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Improving the Health and Education of Elementary Schoolchildren in Rural China: Iron Supplementation Versus Nutritional Training for Parents

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ABSTRACT *We report on the results of a randomised controlled trial conducted among over 2,000 children in 60 elementary schools in rural Shaanxi Province, North-west China. We find that providing children with daily iron supplements for six months improved children's haemoglobin levels and standardised maths scores. In comparison, educating parents about nutrition and anaemia in a special parents meeting produced a modest impact on children's haemoglobin levels. We also find heterogeneous intervention effects by children's gender, anaemia status and boarding status. Overall, iron supplementation is more effective. However, given its low cost and simple implementation, parental education should still be considered.*

1. Introduction

Poor diets and malnutrition problems can negatively affect children's health and education (Alderman, Behrman, Lavy, & Menon, 2001; Alderman, Hoddinott, & Kinsey 2006; Glewwe, Jacoby, & King, 2001). In particular, children who have poor diets and malnutrition problems can get iron deficiency anaemia and suffer from fatigue, physical impairment, inattention and other barriers to school learning (Bobonis, Miguel, & Puri-Sharma, 2006; Grantham-McGregor & Ani, 2001; Iannotti, Tielsch, Black, & Black, 2006). As such, it appears that measures that improve children's diets and address their malnutrition problems have the potential to raise both their health and educational outcomes.

In China, despite rapid economic growth and government's commitment to rural education in recent years, a large share of rural children are still anaemic and fail to study well at school (Luo et al., 2010; Luo, Wang, et al., 2011; Luo, Zhang, et al., 2011). Fortunately, there exists a simple and effective solution. A study by Luo, Shi, Zhang, Liu, et al. (2012) shows that when elementary schoolchildren in poor, rural counties were given iron supplement tablets every day for a period of five months, their haemoglobin (Hb) levels rose, anaemia rates fell and standardised test scores went up.

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Given that iron supplementation brings many benefits to children and basically no side effects, it would seem that China's local governments – which are responsible for basic education in the country – would quickly act to provide iron to all rural children. In fact, such a policy option can be seen as 'low-hanging fruit' for local government officials. Iron supplementation costs only 0.25 yuan per child per day, and current subsidies to poor children are already 10 times of that amount (China Radio International Online, 2011). To date, however, no local government in China has shown any intention to implement an iron supplementation programme. While in personal interviews some local government officials agree with us that anaemia is still prevalent among rural children, they typically share the view that the provision of quality diets to children is the duty of the parents, not that of the government.

Interestingly, however, many local government officials actually acknowledge that parents' ignorance of anaemia can be a major cause of its prevalence among rural children. Anaemia occurs when the Hb level is low and its symptoms are, very often, not obvious. Therefore, some government officials believe that educating parents about nutrition and anaemia can help parents improve children's diet and ultimately raise both children's health and educational outcomes. The logic behind this view is in fact simple: parents who are educated often raise children who are healthy and study well in school (Cochrane, Leslie, & O'Hara, 1982; Desai & Alva, 1998).

Following this argument, then, raises two important questions: Should a health education programme that targets the parents be expected to work? And if the answer is yes, can such a health education programme be as effective (or as cost-effective) as an iron supplementation programme? Unfortunately, the literature provides no clear answer to both of these two questions. One major reason relates to the research design of existing studies. Specifically, some of the existing works do not include a valid control group for comparison (Badruddin et al., 2008; Onyango-Ouma, Aagaard-Hansen, & Jensen, 2005) and some other works instead bundle health education programmes with the provision of free or subsidised health inputs (Huttly et al., 1990; Luby et al., 2004; Quick et al., 2002; Rhee et al., 2005). Because of the issues in the research design, in these studies the observed changes in health behaviours and health outcomes cannot be attributed to the health education programmes alone.

