational studies is their inability to distinguish between gender differences arising from sex-specific dietary patterns and physiological differences between males and females in sensitivity to iodine.

However, more conclusive evidence of biologically-driven gender differences in iodine sensitivity comes from a recent laboratory experiment of maternal thyroid deficiency in rats, which found that the effect of artificially restricting maternal thyroid hormone transferred in utero on fetal neurodevelopment and behavioral outcomes was significantly larger in female progeny (Friedhoff et al, 2000). Despite the fact that thyroid conditions of all types are consistently higher among women than among men, the same study notes that, "Few [laboratory] studies have addressed the role of biochemicals of maternal origin on sex differences in fetal neurodevelopment and behavioural outcomes." Although the biological pathway is not fully understood, the finding is possibly related to differences between males and females in the onset of fetal thyroid production, and resulting gender differences in dependency on maternal thyroid transfers.

3 Setting

3.1 Iodine deficiency in Tanzania

Our study examines the long-run impact of an intensive iodized oil supplementation program that took place in Tanzania between 1986 and 1994. Tanzania, like many countries on the African continent, traditionally suffered high rates of IDD. According to a nationwide survey of iodine levels in the early 1970s, about 40% of the Tanzanian population, or 10 million people, lived in iodine-deficient areas and 25% of the population was estimated to have iodine deficiency disorders, including 3% with severe IDD and 22% with moderate symptoms. In severely affected regions, 13% of children under five and 52% of pregnant and lactating women showed manifestations of iodine deficiency prior to the intervention (van der Haar et al, 1998).

3.2 Schooling in Tanzania

The Tanzanian formal education system involves seven years of primary education, four years of junior secondary (Ordinary level), and two years of senior secondary (Advanced Level). In 2001, gross enrollment in primary school was 85% but only 7% at the secondary school level, largely due to an insufficient supply of secondary schools. According to data from 2001, one quarter of rural households reported being over 20 kilometers from a secondary school (THBS, 2001). Meanwhile, distance to primary schools is an issue only for a minority of rural households, 8 percent of which reported the nearest primary school to be more than 6 kilometers away. Admission to the existing secondary schools is screened by performance on the mandatory Primary School Leaving Exam (PSLE), which students take one or two years after grade 6.

Although gender parity in primary enrollment was more or less achieved by 1998, female students represented only 36% of the secondary level student population in 2000. In the standard primary age group of 7 to 13, boys have a slightly lower participation rate than girls because they start school slightly later, while the reverse is true for older children. Girls are less likely to be in school than boys after age thirteen, and the difference increases steadily thereafter. Gender differences in secondary enrollment are almost entirely accounted for by differences in PSLE pass rates for boys and girls, who are equally likely to take the test. As there is substantial cost and no benefit other than high school admission to taking the test, this fact alone suggests that traditional social roles and explicit parental preferences for male over female secondary schooling are not solely responsible for gender differences in education outcomes.

3.3 Iodized Oil Capsule (IOC) Distribution in Tanzania

Unlike many afflicted countries, Tanzania was targeted for iodine supplementation relatively early. In 1986, a massive supplementation intervention was scheduled to begin in 27 of the most affected districts of the country as a short-term measure to address the problem while nationwide salt production was slowly phased in. The objective of the program was to cover all iodine deficient sub-populations for ten years with iodized oil capsules (IOC). Iodized oil, taken either orally or through injection, is considered one of the most effective interventions for combating IDD in areas with high rates of TGR and low coverage of iodized salt on account of the immediacy of health improvements and duration of coverage (Delange, 1998). In selected districts, all women of child-bearing age were targeted to receive 200mg and 380mg capsules once every two years, the expected duration of protection.[4] From 1986–1994, approximately five million women and children received at least one dose of iodine through the primary health care system. The IOC program was slowly phased out as iodized salt gradually became available in the late 1990s.

Districts were chosen based on 1984 field measurements of TGR, or the number of children with visible goiters. The minimum TGR for participation in the IOC program was 10%, which resulted in 25 treatment districts encompassing 25% of the country's population (Peterson, 2000). As shown on the map in Figure 1, intervention districts were spread across ten regions of the country, but concentrated geographically in the lake district of the western border. Due to high iodine levels found in fish, coastal soil is rich in iodine so rates of IDD tend to increase with distance to coast and altitude. Furthermore, Pre-Cambrian bedrock, which covers a large ring of central African including western Tanzania, is associated with particularly low concentrations of iodine in soil and ground water.

Program roll-out and coverage rates across districts, collected from the archives of the Tanzania Health and Nutrition Office annual reports of program activity, are detailed in Table 1. Although all districts were scheduled to begin IOC by 1988, in practice there were significant delays in implementing the program. Only ten of the districts had begun by 1988, and three did not start until 1992. Furthermore, penetration rates were lower than planned, ranging from 60 to 90 percent of the target population with average coverage across all districts and all years of 64%.[5] Coverage declined inversely to distribution round, in part due to rumors that IOC was a "family planning" aide which reduced motivation for participation (Magombo, 1990). Finally,

[4] The target groups for supplementation were, in order of importance: 1) women of childbearing age; 2) children 1-5 years; 3) older children; and 4) adult men 15-45 years of age (Peterson, 2000). In people older than 45, iodized oil was not encouraged due to increased risks of hyperthyroidism (Dunn 1987b).

districts were reached less frequently than once every two years due to administrative problems and caution over administering more than one dose within two years. It is estimated that 42% of the uncovered target population was not reached due to less than total coverage and 58% due to delayed repeat distribution beyond the planned two year interval (Peterson, 2000).

Although the long-term impacts of the program have not been evaluated, the program was deemed a success on account of the overall cost-effectiveness of the intervention (the average cost per dose was between 51-56 cents) and a handful of initial studies indicating that visible and total goiter (VGR, TGR) decreased among individuals who received supplements (Peterson, 2000; Kavishe, 2000). A 1991 evaluation in three of the intervention districts found that VGR had decreased by over 50% and TGR by over 25% (Peterson, 2000). In surveys of school children aged 7-18 in the district of Mahenge, TGR was 74.9% before IOC and 51.9% three years afterwards. Based on the importance of adequate thyroid hormone during brain development and higher recommended daily intake of iodine during pregnancy, the program impact on children of women who were protected from IDD during pregnancy is likely to be even higher.

3 Empirical Strategy

3.1 Data

We examine the program effect on children born to mothers who were targeted for IOC during pregnancy using data from the 2000 Tanzanian Household Budget Survey (THBS), a nationally representative survey of 22,178 households conducted by the National Statistics Office. The THBS is the largest household budget survey in Tanzania and one of the largest in Africa. In addition to detailed household information on community and family background, the data contain information on child school enrollment, grade attainment, and childhood health status. To these data, we append the district-level information from Table 1 on timing of IOC distribution across intervention districts. Among THBS households, 25.2% live in districts targeted for IOC.

Table 2 presents summary statistics from THBS sub-samples divided according to the timing of the IOC start date in participating districts. Comparisons across intervention and non-intervention districts show clearly that the program favored needier areas, as was its intention. Relative to non-participating districts, IOC districts are more rural, have fewer households with private sources of drinking water and solid floors, and have lower consumption of fish, a rich source of iodine. The average distance between a household and the nearest secondary school is

[5] The average coverage rate among districts and years included in our analysis sample was 68%.

also higher in IOC districts. Such differences make comparisons between participating and non-participating districts difficult.

With respect to comparisons among participating districts according to program timing, the patterns are less clear. School enrollment for both boys and girls between the ages of 5 and 15 in IOC districts falls monotonically with start date of the program, as does the fraction of households with safe drinking water. Similarly, the occurrence of illness due to fever or malaria and the average distance between a household and the nearest school are significantly higher for districts in which the program started late. However the average annual consumption of durable goods is significantly higher in late districts. Similarly, while the fraction of households who report having "often" suffered from hunger in the last year is higher, the average number of meals consumed per-day as well as the average number of fish consumed per-week in the previous month are relatively constant across program start dates. Nonetheless, the general patterns suggest that the first districts targeted for intervention were better off than late districts, consistent with the most common source of delay being poorly organized distribution networks. This pattern could substantially bias program effect estimates based on cross-district comparisons even restricting the analysis to participating districts.

For the empirical analysis, we restrict our sample to all children or grandchildren of the household head between the ages of 10-13 living in the 25 intervention districts that start IOC prior to 1992. The lower bound on age was chosen based on regional patterns in the age at which children start school. According to data from intervention districts as well as rural districts outside of the intervention areas, school enrollment for both boys and girls peaks at age 10 and falls monotonically thereafter. The upper age limit reflects the fact that oldest children in intervention districts affected by the program are 13 in 2000 (the 1986 program first affected those born in 1987). As a result of the age cut-offs and the delayed start of the program in ten districts, only 17 of the 27 districts contain program activity that affects children in the sample. The full sample contains 2276 children in 1696 households. Within-household estimates reduce the sample to 1080 kids in the 499 households that have more than one family member aged 10-13. Sex-specific estimates, which further restrict the analysis sample to households with more than one child of the same sex in this age distribution, are limited to 336 boys in 159 households and 307 girls in 148 households.

Among children in our sub-sample, 89 per cent are currently enrolled in Standards I to VII (primary school). The vast majority of the remaining 11 per cent are not studying, although three 13-year-olds report enrolment in secondary school. Consistent with national trends, gross enrolment ratios are higher than net enrolment ratios because many over-age children are present in primary schools. This is largely due to beginning schooling late, which is particularly common in rural areas where only a little over 50 percent of children are studying by age nine.

3.2 Definition of Program Participation

To analyze the impact of the program, we defined an indicator of program participation equal to one if an individual was born one to three years after an intervention year *t*. The period of treatment was based on the likelihood that the mother of a child was protected from IDD at some point during her first trimester of pregnancy, given the IOC dosage of 380 mg. According to previous studies, this level of iodine, which is stored in the muscles, should have a prophylactic effect for approximately 24 months. First trimester was chosen based on previous scientific studies indicating that early maternal hypothyroxinemia increases the risk of neuro-developmental deficits of the fetus only before mid-gestation, a period during which the mother is the only source of thyroid hormone for the fetus (Cao et al., 1994a; Hetzel & Mano, 1989; Pharoah & Connolly, 1987). Since brain development of the fetus takes place during the first month of pregnancy, it is believed that most of the consequences become permanent by the second trimester. Focusing on first trimester iodine availability is also consistent with general scientific thought regarding the importance of micronutrients during the "critical period" of the first three months of pregnancy (Barker et al., 1989).

Since we do not have data on either month of birth or month of IOC distribution, we calculate the likelihood that the mother of a child born *x* years after a program year was protected from IDD at any point during the first trimester and at month one of pregnancy assuming a uniform probability of receiving iodine and giving birth across months of the year. These likelihoods are the following:[6]

Birth year - program year (x):	-1	0	1	2	3	4
Likelihood of IDD protection, any time trimester 1:	0	5/48	41/48	46/48	12/48	0
Likelihood of IDD protection, month 1 of pregnancy:	0	2/48	33/48	46/48	12/48	0

Based on the above probabilities, we treat individuals born one to three years after IOC distribution as protected from IDD in utero.[7] Although the likelihood of IOC for a child born

[6] In a longitudinal study carried out for two years in the Darfur region, western Sudan, researchers concluded that a single 400 mg oral dose of iodized oil is effective in the correction of iodine deficiency, reducing the goiter size and preventing the recurrence of goiter for at least two years (Eltom et al., 1985).
[7] Month of birth is not reported in the THBS.

three years after the program is only 25%, we include these children in the treatment category on account of the fact that levels of IDD protection will fall gradually from optimal levels during year 3, so that a much higher percentage of children are likely to be partially covered. In contrast, we classify children born in the same year as the program as untreated since during year 0 only 10% of children are expected to receive *any* coverage, and they are more likely to receive it in month 3 than in month 1 of pregnancy.

As a robustness check, we run all regressions using an alternative indicator of program participation based on two rather than three years duration of prophylactic effects, as well as a continuous variable measuring the probability of first-trimester supplementation rather than the binary indicator.

Because iodine dosage administered to pregnant women varied according to whether they were above age 22, we adjust the binary indicator of treatment according to mother's age at birth. Since children born to mothers who were younger than 23 during pregnancy were given IOC that contained half the level of iodine as a precaution against supplement-induced fetal hyperthyroidism, we assume that these children experienced half the protective effect as children with older mothers so assign them a treatment value of 0.5.

The analysis is complicated by the fact that household members can not be perfectly linked across generations. Based on age a relationship to household head, approximately 80% of children in our sample can be matched to mothers with relative certainty. In the results presented here, children that cannot be matched are assumed to have mothers that were older than 23 at birth, however the results are robust to making the opposite assumption and to excluding unmatched observations from the analysis.[8] Given high reported rates of orphanhood in Tanzania, some fraction of mother-child pairs are likely to be matched incorrectly, reducing the precision of the estimates without introducing any obvious bias. In contrast, incorrectly matching sibling pairs in the baseline specification is unlikely to matter since the predictions regarding fetal iodine deficiency are the same as long as the children were both born in the same district.

3.3 Regression Analysis

The primary outcome of interest is grade attainment, or the highest level of completed schooling reported by the respondent. Since few children drop out of school in the age range to

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[8] We matched mothers and kids with the following algorithm: A woman was considered the mother of the child of the head or spouse if she herself was the head or spouse and fell within the right age range (12 to 45 at birth of that child). Out of 3397 observations (kids between 8 and 14), 725 could not be linked to mothers; of these, 342 are not the child of the head of household, 191 live in households in which there are

which our analysis is restricted (primary school), rate of progression is a considerably more sensitive indicator of future educational attainment than is enrollment.

We identify the program effect on grade attainment by comparing children born to women in the target population one to three years after the intervention to those born in the same district immediately prior to or during the intervention. Because we have little information on how districts were chosen for participation, we avoid making comparisons across districts inside and outside the sample. Similarly, because the order of intervention appears to be correlated with district-level poverty, we rely on differences in treatment status across cohorts of children born in the same district with the following fixed-effect regression:

$$grade_{\text{if}} = \alpha + \beta_1 (\text{T}_{\text{if}}) + \beta_2 (\text{A}_{\text{if}}) + \beta_3 (\text{X}_{\text{if}}) + \mu_{\text{f}} + \varepsilon_{\text{if}}$$

where T_i is whether child i in district f was protected from IDD during his or her first trimester of pregnancy, A is a vector of birth year dummies, and X includes the following set of binary controls: gender, birth order, and sex-specific birth order. Since the fetal effects of IDD have been hypothesized to be stronger for females, we also run the above regression separately by gender. We also estimate the effect of the intervention within households by comparing children born to the same mother before and after the program, which minimizes the potential confounding role of unobservable cohort effects that might vary systematically by district and increases the precision of our estimates by holding family background constant,. Note that the gender-specific regressions are run on the subset of families with at least two children of the same gender, which gives rise to potential selection issues relevant for comparison across estimates.

