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Impact of delivering iron-fortified salt through a school feeding program on child health, education and cognition: Evidence from a randomized controlled trial in rural India

Marion Krämer[1], Santosh Kumar[2], Sebastian Vollmer[3]

Abstract

We present experimental evidence on the impact of delivering double-fortified salt (DFS), salt fortified with iron and iodine, through the Indian school-feeding program called "midday meal" on anemia, cognition and math and reading outcomes of primary school children. We conducted a field experiment that randomly provided one-year supply of DFS at a subsidized price to public primary schools in one of the poorest regions of India. The DFS treatment had significantly positive impacts on hemoglobin levels and reduced the prevalence of any form of anemia by 9.3 percentage points (or about 20 percent) but these health gains did not translate into statistically significant impacts on cognition and test scores. While exploring the heterogeneity in effects, we find that treatment had statistically significant gains in anemia and test scores among children with higher treatment compliance. We further estimate that the intervention was very cost effective and can potentially be scaled up rather easily.

Keywords: Double-fortified salt, education, anemia, school feeding, India and randomized controlled trial.

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1. Introduction

Adequate nutrition, both in terms of micro- and macro-nutrients, is critical for human capital formation, which broadly includes education, cognitive skills, and health of individuals (Becker 1962). Many studies have emphasized the importance of early life nutritional interventions on formation of human capital (Bloom, Canning and Jamison 2004, Currie and Vogl 2013, Miguel and Kremer 2004, Baird, et al. 2016), particularly because their effects are thought to accumulate over time (e.g. Maluccio, et al. 2009 for a protein-energy intervention; Lozoff, et al. 2006 for iron supplementation). Iron deficiency anemia (IDA) is a particularly widespread nutritional deficiency with 20 percent of the world's population being anemic, with anemia prevalence among school-aged children being as high as 50 percent (World Health Organization 2008). The global prevalence of anemia in children aged 6-59 months is 43% and anemia prevalence rate of 59% in India is substantially above the global average (International Institute for Population Sciences 2015). IDA is considered a leading risk factor for childhood mortality and morbidity and is linked to impaired brain development and cognitive functions (Halterman, et al. 2001, Bobonis, Miguel and Puri-Sharma 2006).

There is a strong biological basis for the positive impacts of increased iron consumption on health and cognitive development (e.g. Beard 2008; Kretchmer, et al. 1996). Different strategies and technologies have been proposed to increase iron intake, for example nutritional supplements, different fortified products, and dietary diversification. Various means to deliver these products have also been tested through retail markets, agricultural extensions, and public institutions such as hospitals or schools. Salt is a very promising channel to deliver iron due to the steady consumption of salt, irrespective of location, socioeconomic status or food preferences. In contrast to supplementation, fortified products are believed to have a high compliance as they are a substitute for the conventional product. However, empirical evidence shows that if people are given the choice between conventional and fortified salt, they do not necessarily choose the fortified option. Banerjee et al. (2014) offered double-fortified salt (DFS), salt fortified with iron and iodine, to rural populations in Bihar, India at a subsidized price through regular local shops and the Public Distribution System (local shops in which people identified as poor by means-testing are entitled to buy certain food items at subsidized prices), and found relatively low take-up rates in both delivery channels.

In another study, Banerjee et al. (2016) provided DFS directly to rural households in Bihar. After two years of treatment, they did not find "an economically meaningful or statistically significant impact on hemoglobin, anemia, physical health, cognition or mental health". In contrast, Thomas et al. (2006) found large positive impacts of iron supplementation in a study in Indonesia that had high compliance and large dosage. The insignificant impacts on health outcomes in Banerjee et al. (2016) could be either due to low take-up rates or smaller dosage of iron delivered through fortification. The mixed evidence suggests that understanding proper delivery of effective technologies to combat anemia is important because adoption of new technologies often depends on household's learning and preference.

In this paper, we examine another potential channel to increase iron intake – India's school feeding program, the "midday meal" (MDM). The MDM is provided free of charge to all school children that attend a public school up to grade eight. In some schools the MDM is provided through a centralized kitchen and in others it is cooked directly in the school-kitchen. Similar to Banerjee et al. (2014, 2016) the setting of our study is Bihar. We selected two blocks in Jehanabad district where the MDM is directly cooked in schools,. We supplied DFS for one school year to 54 primary schools that were randomly allocated to the treatment group at a subsidized price for preparation of the MDM, and we had a control group of the same size. We analyzed the impact of the DFS intervention on hemoglobin and anemia, cognitive ability, and education outcomes of children who were in the second grade at the baseline. The baseline data was collected between November 2014 and January 2015, treatment started in August 2015, and the follow-up survey was implemented after a year in August 2016.

The main rationale for considering the MDM as distribution channel of iron, and potentially other micronutrients, is that the usage of fortified products in a public school feeding program is not an individual decision but a governmental one, which is in contrast to the approach chosen by Banerjee et al. (2014, 2016). Therefore, if properly implemented, it has the potential of high compliance, as using DFS in the MDM is comparable to a (partly) mandatory fortification policy (similar to Thomas et al. 2016). The usage of DFS in the MDM further enables a regular and nearly daily provision of iron dosage to children, which is the recommended proper intake. Since public school infrastructure is well established, even in rural areas where nearly every village in India has a school and many children from low-income households attend public schools, school-feeding programs are capable to reach a high-risk population. In addition, the MDM is likely a very cost-effective distribution channel because an existing logistical infrastructure is in place. A couple of other randomized trials have used school meals to deliver micronutrients to school-aged children: Van Stuijvenberg (2005) in South Africa; Zimmermann et al. (2003) in Morocco; Andang'o et al. (2007) in Kenya; Moretti et al. (2006) and Radhika et al. (2011) in India. All these studies found school feeding programs to be an effective distribution channels for micronutrients.

We find that, after one year of treatment, prevalence of any form of anemia reduced by more than 20 percent and the prevalence of mild anemia reduced by approximately 30 percent. On average, we do not find statistically significant impacts of the intervention on cognitive ability or math and reading scores. However, we find positive treatment effects of about 0.2 standard deviations on math and reading scores in the subgroup of students with school-attendance above 80 or 90 percent, who consumed the MDM more frequently at school and therefore had a stronger exposure to the treatment. To the best of our knowledge, this is the first large-scale study that rigorously evaluates the usage of salt as an iron carrier in a school-feeding program in India. Furthermore, in contrast to existing studies, we assess not only health, but also productive outcomes such as cognitive abilities and education outcomes.

The remainder of this paper is structured as follows: section 2 describes the intervention and the context. The study design and data are explained in section 3 and section 4 outlines the estimation strategy. The estimation results are presented in section 5. In section 6, we discuss the challenges to the internal validity of our results and in section 7 we perform a cost-effectiveness analysis of the intervention. We conclude in section 8.

2. Context and intervention

2.1 India's school-feeding program

By the mid-1980s, India's school-feeding program was initiated in Tamil Nadu and Gujarat as an initiative of the respective state governments. The implementation of the MDM aimed at overcoming classroom hunger, increasing the nutritional level of school children and enhancing the enrolment and attendance. It also aimed at reducing caste discrimination and improving gender equity. Covering an estimated 104.5 million school children in 1.16 million schools during the 2013-2014 school year, the program is the largest school-feeding program in the world (Ministry of Human Resource Development, 2016). The MDM in Bihar covers all children from grade one to eight (Ministry of Human Resource Development 2016).