There are, of course, a few well-designed studies on the effects of health education programmes; however, a review of these studies shows that the evidence is decidedly mixed. While some studies find that health education programmes increase the adoption of targeted health behaviours (Eurlkar, Ettyang, Onoka, Nyagah, & Muyonga, 2004; Fitzsimons, Malde, Mesnard, & Vera-Hernández, 2012; Hu et al., 2005; Jalan & Somanathan, 2008), other studies detect no significant change (Kamali et al., 2003; Kremer & Miguel, 2007). Moreover, behaviour changes occur more likely on the intensive margin rather than on the extensive margin (Dupas, 2011) or occur primarily when the cost of behaviour change is very low (Madajewicz et al., 2007). Even when behaviour change is documented, the ultimate impact and effectiveness on health outcomes can still be questionable (Davis, Pickering, Rogers, Mamuya, & Boehm, 2011). In the case of addressing childhood anaemia, it has been shown that simply sending letters to inform parents about children's anaemia status and suggest courses of action is less effective than direct iron supplementation (Luo, Shi, Zhang, Liu, et al., 2012).

In this article we have two specific research goals. The first goal is to examine the effects of two separate interventions – an *iron supplementation* programme and a *parental education* programme – on children's Hb levels and anaemia status. In light of the findings in Luo, Shi, Zhang, Liu, et al. (2012), in our parental education programme we train parents much more intensively and interactively about nutrition and anaemia in a special parents meeting (rather than simply providing them health information in the form of letters). The iron supplementation programme is almost identical to the programme in Luo, Shi, Zhang, Liu, et al. (2012) and can be considered as a standard one. In the supplementation programme we provide children iron supplement tablets every day for a period of six months. The second goal builds upon the first one. The second goal is to test whether the two health-promoting interventions can also improve children's standardised maths scores. We choose standardised maths scores to be our measure of educational outcomes because this measure is simple and objective. We acknowledge that there can be other margins of educational outcomes on which our interventions can have an effect.

In pursuing these two research goals, we are going to examine what overall effects our two interventions can bring to the rural children and whether the intervention effects actually differ among different groups of children. Therefore, in addition to the estimation of the average effects of the two interventions, we also conduct three different sets of impact heterogeneity analyses. First, we examine whether the intervention effects differ by children's gender. In China, boys are typically more treasured and invested than girls (Gustafsson & Li, 2000; Hannum, 2005). Therefore, we seek to examine whether or not our interventions can help girls. Second, we examine whether the intervention effects differ by children's anaemia status at the baseline. We seek to understand whether the two interventions can help those who are more vulnerable.

Third, we study whether the effects also differ by whether children live at home or board at school. In the early 2000s the Ministry of Education (MOE) launched a school merger programme to merge small elementary schools in remote rural areas into larger ones (Liu, Zhang, Luo, Rozelle, & Loyalka, 2010). As a result, for many children the distance between home and school increased substantially and school administrators started to let children board at school (Ma, 2009). Although the government has allocated funds to build dormitory and dining facilities and give boarding children a food subsidy, the amount of the funds still greatly fall short of the needs.[1] Boarding children often have to bring pre-processed food from home to supplement the meagre meals provided by their schools. As such, the nutritional values of the daily diets among boarding children are often poor. In fact, a study of 144 rural boarding schools in North-west China shows that boarding children suffer particularly more from malnutrition problems (Luo et al., 2009).

The rest of this article is organised as follows. Section 2 describes our methodology, including the sampling methods, interventions/experimental arms, data collection and statistical approach. Section 3 reports the average effects of the two interventions on children's Hb levels, anaemia rates and standardised maths scores. Section 4 examines the heterogeneous effects of the two interventions. Section 5, the final section, discusses the results and concludes.