Since within-district (or within-family) treatment is determined entirely by age, in the above equation β_1 reflects the program effect averaged across all treated cohorts. As in all fixed effect estimates, identification of the causal effect of T in the above regression requires that the error term be uncorrelated with the outcome conditional on the observables contained in X and district (or sibling) average grade attainment (μ_{f}). If differences in treatment are positively correlated with other factors that have a negative effect on grade attainment for specific cohorts, the estimates will overstate the true effect of iodine on schooling. Since treatment occurred at the district level, there are few potential factors systematically correlated with treatment that will not be captured by fixed effects. Importantly, since all variation comes off of differences in year of birth, confounding factors must also be those which affect child i in utero *and* have a lasting effect on i's schooling relative to children in the district who are slightly older or slightly

no eligible women (i.e., no female head of household or no spouse in the right age range), and 192 live in younger, which essentially boils down to sharp differences in other health inputs that have a lasting effect on schooling. In other words, the principal concern is that gaps in program coverage coincided with reductions in other child inputs that influenced schooling. For instance, if program delays or gaps in coverage were driven by intermittent declines in the overall quality of health care services, children who were in utero during program gaps may also experience greater calorie or other micronutrient deprivation relative to those born immediately before or immediately after, which could lead to systematically poorer health among children who did not receive iodine supplements that is independent of reductions in IDD.

We assess the extent of this problem by estimating comparable models that replace schooling outcomes with health status and observe whether variation in IOC is related to physical health status of children. Furthermore, given that the majority of variation in treatment in our sample comes from delays in start dates, information on causes of delays provides evidence that variation in treatment was independent of other health shocks in utero. A post-intervention study by Peterson provides a detailed account of sources of program delay encountered during the intervention gleaned from IOC distribution reports and administrative records, interviews with past and present program managers, and supervision visits to selected districts. According to the author's report, distribution occurred with a mean delay of 1.25 years, in all cases due to "administrative delays" resulting from the logistical challenges of district-wide IOC distribution.[9] Delays of one to two years were most likely to have resulted from delayed receipt of IOC from the central government, which was distributed to district health centers between 1986 and 1988. In these cases the start date was driven by an external rather than an internal force. In the remainder of cases, districts started late because they were slow to organize a distribution system such that poorly organized and under-funded districts were more likely to experience delays. In four of five districts that were delayed beyond 1988, delays were eventually resolved externally through the establishment of "national district teams." Although late districts are not safely comparable to early ones, in light of the central role of external resource provision in determining distribution timing in all but one district, there is little reason to suspect that variation in program timing was related to sudden district-level improvements in the quality of health care services.

households in which there is more than one eligible mother due to polygamy.

[9] Basic distribution involved organizing mass campaigns on one particular day in each village through one of two strategies: In addition to IOC, some districts received central funding for fuel and health worker per-diems and set up a "district team" which toured the area using government vehicles. Other districts initially received only the IOC and were told to integrate distribution into primary health care facilities. Eight out of nine districts attempting the latter did not accomplish the task before the capsules were close to expiring. To ensure rapid distribution before expiration date, in four of those eight districts, the central government

3.4 Heterogeneous Program Effects

To refine our estimates of program impact, our analysis makes use of anticipated variation in the impact of the supplementation program based on district variation in the consumption of goitrogenous foods. Goitrogens – including cabbage, legumes, chaya leaves, and cassava – are foods that contain cyanogenic glycosides, which impede absorption of iodine by the thyroid gland (Bourdoux et al, 1978). Frequent consumption of such foods is one of the leading causes of IDD, and diets high in natural goitrogens can induce IDD even if the diet is rich in iodine (Gaitan 1990; Thilly 1992). Consistent with this, evidence from laboratory studies suggests that goitrogens play a significant role in influencing biochemical events that are unique to the developing brain (Rao and Lakshmy, 1995).

Cassava is a staple in much of Africa and a large part of the diet in rural Tanzania. According to the 1991 THBS data, which contain detailed information on household food items consumed, cassava (either flour, dried or fresh) was the second most important food product after maize in terms of calories per day, and in 2000 it was ranked third after maize and sorghum.[10] As one of the most goitrogenic food products, cassava has the potential to significantly decrease iodine absorption if not properly fermented. While the adverse effects of cassava can be countered with proper processing, there have been few efforts to train local communities in alternative processing methods (Bilabina et al, 1995;Delange et al, 1994).[11] Hence, in addition to serving as a central explanatory factor for widespread baseline rates of IDD in the study population, the cyogenic effect of high cassava consumption may have impaired the effect of IOC in certain districts.

Importantly, given that the level of iodine provided through IOC supplements was uniform across districts and program coverage was not explicitly based on level of need, the relationship between baseline IDD rates and program impact is likely to be non-linear. In other words, we anticipate a threshold level of IDD below which rates are too low to observe a significant treatment effect, and a second threshold above which 380 mg of iodine will be insufficient to protect against maternal iodine deficiency due to factors such as cassava consumption which raise daily requirements for iodine intake. Since all participating districts had

established "national district teams" to speed up the process in which staff from the national program initiated and supported the distribution with government cars and money for fuel and per-diem pay.

[10] For a description of these data, see Appendix 3. CALCULATING THE FOOD POVERTY LINE IN 2000/01 of the IFPRI document, "Analysis of the Tanzanian Household Budget Survey – Income poverty: Technical note on estimating poverty levels in Tanzania" prepared by Trudy Owens in March 2002.

[11] In one study in Tanzania, insufficient cassava processing was correlated with TGR (Peterson, 1994).

high pre-program TGR, the program impact among districts in the lower tercile of the treated population is likely to be larger than it is in districts with the highest baseline rates of IDD.

These predictions are tested by studying variation in program effect by intake of goitrogens. Although the need for iodine increases with consumption of goitrogenous foods, so does the rate at which iodine – including that provided by the supplement – is depleted from the body by regular intake of goitrogens. The district rate of cassava production is used to proxy for variation in dietary intake 10 to 13 years prior. To construct this measure, a household was defined as a cassava producer if they reported consuming during the past month any fresh or dried cassava or cassava flour that was produced at home, and districts were classified according to the fraction of households in the district that reported consuming home-produced cassava. Given that households also eat cassava that is not produced at home, this is clearly an underestimate of the actual intake of goitrogens. However, it is intended as an indicator of geographic variation in produce availability, and therefore a reasonable predictor of dietary differences a decade earlier. Given that diets of non-agricultural households may have changed over the past ten years, this is arguably a preferable proxy of past diet, and hence baseline TGR, than is current consumption.

In the initial regressions, districts were divided into terciles of cassava production. In high production regions, between 41 and 60% of households consume home-grown cassava; in medium production regions between 11 and 40% of households do so; and in low productions districts fewer than 10% of households consume home-grown cassava. Although sample sizes prevent us from undertaking a detailed study of the amount of goitrogens consumed, the relationship between program impact and diet is studied more closely by testing for non-linearities in program impact across quintiles of cassava production.

4 Results

4.1 Grade Attainment

Regressions of grade attainment on program participation yield large and significant estimates of the impact of IOC on progression through school. In fixed-effects estimates comparing sibling education outcomes conditional on age and program participation, children who participate in the program are an average of 0.36 years ahead in school. Over this interval, the gap widens continuously as children age, a trend which is illustrated in Figure 2. Since enrollment is virtually unchanged over this interval, this suggests that fetal IDD influences the rate at which students progress through school. The main results are also present in OLS regressions that exclude household fixed effects, though the point estimate is smaller. Similarly, the effect is robust to using a two-year indicator of program participation, and virtually identical in magnitude. This is consistent with the fact that similar fractions of children born three years after the program are treated and not treated, such that the control group in the two-year treatment estimate is contaminated to a similar extent that the treatment effect in the three-year treatment estimate is diluted.

One of the most striking features of the Table 3 estimates is the consistently higher estimated program effect on girls. In both within-sibling and within-district estimates, girls appear to benefit twice as much as boys from IOC in utero, although the difference is only significant at the 10% level in the district-level fixed effects estimates.

One possible concern is that, because we are making inferences about program effect based on cohort differences, our results may simply be picking up time trends in schooling attainment that vary systematically with program start dates. For instance, the age gap between 10 and 12 year-olds may be lower in districts in which younger but not older siblings were treated simply because education is increasing faster in districts that received IOC later. Importantly, because IOC was rarely distributed with the intended 2-year gap, there are multiple instances of an older but not a younger sibling receiving IOC, allowing us to check whether the program both reduces the grade attainment gap when a younger sibling is treated and increases the gap when an older sibling is treated. In total, among sibling pairs in which only one individual was treated, the older sibling was treated in 23% of cases. The asymmetry reflects the fact that most variation in program activity on children in this age group arises from program delays rather than gaps.

Figure 3 shows the average difference in grade attainment across all sibling pairs in the sample, for three categories of sibling pairs: (1) those in which both either did or did not benefit from IOC; (2) those in which the older but not the younger sibling benefited from IOC; and (3) those in which the younger but not the older sibling benefited from IOC. Comparison across these groups reveals that the program effect is symmetric across the latter two cases: When an older but not a younger sibling is protected from IDD in utero, the difference in schooling attainment widens, and when the younger but not the older sibling is protected, the difference narrows. Such a pattern could only be explained by a very complicated non-monotonic and district-specific time-trend in schooling. Furthermore, there is no measurable difference in average schooling attainment when both siblings are treated versus when neither is treated. Regression estimates of grade differences on sibling age gaps and indicators of which sibling received IOC reveal statistically significant program effects of the expected sign in both comparisons (Table 5).

Estimates in Table 4 of differences in the program effect across levels of cassava consumption are also consistent with the previous predictions. Dividing districts in the sample according to cassava production reveals an inverted u-shaped relationship between amount of goitrogens consumed and impact of IOC on fetal development: In areas with highly goitrogenous diets the program appears to have had little effect, suggesting that maternal iodine levels were being depleted by intake of food products such as cassava. Meanwhile, in areas with very low levels of cassava in the diet, the program effect is also small, which presumably reflects the fact that these were the districts with the lowest levels of TGR at the start of the program. Figure 4 splits the sample even further into five categories of cassava production. Results from regressions on the separate sub-samples indicate that only the extreme outliers were unaffected by the intervention. Most striking is the indication that the areas with the highest levels of TGR in fact benefit the least from even a program as intensified as IOC. For these areas, salt legislation, even if it were to reach households on a daily basis, is unlikely to make any improvements in the rate of IDD and consequent health and cognitive impairments. Similarly, the program effect varies in an anticipated fashion when dividing the sample according to level of maternal iodine received. Among children of mothers who were targeted to receive 200 mg of iodine, the estimated program effect is close to zero and insignificant while the estimated program effect on children whose mothers were targeted to receive 380 mg is 0.43 years and highly significant.

The measured effects underestimate the cognitive impact of IDD to the extent that not all pregnant women in a district were reached by the program. Data on program coverage rates by district (Table 1) indicate that 68% of the target population was reached in program areas between 1986 and 1990, although it is unclear whether coverage was higher among specific target groups.[12] If the rate applies equally to pregnant women, total coverage implies an average program effect of 0.53 years. However, for two reasons it may be inappropriate to inflate the baseline estimate by average coverage. First, women of childbearing age were reportedly first in the priority list for receiving IOC, so are likely to have been targeted more aggressively by practitioners and program administrators. Even if they were not, coverage might be higher than average among pregnant women since they are more likely than men or children over age 1 to visit health centers where IOC were frequently distributed in regions with low coverage. Third, an evaluation of program implementation suggested that coverage rates were higher in areas with higher incidence of goiter, which also implies that effective coverage (coverage of those in need) was over 68% (Peterson, 2000).

The estimates of grade attainment also underestimate the effect of the program on final schooling attainment since schooling outcomes are right-censored. Furthermore, given that primary school enrollment levels reached 94% by 2000, it is possible that schooling outcomes are

[12] Rate was calculated by multiplying each district's coverage rate by the fraction of children from that district in our sample.

far more sensitive to learning disabilities at the secondary relative to the primary level. Unfortunately, the THBS data were collected too early to enable an examination of secondary school outcomes. Censored data models are unlikely to be appropriate for estimating the total effect of the program on schooling attainment given the substantial barriers to secondary school enrollment which are likely to generate sharp discontinuities in grade attainment around age 14. To get a better sense of the total effect of IOC on schooling, sections 4.4 and 5.1 utilize household survey data and administrative data on early secondary school transition rates in 2004.

4.2 Control Experiment

To verify that estimated program effects are not driven by time invariant district-specific patterns of schooling attainment by age, we regress grade attainment of children in the sample districts that were 10 to 13 in 1988. For this sample, we construct a pseudo-indicator of IOC program participation that is equivalent to the indicator assigned to kids of the same age and district in the 2000 data. Since children who were between 10 and 13 in 1988 were indisputably too old to benefit from IOC in utero, if our results truly reflect an effect of IOC we should observe no relationship between the program variable and education outcomes in within-sibling regressions on this sample. These results are presented in Table 6. For consistency with the previous estimates, we run the regressions separately by gender and also divide the sample according to 2000 levels of cassava production. All regressions yield insignificant estimates of the effect of our age- and district-specific indicator of program participation on 1988 schooling.

4.3 Health Outcomes

Our principal identifying assumption is that variation in program activity (including both program gaps and delays in program start dates) is uncorrelated with other in utero influences on schooling attainment. The most compelling potential violation of this assumption is the possibility that gaps in program coverage were associated with changes in access to antenatal care, which in turn affected fetal health and cognitive development. Unfortunately, it is impossible to distinguish between in utero cognitive damage that resulted from iodine deficiency from that which resulted from the absence of other health inputs. However, since the effects of fetal iodine deficiency are thought to be overwhelmingly cognitive, whereas deficiencies in other health inputs are more likely to show up in overall health status, we test whether our observed program effects may reflect differences in fetal health inputs other than iodine by looking for differences across siblings in childhood health outcomes according to program timing.

Table 7 presents results from regressions of child health on program participation analogous to the Table 4 estimates. The following health outcomes are available from the THBS: whether the child experienced fever/malaria, diarrhea, an ear/nose/throat condition, a skin condition, an eye condition, or an accidental injury during the last four weeks, as well as the total days of work or school missed during the last four weeks due to any sickness or injury. The latter outcome is a particularly useful test of the alternative hypothesis since school days missed due to illness is one of the most likely mechanisms through which in utero health damage could account for some or all of the observed program effect on schooling.