Each child is supposed to receive a daily lunch meal that is predefined in calories and composition of food items. The menu is fixed by the state government for all schools and varies on a daily basis, but is repeated every week. In most Indian regions, including the state of Bihar, the MDM is prepared directly at the schools in school kitchens explicitly built for this purpose.[1] The Food Corporation of India provides grains directly to the schools and a representative of the school, usually the headmaster, individually buys the remaining ingredients (for example vegetables, pulses, oils and spices) at the local market. For every primary school child (class one to five) the schools receive 3.59 Rs. (0.05 USD)[2] from the government, and for every upper-primary school child (class six to eight) the schools receive 5.38 Rs. (0.07 USD) per day to cover the cost of the additional ingredients. The MDM is served every day except Sundays and holidays (Ministry of Human Resource Development 2016).

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[1] In other regions, mostly in urban areas, the MDM is prepared centralized in large kitchens or provided by organizations of international assistance.

[2] Average exchange rate 2016. 1 Rs. equals 0.015 USD.

2.2 Distribution of double fortified salt

We delivered DFS to 54 randomly selected public schools in Bihar, India. The DFS was subsequently used to prepare the MDM at the school level. The DFS formula has been developed by the National Institute of Nutrition (NIN) Hyderabad and is produced by different manufacturers. We purchased the DFS from a large Indian company and it includes 0.86 mg/g of iron. The daily requirement of a child between 7 and 9 years of age is 10 mg while for children between 4 and 6 years it is 8 mg (World Health Organization 1959). By matching the daily amount of salt used, as reported by the cooks, and the number of children that go to the respective school, we calculate an average amount of 4g of DFS per meal served in our study. This accounts for roughly 35 percent of the daily iron requirement of a child.

Laboratory studies show good stability of the iron and iodine content of the NIN formula of DFS. In a few small-scale experimental studies, where regular consumption was closely monitored, acceptability and effectiveness in increasing hemoglobin levels were also tested (Sivakumar, et al. 2001, Nairl, et al. 2013, Haas, et al. 2014). Most of these studies found good acceptability and increases in hemoglobin levels at least for subgroups.

In our study area DFS was unavailable and mostly unknown throughout the study region. Starting in April 2012, DFS was sold in larger Indian cities, however it did not stay on the market due to little demand. As instructed by the Department of Women and Child Welfare, DFS is supposed to be available in governmental food security programs, including the Integrated Child Development Program and the Midday Meal Scheme (Mudur 2013). This instruction is however not enforced and consequently the availability and usage of DFS is still very limited. DFS was introduced in Bihar in early 2017 in the capital city Patna, which is a two to three hour drive by car from the study region but throughout the study period it was not available in the study region, which reduces the concerns of contamination of the control groups.

We received DFS directly from the manufacturer and delivered it to the treatment schools either every month or every second month, depending on consumption. Headmasters were encouraged to contact our team in the event that they ran out of DFS before the next delivery date. The regular school visits also functioned as a monitoring system (see section 6.1 for a detailed discussion of compliance with the treatment). To account for the potential of a budgetary effect, DFS was sold to headmasters to a subsidized price of Rs. 12 (0.18 USD), which is close to the price of local salt. At endline, headmasters and cooks stated that they did not have any major difficulties with the delivery and usage of the DFS. Only the headmasters and cooks were aware of the intervention.[3]

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[3] The usage of DFS in the MDM had already been instructed by an official note of the Central Government (Mudur 2013). By sending their children to public schools, parents allow them to participate in the MDM and hence agree to the consumption of DFS as well.

2.3 Theory of change

Given that DFS is regularly used when cooking the MDM (an assumption that is discussed in section 6.1) and that children regularly attend school (an assumption that is discussed in section 5.2), we expect that the children's average hemoglobin value will increase and that anemia prevalence will be reduced. If positive effects on hemoglobin and anemia can be found, we would expect as a next step that cognitive skills and education outcomes might be positively affected too. Iron deficiency affects cognitive development through immediate neurobiological processes, i.e. the inhibition of the central nervous system to develop properly (e.g. the brain and the spinal cord) (J. Beard 2003), and functional isolation. Functional isolation emerges from the symptoms of iron deficiency. Children deficient in iron engage less with their environment, have lower interpersonal interactions, show lower attention and are relatively unresponsive to stimuli in comparison to their non-iron deficient counterparts. Thus, they have difficulties in accumulating new skills (Lozoff, et al. 1998). Cognitive development directly influences the education outcomes of children. For example, if students are unable to focus their attention and ignore distraction, they are likely to have trouble concentrating and have difficulties in acquiring new skills and knowledge. The same is likely to be true for the symptoms of anemia, such as frequent illness or tiredness (Halterman, et al. 2001, Bobonis, Miguel and Puri-Sharma 2006).

3. Study design and data

3.1. Sample and randomization

The study was conducted in the two blocks of Kako and Modanganj in the district Jehanabad, located in the state Bihar, India. A simple random sample of 108 schools from a list of 228 public schools in the two blocks was drawn prior to the DFS intervention. From the 108 schools, 54 were randomly chosen and allocated to the treatment group. 53 schools did not receive any treatment and continued to use the conventional iodized salt, and one school was inaccessible at endline due to monsoon flooding and hence had to be excluded from the study. A computer-generated list of random numbers was used for the allocation of the treatment and control groups.

On average, 20 children from the second grade were randomly selected from each of the 108 schools for the survey, which results in an initial sample size of approximately 2000 children. Second graders were chosen because of the strong biological basis for post-infancy effects of iron deficiency on the neurobiological development of the brain. Specifically, the frontal lobes continue to develop until adolescence and experience spurts of development between the age of 7 and 9, and in mid-teenage years (Anderson 2002, Hudspeth and Pribram 1990, Thatcher 1991). Children in the second grade are about 6 years old and hence just before one of the critical post-infancy periods of brain development. Among other functions, the frontal lobes are known to mediate advanced interrelated cognitive skills. These include the so called executive functions, such as response inhibition, task switching, planning and organizing, working memory, abstraction, initiation, self-monitoring and volition (V. Anderson 2001, Lezak 1995, Salimpoor and Desrocher 2006).

3.2. Data

Between November 2014 and January 2015 a baseline survey was carried out. Implementation of the treatment was delayed because of the earthquake in Nepal in 2015 that also affected Bihar and led to a postponement of school holidays. It was further delayed because of a contract teacher strike, which led to the circumstance that many schools were not functioning for several months. Treatment therefore began in August 2015. An endline survey with the same children was conducted from August to October 2016. Three different teams collected data at both the baseline and endline. The first team went to the homes of the children to get parental consent for participation in the study and to conduct a parental interview. A second team visited the schools and performed cognitive and education tests on the children. They also interviewed the headmasters and cooks and observed the cooking and distribution of the MDM. The third team comprised of local medical staff that performed medical tests, including a blood test for hemoglobin levels. These tests were done at the children's homes or in their villages to give the parents the opportunity to attend the procedure.

Outcome variables

Anemia – The hemoglobin level of each child was assessed directly in the field by a minor blood test administered through the portable HemoCue® Hb 301 device (AB Leo Diagnostics, Helsinborg, Sweden). In both the baseline and endline surveys, less than one percent of the children refused the hemoglobin test. The demand for the medical check was very high, as parents perceived the health survey as a free health service. According to WHO (2001), we define *any anemia* as a hemoglobin value < 11.5 g/dl, *mild anemia* as a hemoglobin value ≥ 11 & < 11.5 g/dl, *moderate anemia* as a hemoglobin value ≥ 8 & < 11 g/dl and *severe anemia* as a hemoglobin value < 8 g/dl. We only observed a few cases of severe anemia at baseline and endline, and thus collapsed moderate and severe anemia into one category of moderate or severe anemia.

Cognitive ability – Cognitive ability was measured by five different cognitive tests: forward digit-span, backward digit-span, block design, *Stroop*-like day-and-night test and Raven's Colored Progressive Matrices (Hale, Hoeppner and Fiorello 2002, Carlson 2005, V. Anderson 2001, Gerstadt, Hong and Diamond 1994, Raven and Court 1998).