2. Methodology

We conducted a randomised controlled trial (RCT) in 60 elementary schools located in China's Shaanxi Province. The RCT consisted of three main stages. In the first stage, in November 2009, we conducted a baseline survey and collected data from over 2,000 fourth-grade children (mostly aged 9 to 12 – menstruation had not started yet for most girls). In the second stage, we implemented the supplementation intervention and the parental education intervention each in a random set of 15 schools. The remaining 30 schools served as an untreated control group. In the final stage, in June 2010, we followed up with the children and conducted an endline survey. The following four subsections review the sampling methods, interventions/experimental arms, data collection and statistical approach.

2.1 Sampling Methods

The 60 schools in this study were selected from 10 rural counties in Shaanxi Province. After gathering a list of all counties in the province, we kept only those that had a majority population in rural areas and randomly selected 10 of them to form our county sample. Then, with the help of the county education bureaus, we compiled a list of all elementary schools in these 10 counties. Because large schools with boarding facilities will be the most common type of schools in rural China in the coming years (as discussed in the introduction), in choosing our school sample we required that each of the shortlisted schools had to have at least 200 students and that at least 50 of the students have to be boarding at school. Overall, 80 elementary schools in these counties met these two selection criteria. We randomly chose 60 of them to comprise our school sample.[2]

At the baseline, there were 2,360 fourth-grade children in the 60 schools and we gave maths tests to all these children. Yet, power calculations indicated that we did not need such a large sample for the Hb analysis. Because of funding consideration, we randomly chose 1,654 of them (around 70%) to undergo the Hb testing. We call these two children samples the *maths sample* and the *Hb sample*.

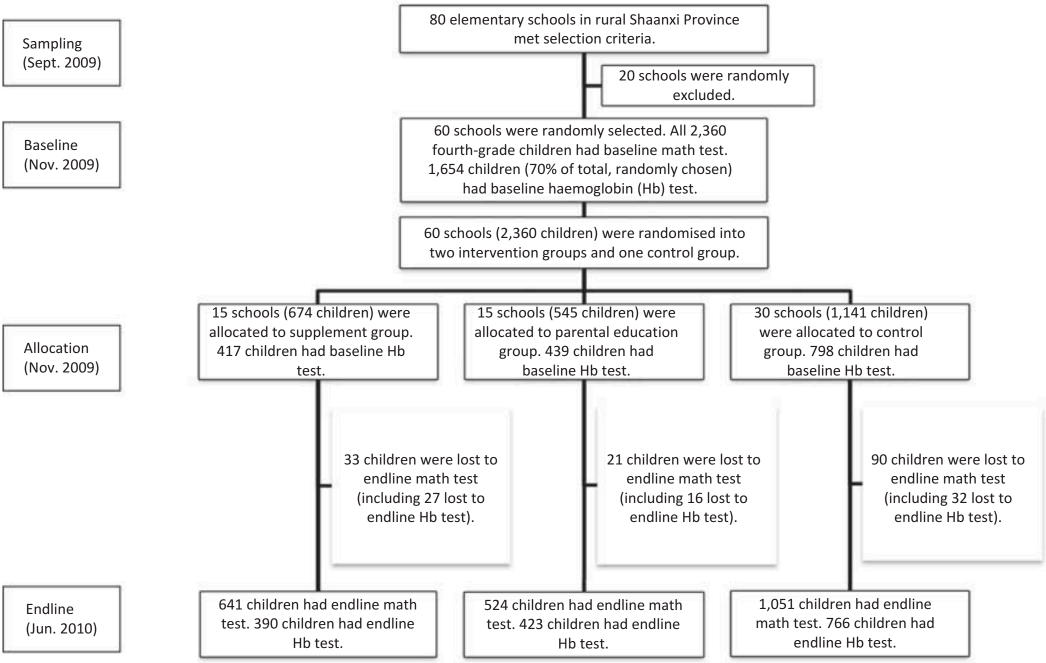

Figure 1. Profile of randomised controlled trial

Due to attrition (often migration to the city with parents), the final children sample was slightly smaller. During the endline survey we were only able to follow up with about 95 per cent of the children (2,216 children in the maths sample; 1,579 children in the Hb sample – see Figure 1). We compared the baseline characteristics of children in the final sample with the baseline characteristics of those who were lost in the endline survey and found no systematic difference between them. Most importantly, the propensity to attrite was not correlated with the three experimental arms.[3]