The resulting estimates indicate no relationship between IOC coverage and school days missed due to illness, nor is there any evidence that children covered by the program report fewer episodes of ill health. Although the long run health effects of in utero deficiencies could show up in a number of different childhood health outcomes given that fetal micronutrient deficiencies are thought to weaken an individual's overall immune system, none of the estimates in columns 2 through 6 reveal any sign of a program effect on child health at ages 10-13.

4.4 TDHS Estimates

The 2004 Tanzanian Demographic and Health Survey (TDHS) also contains information on schooling and district of residence for children affected by the IOC program. Because schooling data were collected only for children living in the household, it was necessary to restrict the sample to children under the age of 15 to avoid high attrition rates and related sample selection complications. Although the sample is considerably smaller than the THBS, there are two principal advantages to the TDHS. First, month of birth is available for approximately 80% of children in the sample, allowing us to construct a more precise indicator of treatment.[13] Second, data from 2004 captures schooling outcomes for children born during a distinct set of program years, allowing us to make use of greater variation in program activity within and across districts. In addition, because the data were collected four years after the THBS, more program children have had slightly more opportunity to transition from primary to secondary school, enabling us to better gauge whether the benefits of IOC in utero extend to improved rates of secondary school enrollment. However, since it is necessary to restrict the sample to children under 15, the ability to observe secondary school transition remains limited: The modal age for entering secondary school is 16; among children in the DHS sample who are enrolled in the first year of secondary school, 9% are 12 or 13, 23% are 14, 26% are 15, 28% are 16, and 14% are 17.

[13] Month of birth is missing for 1,313 (~20%) children of the head between ages 9 and 17 either because their mother did not live in the household (34 cases) or because their mothers were not included in the individual survey (740 cases) that collected birth histories.

Using the DHS sample we estimate a model of grade attainment analogous to the Table 4 regressions. The only difference is the construction of program indicator, which is assumed to be linearly increasing in month of birth.[14] Birth month is also added to the set of control variables. These results are presented in Table 8. The first two columns are consistent with the 2000 estimates, and indicate that grade attainment was positively affected by IOC for girls but not necessarily boys. Although the sample members were born in different years and in distinct enumeration areas to the THBS sample, the estimated program effect is nearly identical in magnitude to the Table 4 estimate. The gender difference is particularly stark – and statistically significant – when the sample is restricted to children under the age of 13, possibly reflecting "catch-up" on the part of boys as girls begin to drop out of school. Meanwhile, the likelihood of transitioning to secondary school is positively correlated with IOC for both genders, where once again the point estimate is suggestively though not significantly larger for girls.

4.5 Discussion

The patterns of results observed in Tables 4-8 are consistent with a change in the cognitive cost of schooling resulting from lower incidence of fetal IDD, which is widely believed to lead to permanent reductions in cognitive capacity. Although IQ is unobservable, it is difficult to imagine other possible channels through which program participation could have influenced those children of mothers born during the program relative to their siblings or peers born a few years earlier and later. One such possibility is that iodine levels in utero influenced overall physical health of offspring which in turn increased their ability to attend and progress in school. Two arguments suggest that this is not the primary channel: First, iodine deficiency has been demonstrated in laboratory studies to influence brain development much more readily than physical development in utero. Second, data on incidence of illness indicate that children born during the program are no more likely to become sick (Table 5).

Another possible channel of influence related to the effects of iodine on physical development is a selection story in which iodine in utero protects children against fetal or childhood mortality. Although we cannot test this directly without information on children in the household that have died, age patterns do not indicate fertility or cohort size effects of the

[14] In particular, the likelihood that children born one year after IOC distribution are protected during the first trimester of pregnancy is linearly increasing in month of birth, while the likelihood that children born three years after IOC distribution are protected during the first trimester of pregnancy is linearly decreasing in month of birth. Hence the treatment indicator for the former is equal to 1*(birthmonth/12), and the treatment indicator for the latter is equal to 1*((12-birthmonth)/12). Children born 2 years after IOC are protected with a probability of 1 regardless of birth month.

program. Secondly, it is unlikely that increases in survival rates would give rise to higher rates of schooling attainment at ages 10 to 13.

The results on gender differences are more ambiguous. While observed gender differences in the impact of IOC may reflect physiological differences in the importance of iodine for fetal brain development, there are two other possible interpretations for this finding. First, gender differences may reflect the fact that girls in Tanzania systematically enter school at an earlier age than boys, a pattern that is observed in the 1988 Census data as well as the 2000 THBS and 2004 TDHS data. Hence, by a given age they have already reached a higher grade than their male peers. If the importance of cognitive ability on school pass rates increases with grade, as is likely to be the case, girls between the ages of 10 and 13 will benefit more from the intervention simply because they are more likely to be on the margin of influence. Although the two trends are impossible to separate without information on age of entry (unavailable from these sources), it is relevant to note that baseline gender differences in grade for age are relatively small. To account for the full gender difference in IOC, an 0.2 year difference in age of entry would have to correspond to twice the effect of IOC on attainment, which could only happen if the influence of ability on pass rates were highly non-linear.

The second possible reason we might observe differences across girls and boys in the impact of IOC in utero is that parents' decision to invest in girls' schooling is more sensitive to differences in cognitive capacity. This could be the case if, for instance, the opportunity, financial or social cost of enrolling girls in school were higher than that of boys due to girls' higher productivity at home or opportunities for marrying young. If this is true, boys and girls might experience the same cognitive benefits of IOC at a biological level, but that translates into greater schooling benefits for girls.

Unfortunately, without data on cognitive capacity, there is no simple way to distinguish the last story from a disproportionate improvement in cognitive capacity among girls. The following section attempts to take a step in this direction by utilizing information on the rates at which students pass the Primary School Leaving Examination (PSLE).

5 PSLE Test Scores

In order to better connect our results on schooling attainment to improvements in cognitive ability, we make use of district-level aggregate data on 2004 Primary School Leaving Examination (PSLE) pass rates by gender, available from the Ministry of Education for 83 of the

106 districts in the country.[15] PSLE data are available on the number of boys and girls in each district who take the test in 2004, and the number of boys and girls who receive each of five categories of test grade, three of which constitute passing grades. Test-takers in 2004 are likely to fall between the ages of 14 and 18, so correspond almost perfectly to the cohort of children most affected by IOC distribution, or kids aged 10-14 in the 2000 THBS data.

At the end of primary school (standard 7), children sit for the PSLE, which is required for admittance to any lower secondary school in the country. The pass rate for this examination has traditionally been abysmal despite the government's ongoing goal of increasing the proportion of children passing to 50 percent. In 1997, only 20.1 percent of pupils who sat for the PSLE passed the examination, which has since increased to 22.0 percent in 2000 and 28.6 percent in 2001. Although roughly equal numbers of boys and girls take the test, gender differences in PSLE pass rates are striking: In 2001, only 21.4 percent of girls who sat for the PSLE passed the examination compared to 36.2 percent of boys. By 2004, although the number and gender ratio of test-takers had changed little, the pass rate had improved considerably, most likely due to a reported (though not well documented) change in the grading policy: 43% of female and 57% of male test-takers passed the exam, reducing the gender difference considerably in terms of pass rates while maintaining roughly the same percentage point gender gap.

Our empirical analysis tests whether secondary school transition rates are higher in IOC districts conditional on district secondary school enrollment reported in the 1988 population census, and whether transition rates improved disproportionately for girls.[16] We examine the fraction of students who take the PSLE, and the fraction of test-takers who pass and therefore transition to secondary school with the following set of regressions, run separately by gender:

$$\ln(testtakers04_{d}) = \alpha + \beta_1 (\mathrm{T}_{d}) + \beta_2 (\ln(pop04_{d})) + \beta_3 (hsrate88_{d}) + \beta_4 (X_{d}) + \varepsilon_{d} \quad (2)$$

$$\ln(testtpassers04_{d}) = \alpha + \beta_1 (\mathrm{T}_{d}) + \beta_2 (\ln(testtakers04_{d})) + \beta_3 (hsrate88_{d}) + \beta_4 (X_{d}) + \varepsilon_{d} \quad (3)$$

In both estimates, an observation is a district. The first outcome, *testtakers04,* is the number of male or female individuals in district *d* who take the PSLE in 2004, *T* is whether there was IOC distribution in district *d* between 1986 and 1992, *pop04* is the number of males or

[15] No PSLE data are available from any district in the region of Iringa. Data are also missing from the following other districts: No explanation is available from the Ministry of Education for the absence of PSLE data from certain districts.

[16] Since 2002 Census data is only available in five-year age groups, the transition rate is approximated by dividing the number of boys and girls passing the exam in 2004 by the number of boys and girls between

females in district *d* between the ages of 10 and 14 in the 2002 Census (therefore the population of high-school age in 2004), and *hsrate88* is the fraction of females or males age 21-25 in district *d* who were ever enrolled in form 1 or above according to the 1988 Census. In the second regression, the outcome is the number of girls or boys who *pass* the 2004 PSLE (achieve a grade of C or above) controlling for the number of test-takers. In both regressions, X_d contains the following set of district-level controls: 2000/2001 Gini coefficient of income inequality and percent of population below poverty line.[17] Unfortunately, 2002 census data on school enrollment are currently unavailable, but 2004 PSLE pass rates are likely to be a reasonable proxy for the secondary school transition rate in the cohort of test-takers. As such, one caveat is that conclusions about secondary school enrollment drawn from this analysis depend on a low rate at which children who pass the test fail to enroll in secondary school, which is likely to be the case given the extreme competition for slots in Tanzanian secondary schools and low PSLE pass rates.

Results from these regressions are presented in Table 9. The estimates in the first two columns reveal that the rate at which students take the PSLE is not significantly higher for IOC districts for either gender. The point estimates are positive but small and fall short of statistical significance. We do, however, observe that the number of individuals passing the PSLE is higher in IOC districts and particularly so for females. The point estimates of 0.22 and 0.14 are significant at 10% for females and males respectively. While far from conclusive, these results suggest that the IOC intervention may have positively affected the distribution of scores on the PSLE, particularly the distribution of female scores. This is particularly evident in a comparison of test score distributions across gender and program participation (Figure 5), which reveals little difference in the distribution of male test scores across program and non-program regions and a significantly lower fraction of scores in the lower tail of the grade distribution for girls. Regression estimates that control for district characteristics suggest that districts that participated in IOC experienced a significant decrease in the number of individuals receiving the lowest grade “F” while there is no visible difference in the proportion of individuals in the upper tail of the distribution. The decrease is statistically significant for both genders but is larger in magnitude for females.

6 Impact of universal salt iodization on cross-country comparisons

the ages of 10 and 14 in 2002, or 12 to 16 in 2004. This is slightly younger than the average age of test-takers, which is unavailable in 2004, but the population figures are unlikely to differ across close cohorts.

[17] Data on education come from the 2004 Ministry of Education Basic Education Statistics (MoEC), and the 2000/01 THBS, as reported in R&AWG (2005).

The magnitude of the estimated effect of IOC on schooling in Tanzania implies that comparable reductions in iodine deficiency worldwide that have resulted from universal salt iodization (USI) over the past two decades should be visible in improvements in aggregate schooling between 1980 and 2000. Hence, partly as a robustness check, the last section of the paper examines whether cross-country differences in reductions in iodine deficiency that resulted from differences in the timing and intensity of USI and differences in baseline levels of IDD are correlated with improvements in schooling attainment over the same period.

6.1 Global trends in IDD and Salt Iodization

The International Council for the Control of Iodine Deficiency Disorders (ICCIDD) came into existence in 1985 with the single purpose of achieving optimal iodine nutrition worldwide, and has since worked closely with UNICEF and the World Health Organization towards this objective. The resulting Universal Salt Iodization (USI) movement was based on the notion that IDD is easily and inexpensively preventable through iodized salt (Mannar, 1996). In 1990, participants in the World Summit for Children set a goal to eliminate IDD by the year 2000 through USI. Approximately 40 countries passed USI legislation between 1970 and 2000, the majority during the 1990s, resulting in an increase of iodized salt intake from 20% of the world population to over 70%. Figure 6 shows the current prevalence of IDD, and Figure 7 shows current estimates on the fraction of households consuming iodized salt. On account of USI legislation and local distribution efforts, approximately two-thirds of the previously IDD-affected population of Africa now consumes adequately iodized salt (Unicef, 2005).

6.2 Cross-country regression analysis

For the cross-country empirical analysis, data were compiled from 81 countries on the following four key variables along with a standard set of controls: primary and secondary enrollment in 1980 and 2000, which spans the period during which the bulk of USI activity took place[18]; the most common indicator of iodine deficiency, total goiter rate (TGR); and a widely available indicator of recent improvements in iodine coverage, the percentage of households consuming iodized salt. All countries for which these four measures were available were included in the analysis. School enrollment information was taken from the World Bank's World Development Indicators supplemented by the Barro-Lee Educational Attainment Data for the 1980s; household consumption of iodized salt was gathered from UNICEF's Global Database on

[18] The year 1980 is an appropriate pre-legislation measure of schooling for all countries that passed USI after 1975 due to the fact that children even in primary school in 1980 were born prior to the policy change.

Universal Salt Iodization; and goiter rates were taken from the World Health Organization's Database on Iodine Deficiency, part of the WHO 2006 Micronutrient Deficiency Information System (MDIS), and supplemented with Current Iodine Deficiency Status (CIDDS) database maintained by the ICCIDD.[19] To approximate the level of iodine deficiency prior to salt iodization, TGR was taken from a year prior to 1980 whenever possible, although in many cases it was necessary to include TGR measured between 1990 and 1995.

In the first set of estimates, we examine the impact of iodine deficiency on changes in schooling attainment over the past two decades by regressing male and female primary and secondary enrollment in 2000 on 1980 enrollment along with baseline TGR and a standard set of explanatory variables.[20] We then test whether reductions in IDD over this period are associated with improvements in schooling attainment by adding to the regression the fraction of households consuming iodized salt in 2000. The results are presented in Table 10.

Three important findings emerge: First, iodine deficiency is negatively associated with improvements in female secondary school enrollment between 1980 and 2000. In particular, baseline TGR appears to have a significant adverse effect on female secondary enrollment in 2000 conditional on enrollment rates in 1980. Our results suggest that reducing TGR from 30 to 10 will increase average female secondary school participation by approximately 7%.[21] The point estimates are also negative but lower and insignificant for males. Surprisingly, the estimated effect of baseline TGR on 1980 and 2000 *primary* school participation is not significantly different from zero in any of the regressions. This is likely due to the higher degree of collinearity between TGR and 1980 primary enrollment relative to TGR and 1980 secondary enrollment. In particular, secondary school enrollment was so low in 1980 in many affected countries that IDD was less likely to pose a binding constraint.