These are frequently used measures of cognitive ability for child populations, for example the forward and backward digit-span tests and the block design tests are tests from Malin's Intelligence Scale for Indian Children (Malin 1969), the Indian adaption of the Wechsler Intelligence Scale for children (WISC). Most of the cognitive tests assess higher executive functions, which as described in 3.1, are supposed to develop at the age of the children in our sample. The sequence of cognitive and educational tests was administered in a one-to-one setting and on average lasted for about 15 minutes. Table 1 summarizes the test and a more detailed description of the different indicators is provided in the appendix.

Education outcomes – In addition to five cognitive outcomes, we collected data on on math and reading skills. The math and reading tests were adapted from the Annual Status of Education Report (ASER Centre 2014) test material developed by the Indian Non-Governmental Organization *Pratham*. Reading scores ranged from 0 to 4, while math scores ranged from 0 to 15. Both scores were normalized using the same procedure described above. We also captured school attendance from the school's official attendance record. The school attendance for each child was calculated by the total number of days that the child was present divided by the total number of school days in the past 12 months before the survey. We use school attendance to estimate heterogeneous treatment effects by exposure to the treatment, e.g. by how frequently a student ate the MDM. To show that this is reasonable we first document that school attendance is not affected by the treatment, which is reasonable because children were not aware of the DFS usage and those that did not eat the MDM regularly could not improve their health and indirectly their school attendance through the treatment.

Covariates

In accordance with the existing literature, we collected covariates that are typically associated with the tested outcomes. For the anemia outcomes these include socioeconomic characteristics (rural or urban, block, wealth index[4], father's years of schooling, mother's years of schooling, caste, religion and number of household member), nutritional factors (the children's dietary diversity score, an indicator for household food security, the number of meals the child eats every day, the average intake of calories and iron from the school meal, an indicator for maternal health knowledge, if the child consumes any meat, poultry or fish and if the child received iron supplements), access to health care (dummy for institutional delivery of the child and if any household member is covered by health insurance), morbidity indicators (if the child suffered from diarrhea in the last 30 days and if the household possesses an improved sanitation facility), as well as one biological factor (sex of the child).

For the cognitive outcomes, these were the same socio-economic indicators as above, but with another set of nutritional factors (the children's dietary diversity score, an indicator for household food security, the number of meals the child eats every day, the average intake of calories and iron from the school meal, an indicator for maternal health knowledge). Additionally, we collected indicators for psychosocial stimuli

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[4] The asset index was constructed by principle component analysis. The following variables were included: Type of toilet facility (improved and unimproved according to WHO), Source of drinking water (improved or unimproved), type of house, wall, roof and floor, possession of assets like chair, table, radio, pressure cooker etc., the amount of agricultural land owned, amount of different farm animals owned, BPL card holder, MNREGA card holder and the dependency ratio.

(dummy if the mother helps the child with its homework, the time the mother spends on giving physical care to the child, if parents participate in parent-teacher meetings at school and a dummy if the father lives in the household) and a dummy for the test administrator. Further indicators for quality of schooling (total school enrollment, student-teacher ratio, the number of children that attended second-grade at the baseline and the fourth-grade at the endline on the day of the interview and the distance to school) were collected for the education outcomes.

4. Estimation strategy

4.1. Empirical specification

Due to the random assignment of schools to the treatment and control groups, the causal effect of the DFS intervention can be estimated by comparing the averages of the outcome variables between the treatment and control schools after the treatment was given (simple difference, SD).

However, the panel structure of our dataset further allows us to combine the randomized design with a difference-in-differences approach (DD). This approach enables us to control for any remaining observable and unobservable pre-intervention differences between groups that could confound our results. For the same purpose, we also include child fixed effects and additional time-variant covariates. We estimate the DD as an OLS regression in the form:

$$Y_{ait} = \alpha_i + \beta_1 Post_t + \beta_2 Post_t * Treat_a + \delta_1 X_{at} + \delta_2 W_{it} + \epsilon_{ait} \qquad (1)$$

where Y_{ait} is an outcome for child i at school a at time t. α_i is the child specific intercept. $Post_t$ is a dummy variable, which takes on the value of one for the post-treatment time period and hence captures the time trend. $Treat_a$ is a dummy for going to a treatment school. β_2 is the intention to treat (ITT) effect, the main coefficient of interest. It represents the coefficient for the interaction of $Post_t$ and $Treat_a$, which is equal to one for all observations in the post-treatment period that are in the treatment group. X_{at} is a vector of time-variant school control variables and W_{it} is a vector of time-variant child and household control variables. ϵ_{ait} is the error term. Standard errors are clustered at the school level.

We constructed one balanced panel for the anemia outcomes and one balanced panel for the cognitive and education outcomes.[5] Initially we sampled 2005 children. For the balanced sample of the anemia outcomes, for which medical and household data is required, we had a total of 1791 observations at the baseline. Of these 1791 children, we collected hemoglobin values for 1406 children at the endline and the required covariates from the household questionnaire (attrition is analyzed in section 4.3).

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[5] The DD estimation requires a balanced panel such that the data requirements are much higher and the number of children included in the analysis is smaller compared to simple difference estimation.

Similarly, at the baseline we had 1772 children with all of the required cognitive and education outcomes, as well as household covariates. Out of these 1772 children, the cognitive and education data and the required covariates were collected for 1395 children at the endline.

4.2. Pre-intervention balance of the treatment and control group

This section discusses the balancing of the two randomized groups with respect to baseline characteristics. As the allocation of schools into the treatment and the control groups was random, there should not be any systematic differences between the treatment and control groups at the time of baseline survey. Table 2, panel A, shows the baseline summary statistics of the socio-economics characteristics of the sample for anemia outcomes. The equivalent table for the cognitive and education outcomes is reported in panel A in the appendix table A.2. For each variable, we present the baseline means for all of the outcome variables and covariates, as well as the standard deviation for the continuous variables. We also present the p-values for the difference in means between the treatment and control group.

Table 2, panel A shows that there are no statistically significant differences between the two groups. Furthermore, there is no evidence of imbalance in the cognitive and education sample (appendix table A.2). These results strongly indicate that the randomization was successful and treatment status is likely to be orthogonal to observed and unobserved characteristics of the sample.

The baseline hemoglobin level is not perfectly equalized between the treatment and control groups. In all samples, the baseline hemoglobin level was a bit higher in the control group and the prevalence of anemia was lower. This difference would lead to an underestimation of the true treatment effect and it is always controlled for in the DD model.

4.3 Attrition

The implementation of the experiment was carried out very carefully, yet non-random attrition is one issue that can potentially bias the estimates. Attrition might threaten internal validity if the characteristics of the participants that are lost systematically differ between the treatment and control groups, and if those characteristics are correlated with the outcome. To minimize attrition, enumerators were assigned a smaller number of interviews per day that they had sufficient time to extensively search for parents and children and in some cases, when this was not sufficient, villages were revisited for a second attempt.

The attrition rate in the anemia sample was 21.5 percent (385/1791).[6] This is within the normal range of other RCTs, for example Glewwe et al. (2009) report 25 percent attrition after one year of an intervention and a bit more than 30 percent two years after an intervention, and Ashraf et al. (2014) report 26 to 28 percent attrition in their follow-up survey. Attrition rates were similar in treatment and control groups.

Comparing the balancing tests without attrited children (Panel A) to the balancing test of the full baseline sample (Panel B) in Table 2, we do not find any evidence of non-random attrition, as characteristics of the two samples are nearly identical. In the appendix table A.2 we perform the same exercise for the cognitive and education sample and do not find any evidence of non-randomattrition across treatment and control groups.