Following the baseline survey, we randomly assigned each of the 60 sample schools to one of the three experimental arms of this study. In particular, we assigned 15 schools to an intervention group in which children received daily iron supplement tablets; 15 schools to an intervention group in which parents attended a school-based training session on nutrition and anaemia; and 30 schools to a control group that received no intervention. None of the sample schools opted out from our assignment. We designate these three types of schools as *supplement schools, parental education schools* and *control schools* (see Table 1).

Table 2 provides a summary of the baseline characteristics of the sample children and their parents.[4] The key outcome variables (Hb levels, anaemia status, raw and standardised maths scores – rows 1 to 4) are mostly balanced across the intervention and control groups (differences are not significant at the 5% level). However, for a few other characteristics the averages of the supplement schools are statistically different (rows 5 to 10).[5] Because of the observed baseline differences, we will include these characteristics as control variables in our statistical analysis.[6]

2.2 Interventions/Experimental Arms

The two interventions of our RCT were designed to be straightforward and easy to administer. In order to make sure that our interventions were properly carried out, we worked closely with the principals of the 60 schools and also all fourth-grade homeroom teachers of the supplement schools. Besides, we provided them a small honorarium (100 yuan – about one to two days' salary) to encourage a high level of compliance.

Table 1. Distribution of sample fourth-grade children

	Number of sample schools	Number of sample children in the maths sample	Number of sample children in the Hb sample			
	All	All	All	Supplement group	Parental education group	Control group
	(1)	(2)	(3)	(4)	(5)	(6)
Full sample	60	2,216	1,579	390	423	766
County 1	6	209	178	59	32	87
County 2	5	181	141	20	78	43
County 3	8	345	219	30	53	136
County 4	10	411	280	124	85	71
County 5	6	230	169	22	85	62
County 6	6	276	137	17	0	120
County 7	6	209	149	72	0	77
County 8	5	130	127	14	0	113
County 9	3	77	57	0	0	57
County 10	5	148	122	32	90	0

Data source: Authors' survey.
Notes: There are 15 schools in the supplement group, 15 schools in the parental education group and 30 schools in the control group. All 2,216 children took maths tests in both the baseline and endline surveys. Of the 2,216 children, 1,579 of them (randomly chosen) also took haemoglobin tests.

2.2.1 Supplementation intervention. The first intervention was the school-based provision of iron supplement tablets (containing 5 milligrams of iron and 20 other vitamins and minerals per tablet) in the 15 supplement schools. In each supplement school we trained the fourth-grade homeroom teachers using an intervention protocol and hung a large poster inside classrooms to remind them about the protocol. The protocol was simple. During each school day children typically attend a homeroom class right after lunch. Therefore, we asked the teachers to distribute the iron supplement tablets during that class period and prepare a large kettle of drinking water in advance. During the class period, the teachers would distribute to each child an iron supplement tablet in one paper cup and drinking water in another cup. The teachers would then monitor all children taking the tablet. Every Friday afternoon, the teachers would also give the children two extra pieces of tablets for the coming weekend.

Iron supplement tablets were dispensed for six months from December 2009 to May 2010, with the exception of a three-week winter break in January 2010.[7] Each month we supplied the teachers with five weeks' worth of tablets to make sure that there were enough tablets for distribution. We also gave the teachers equipment to prepare drinking water and disposable paper cups for distribution.

About once a month the research team organised a surprise inspection visit to the supplement schools to check on the level of compliance. During the checks the inspectors interviewed the sample children, their parents, the homeroom teachers and other teachers who were not part of the intervention (for example, third-grade teachers). According to the interviews, the level of compliance was nearly perfect.