Second, *reductions* in IDD between 1980 and 2000 appear to have had an important

[19] WHO data, along with a detailed description of data sources and inclusion criteria are accessible on-line at: http://www3.who.int/whosis/mn/mn_iodine/. Both sources of TGR information compile estimates from a number of government and scientific sources, and there is a great deal of overlap. However, whenever more than one estimate was available, data were taken from the WHO database given that CIDDS estimates of goiter prevalence appear to be noisier due to the variety of ways TGR is calculated (palpation vs. ultrasound; range of the goiter rate vs. a single number, etc).

[20] Control variables collected primarily from the World Bank Group's World Development Indicators. All regressions include the following set of development indicators for controls from the World Development Indicators: Malaria prevalence, HIV prevalence, urbanicity (urban population as % of total population), population density (per square kilometer), log GDP per capita, log GDP per capita squared, and terms of trade (Export value Index / Import value index).

[21] A 10% reduction in TGR is equivalent to a 3 base point drop in average TGR from 30.66 in our dataset. We calculate the average increase in female secondary school participation (.7) based on the estimated effect of TGR in Table 10b (column 5). We calculate the percentage increase in female secondary school

positive effect on both male and female primary school participation, evidenced by the fact that both males and female primary school participation in 2000 is increasing in the fraction of households consuming iodized salt. The absence of a concomitant effect of USI on secondary enrollment is consistent with this interpretation given that the bulk of changes in household use of iodized salt were too recent to affect the cohort of children eligible for secondary school (children above age 12 in 2000).

Third, the effect of reductions in IDD on primary school enrollment appears to be significantly larger for females. The influence of iodized salt on primary schooling enrollment is estimated to be 0.137 for females and significant at the 5% level (column 3). This estimate suggests that moving from the current sample average of 60% to universal salt iodization (100%) would increase female primary school participation by as much as 7%. Meanwhile, the point estimate remains positive but lower and insignificant for males (column 4), consistent with the estimated effect of IOC in Tanzania.

These findings suggest that recent increases in iodine intake have had a beneficial impact on cognitive development worldwide, particularly for females. Together with the previous results, they underscore the importance of universal salt legislation for endemic regions, along with complimentary measures to ensure deeper penetration in countries, including the majority of Western Africa, for which legislation has failed to provide adequate protection.

6.3 Projections

Our last exercise uses international data on USI legislation to calculate the expected gains in education that should be observed in the near future. According to project reports, the districts in our sample had average baseline levels of TGR of 30%. All IOC districts had a TGR of at least 10%, and the most severely affected district had TGR of 75%. The projections in Table 11 include 42 countries ranging in TGR from 10% to 52% prior to 1995 that have experienced recent reductions in IDD through USI legislation. Based on the fraction of households using iodized salt in 2002, which varies from 7% in Niger to 86.1% in Nicaragua, we calculated the number of children that were protected from fetal IDD over the past decade. According to our estimates, approximately 41.1 million children between the ages of 5 and 9 in 2002 have benefited from increases in iodine intake over the past decade in these countries alone, with the largest populations of newly protected children in Algeria, Indonesia and Nigeria. The expected number of children that received adequately iodized salt in treatment of IDD is calculated using the

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participation (1.5%) by dividing the increase in participation (.7) by the average participation rate of 50.71 in our dataset.

fraction of households using adequately iodized salt and the expected TGR of our target population. The rate of en utero IDD is assumed to be twice the TGR. The reasoning behind this assumption is that the rate of IDD is larger for women and the rate of IDD en utero occurs more quickly than adult IDD. The number of children suffering from IDD is calculated as the rate of en utero IDD times the population of children. The number of protected children is calculated by taking the number of children suffering from IDD and multiplying it times the fraction of households using adequately iodized salt.

Based on our previous estimates, the expected increase in grade attainment is a minimum of 0.73 years for children who are protected from fetal IDD.[22] The expected increase in other countries will depend on the likelihood that the protected child would have experienced fetal IDD, which is assumed to be twice the rate of TGR based on the ratio of recommended iodine intake for pregnant women relative to school-age children. From that number, we calculate the anticipated increase in schooling attainment for each country by multiplying the expected increase in schooling per treated child by the fraction of households using iodized salt (rate of treatment). Based on this formula, we anticipate an overall impact of IOC on schooling attainment in these countries amounting to a 4.1% increase in average schooling attainment. For the countries of Central Africa, the predicted improvement in average schooling is 5.3%.

7 Conclusions

We emphasize three conclusions from this analysis. First, reduced levels of IDD due to wide-scale salt iodization in the 1990s are likely to have a visible impact on schooling attainment in highly afflicted areas over the next two decades. Our estimates indicate that at least 25.5 million children have been affected by these reforms, which could increase average schooling attainment in many countries by over 10%. The possible role of reduced fetal IDD among the birth cohorts of 1990-2000 will be important to bear in mind when interpreting changes in schooling attainment in much of Africa and other parts of the developing world over the coming decade.

Second, our findings support the laboratory evidence that female fetuses are more sensitive to in utero iodine exposure, which implies that future improvements in schooling attainment are likely to disproportionately benefit girls. In areas with baseline IDD comparable to districts in the middle range of our sample, universal salt iodization could go far towards achieving gender parity in schooling attainment. More fundamentally, this finding indicates that

[22] This effect is calculated from the baseline effect (.34 years) observed in Tanzania adjusted for the 78% average take-up rate of IOC and the average rate of maternal IDD (60%) in the target population.

physiological gender differences may be quite important, which has important implications for how we interpret current gender differences in schooling attainment across the globe. An important caveat in interpreting the differential impact of IDD by gender is that we cannot fully rule out the possibility that gender differences are driven by gender differences in or by variation across genders in household responses to improvements in cognition. However, the corresponding evidence of gender differences in fetal sensitivity to maternal iodine levels from controlled laboratory studies in rats should not be discounted.

Third, from a policy perspective, our findings indicate that even universal salt iodization will not eliminate the adverse cognitive effects of fetal IDD among populations in the most afflicted settings, where diets high in goitrogens necessitate higher supplement levels or other dietary changes to overcome maternal IDD. In these areas, more intensive interventions such as IOC distribution or changing methods of cassava production will be needed in order to achieve current Millennium Development Goals regarding micronutrient deficiency. Although such approaches are significantly more costly than salt iodization, future returns to gains in schooling attainment are likely to outweigh the costs.

References

Allen L, Gillespie S (2001). What Works? A review of efficacy and effectiveness of nutrition interventions. *UN (ACC/SN)*.

Barker DJ, Winter PD, Osmond C, Margetts B, Simmonds SJ. (1989). Weight in Infancy and Death from ischaemic heart disease. *Lancet* 2: 577-80.

Basta SS, Soekirman Karyadi D, Scrimsha NS. (1979). Iron deficiency anemia and the productivity of adult males in Indonesia. *American Journal of Clinical Nutrition* 32: 916-25.

Beaton GH, Martorell R, L'Abbe KA, Edmonston B, McCabe G, Ross AC and Harvey B. (1992). Effectiveness of Vitamin A Supplementation in the Control of Young Child Morbidity and Mortality in Developing Countries. SCN State-of-the-Art Nutrition Policy Discussion Paper No. 13

Behrman JR, Hoddinott J, Maluccio J, Martorell R, Quisumbing A, Stein A. (2003). The Impact of Experimental Nutritional Intervention in Childhood on Education Among Guatemalan Adults. International Food Policy Research Institute: Brief Discussion Paper 207.

Biassoni P, Ravera G, Schenone F, Green J, Bertocchi J. (1990). Ouham-Pende: A new endemic goiter area in the Centroafrican Republic (CAR): epidemiological survey on 7261 subjects. *Thyriodology* 2: 35-40.

Bleichrodt N, Born MA (1994). A meta-analysis of research on iodine and its relationship to cognitive development. *Report of the Franklin Symposium: Iodine deficiency and brain damage*. Cognizant Communications Corporation.

Benoist B, Andersson M, Egli I, Takkouche B, Allen H. (2004). Iodine Status Worldwide: WHO Global Database on Iodine Deficiency. World Health Organization. ISBN 92 4 159200 1.

Boyages SC, Halpern JP, Maberly GF, Eastman CJ, Morris J, Collins J, Jupp JJ, Jin CE, Wang ZH, You CY. (1988). A comparitive study of neurological and myxedematous endemic cretinism in Western China. *Journal of Clinical. Endocrinology & Metabolism.* v67: 1262-66.

Bourdoux P, Delange F, Gerard M, Mafuta M, Hanson A, Ermans AM. (1978). Evidence that Cassava Ingestion Increases Thiocyanate Formation: A Possible Etiological Factor in Endemic Goitre. *Journal of Clinical. Endocrinology & Metabolism* 46: 613-621.

Cao XY, Jiang XM, Dou ZH (1994). Timing of vulnerability of the brain to iodine deficiency in endemic cretinism. *New England Journal of Medicine* 331: 1739–44.

Connolly KJ, Pharoah PO, and Hetzel BS (1979). Fetal iodine deficiency and motor performance during childhood. *Lancet* 2:1149 –51.

Commission on Macroeconomics and Health (2001). Macroeconomics and Health: Investing in Health for Economic Development. Geneva: WHO

Delange F, Lecomte P (2000). Iodine supplementation: benefits outweigh risks, *Drug Saf*ety Feb;22(2):89-95.

Delange F (2000). The role of iodine in brain development, *Proceedings of Nutrition Society* 2000 Feb; 59(1): 75-80.

Delange F, Ekpechi L, Rosling H. (1994). Cassava cyanogenesis and iodine deficiency disorders. Paper presented to the International workshop on cassava safety, Ibadan, Nigeria, Acta Horticulturae, International Society for Horticultural Sciences.

Delange F (1998). Risks and benefits of iodine supplementation, *Lancet*. 351(9107): 923-924, March 28.

Dugbartey, A (1998). Neurocognitive aspects of hypothyroidism, *Archives of Internal Medicine*.158(13):1413-1418, July 13.

Eltom M, Karlsson FA, Kamal AM, Bostrom H, and Dahlberg PA (1985). The effectiveness of oral iodized oil in the treatment and prophylaxis of endemic goiter. *Journal of Clinical Endocrinology and Metabolism*, 61(6):1112-7.

Friedhoff AJ, Miller JC, Armour M, Schweitzer JW, and Mohan S. (2000). Role of maternal biochemistry in fetal brain development: effect of maternal thyroidectomy on behaviour and biogenic amine metabolism in rat progeny. *International Journal of Neuropsychopharmacoogy* 3: 89–97.

Gaitan E and Dunn J (1990). Goitrogens in food and water. *Annual Review of Nutrition* 10: 21-39.

Galler JR, Ramsey F, Solimano G, Kucharski LT, Harrison R. (1983). The influence of early malnutrition on subsequent behavioral development, II, Classroom behavior. *Journal of the American Academy of Child Psychiatry* 22 : 16-22.

Galler JR (1984). Behavioral consequences of malnutrition in early life. In : JR Galler (ed.) *Nutrition and Behavior*. New York : Plenum Press.

Glasizou PP, Mackerras DEM (1993). Vitamin A supplementation in infectious diseases: a meta-analysis. *British Medical. Journal* 306: 366-70.

Haddow, J, Palomaki G, Allan W, Williams J, Knight G, Gagnon J, O'Heir C, Mitchell M, Hermos Rosalie, Waisbren S, Faix J, Klein R. (1999). Maternal thyroid deficiency during pregnancy and subsequent neuropsychological development of the child, *New England Journal of Medicine*.August; 341(8):549-555.

Halpern J-P, Boyages SC, Maberly GF, Collins JK, Eastman CJ, Morris JG. (1991). The neurology of endemic cretinism: A study of two endemias. *Brain* 114: 825-41.

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

Hussain KHD et al. (1981). Evaluation of nutritional anemia intervention among anemic female workers on a tea-plantation. *Iron Deficiency and Work Performance* 73. Washington DC: Nutrition Found.

Lamberg BA. (1991). Endemic Goiter-Iodine Deficiency Disorders. *Annalsof Medecine* 23: 367-372.

Maberly G, Trowbridge F, Yip R, Sullivan K, West C. (1994). Programs against micronutrient malnutrition: Ending hidden hunger. *Annual Review of Public Health* 15:277-301.

Magombo F et al (1990). An investigation into factors leading to some resistance to a new innovation: The case of iodinated oil capsule distribution: Rukwa Region, Tanzania. Tanzania Food and Nutrition Centre, TFNC report No 1242.

Mannar M (1996). The iodization of salt for the elimination of iodine deficiency disorders. *SOS for a Billion*. Hetzel & C. Pandav. Dehli: Oxford University Press.

Merke F. (1984). The History and Ichnography of Endemic Goitre and Cretenism. *Lancaster:* MTP Press

Miguel E, Kremer M (2004). Worms: Identifying Impacts On Education And Health In The Presence Of Treatment Externalities. *Econometrica* 72: 159-217.

Pandav CS, Kochupillai N. (1982). Endemic goitre in India: Prevalence, etiology, attendant disabilities and control measures. *Indian Journal of Pediatrics* 50: 259

Peterson S (2000). Controlling Iodine Deficiency Disorders: Studies for Program Management in Sub-Saharan Africa. *Uppsula Dissertations from the Faculty of Medecine 943.*

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

Pop V, Kuijpens J, van Baar A, Verkerk G, van Son M, Vijlder J, Vulsma T, Wiersinga W, Drexhage H, Vader H. (1999). Low maternal free thyroxine concentrations during early pregnancy are associated with impaired psychomotor development in infancy; *Clinical Endocrinology*. 50(2):149-155.

Research and Analysis Working Group (R&AWG) (2005). Tanzania poverty and human development report 2005. Ministry of Planning, Economy and Empowerment, Poverty Eradication Division. Dar es Salaam, Tanzania. Available at: www.povertymonitoring.go.tz

Richardson et al (1995). The behavior of children at home who were severely malnourished in the first 2 years of life. *Journal of Biosocial Science* 7: 255-67.

Rao PS, and R Lakshmy (1995). Role of goitrogens in iodine deficiency disorders & brain development. *Indian Journal of Medical Research* 102: 223-6

Shrestha, R. M. and C. E. West (1994). *Role of Iodine in Mental and Psychomotor Development: An Overview*. Wageningen, Netherlands: Grafisch Service Centrum.