5. Results

5.1 ITT effects

Tables 3, 4 and 5 show the regression results of the ITT effect based on specification (1). The main outcomes are hemoglobin, anemia, and cognition and math and reading scores.

Anemia - Results in Table 3 show that the usage of DFS for the preparation of the MDM increased the average hemoglobin level by 0.136 g/dl.[7] Treated students were 9.3 percentage points less likely to suffer from any form of anemia (hemoglobin < 11.5 g/dl). This translates to about 20 percent reduction in anemia prevalence in the treatment group relative to the control group.[8] The usage of DFS in the MDM reduced the likelihood that a child suffers from mild anemia (hemoglobin ≥ 11 & < 11.5 g/dl) by 6.0 percentage points on average, which is equivalent to a reduction in the prevalence of mild anemia by nearly 30 percent (6.0/19.3). The DFS has negative impacts on moderate and severe anemia but these estimates were imprecisely estimated and were statistically insignificant.

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[6] The initial baseline sample was 2,005 students. After refusals and non-availability we could interview 1,791 students for the anemia outcome at baseline. Of these 1,406 students were reinterviewed at the follow-up survey.

[7] The size of the effect found in our study is a bit smaller than the effect found in other DFS intervention studies. Haas et al. (2014) found an increase in hemoglobin of 0.24 g/dl among Indian tea pickers. In a household level DFS intervention, Nairl et al. (2013) found an increase in hemoglobin due to a DFS intervention among Indian school-aged children of 0.5 g/dl. Zimmermann et al. (2003) found an increase of 1.4 g/dl in their DFS intervention in Moroccan school children; however their DFS formula contained 2 mg of iron per gram of salt. For the subgroup of adolescents, Banerjee et al. (2016) found an increase in the average hemoglobin value of 0.41 g/dl.

[8] The reduction in the prevalence of anemia is similar to the reduction found in other studies. Haas et al. (2014) found that DFS decreases the prevalence of anemia among Indian tea pickers by about 25%. Nairl et al. (2013) report a reduction in anemia by about 20% and Banerjee et al. (2016) of about 26% for a subgroup of adolescents.

Cognition and education - Table 4 shows the estimation results for the cognition and Table 5 for the education outcomes. None of the coefficients are statistically significant at conventional levels. The point estimate for school attendance is close to zero as previously expected.

5.2 Heterogeneous effects by school attendance rate

We investigate the treatment effect depending on school attendance. Figure 1 shows the distribution of school attendance during the treatment period. To investigate the treatment effect at higher rates of school attendance we centered the school attendance variable at 70, 80 and 90 percent respectively. We then interact each centered attendance rate with the treatment dummy. The DD regression equation is as follows

$$Y_{ait} = \alpha_i + \delta_1 Post_t + \delta_2 School\ attendance + \delta_3 Treat * Post_t + \delta_4 Post_t * School\ atteandance_i + \delta_5 Treat_a * School\ attendance_i + \delta_6 Post_t * Treat_a * School\ attendance_i + \gamma_1 X_{at} + \gamma_2\ W_{it} + \ \epsilon_{ait} \qquad (2)$$

where abbreviations are the same as described in equation (1). As shown in Table 4, the treatment did not have any effect on school attendance such that this subgroup analysis is reasonable. The DD estimates in tables 6, 7 and 8 report the three coefficients δ_6, i.e. the effect for a child with 70, 80 and 90 percent school attendance.

We observe a consistent pattern that the point estimates for all outcomes tend to increase with higher school attendance. The hemoglobin and anemia results at higher levels of school attendance are still statistically significant and the point estimates are larger than before. Treatment effects for cognition outcomes remain statistically insignificant. Treatment effects for math and reading scores become statistically significant at the 10 percent level for high levels of school attendance – point estimates were close to a 0.2 standard deviation increase.

6. Threats to internal validity

6.1 Partial compliance

Compliance with the treatment might be disrupted due to non-usage, insufficient use of DFS, or insufficient availability of salt due to imperfect delivery channels. We believe that these issues are unlikely to have introduced bias because of the strong monitoring system that we had in place. The support of local authorities further strengthened the monitoring mechanism and reduced the possibility of partial compliance. Further, during a surprise visit to schools we found DFS salt available in all treatment schools except for two; these schools had run out of DFS the day before the visit. With regard to supply of DFS, very few schools reported to have interrupted supply of DFS for more than five days during the treatment year.

Another potential source of bias is if the DFS from the treatment schools was resold to the control schools and households. However, this is unlikely as the financial incentive of reselling DFS is very small since salt is a relatively inexpensive product. Furthermore, we know from anecdotal evidence that awareness of the benefits of DFS and the demand for it is very low, at least among the rural households in our study region. In the endline survey, a negligible proportion of 0.28 percent of the households reported to have used DFS, indicating that the reselling of salt to households did not occur.

One could also imagine that the headmasters in the treatment schools sold DFS to control schools, since headmasters in both control and treatment schools were informed of the study as part of their informed consent. The study informed headmasters in the treatment and control schools that a lottery would determine the treatment status of the schools. They were later informed of the results of the lottery. Headmasters were further informed that the local government supports the study and it is unlikely that they would have acted against the government order. Furthermore, headmasters in control schools were told that if the given study would yield positive results, they would also have the possibility to receive DFS. Lack of awareness about the availability and benefits of DFS among school headmasters would further reduce the bias, if any. None of the control headmasters reported to have used DFS in the preparation of the MDM. During the surprise visits, DFS was not found in any of the control schools. The order from the government to obey the study design and the knowledge that control groups would have access to DFS after the completion of the study led to high compliance at the school level.

Non-compliance at the child level due to low school attendance has been discussed in section 5.2. Non-compliance at the individual level could have potentially also occurred if the children that were enrolled in control schools at the baseline went to the treatment schools to receive the treatment and the other way around. This potential concern was circumvented in several ways. Firstly, only headmasters knew about the intervention. Anecdotal evidence further confirms that awareness of the benefits of DFS was very low, such that the incentive for parents to send their child to a treatment school to receive the DFS was non-existent. In our study region, every village generally has one public school, thus attending a school in another village is extremely uncommon.

6.2 Attenuation bias

For ethical reasons, when conducting research with human subjects, especially with vulnerable populations such as children, it has to be ensured that the benefits of the research outweigh the risks (Medical Research Council 2004). To maximize the benefit for the children involved in the survey, in the treatment and the control group, survey teams were instructed to inform parents in case their child was moderately or severely anemic and to advise them to feed their children more diversely and more food items with high iron content (green leafy vegetables and meat in case they were non-vegetarians). In cases of severe anemia, parents were instructed to consult a doctor (which was only the case for 14 children).

This additional intervention is unlikely to bias our results, since this information intervention affected the treatment and control groups equally and its effect is therefore balanced between these two groups. However, in case the information intervention did indeed lead to a change in feeding practices or medical treatment, a *saturation effect* might have occurred (i.e. decreasing returns to scale of iron-interventions). Compared to an exclusive DFS intervention, the estimated coefficients in this study could therefore be downward biased and might constitute a lower bound. To encounter this potential threat we included the dietary diversity score of the child as a control variable in our main specification (1). In a companion analysis, we explored the effect of the nutrition information intervention with a regression discontinuity design and did not find an effect on any of the outcomes explored in this study, indicating that the nutrition information did not lead to attenuation bias (Krämer 2017).

6.3 Hawthorne effect

Another issue of concern may be Hawthorne effects, i.e. changes in behavior of the individuals in the control group in response to being part of the DFS experiment. In our experiment individuals in the treatment and control groups were surveyed once at the baseline and once at the endline; any behavioral change that results from the survey itself (being monitored or the evaluation of the education level of the students) is balanced in the treatment and the control group. It might still have been the case that individuals in the treatment group changed their behavior due to the treatment itself (regular delivery of DFS to the school) and that this change affected the outcomes. Since only headmasters were aware of the intervention, this behavioral change is limited to headmasters (and maybe some teachers who knew about the intervention).