2.2.2 Parental education intervention. The second intervention was the training of parents about nutrition and anaemia in the 15 parental education schools. The intervention was a one-off event and was conducted and completed in December 2009. In each of the parental education schools, we asked the principal to have the fourth-grade children take home an announcement letter. The letter stated clearly that each family should send at least one parent (or guardian) to attend a mandatory, special parents meeting at the school. This letter and the parents meeting that followed were the extent of the

Table 2. Sample characteristics across experimental arms in the baseline survey (November 2009)

	N	All children	Supplement group	Parental education group	Control group	(3) – (5)	(4) – (5)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Haemoglobin levels (g/L)	1,579	126.9	125.9	127.2	127.3	–1.36 (1.26)	–0.06 (1.28)
Percentage of children who were anaemic (%)	1,579	26.2	27.7	26.2	25.3	2.37 (3.98)	0.91 (3.94)
Raw maths scores (0–29 points)	2,216	18.5	18.6	19.2	18.2	0.37 (0.45)	1.04* (0.53)
Standardised maths scores (in units of standard deviation)	2,216	0.072	0.075	0.213	–0.000	0.753 (0.093)	0.212* (0.109)
Percentage of boarding children (%)	2,216	40.3	29.2	47.1	43.8	–14.59** (5.96)	3.37 (6.84)
Percentage of female children (%)	2,216	47.5	46.3	46.8	48.6	–2.29 (2.41)	–1.86 (2.23)
Age of children (in months)	2,216	121.5	119.7	122.1	122.4	–2.75*** (0.92)	0.35 (1.22)
Education of mothers (in years)	2,216	6.5	7.0	6.3	6.3	0.64 (0.40)	0.06 (0.31)
Percentage of mothers staying at home (%)	2,215	73.1	70.4	78.4	72.2	–1.83 (4.64)	6.24 (3.62)
Percentage of mothers self-employed or working for wage (%)	2,216	8.5	11.5	6.3	7.7	3.84* (2.00)	–1.41 (1.54)

Data source: Authors' survey.
Notes: Children with haemoglobin levels below 120 g/L are classified as anaemic. Robust standard errors adjusted for clustering at the school level are reported in parentheses. ***, ** and * indicate statistical significance from zero at the 1, 5 and 10 per cent levels.

parental education intervention. Specifically, we did not give children any iron supplement tablet or tell parents about children's Hb levels or anaemia status.

The parents meeting typically lasted for about one hour in the school. During the meeting, nutritionists from the School of Medicine of Xi'an Jiaotong University presented to the parents a set of materials on nutrition and anaemia. The materials were simple and were delivered three times in three different formats: a PowerPoint presentation; a video; and a colourful booklet for each parent to take home with. In each of the three parts the following set of materials were delivered: (a) a basic description of anaemia; (b) a warning that anaemia is prevalent among children in rural areas; (c) a detailed discussion of how anaemia can affect children's health, behaviour and learning; (d) a list of symptoms associated with anaemia; and (e) an instruction of how to treat anaemia, focusing on the importance of a balanced diet that includes food with high iron content (such as red meat and soy beans).

At the end of the parents meeting we gave parents a sufficient amount of time to ask questions. During the time the nutritionists only answered questions that were already explicitly discussed in the three-part presentation. If there were other questions, the nutritionists would take note of the questions and get back to the parents later. About three weeks after all additional questions were collected, a factsheet containing the questions as well as the corresponding answers was sent to the parents with the help of the schools.

During each visit to the supplement and parental education schools, the research teams also visited the control schools to 'check in' on the principals and observed activities inside the fourth-grade classrooms. We detected no abnormal activity in the control schools, and therefore we are confident that the estimated impacts of the two interventions can be solely attributed to the interventions themselves, not contaminated by any Hawthorne Effect (Steven & List, 2011) in the control schools.