Simon, P.A., D.T. Jamison and M.A. Manning. (1990). *Gender differences in Goiter prevalence: A review*. Los Angeles, CA: University of California Press.

Sommer A. Tarwotjo I, Hussaini G, Susanto D, Soegiharto T. (1981). Incidence, prevalence, and scale of blinding malnutrition. *Lancet* 1: 1407-8

Sommer A Tarwotjo I, Djunaedi E, West KP, Loeden AA, Tilden R, Mele L. (1986). Impact of vitamin A supplementation on childhood mortality: A randomized controlled community trial. *Lancet* 1: 1169-73

Sundqvist J, Wijetunga M, Assey V, Gebre-Medhin M, Peterson S. (1988). Salt iodation and risk of neonatal brain damage, *Lancet*. 352(9121):34-35.

Tanzanian Census (1988). Dar Es Salaam: Bureau of Statistics, Ministry of Finance, Economic Affairs and Planning.

Thomas D Frankenberg E. (2002). Bulletin of the World Health Organization. 80.2: 106-113.

Thomas D, Frankenberg E, Friedman J, Habicht J-P, Hakimi M, Jaswadi, Jones N, McKelvey C, Pelto G, Sikoki B, Seeman T, Smith H, Sumantri C, Suriastini W, Wilopo S. (2003). Iron Deficiency and the Well Being of Older Adults: Early Results from a Randomized Nutrition Intervention. Mimeo, UCLA

UNICEF (2004). A pinch of salt can go further In West Africa. Press center: http://www.unicef.org/media/media_23686.html

Untoro, J, Schultink W, Gross R, West CE, Hautvast JG. (1998). Efficacy of different types of iodised oil, *Lancet*. 351(9104): 752-753, March 7.

Utiger, Robert D (1999). Maternal hypothyroidism and fetal development, *New England Journal of Medicine.* August; 341(8):601-602.

Van der Haar F, Kavishe P, Medhin MG (1988). The public health importance of IDD in Tanzania. Cent Afr J Med. Mar 34(3): 60-5.

Vermeersch, C (2003). School Meals, Educational Achievement and School Competition: Evidence from a Randomized Evaluation. Mimeo, University of Oxford.

West KP, Howard JR, Sommer A. (1989). Vitamin A and Infection: Public health implications. *Annual Reiew of Nutrition* 9: 63-86.

WHO (1991). National strategies for overcoming micronutrient malnutrition, EB 89/27.

WHO (1992). National strategies for overcoming micronutrient malnutrition, A45/17.

Zimmermann MB, Aeberli I, Torresani T, Burgi H. Increasing the iodine concentration in the Swiss iodized salt program markedly improved iodine status in pregnant women and children: a 5-y prospective national study. *American Journal of Clinical Nutrition*. Aug 2005;82(2):388-92.

Zoeller, RT and J. Rovet (2004). Timing of Thyroid Hormone Action in the Developing Brain: Clinical Observations and Experimental Findings [REVIEW ARTICLE]. *Journal of Neuroendocrinology* 16: 809–818.

Figure 1: Intervention districts

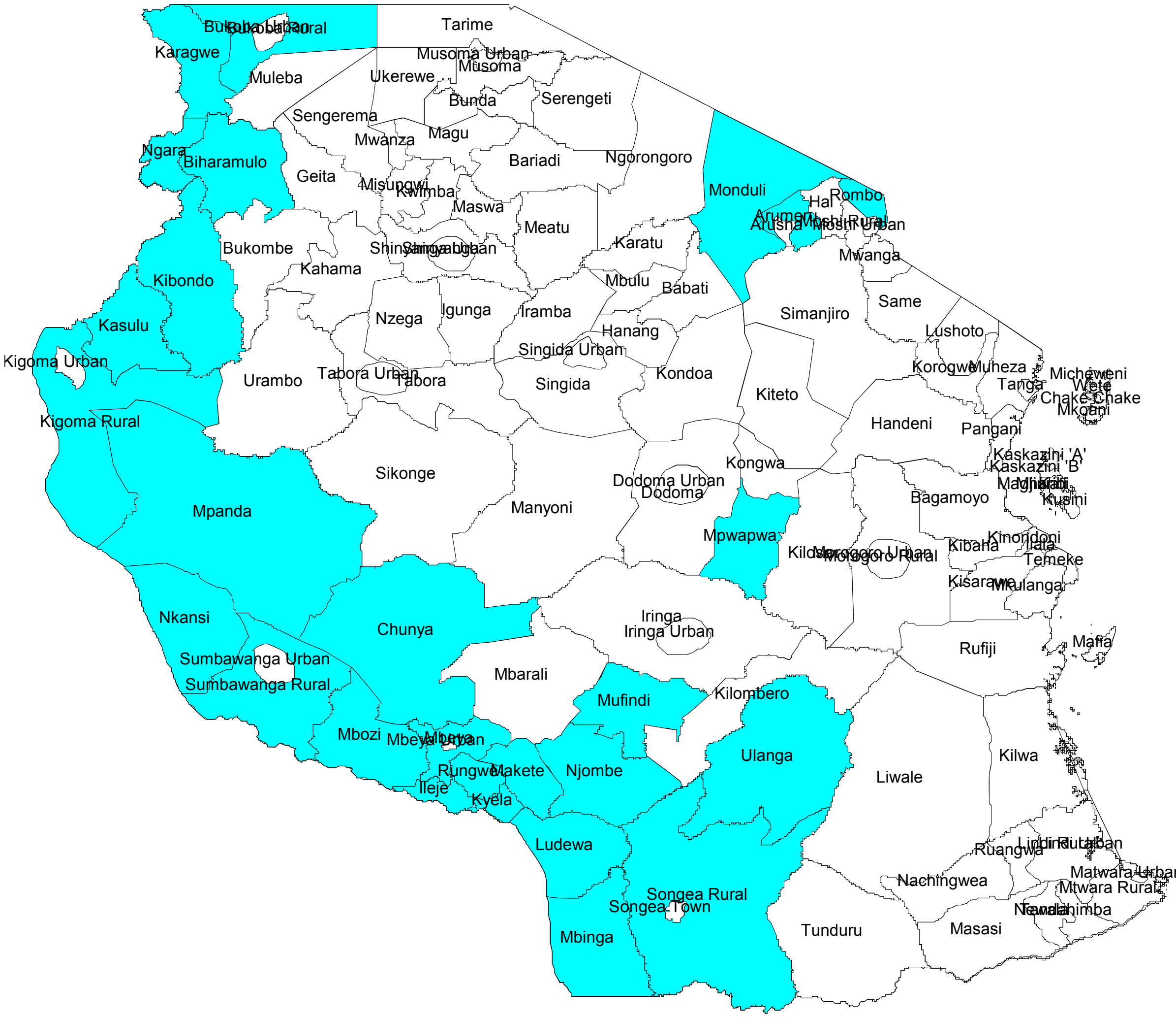
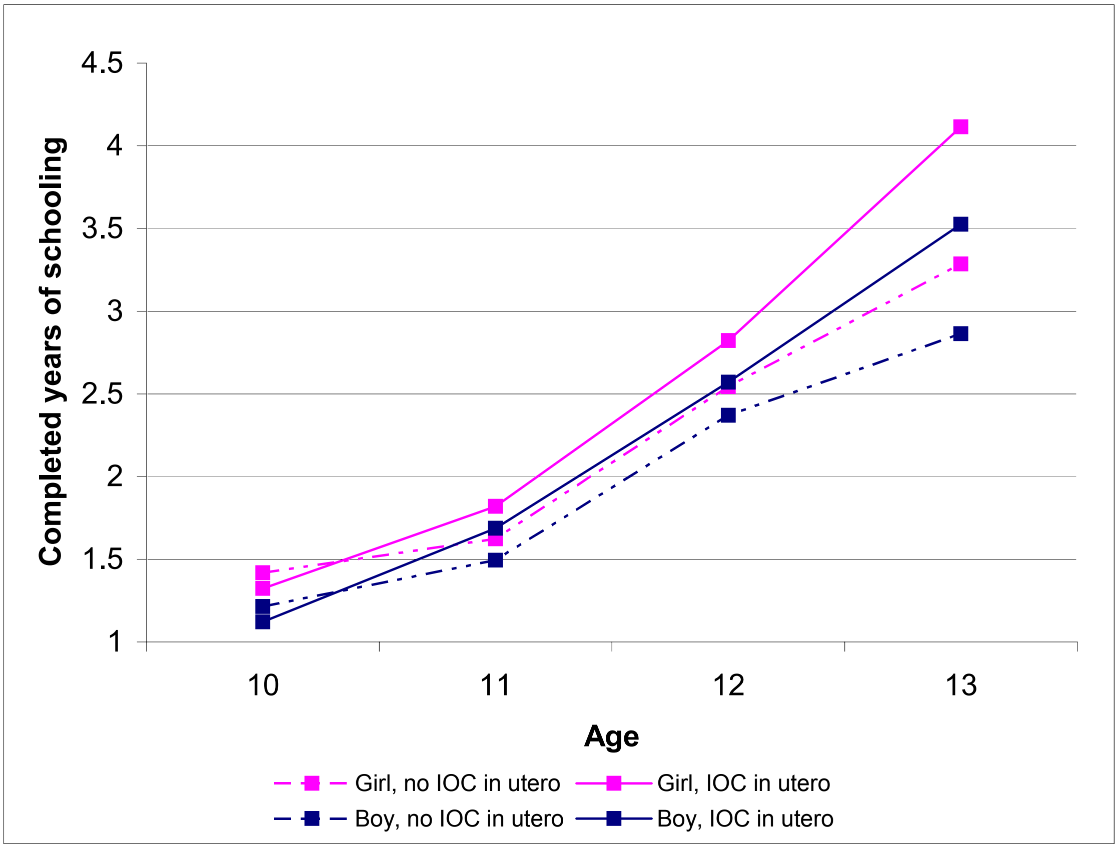
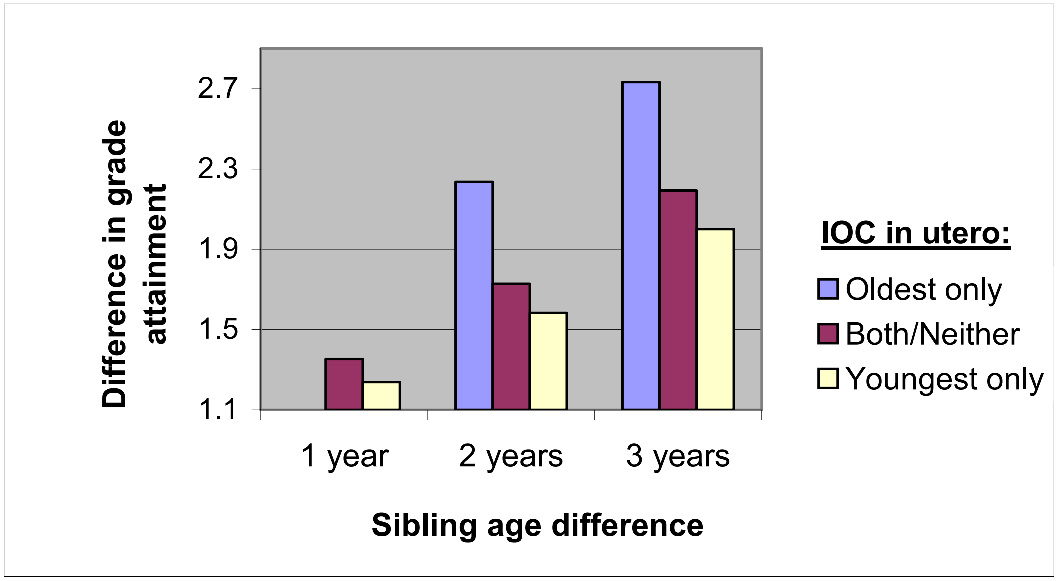


Figure 2: Grade progression by gender and IOC



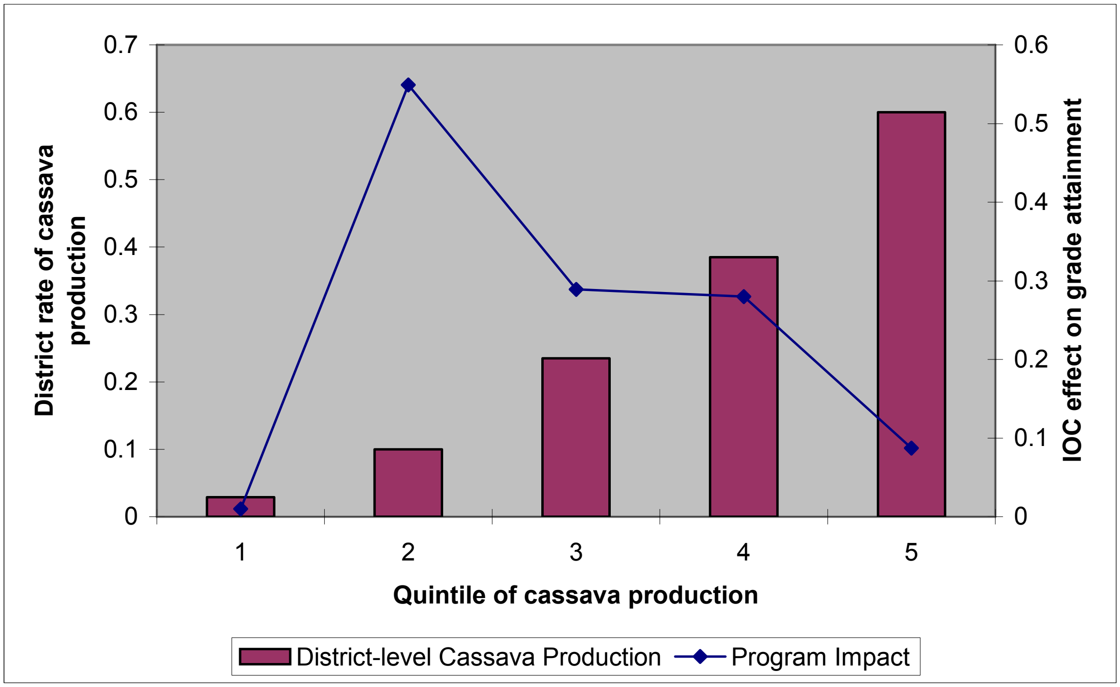
Notes: Data from the 2000 Tanzania Household Budget Survey. 2277 observations are all children in project districts between the ages of 10 and 13 that are children or grandchildren of the household head or spouse. X-axis is child age and y-axis is completed years of schooling. IOC in utero refers to whether iodized oil capsules distributed in district of residence 1 or 2 years prior to child's year of birth. Since IOC prevents maternal iodine deficiency for an estimated 24 months, IOC distributed 1-2 years before birth corresponds to higher likelihood of sufficient maternal iodine level in utero during first two trimesters of pregnancy, what is considered to be the critical intervention period.