A change in hemoglobin values due to a behavioral change by the headmasters, for example spending more money on the MDM to improve dietary diversity, is very unlikely to have occurred since headmasters generally were unaware of the hemoglobin testing and also did not have a higher budget available. Nevertheless, we also control for the average calories and average iron content of the MDM as measured on the survey day. We also believe that the expected benefits of a behavioral change were too small in comparison to the effort needed to manipulate the outcomes. A change in the components of the MDM would involve additional costs and a change in cognitive or education outcomes would need a large quality improvement in teaching (e.g. more teachers, more training material etc.). Therefore, we believe that the Hawthorne effect is less likely to be a concern in this study.

7. Cost-effectiveness analysis

We provide a couple back on the envelope calculations to illustrate the cost-effectiveness of the intervention, and to enable other researchers and policy makers to compare it with other interventions. In total, we spent approximately 332,000 Rs. (4887 USD)[9]on the one-year intervention. The cost of the intervention consists of the cost of the DFS subsidy (we received DFS from the manufacturer for INR 20.04 per kilogram and sold it for INR 12 per kilogram to the headmasters) and the costs of delivering DFS to schools. The subsidy accounts for approximately 106,000 Rs. (1565 USD) and the distribution for approximately 226,000 Rs (3322 USD). The intervention in the 54 schools reached almost 14,000 children (because all children at a school benefited from it and not only those that took part in the study), such that the cost per child was about 24 Rs., which is roughly equivalent to 0.36 USD. With a bit more than 100 USD we provided DFS to about 300 children and, based on the estimated treatment effects, averted 18 cases of anemia – six moderate or severe and twelve mild cases.[10] Applying the disability weights for mild (0.004) and moderate or severe (0.052) anemia this sums to 0.36 disability adjusted life years (DALYs) averted (Murray and Lopez 2013). One DALY averted would therefore cost approximately 280 USD. The WHO assesses interventions as *very cost-effective* if the cost per DALY averted is less than the GNI per capita of the country where the intervention is going to be implemented, and *cost-effective* if it is less than three times the GNI per capita (Sachs 2001). India's GNI per capita in 2015 was 6,030 USD (World Bank 2017), which means that any intervention costing less than 6,030 USD per DALY averted would be considered *very cost-effective* under the WHO definition. This is true for the cost calculation of the intervention tested in this paper. Our estimate is a very conservative assessment of the cost effectiveness of the intervention because it ignores potential long-term effects of the intervention, effects on other outcomes such as education, and the possibility to benefit from economies of scale if included in existing distribution infrastructure.

8. Conclusions

We assessed the Indian MDM as a potential delivery channel to provide school-age children with iron. In a randomized controlled trial we found that DFS provided through the MDM reduces the prevalence of any form of anemia by 20 percent and of mild anemia by 30 percent. Among children that had a high school attendance (80 or 90 percent), and therefore ate the MDM more regularly, the treatment effect was also statistically significant for math and reading outcomes at a magnitude of close to 0.2 standard deviation increase. The intervention was very cost effective according to

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[9] Average exchange rate in 2016.

[10] The point estimates of moderate and mild anemia add up to the point estimate of any anemia, which is statistically significant at the one percent level. Since disability weights only exist for moderate and severe anemia and not for any anemia, we take those point estimates although they have higher p-values, which are likely a consequence of less power compared to the estimation with any anemia as outcome.

international standards.

The findings are particularly interesting in light of the results from the Banerjee et al. (2016) study, which did not find any effect of DFS when sold at a subsidized price through local shops or the PDS system, or offered directly to households. One central difference between the delivery channel of our study and the studies by Banerjee et al. (2011, 2014, 2015, 2016) is that the DFS was mandatorily used in our study (at least by the children through the decision of their headmasters and the school authorities to participate in the study and use DFS for the midday meal), whereas in the studies of Banerjee et al. participation was voluntary and consumers were given the option to buy the fortified product or not. The positive effects from our study provide evidence of the potential advantage of mandatory fortification where a behavioral change in dietary patterns at the household level, which seemed to be a major challenge in the other studies, is not required.

There are some limitations to our study and potentials for further research. Firstly, since our results only apply to the two blocks in Bihar from which we have drawn a random sample of schools, we propose replications of this study in other contexts. In our supply system, a strong and trusting relationship between the headmasters and DFS distributors was maintained and the intervention was strongly supported by the local government, which might not be the case in a different context. Moreover, we would like to point to the duration of the intervention. Though we could not find statistically significant effects for the cognition outcomes and only evidence for positive effects on education outcomes at higher levels of school attendance, it might very well be the case that these effects indeed exist but need longer time periods to materialize. We therefore propose to study the longer-term effects of the intervention.

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Table 1: Cognitive tests

Test	Original Source	Cognitive ability	Executive function
Digit span forwards	Malin's Intelligence Scale for Indian Children	- Short-term auditory memory - Simple verbal expression	
Digit span backwards	Malin's Intelligence Scale for Indian Children	- Store, use and manipulate new information - Attention - Impulse control - Shifting	x
Block design	Malin's Intelligence Scale for Indian Children	- Planning and organizing	x
Stroop-like day-and-night test	Gerstadt et al. (1994)	- Inhibition - Memorizing two rules simultaneously	x
Raven's Colored Progressive Matrices	Raven et al. (1998)	- Abstract reasoning - Capacity to simultaneously solve several problems involving new information	x

Table 2: Sample description and balancing test (DD balanced panel for hemoglobin and anemia outcomes)

	Panel A: DD sample								Panel B: Sample including attrited children							
	Total			Control		Treatment				Total		Control		Treatment		
	(1) Number of children/ schools	(2) Mean	Sd	(3) Mean	Sd	(4) Mean	Sd	(5) P Value of Difference in means t-test	(1) Number of children/ schools	(2) Mean	Sd	(3) Mean	Sd	(4) Mean	Sd	(5) P Value of Difference in means t-test
A. Child level variables																
Anemia																
Hemoglobin	1,406	11.53	1.09	11.62	1.11	11.44	1.07	0.008***	1,791	11.52	1.10	11.59	1.10	11.45	1.10	0.020**
Any anemia	1,406	0.45		0.41		0.50		0.002***	1,791	0.45		0.42		0.49		0.022**
Mild anemia	1,406	0.19		0.16		0.22		0.003***	1,791	0.19		0.18		0.21		0.089*
Moderate or severe anemia	1,406	0.26		0.25		0.27		0.321	1,791	0.26		0.25		0.28		0.186
Number of anemia symptoms	1,406	1.09	1.12	1.07	1.10	1.11	1.14	0.650	1,791	1.08	1.11	1.05	1.09	1.10	1.12	0.609
Cognitive tests																
Block design	1,375	3.61	2.20	3.53	2.22	3.69	2.19	0.450	1,734	3.73	2.23	3.68	2.26	3.79	2.19	0.591
Digit span forward	1,377	4.05	1.01	4.03	1.01	4.07	1.00	0.611	1,736	4.08	1.01	4.05	1.02	4.10	1.00	0.564
Digit span backward	1,377	1.12	1.29	1.07	1.27	1.16	1.30	0.460	1,736	1.12	1.29	1.09	1.29	1.15	1.30	0.559
Progressive matrices	1,376	4.71	1.67	4.76	1.64	4.67	1.69	0.494	1,734	4.76	1.69	4.82	1.67	4.71	1.71	0.440
Day and night	1,375	5.22	3.44	5.25	3.49	5.19	3.40	0.812	1,733	5.33	3.43	5.39	3.48	5.27	3.38	0.662
Cognitive score (pca)	1,372	-0.05	1.00	-0.06	1.01	-0.03	1.00	0.727	1,729	-0.00	1.00	-0.01	1.02	0.00	0.98	0.885
Education outcomes																
Math	1,377	4.60	3.81	4.66	3.85	4.53	3.77	0.772	1,736	4.82	3.83	4.90	3.86	4.74	3.81	0.694
Reading	1,376	0.86	1.11	0.87	1.12	0.85	1.10	0.868	1,735	0.90	1.13	0.94	1.15	0.87	1.10	0.490
School attendance	1,338	0.80	0.16	0.80	0.15	0.79	0.16	0.438	1,694	0.79	0.16	0.79	0.16	0.78	0.17	0.659
Socioeconomic variables																
Muslim HH	1,406	0.02		0.02		0.03		0.886	1,791	0.03		0.03		0.03		0.898
Sc/st	1,406	0.30		0.25		0.34		0.124	1,791	0.29		0.25		0.32		0.167
Block	1,406	0.66		0.71		0.62		0.383	1,791	0.66		0.71		0.62		0.415
Rural HH	1,406	0.98		0.97		0.98		0.590	1,791	0.98		0.97		0.99		0.412
N of HH members	1,406	7.73	3.38	7.85	3.47	7.62	3.29	0.310	1,791	7.75	3.44	7.84	3.53	7.66	3.35	0.408