Figure 3: Sibling differences in schooling by age difference and IOC



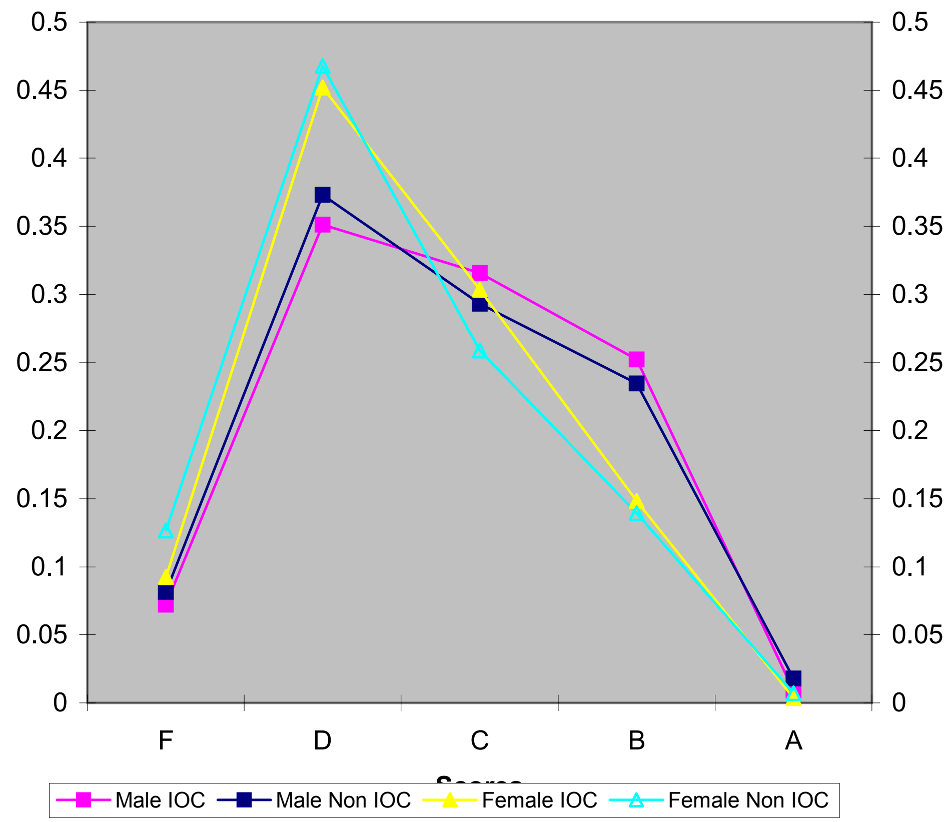
Notes: Data from the 2000 Tanzania Household Budget Survey. 576 observations comprise all sibling pairs in 25 pre-1994 project districts in which both children are between the ages of 10 and 13 and are children or grandchildren of the household head or spouse. Mother-child linkages are not perfectly recorded, so children may not be true siblings. Because month of birth is unobservable, there is no observable variation in likelihood of IOC in utero for siblings of same age. Hence, siblings of same age are excluded from the analysis. Y-axis is sibling difference in completed years of schooling. IOC categories refer to whether iodized oil capsules distributed in district of residence 1 or 2 years prior to the birth year of each child. Since IOC prevents iodine deficiency for 24 months, this corresponds to higher likelihood that sufficient maternal iodine levels in utero during first two trimesters of pregnancy, what is considered to be the critical intervention period.

Figure 4: Schooling Effect of IOC by District Level of Cassava Production



Notes: Data from the 2000 Tanzania Household Budget Survey. 2277 observations are all children in project districts between the ages of 10 and 13 that are children or grandchildren of the household head or spouse. Left-hand side Y-axis is district fraction of households that grow cassava, a highly goitrogenous food; right-hand side x-axis is point estimate of coefficient on IOC in regression of grade attainment on age, gender, birth order and IOC, run seperately for districts in five levels of cassava production. IOC in utero refers to whether iodized oil capsules distributed in district of residence 1 to 3 years prior to child's year of birth. Since IOC prevents maternal iodine deficiency for an estimated 24 months, IOC distributed 1-3 years before birth corresponds to higher likelihood of sufficient maternal iodine level in utero during first two trimesters of pregnancy, what is considered to be the critical intervention period.

Figure 5: PSLE Score Distribution by Gender and IOC participiation



Note: 2004 PSLE test scores were not available for the following districts-regions: Iringa Rural-Iringa, Iringa Urban-Iringa, Njombe-Iringa, Biharamulo-Kagera, Nyamagana-Nzega, Kiteto-Arusha, Namtumbo-Newala, Mvomero-Mwanga, Mufindi-Muheza, Mbulu-Arusha, Ngara-Kagera, Nkansi-Rukwa, Sumbuwanga-Rukwa, Ludewa-Lusoto, Makete-Manyoni, Mwete-Pemba, Cheke-Pemba, Micheweni-Pemba, Mjini-Pemba, Mkoani-Pemba. The grades awarded on the PSLE range from the top grade "A" to the lowest grade "E." At least one male received the highest score "A" on the PSLE in 81 of the districts; at least one female received the highest score "A" on the PSLE in 59 districts.

Figure 6: IDD Prevalence across African countries, 2000-2005

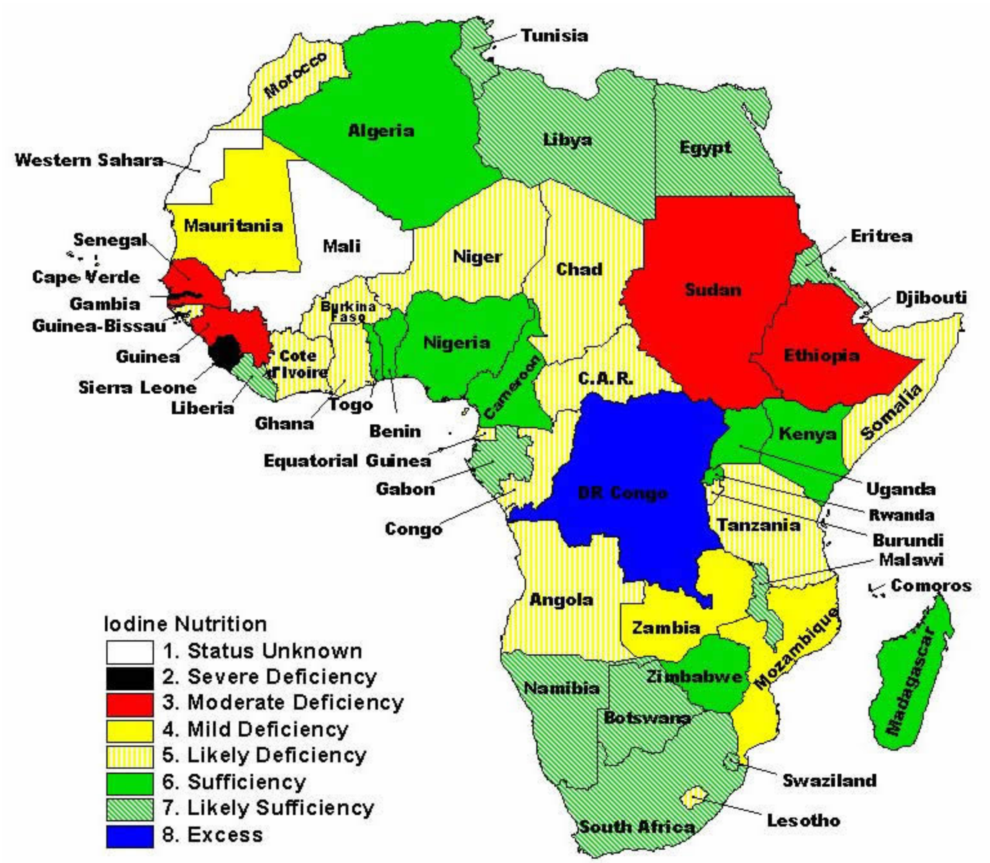


Figure 7: Fraction of households consuming iodized salt, 2000-2005

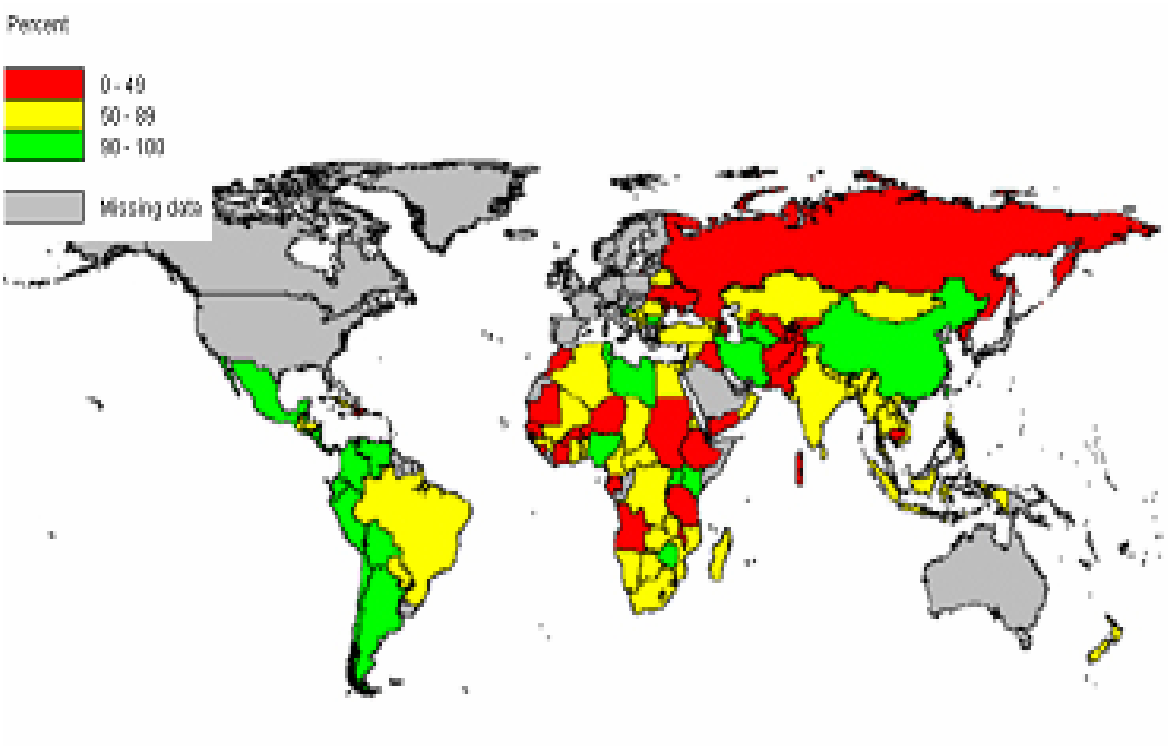


Table 1: Summary of Timing and Coverage of Intervention Across Districts

	Region	District	Year of Intervention (Coverage - %)*					Average Frequency (yr)
			1	2	3	4	5	
1	Dodoma	Mpwapwa	1990	1992				2.00
			(65)	(58)				
2	Arusha	Monduli	1992					n/a
			(71)					
3	Arusha	Arumeru	1991					n/a
			(89)					
4	Kilimanjaro	Rombo	1990					n/a
			(68)					
5	Morogoro	Ulanga	1988	1991	1992			1.33
			(73)	(61)	(34)			
6	Ruvuma	Songea Rural	1987	1991	1995			2.67
			(91)	(74)	(85)			
7*	Ruvuma	Mbinga	1995					n/a
			(92)					
8	Iringa	Mufindi	1986	1991	1995			3.00
			(41)	(63)	(54)			
9	Iringa	Makete	1986	1991	1993	1996		2.50
			(20)	(62)	(62)	(49)		
10	Iringa	Njombe	1989	1992	1995			2.00
			(76)	(68)	(64)			
11	Iringa	Ludewa	1989	1992	1995			2.00
			(59)	(62)	(47)			
12	Mbeya	Chunya	1990					n/a
			(49)					
13	Mbeya	Mbeya Rural	1986	1989	1990	1993	1997	1.75
			(44)	(84)	(90)	(53)	(53)	
14	Mbeya	Kyela	1989	1993				4.00
			(91)	(57)				
15	Mbeya	Rungwe	1986	1990	1993			2.33
			(35)	(73)	(49)			
16	Mbeya	Ileje	1989	1992				3.00
			(94)	(71)				
17	Mbeya	Mbozi	1989	1991				2.00
			(67)	(63)				
18	Rukwa	Mpanda	1987	1991	1993			2.00
			(79)	(60)	(72)			
19	Rukwa	Sumbawanga	1987	1990	1993	1996		2.25
			(76)	(89)	(72)	(51)		
20	Rukwa	Nkansi	1987	1991				4.00
			(89)	(49)				
21	Kigoma	Kibondo	1989	1992	1996			2.33
			(73)	(75)	n/a			
22	Kigoma	Kasulu	1987	1990	1996			3.00
			(50)	(66)	(49)			
23	Kigoma	Kigoma Rural	1991					n/a
			(91)					
24	Kagera	Karagwe	1990	1994				4.00
			(96)	(85)				
25*	Kagera	Bukoba Rural	1994					n/a
			(78)					
26	Kagera	Biharamulo	1990	1994				4.00
			(96)	(38)				
27	Kagera	Ngara	1989	1994				5.00
			(29)	(51)				
		Total	27	20	12	3	1	2.76

Notes: Dates and coverage rates collected from various Tanzanian Food and Nutrition Centre (TFNC) Zafari Reports stored in the archives of TFNC library. Coverage was calculated using 1988 Tanzanian Census data and adjusted for proportion of population in target age group.