Years schooling father	1,406	5.38	4.78	5.48	4.76	5.29	4.81	0.628	1,791	5.49	4.87	5.42	4.85	5.56	4.89	0.708
Years schooling mother	1,406	1.64	3.05	1.70	3.15	1.58	2.94	0.600	1,791	1.80	3.24	1.81	3.27	1.80	3.22	0.971
Asset index	1,406	0.00	1.00	0.01	0.95	-0.01	1.04	0.823	1,791	-0.03	0.97	-0.03	0.95	-0.02	1.00	0.908
Health care																
Institutional delivery	1,406	0.38		0.40		0.37		0.423	1,791	0.39		0.39		0.38		0.632
Health insurance	1,406	0.39		0.40		0.37		0.544	1,791	0.39		0.40		0.38		0.683
Morbidity																
Diarrhea	1,406	0.03		0.04		0.03		0.302	1,791	0.03		0.03		0.03		0.574
Improved sanitation	1,406	0.08		0.07		0.08		0.557	1,791	0.08		0.08		0.09		0.526
Biological factor																
Male child	1,406	0.45		0.44		0.46		0.430	1,791	0.46		0.45		0.47		0.390
Nutrition																
Diet diversity score	1,406	3.87	1.16	3.90	1.18	3.83	1.15	0.446	1,791	3.87	1.17	3.89	1.20	3.86	1.14	0.698
Number of meals	1,406	3.06	1.04	3.04	1.06	3.07	1.01	0.773	1,791	3.02	1.05	3.01	1.07	3.04	1.03	0.660
Cut meals	1,406	0.81		0.82		0.81		0.735	1,791	0.80		0.80		0.80		0.796
Maternal health knowledge	1,406	0.37		0.35		0.38		0.416	1,791	0.38		0.36		0.40		0.187
Child eat meat, poultry or fish	1,406	0.53		0.55		0.52		0.447	1,791	0.53		0.53		0.53		0.895
Child got iron supplements	1,406	0.17		0.16		0.17		0.625	1,791	0.17		0.17		0.17		0.931
B. School level variables																
Calories of MDM per child	107	68.80	23.55	69.57	21.45	68.04	25.62	0.739	107	68.80	23.55	69.57	21.45	68.04	25.62	0.739
Amount of iron of MDM per child	107	0.79	0.35	0.84	0.41	0.75	0.28	0.185	107	0.79	0.35	0.84	0.41	0.75	0.28	0.185

This table presents baseline summary statistics as well as p-values for difference in the means t-tests between children in the treatment and control schools. All variables shown are child level variables from the baseline except for panel B, which shows school level variables. Standard errors are clustered at the school level. Sd: Standard deviation N: Number of observations. MDM: Midday Meal.

Table 3: ITT effects for hemoglobin level and anemia

	(1) Hemoglobin	(2) Any anemia	(3) Mild anemia	(4) Moderate or severe anemia
Treat	0.136*	-0.093***	-0.060**	-0.034
	(0.076)	(0.033)	(0.027)	(0.031)
Mean dependent var	11.529	0.452	0.193	0.260
Child fixed effects	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes
N	2,812	2,812	2,812	2,812

Notes: N: Number of observations. Estimated coefficients are based on a DD estimation. Any anemia is defined as a hemoglobin value < 11.5 g/dl, mild anemia is defined as a hemoglobin value ≥ 11 & < 11.5 g/dl, moderate/severe anemia is defined as a hemoglobin value < 11 g/dl. *, **, *** denote significance at the 10%, 5% and 1% levels, respectively. Standard errors, clustered at the school level, are reported in parentheses.

Table 4: ITT effects for cognitive tests

	(1) Block design	(2) Digit span forward	(3) Digit span backward	(4) Progressive matrices	(5) Day and night	(6) Cognitive Index
Treat	0.012	-0.105	0.009	0.070	0.116	0.028
	(0.082)	(0.074)	(0.084)	(0.095)	(0.098)	(0.080)
Mean dependent var	0.048	0.030	0.033	-0.020	0.000	-0.038
Child fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes	Yes
N	2,790	2,790	2,790	2,790	2,790	2,790

Notes: Estimated coefficients are based on a DD estimation. All outcomes are normalized with reference to the baseline mean in the control group. *, **, *** denote significance at the 10%, 5% and 1% level, respectively. Standard errors, clustered at the school level, are reported in parentheses.

Table 5: ITT effects for education

	(1) Math	(2) Reading	(3) School attendance
Treat	0.129	0.104	-0.005
	(0.090)	(0.081)	(0.022)
Mean dependent var	-0.007	-0.019	0.798
Child fixed effects	Yes	Yes	Yes
Controls	Yes	Yes	Yes
N	2,790	2,790	2,715

Notes: Estimated coefficients are based on a DD estimation. All outcomes, except attendance, are normalized with reference to the baseline mean in the control group. *, **, *** denote significance at the 10%, 5% and 1% level, respectively. Standard errors, clustered at the school level, are reported in parentheses.

Table 6: Heterogeneous treatment effects for hemoglobin and anemia by school attendance rate

	(1) Hemoglobin	(2) Any anemia	(3) Mild anemia	(4) Moderate or severe anemia
Treat (70% attendance)	0.138*	-0.089***	-0.060**	-0.029
	(0.075)	(0.032)	(0.027)	(0.031)
Treat (80% attendance)	0.144	-0.093**	-0.058*	-0.036
	(0.089)	(0.039)	(0.030)	(0.034)
Treat (90% attendance)	0.151	-0.098*	-0.056	-0.042
	(0.113)	(0.051)	(0.039)	(0.042)
Mean dependent variable	11.530	0.451	0.191	0.260
Child fixed effects	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes
N	2,780	2,780	2,780	2,780

Notes: Standard errors, clustered at the school level, are reported in parentheses. All coefficients are from separate regression, except for the last coefficients that are from one regression where treatment and attendance are interacted. Estimated coefficients are based on a DD estimation. Any anemia is defined as a hemoglobin value < 11.5 g/dl, mild anemia is defined as a hemoglobin value ≥ 11 & < 11.5 g/dl, moderate/severe anemia is defined as a hemoglobin value < 11 g/dl. *, **, *** denote significance at the 10%, 5% and 1% level, respectively.