Table 2: Summary Statistics by Timing of Intervention Across Districts

	IOC Program Timing				t_{Δ}
	No Program	1986-1987	1988-1989	1990-1995	2 - 4
Total members per household	4.86	5.02	4.58	5.08	-0.52
	(3.13)	(2.90)	(2.50)	(3.11)	
Head of household education	10.95	10.84	10.72	10.44	1.87
	(6.48)	(6.53)	(6.65)	(6.71)	
Enrollment (ages 5-15)					
Boys	65.4%	68.7%	63.2%	61.6%	4.00
Girls	67.0%	66.8%	67.4%	61.2%	3.09
Total	66.2%	67.7%	65.4%	61.4%	5.01
Urban	69.9%	52.2%	49.6%	56.8%	-2.83
Purchases of durables, services (Tsh - 12 mo)	32,362.47	21,341.32	25,126.56	25,626.35	-4.19
Head of household farmer	40.6%	56.8%	62.3%	55.8%	0.62
Main source of cash income					
Harvest crops	31.9%	53.1%	56.3%	43.8%	5.71
Business income	23.8%	17.8%	16.6%	15.8%	1.60
Wage income	21.5%	14.8%	12.1%	14.4%	0.35
Safe Water	73.15%	79.58%	73.63%	67.62%	8.52
Drinking water source					
Private Indoor	12.7%	7.4%	4.9%	4.5%	3.78
Private Outdoor	13.4%	11.3%	6.1%	9.4%	2.01
Community/Neighbor	31.7%	38.1%	33.6%	41.5%	-2.07
Private/Public Well	27.4%	30.3%	34.8%	25.5%	3.32
Hunger (self-reported)					
Never	33.3%	44.5%	43.9%	34.6%	6.26
Seldom	42.8%	39.1%	36.1%	42.9%	-2.37
Sometimes	7.2%	5.5%	7.8%	4.8%	0.99
Often	15.7%	10.3%	11.5%	16.7%	-5.87
Meals per day	2.74	2.51	2.49	2.48	1.45
	(0.48)	(0.53)	(0.52)	(0.55)	
Fish per week	2.27	1.87	1.59	1.79	1.48
	(1.80)	(1.59)	(1.45)	(1.84)	
Toilette facilities					
Flush toilette	9.1%	4.4%	2.8%	2.0%	3.97
Pit Latrine	84.2%	92.1%	90.8%	74.4%	-2.03
Illness in previous month					
Fever/Malaria	66.2%	60.4%	63.4%	67.6%	-5.42
Diarrhea	10.0%	11.0%	12.0%	12.2%	-1.39
Ear/Nose/Throat	7.1%	9.0%	8.7%	8.2%	1.08
Dirt floor	53.3%	65.5%	67.6%	68.0%	-1.81
Mudd or grass roof	36.7%	53.4%	46.2%	40.8%	8.87
Metal roof	60.3%	45.9%	53.6%	58.6%	-8.94
Distance to nearest Health Center (km)	2.29	2.78	2.33	2.59	1.39
Distance to nearest Hospital (km)	10.19	20.18	12.94	22.88	-2.73
Distance to nearest Primary School (km)	1.07	1.06	1.30	1.48	-5.76
Distance to nearest Secondary School (km)	1.63	2.59	3.41	3.88	-2.79
Observations	*17067*	*2152*	*819*	*1711*	

Source: 2000 Tanzanian Household Budget Survey (THBS). IOC Program refers to government-sponsored iodized oil capsule distribution that was in itiated between 1985 and 1995 in 27 districts of the country.

Table 3: Grade Attainment and IOC Supplementation in Utero

	Boys and girls	Boys	Girls	Boys and girls	Boys	Girls	Boys	Girls
IOC in utero	0.357	0.315	0.77	0.157	-0.027	0.383		
(IOC in utero =born 1-3 years after program)	[0.142]*	[0.267]	[0.298]*	[0.112]	[0.154]	[0.166]*		
IOC in utero							-0.023	0.408
(IOC in utero =born 1-2 years after program)							[0.177]	[0.187]*
Age 11	0.558	0.571	0.743	0.401	0.45	0.296	0.451	0.251
	[0.140]**	[0.272]*	[0.256]**	[0.091]**	[0.125]**	[0.135]*	[0.126]**	[0.135]
Age 12	1.293	1.237	1.531	1.18	1.206	1.148	1.209	1.08
	[0.118]**	[0.216]**	[0.234]**	[0.086]**	[0.120]**	[0.124]**	[0.121]**	[0.125]**
Age 13	2.049	1.952	2.657	1.866	1.714	2.015	1.719	1.941
	[0.148]**	[0.278]**	[0.293]**	[0.096]**	[0.132]**	[0.141]**	[0.127]**	[0.134]**
Female	0.247			0.213				
	[0.090]**			[0.063]**				
Mother < age 23 at birth	-0.195	0.128	-0.31	0.071	0.022	0.11	0.024	0.093
	[0.202]	[0.356]	[0.501]	[0.070]	[0.096]	[0.103]	[0.095]	[0.101]
Number same sex siblings				0.208	0.187	0.25	0.187	0.258
				[0.076]**	[0.104]	[0.113]*	[0.104]	[0.113]*
Fixed effects	*House-hold*	*House-hold*	*House-hold*	*District*	*District*	*District*	*District*	*District*
Observations	*2251*	*1154*	*1097*	*2251*	*1154*	*1097*	*1154*	*1097*

Notes: Data from the 2000 Tanzanian Household Budget Survey, sample restricted to children ages 10-13 in 27 districts targetted for iodized oil capsule (IOC) distribution between 1986 and 1995. In columns 1-6, IOC in utero is equal to 1 or 0.5 (depending on mother's age at birth) if a child was born 1-3 years after IOC was distributed in the district; in columns 7-8, IOC in utero is equal to 1 or 0.5 (depending on mother's age at birth) if a child was born 1-2 years after IOC was distributed in the district. All regressions control for birth order and sex-specific birth order. * significant at 5%; ** significant at 1%

Table 4: Difference in Grade Attainment and IOC Supplementation By Birth Order

IOC in utero, eldest only	0.383	0.383
	(0.201)*	(0.212)*
IOC in utero, youngest only	-0.225	-0.225
	(0.129)*	(0.134)*
IOC in utero, both		-0.001
		(0.127)
Age difference = 1 year	0.616	0.616
	(0.176)**	(0.176)**
Age difference = 2 years	0.99	0.99
	(0.160)**	(0.159)**
Age difference = 3 years	1.333	1.333
	(0.197)**	(0.198)**
Age oldest	0.157	0.157
	(0.057)**	(0.088)**
Both female	-0.041	-0.041
	(0.123)	(0.124)
Both male	-0.115	-0.115
	(0.117)	(0.117)
Birth order	-0.008	-0.008
	(0.030)	(0.030)
Observations	*667*	*667*

Notes: Data from the 2000 Tanzanian Household Budget Survey, sample restricted to children ages 10-13 in 25 districts targetted for iodized oil capsule (IOC) distribution between 1986 and 1992. Observations are sibling pairs from 667 different households in sample in which more than one child between 10 and 13. To balance sample across treatment orders, in households with more than one sibling pair, pair in which older sibling treated and younger not was selected first, pair in which younger sibling treated and yolder not treated was selected second, otherwise two siblings chosen at random.

Table 5: Variation in Effect on Schooling of IOC Supplementation in Utero

	Rate of Cassava Consumption in District			*Amount of IOC*	
	High (0.41-0.62)	Medium (0.10-0.40)	Low (< 0.10)	Mother>22 at birth (380 mg)	Mother<23 at birth (200 mg)
IOC in utero	0.046	0.508	-0.02	0.431	0.066
(IOC in utero =born 1-3 years after program)	(0.391)	(0.165)**	(0.252)	(0.198)*	(0.199)
Female	0.417	0.172	0.154	0.252	0.304
	(0.188)*	(0.146)	(0.148)	(0.146)	(0.156)
Age 11	0.68	0.46	0.451	0.783	0.401
	(0.281)*	(0.222)*	(0.245)	(0.225)**	(0.242)
Age 12	1.64	1.224	0.967	1.524	1.232
	(0.241)**	(0.179)**	(0.205)**	(0.195)**	(0.210)**
Age 13	2.086	2.051	1.724	2.27	1.684
	(0.298)**	(0.232)**	(0.295)**	(0.253)**	(0.263)**
Household fixed effects	yes	yes	yes	yes	yes
Observations	*669*	*804*	*778*	*983*	*799*

Notes: Data from the 2000 Tanzanian Household Budget Survey, sample restricted to children ages 10-13 in 27 districts targetted for iodized oil capsule (IOC) distribution between 1986 and 1995. Children and women below age 23 were given IOC containing 200mg of iodine and women over 22 were given IOC containing 380 mg of iodine. In all regressions, IOC in utero is equal to one if a child was born 1-3 years after IOC was distributed in the district. Regressions also control for birth order and sex-specific birth order. Rate of cassava consumption defined as fraction of THBS households in district that report growing cassava.

Table 6: Control Experiment, IOC Distribution and Grade Attainment of Older Cohort

				Rate of Cassava Consumption in District		
	Boys and girls	Boys	Girls	*High*	*Medium*	*Low*
IOC in utero	-0.021	0.058	-0.035	-0.002	0.070	-0.021
(IOC in utero =born 1-3 years after program)	(0.020)	(0.037)	(0.036)	(0.058)	(0.057)	(0.039)
Age 11	0.647	0.672	0.563	0.691	0.67	0.55
	(0.023)**	(0.045)**	(0.043)**	(0.043)**	(0.040)**	(0.040)**
Age 12	1.505	1.51	1.351	1.458	1.573	1.416
	(0.027)**	(0.055)**	(0.053)**	(0.050)**	(0.046)**	(0.047)**
Age 13	2.38	2.372	2.225	2.377	2.424	2.248
	(0.035)**	(0.072)**	(0.069)**	(0.062)**	(0.059)**	(0.063)**
Female				0.251	0.288	0.267
				(0.027)**	(0.025)**	(0.024)**
Household fixed effects	*yes*	*yes*	*yes*	*yes*	*yes*	*yes*
Observations	*113932*	*57613*	*56319*	*37144*	*36900*	*39888*

Notes: All data except for cassava consumption from the 1988 Census of Population and Housing, sample restricted to children ages 10-13 in 1988 in 27 districts targetted for iodized oil capsule (IOC) distribution between 1986 and 1995. Cassava data from the 2000 Tanzanian Household Budget Survey. Rate of cassava consumption defined as fraction of THBS households in district that report growing cassava. In all regressions, IOC in utero is equal to one if a child was born 9-11 years before IOC was distributed in the district. Regressions also control for birth order and sex-specific birth order.

Table 7: Effect of IOC Distribution on Reported Health Status

	Whether any sickness last 4 weeks	*Whether fever*	*Whether diarrhea*	*Whether ear/nose/throat condition*	*Whether eye condition*	*Whether skin condition*	*Whether dental condition*	*Whether accident-related condition*	*Whether other health problem*	*Days school/work missed due to illness*
IOC in utero	0.013	0.039	-0.017	-0.011	0.007	0.008	-0.009	0.008	-0.008	-0.062
(IOC in utero =born 1-3 years after program)	[0.038]	[0.033]	[0.013]	[0.014]	[0.008]	[0.011]	[0.008]	[0.006]	[0.019]	[0.153]
Age 11	-0.026	0.043	-0.015	-0.002	-0.011	0	-0.012	-0.003	-0.016	-0.01
	[0.044]	[0.038]	[0.015]	[0.016]	[0.010]	[0.013]	[0.010]	[0.007]	[0.022]	[0.182]
Age 12	-0.002	-0.018	-0.018	-0.013	-0.001	0.012	0.005	0.005	0.01	0.135
	[0.037]	[0.031]	[0.013]	[0.013]	[0.008]	[0.010]	[0.008]	[0.006]	[0.018]	[0.202]
Age 13	0.002	0.036	-0.023	0	-0.015	0.003	-0.005	0.003	0.018	0.161
	[0.047]	[0.040]	[0.016]	[0.017]	[0.010]	[0.013]	[0.010]	[0.008]	[0.023]	[0.222]
Household fixed effects	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Observations	2277	2277	2277	2277	2277	2277	2277	2277	2277	2277

Notes: Outcome is whether child reported by respondent to have experienced any of above health problems during last four weeks; last column is amount of absence due to sickness during 4 weeks, a four-category variable indicating: none, 0-1 week, 1-2 weeks, and 2-4 weeks. All data from the 2000 Tanzanian Household Budget Survey, sample restricted to children ages 10-13 in 1988 in 25 districts targetted for iodized oil capsule (IOC) distribution between 1986 and 1992. In all regressions, IOC in utero is equal to one if born 1-2 years before IOC distributed in district. Regressions also control for sex, birth order and sex-specific birth order.

Table 8: Grade Attainment and IOC Supplementation in Utero, 2004

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Grade attainment, ages 10-14			*Grade attainment, ages 10-12*			*Enter secondary school, ages 10-14*		
	All	Girls	Boys	All	Girls	Boys	All	Girls	Boys
IOC in utero	0.487	0.870	0.403	0.189	1.604	0.276	0.081	0.139	0.096
	[0.184]**	[0.424]*	[0.331]	[0.150]	[0.606]*	[0.662]	[0.031]**	[0.081]+	[0.058]+
Age 11	0.317	0.302	0.405	-0.191	-0.593	0.585	-0.016	-0.045	0.02
	[0.108]**	[0.247]	[0.195]*	[0.098]+	[0.454]	[0.420]	[0.018]	[0.047]	[0.034]
Age 12	0.94	0.884	1.135	-0.124	0.644	1.203	-0.001	-0.098	0.065
	[0.124]**	[0.300]**	[0.226]**	[0.086]	[0.547]	[0.441]**	[0.021]	[0.058]+	[0.040]
Age 13	1.349	1.682	1.267				0.035	-0.03	0.102
	[0.166]**	[0.428]**	[0.307]**				[0.028]	[0.082]	[0.054]+
Age 14	2.036	2.185	2.152				0.117	0.005	0.234
	[0.202]**	[0.507]**	[0.375]**				[0.034]**	[0.097]	[0.066]**
Month of birth	-0.027	-0.051	-0.024	0.003	-0.030	0.018	-0.002	-0.005	-0.004
	[0.010]**	[0.023]*	[0.017]	[0.009]	[0.031]	[0.029]	[0.002]	[0.004]	[0.003]
Female	0.352			0.309			0.015		
	[0.062]**			[0.060]**			[0.010]		
Household fixed effects	yes	yes	yes	yes	yes	yes	yes	yes	yes
Observations	*3672*	*1797*	*1875*	*4984*	*1147*	*1178*	*3672*	*1797*	*1875*

Notes: Data from the 2004 Tanzanian Demographic and Health Survey, sample restricted to children ages 10-14. IOC in utero is equal to (birth month/12) if a child was born 1-3 years after IOC was distributed in the district. All regressions control for dummy indicators of birth order and sex-specific birth order. + significant at 10%; * significant at 5%; ** significant at 1%.