Table 7: Heterogeneous treatment effects for cognitive outcomes by school attendance rate

	(1) Block design	(2) Digit span forward	(3) Digit span backward	(4) Progressive matrices	(5) Day and night	(6) Cognitive Index
Treat (70% attendance)	0.005	-0.117	0.001	0.065	0.109	0.017
	(0.081)	(0.073)	(0.090)	(0.099)	(0.100)	(0.083)
Treat (80% attendance)	0.025	-0.128	-0.011	0.089	0.160	0.038
	(0.086)	(0.081)	(0.084)	(0.097)	(0.102)	(0.084)
Treat (90% attendance)	0.045	-0.139	-0.023	0.112	0.210	0.058
	(0.104)	(0.099)	(0.095)	(0.110)	(0.114)	(0.096)
Mean dependent var	0.049	0.035	0.036	-0.023	-0.002	-0.039
Child fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes	Yes
N	2,766	2,766	2,766	2,766	2,766	2,766

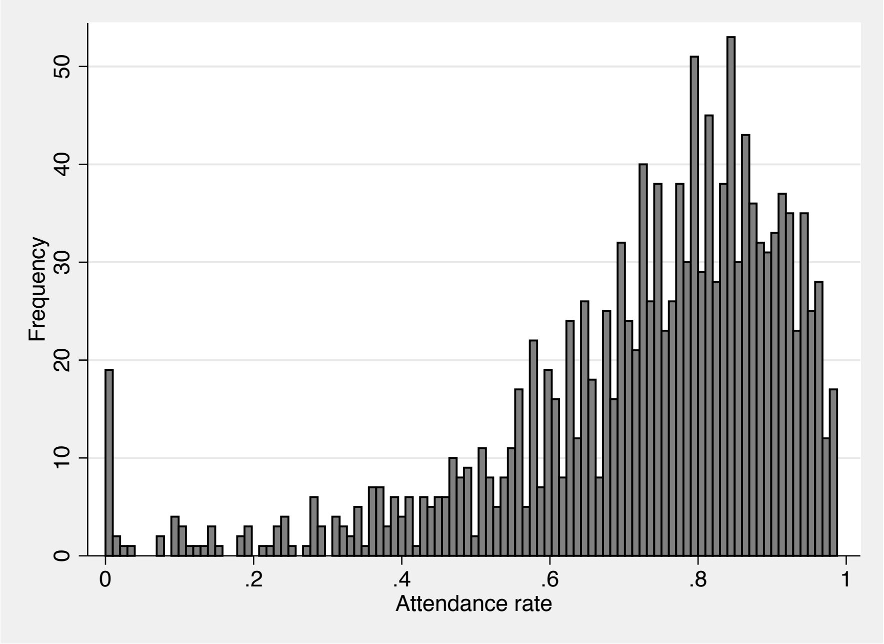
Notes: All coefficients are from separate regression, except for the last coefficients that are from one regression where treatment and attendance are interacted. Estimated coefficients are based on a DD estimation. All outcomes are normalized with reference to the baseline mean in the control group. *, **, *** denote significance at the 10%, 5% and 1% level, respectively. Standard errors, clustered at the school level, are reported in parentheses.

Table 8: Heterogeneous treatment effects for education outcomes by school attendance rate

	(1) Math	(2) Reading
Treat (70% attendance)	0.124	0.096
	(0.088)	(0.081)
Treat (80% attendance)	0.161*	0.139
	(0.092)	(0.087)
Treat (90% attendance)	0.197*	0.182*
	(0.105)	(0.104)
Mean dependent var	-0.008	-0.019
Child fixed effects	Yes	Yes
Controls	Yes	Yes
N	2,766	2,766

Notes: All coefficients are from separate regression, except for the last coefficients that are from one regression where treatment and attendance are interacted. Estimated coefficients are based on a DD estimation. All outcomes are normalized with reference to the baseline mean in the control group. *, **, *** denote significance at the 10%, 5% and 1% level respectively. Standard errors, clustered at the school level, are reported in parentheses.

Figure 1: Distribution of school attendance during treatment period (0 to 100%)



A. Appendix

Indicators for cognitive ability

The *forward digit-span* assesses short-term auditory memory and simple verbal expression (Hale, Hoeppner, & Fiorello, 2002). It is the only test that does not directly involve executive functions. The child was asked to repeat a series of numbers immediately after the enumerator read the series. The number of digits continuously increased and the longest list of numbers that the child could remember is defined as the digit-span.

The *backward digit-span* test measures the ability to store, use and manipulate new information. Backward digit-span also involves attention, impulse control and shifting from a forward to backward sequence. All of these abilities are commonly considered to be a part of the group of executive functions (Carlson, 2005; Hale, Hoeppner, & Fiorello, 2002; Lezak, 1995). The administration of the backward digit-span test is the same as in forward digit-span test, however the child is requested to repeat the digit sequence in its reverse order.

The *Block design* test assesses planning and organizing (Anderson V. , 2001). In this test, children were asked to arrange red and white colored blocks in a way that they match the pattern of a picture. Children received two points if they correctly arranged the blocks on the first try, one point if they correctly arranged the blocks on the second try after the test administrator had shown the correct solution to the child, and zero otherwise. They were asked to arrange four different pictures in the baseline survey, each increasing in difficulty. To account for a general increase in cognitive ability at the endline survey, two more pictures were added.

The *Stroop-like day-and-night* test (Gerstadt, Hong, & Diamond, 1994) assesses the ability of inhibition (suppressing a habitual response), which is also considered to be a classical executive function (Anderson V. , 2001; Carlson, 2005). We used an extended version of this test, where six pairs of cards that show pictures of opposites (day–night, boy–girl, large–small, up–down, warm-cold and young-old) were presented to the child. After shuffling the pictures, they were presented to the child one after the other and the child was asked to say the opposite of what they were seeing on the card. The scale for the day-and-night test ranges from 0 to 12. Initial errors that were self-corrected by the child were scored as a half point. Apart from inhibition, this test also requires memorizing two rules simultaneously. Firstly what the picture on the cards represents, and secondly to always say the opposite.

Lastly, we used an abbreviated version of *Raven's Colored Progressive Matrices* (RCPM) (Raven & Court, 1998) that measures abstract reasoning and the capacity to simultaneously solve several problems involving new information (Carpenter, Just, & Shell, 1990). There is some debate to what extent the RCPM test measures executive functions (Ardila, Rosselli, Matute, & Guajardo, 2005; Giovagnoli, 2001; Leeds, 2001).

In this test the child was shown an array of pictures with one missing box. Out of the six options, they were to select the picture that fits the missing box. The pictures progressively increased in complexity and abstraction. We score each correct answer with one point, hence the scale for RCPM ranges from 0 to 12. The RCPM are designed for children between 5 and 11 years old.

Since the unit in which cognitive ability is measured is arbitrary, we normalized the test scores of the five cognitive tests and express it in z-scores. We calculated a *cognitive index* out of the five cognitive tests by using principle component analysis.

Table A.1: MDE for different outcomes and different % of take-up

	Sd	Baseline ICC	MDE (c = 0.7)	MDE (c = 0.8)	MDE (c = 0.9)
Anemia					
Hemoglobin	1.10342	0.03130	0.23313	0.20399	0.18132
Any anemia	0.49803	0.02208	0.09889	0.08653	0.07691
Mild anemia	0.39225	0.00000	0.06438	0.05633	0.05007
Moderate anemia	0.43686	0.02087	0.08599	0.07524	0.06688
Severe anemia	0.08848	0.00000	0.01452	0.01271	0.01129
N anemia symptoms	1.09933	0.08387	0.29981	0.26233	0.23318
Perceived child health	0.40007	0.09271	0.11272	0.09863	0.08767
Cognition and education					
Block design	0.98478	0.13069	0.31275	0.27366	0.24325
Digit span forwards	0.98601	0.06170	0.24519	0.21454	0.19070
Digit span backwards	1.00564	0.10957	0.29987	0.26239	0.23323
Progressive Matrices	1.01746	0.11758	0.31103	0.27215	0.24191
Day and night	0.98825	0.09899	0.28460	0.24902	0.22135
Education					
Math	0.98212	0.13875	0.31888	0.27902	0.24802
Reading	0.99259	0.20815	0.37754	0.33035	0.29364
School attendance	0.17110	0.19551	0.06345	0.05552	0.04935

Sd: Standard deviation. ICC: Inter-cluster correlation. MDE: Minimal detectable effect. c: Take up rate. Assumptions: Sample size per cluster 22, number of clusters: 108 schools, division of observations between treatment and control: 50:50. Hemoglobin in expressed in g/dl and the different forms of anemia represent percentage points). Cognitive and education outcomes are normalized with respect to the control group mean and standard deviation.

Table A.2: Sample description and balancing test (Balanced panel for cognitive and education outcomes)

	Panel A: DD sample								Panel B: Sample including attrited children							
		Total		Control		Treat				Total		Control		Treat		
	(1) Number of children/ schools	(2) Mean	Sd	(3) Mean	Sd	(4) Mean	Sd	(5) P Value of Difference in means test	(1) Number of children/ schools	(2) Mean	Sd	(3) Mean	Sd	(4) Mean	Sd	(5) P Value of Difference in means test
A. Child level variables																
Anemia																
Hemoglobin	1,368	11.52	1.11	11.62	1.10	11.42	1.10	0.004***	1,729	11.52	1.10	11.60	1.10	11.44	1.10	0.010**
Any anemia	1,368	0.46		0.41		0.50		0.007***	1,729	0.45		0.42		0.49		0.019**
Mild anemia	1,368	0.20		0.18		0.21		0.140	1,729	0.19		0.18		0.21		0.133
Moderate or severe anemia	1,368	0.26		0.24		0.29		0.068	1,729	0.26		0.24		0.28		0.130
Cognitive tests																
Block design	1,395	3.65	2.20	3.54	2.22	3.75	2.19	0.308	1,772	3.74	2.22	3.68	2.25	3.80	2.19	0.551
Digit span forward	1,395	4.06	0.99	4.03	0.99	4.09	0.99	0.462	1,772	4.08	1.01	4.07	1.02	4.09	0.99	0.697
Digit span backward	1,395	1.12	1.29	1.07	1.27	1.15	1.30	0.492	1,772	1.12	1.30	1.10	1.29	1.14	1.30	0.703
Progressive matrices	1,395	4.71	1.66	4.75	1.62	4.68	1.69	0.670	1,772	4.75	1.68	4.81	1.66	4.69	1.71	0.386
Day and night	1,395	5.23	3.41	5.23	3.45	5.24	3.37	0.994	1,772	5.36	3.43	5.46	3.49	5.27	3.37	0.489
Cognitive score (pca)	1,395	-0.04	0.99	-0.07	1.00	-0.01	0.97	0.569	1,772	0.00	1.00	0.00	1.02	-0.00	0.98	0.980
Education outcomes																
Math	1,395	4.58	3.78	4.61	3.83	4.55	3.73	0.894	1,772	4.83	3.83	4.90	3.86	4.75	3.80	0.698
Reading	1,395	0.87	1.12	0.89	1.15	0.85	1.09	0.698	1,772	0.91	1.13	0.95	1.16	0.87	1.10	0.453
School attendance	1,334	0.80	0.16	0.80	0.15	0.79	0.16	0.539	1,680	0.79	0.16	0.79	0.16	0.79	0.17	0.653
Socioeconomic variables																
Muslim HH	1,395	0.03		0.03		0.03		0.941	1,772	0.03		0.03		0.03		0.965
Sc/st	1,395	0.29		0.26		0.33		0.181	1,772	0.28		0.25		0.31		0.233
Block	1,395	0.65		0.71		0.59		0.251	1,772	0.67		0.71		0.63		0.417
Rural HH	1,395	0.98		0.97		0.98		0.606	1,772	0.98		0.97		0.98		0.541
N of HH members	1,395	7.66	3.23	7.75	3.34	7.57	3.13	0.434	1,772	7.73	3.35	7.78	3.40	7.68	3.31	0.618
Years schooling father	1,395	5.42	4.78	5.43	4.75	5.42	4.82	0.973	1,772	5.44	4.84	5.37	4.82	5.52	4.87	0.678
Years schooling mother	1,395	1.72	3.15	1.78	3.22	1.66	3.08	0.616	1,772	1.79	3.24	1.80	3.26	1.78	3.22	0.935

Asset index	1,395	-0.00	1.00	0.02	0.99	-0.02	1.01	0.635	1,772	-0.02	0.97	-0.01	0.96	-0.04	0.99	0.707
Health care																
Institutional delivery	1,395	0.39		0.40		0.37		0.387	1,772	0.38		0.39		0.38		0.695
Health insurance	1,395	0.39		0.40		0.38		0.701	1,772	0.39		0.40		0.38		0.592
Morbidity																
Diarrhea	1,395	0.03		0.04		0.03		0.258	1,772	0.03		0.03		0.03		0.490
Improved sanitation	1,395	0.08		0.08		0.08		0.732	1,772	0.08		0.08		0.09		0.584
Biological factor																
Male child	1,395	0.45		0.44		0.46		0.456	1,772	0.45		0.45		0.46		0.729
Car taking																
Help with homework	1,395	0.16		0.18		0.14		0.264	1,772	0.16		0.17		0.16		0.459
Time physical care	1,395	45.59	25.83	44.15	24.93	46.95	26.60	0.222	1,772	45.22	24.95	44.00	24.27	46.43	25.56	0.251
School meetings	1,395	0.63		0.63		0.63		0.937	1,772	0.62		0.63		0.61		0.732
Father at home	1,395	0.88		0.89		0.87		0.514	1,772	0.87		0.88		0.86		0.548
Distance to school																
Distance to school	1,395	10.41	6.24	10.18	6.00	10.63	6.46	0.434	1,772	10.41	6.29	10.30	6.03	10.52	6.55	0.688
Nutrition																
Diet diversity score	1,395	3.87	1.18	3.89	1.21	3.84	1.15	0.598	1,772	3.87	1.17	3.90	1.21	3.84	1.14	0.566
Number of meals	1,395	3.04	1.08	3.00	1.11	3.07	1.04	0.444	1,772	3.02	1.06	3.01	1.08	3.04	1.05	0.652
Cut meals	1,395	0.82		0.82		0.81		0.610	1,772	0.80		0.80		0.80		0.949
Maternal health knowledge	1,395	0.38		0.36		0.40		0.361	1,772	0.38		0.36		0.40		0.218
B. School level variables																
Total enrollment	107	222.21	158.24	222.15	168.29	222.28	149.30	0.997	107	222.21	158.24	222.15	168.29	222.28	149.30	0.997
Class size	107	28.19	16.87	28.87	20.41	27.52	12.63	0.682	107	28.19	16.87	28.87	20.41	27.52	12.63	0.682
Student teacher ratio	107	35.68	11.63	37.52	12.55	33.87	10.46	0.105	107	35.68	11.63	37.52	12.55	33.87	10.46	0.105
Calories of MDM per child	107	68.80	23.55	69.57	21.45	68.04	25.62	0.739	107	68.80	23.55	69.57	21.45	68.04	25.62	0.739

This table presents baseline summary statistics as well as p-values for difference in the means tests between children in the treatment and control schools. All variables shown are child level variables from the baseline except for panel B, which shows school level variables. Standard errors are clustered at the school level. N: Number of observations. MDM: Midday Meal.