Table 9: Male and Female PSLE Performance by IOC Intervention

Dependent Variable:	ln (number individuals taking PSLE)		ln(number individuals with passing grade on PSLE)		ln (number of individuals with grade "F" on PSLE)[1]		ln (number of individuals with grade "A" on PSLE)[1]	
	Female	Male	Female	Male	Female	Male	Female	Male
IOC Intervention between 1986-1992	0.12	0.10	0.22 *	0.14 *	-0.92 ***	-0.84 ***	-0.30	0.01
	(0.09)	(0.09)	(0.11)	(0.08)	(0.27)	(0.28)	(0.39)	(0.42)
Percent of population below poverty line (%), 2000/01	-0.05	-0.16	0.33	0.53	-0.58	-1.03	0.33	1.45
	(0.36)	(0.35)	(0.46)	(0.32)	(1.13)	(1.15)	(1.59)	(1.71)
Gini coefficient, 2000/01	0.99	1.19	-0.49	1.64	3.28	-3.21	3.45	9.80
	(1.38)	(1.38)	(1.74)	(1.24)	(4.31)	(4.54)	(6.06)	(6.71)
Male secondary school attainment rate, 1988		-1.74 *		1.29 *		-5.26 *		-0.52
		(0.88)		(0.77)		(2.81)		(4.15)
Female secondary school attainment rate, 1988	-2.07 *		4.24 ***		-12.44 ***		1.77	
	(1.23)		(1.48)		(3.66)		(5.15)	
ln(2002 population males 10-14)		0.57 ***						
		(0.04)						
ln(2002 population females 10-14)	0.58 ***							
	(0.04)							
ln(2004 population male test-takers)				0.93 ***		1.68 ***		1.53 ***
				(0.05)		(0.18)		(0.27)
ln(2004 population female test-takers)			0.91 ***		1.67 ***		1.20 ***	
			(0.07)		(0.17)		(0.24)	
[2] *Observations*	*83*	*83*	*83*	*83*	*83*	*83*	*83*	*83*

Notes:

[1] The grades awarded on the PSLE range from the top grade "A" to the lowest grade "E." We have altered the lowest grade from "E" to "F" to match the U.S. grading system for ease of comprehension. The top grade of "A" and lowest grade of "E" were not received in several districts: no females received a top grade "A" in 28 region-districts, no males received a top grade of "A" in 11 region-districts and no males received the lowest grade of "E" in one region-district. The dependent variable was adjusted to zero [ln(0) = 0] in cases where the natural log would otherwise be undefined in the above-mentioned region-districts.

[2] 2004 PSLE test scores were not available for the following districts-regions: Iringa Rural-Iringa, Iringa Urban-Iringa, Njombe-Iringa, Biharamulo-Kagera, Nyamagana-Nzega, Kiteto-Arusha, Namtumbo-Newala, Mvomero-Mwanga, Mufindi-Muheza, Mbulu-Arusha, Ngara-Kagera, Nkansi-Rukwa, Sumbuwanga-Rukwa, Ludewa-Lusoto, Makete-Manyoni, Mwete-Pemba, Cheke-Pemba, Micheweni-Pemba, Mjini-Pemba, Mkoani-Pemba. At least one male received the highest score "A" on the PSLE in 81 of the districts; at least one female received the highest score "A" on the PSLE in 59 districts. 2002 Census data is not available for the following districts-regions: Ilala-Dar es Salaam, Kinondoni-Dar es Salaam, Temeke-Dar es Salaam, Kibaha-Pwani, Mwanza-Mwanza, Tabora Rural-Tabora, Tanga Urban-Tanga. 1988 Census data is not available for the following districts-regions: Bukombe-Shinyanga, Karatu-Arusha, Mbarali-Mbeya, Misungwi-Mwanza, Sikonge-Tabora, Simanjiro-Manyara, Tandahimba-Mtwara.

* Significant at 10% ** Significant at 5% *** Significant at 1%

Sources:

Dependent variable in columns 1 and 2 is the number of girls/boys who take the 2004 PSLE; dependent variable in columns 3 and 4 is the number of students who receive a passing grade of A, B, C on the PSLE. Secondry school enrollment rate in 1988 is fraction of girls/boys enrolled in form 1 or above from the 1988 Census (National Bureau of Statistics). Data on female/male populations age 10-14 come from the 2002 Census (National Bureau of Statistics); 2004 PSLE Examination Statistics from the National Examinations Council of Tanzania.

Table 10: 2000 School Participation by Gender

Dependent Variable:	2000 Primary School Participation				2000 Secondary School Participation			
	Female (1)	Male (2)	Female (3)	Male (4)	Female (5)	Male (6)	Female (7)	Male (8)
[1] TGR	0.025	0.093	0.010	0.085	-0.241 **	-0.158	-0.250 **	-0.161
	(0.123)	(0.114)	(0.120)	(0.114)	(0.115)	(0.125)	(0.115)	(0.126)
[2] % Household use of adequately iodized salt			0.137 **	0.091			0.075	0.021
			(0.068)	(0.066)			(0.066)	(0.073)
1980 Female Primary School Participation	0.229 ***		0.221 ***		0.231 **		0.232 **	
	(0.080)		(0.078)		(0.10)		(0.10)	
1980 Male Primary School Participation		0.273 ***		0.255 ***		0.180 *		0.182 *
		(0.073)		(0.073)		(0.107)		(0.108)
Prevelance of Malaria (2000/01)	9.087	-6.512	11.033	-5.640	-6.946	-4.864	-5.734	-4.511
	(14.333)	(13.520)	(14.046)	(13.443)	(13.509)	(14.631)	(13.524)	(14.783)
Prevalence of HIV (2003)	0.574	0.471	0.479	0.410	0.714	0.486	0.655	0.470
	(0.350)	(0.314)	(0.345)	(0.315)	(0.317)	(0.342)	(0.321)	(0.349)
Urban Population (1990 - % of Total)	0.200	0.039	0.232	0.060	0.861	0.751	0.877	0.755
	(0.133)	(0.124)	(0.131)	(0.124)	(0.131)	(0.138)	(0.008)	(0.140)
Population Density (1990 - per sq. km)	-0.024	0.012	0.028	0.014	0.006	-0.002	0.008	-0.001
	(0.020)	(0.019)	(0.020)	(0.019)	(0.020)	(0.022)	(0.020)	(0.022)
Log GDP per capita (1990 - Constant LCU)	15.521	13.383	11.507	10.779	14.767	14.869	12.599	14.278
	(6.810)	(6.407)	(6.950)	(6.637)	(6.506)	(7.138)	(6.771)	(7.468)
Log GDP per capita ^{2} (1990)	-1.865	-1.434	-1.482	-1.187	-1.706	-1.649	-1.501	-1.593
	(0.785)	(2.881)	(0.790)	(0.753)	(0.748)	(0.821)	(0.768)	(0.848)
[3] Terms of Trade (1980)	5.832	4.337	7.097	5.106	6.225	5.498	6.956	5.711
	(3.092)	(2.881)	(3.087)	(2.915)	(2.884)	(3.134)	(2.951)	(3.239)
Region Effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
[4] *Observations*	*81*	*81*	*81*	*81*	*81*	*81*	*81*	*81*

Notes:

1 TGR is a reported measure of TGR prior to 1995.

2 Reported % of households using adequately iodized salt in mid-1990s.

3 Terms of Trade is the ratio of the Export Value Index and Import Value Index for year 2000.

4 [illegible] primary school enrollment data; 14% of countries were missing secondary school participation data; and 15% were missing other variables included in the above analysis.

Sources:

Enrollment data is from the World Bank's WDI database and supplemented by data from UNESCO (United Nations Educational, Scientific and Cultural Organization) and NBER (National Bureau of Economic Research). Other national statistic data is from the World Bank's WDI database and supplemented by data from the WHO (World Health Organization) and UN (United Nations). Information on goiter rates and salt legislation years were culled from the Current Iodine Deficiency Status (CIDDS) database maintained by the International Council for the Control of Iodine Deficiency Disorders and supplemented by the WHO's Micronutrient Deficiency Information System.

Table 11: Projected impact on school participation worldwide

Country	% of households using adequately iodized salt	Year	Total Goiter Rate [1]	TGR Year	Population [2] 5-9 yr 2002	Expected Treated Population [3]	Total increase in grade attainment [4]	National percentage increase [5]	Weighted increase in grade attainment [6]	Wt. increase relative to Central Africa
Algeria	92.0	1995	48	1995	3,628	3,204	2,328	11.9%	0.25%	
Argentina	92.0	1996	19.0	1995	3,373	1,179	857	2.9%	0.06%	
Bangladesh	44.0	1995	10.5	1982	13,782	1,273	925	2.6%	0.21%	
Bhutan	82.0	1996	21.0	1988	276	95	69	2.8%	0.00%	
Croatia	70.0	1997	20.0	1995	267	75	54	3.2%	0.01%	
Indonesia	62.1	1997	25.0	1988	23,114	7,177	5,214	4.5%	0.61%	
Jordan	95.0	1997	37.7	1993	677	485	352	7.5%	0.03%	
Kazakhstan	52.9	1995	52.1	1993	1,379	760	552	4.5%	0.04%	
Kyrgyz Republic	27.0	1997	49.1	1993	530	141	102	2.4%	0.01%	
Malawi	58.1	1995	51.2	1993	1,734	1,032	749	13.5%	0.14%	
Malaysia	85.0	1998	36.9	1993	2,618	1,642	1,193	6.7%	0.10%	
Maldives	55.0	1999	23.6	1995	49	13	9	2.7%	0.00%	
Mongolia	46.0	1999	22.0	1993	256	52	38	1.8%	0.00%	
Myanmar	64.8	1997	33.1	1994	4,019	1,724	1,253	11.3%	0.26%	
Nicaragua	86.1	1998	35.8	1994	653	403	292	9.8%	0.04%	
Oman	35.0	1996	10.0	1994	376	26	19	0.6%	0.00%	
Pakistan	19.0	1995	13.2	1990	19,761	991	720	0.9%	0.11%	
Panama	91.6	1996	13.2	1990	302	73	53	2.1%	0.00%	
Paraguay	64.0	1995	48.7	1988	762	475	345	7.3%	0.03%	
Philippines	14.6	1996	29.5	1991	10,180	877	637	0.8%	0.05%	
Russian Federation	30.0	2000	50	1990	7,069	2,121	1,541	2.2%	0.09%	
Syrian Arab Republic	40.0	2000	42	1994	2,152	723	525	4.2%	0.05%	
Thailand	60.2	1999	32	1992	5,264	2,028	1,473	4.3%	0.13%	
Tunisia	63.0	1996	30.5	1988	926	356	259	5.6%	0.03%	
Turkey	18.2	1995	23.0	1994	6,274	525	382	1.1%	0.04%	
Uzbekistan	16.7	1996	17.2	1981	2,906	167	121	0.5%	0.01%	
Venezuela, RB	90.0	1998	39.7	1986	2,601	1,859	1,350	7.8%	0.12%	
Vietnam	49.4	1996	22.0	1993	8,312	1,807	1,313	4.1%	0.20%	
Central Africa:					*48,996*	*9,863*	*7,166*		*1.50%*	
Botswana	60.2	1994	16.5	1994	214	43	31	2.3%	0.00%	0.01%
Burundi	80.0	1993	30	1990	932	447	325	25.3%	0.14%	0.48%
Cameroon	82.5	1998	26.5	1993	2,142	937	680	9.0%	0.11%	0.39%
Congo, Dem. Rep.	12.3	1995	20.0	1995	8,806	433	315	0.7%	0.04%	0.12%
Cote d'Ivoire	31.0	2000	43	1992	2,490	664	482	4.8%	0.07%	0.25%
Gabon	15.0	2000	34.4	1989	179	18	13	1.2%	0.00%	0.00%
Guinea	36.8	1996	26.4	1992	1,277	248	180	16.8%	0.12%	0.44%
Kenya	100.0	1995	16.3	1984	4,420	1,441	1,047	5.6%	0.14%	0.51%
Lesotho	73.0	1996	42.9	1993	234	147	106	10.8%	0.01%	0.05%
Mozambique	62.0	1995	34.5	1991	2,409	1,031	749	28.0%	0.39%	1.38%
Namibia	59.0	1996	34.5	1990	270	110	80	3.0%	0.00%	0.02%
Niger	7.4	1996	20.0	1993	1,661	49	36	2.1%	0.02%	0.07%
Nigeria	83.2	1995	10.0	1993	18,766	3,123	2,269	2.4%	0.26%	0.93%
Tanzania	73.8	1995	15.3	1991	5,196	1,173	852	6.1%	0.18%	0.64%
Total	7.4				172,236	41,145	29,892		4.11%	5.29%

Notes:

1 Only countries with goiter rates similar in magnitude to Tanzania are included in the analysis. Countries with significantly lower goiter rates than Tanzania are not likely to benefit similarly from adequately iodized salt since the severity of IDD is likely to be considerably lower. Countries with significantly larger goiter rates are likely to have larger benefits if salt is adequately iodized since the severity of IDD is likely to be considerably higher. However, these countries may have lower or no benefits if salt is not properly iodized to combat the severity of IDD.

2 Population (000's) is limited to children 5-9 yrs old in 2002 on the premise that this population will be eligible for secondary school participation in 2010 at the ages of 13-17.

3 This is the expected number of children (000's) that received adequately iodized salt in treatment of IDD. The rate of en utero IDD is assumed to be twice the TGR (Total Goitre Rate). The reasoning behind this assumption is that the rate of IDD is larger for women and the rate of IDD en utero occurs more quickly than adult IDD. The number of children suffering from IDD is calculated as the rate of en utero IDD times the population of children. The number of protected children is calculated by taking the number of children suffering from IDD and multiplying it times the fraction of households using adequately iodized salt.

4 The observed increase in grade attainment (.34 yrs) in Tanzanian IOC districts is used as a baseline measure of grade attainment (yrs) for countries. This baseline is adjusted for the estimated participation of 78% in the target population of Tanzania as well as the estimated TGR level in Tanzania (30%). The total increase in grade attainment (yrs) is the product of the number of protected children times the expected average increase in years of schooling (.73 yrs).

5 This is the percentage increase in grade attainment for the national relevant age-group population.

6 This is the population-weighted average increase in grade attainment using the relevant age-group population of all affected countries.

7 This is the proportional increase in grade attainment relative to the total grade attainment of all relevant age-group population in affected Central Africa.

Sources:

Information on goiter rates and salt legislation years were culled from the Current Iodine Deficiency Status (CIDDS) database maintained by the International Council for the Control of Iodine Deficiency Disorders and supplemented by the WHO's Micronutrient Deficiency Information System. Population data is from the *Global Population Profile: 2002 report by the* International Programs Center (IPC), Population Division, U.S. Census Bureau. Baseline education information was obtained from the Barro-Lee Educational Attainment Data (1960 - 2000) available at the National Bureau of Economic Research.