2.3 Data Collection

We measured children's baseline Hb levels in November 2009 and their endline levels in June 2010. Five nurses from the School of Medicine of Xi'an Jiaotong University conducted Hb tests onsite using the HemoCue Hb 201+ system. This system is portable and is known to provide rapid, accurate measurements of Hb levels in the field.

Data on the Hb levels were also used to create a measure of anaemia status. The World Health Organisation (WHO) recommends an anaemia cutoff of 115 g/L for children aged 5–11 and a cutoff of 120 g/L for children aged 12–14 (Gleason & Scrimshaw, 2007; United Nations Children's Fund, United Nations University, & World Health Organization, 2001). Since almost all of our sample children fall into these two age groups and since Hb levels borderline for anaemia have also been shown to affect cognitive functioning (Halterman, Kaczorowski, Aligne, Auinger, & Szilagyi, 2001), in this study we used the 120 g/L cutoff and created a binary measure of children's anaemia status accordingly (that is, Hb level below 120 g/L=1; if not=0).

Data on the standardised maths scores were collected from maths tests administered as part of the survey. Using questions from the question pool of the Trends in International Mathematics and Science Study (TIMSS) test (Mullis, Martin, Ruddock, O'Sullivan & Preuschoff, 2009), we created two different maths tests (one test for the baseline and another test that was slightly more difficult for the endline). In each of these two tests there were 29 multiple choice questions in total, and children were given 30 minutes to work on them. The two tests then gave us two raw maths scores (0–29 points) for each child (one from the baseline test and another from the endline test).[8]

In order to make the findings from our test score analysis comparable and easy to understand, we standardised the raw maths scores and created the variable *standardised maths scores.* The standardised scores were calculated as *individual standardised maths score = (individual raw maths score – average of raw maths scores in the control group)/standard deviation of raw maths scores in the control group.* Specifically, we used the baseline standard deviation from the control group to standardise the baseline scores and the endline standard deviation to standardise the endline scores. We did so for two reasons. First, the use of the standard deviation as a unit of measure is a common practice in the economics of education. The conversion from raw scores to standardised scores allows us to compare easily our findings with findings that are based on the same maths test and with others that are based on other types of maths tests. Second, we use the standard deviation of the control group as the unit because raw scores in the control group were not affected by the interventions. Raw scores in the intervention groups, particularly those that were collected after the interventions, could be affected and should not be used in the standardisation.

During both the baseline and endline surveys we also collected a good amount of other data, including different basic characteristics of the children, their parents, their teachers and their schools. We asked the children to take home a household survey for their parents to complete and, by doing so, collected information on the children themselves and also their parents. Furthermore, we collected data about the schools from the school principals and about the fourth-grade homeroom teachers using a teacher survey.

2.4 Statistical Approach

We use both descriptive statistics and regression analyses to estimate the impact of the supplementation and parental education interventions on children's Hb levels and standardised maths scores. In both of these two sets of analyses, we estimate the standard error terms with the use of clustering of observations obtained from the same school.

Our basic regression model is a *county fixed effects (FE) model* in a value-added approach:

$$Y_{ijk}^{endline} = a_0 + a_1{}^{*}Supplement_{jk} + a_2{}^{*}Parental\ education_{jk} + a_3{}^{*}Y_{ijk}^{baseline} + \mu_k + e_{ijk} \tag{1}$$

where $Y_{ijk}^{baseline}$ and $Y_{ijk}^{endline}$ are the baseline and endline outcome variables (Hb levels, anaemia status or standardised maths scores) for child i in school j in county k. The two independent variables, $Supplement_{jk}$ and $Parental\ education_{jk}$, are dummy variables that equal 1 if the child is in a supplement school or in a parental education school and equal 0 if otherwise. In other words, the base group for comparison is the control schools. County fixed effects, μ_k, are included to control for any unobserved, time-invariant county heterogeneity. The estimates of the parameters a_1 and a_2 are thus the average within-county effects of the supplementation and parental education interventions. We want to test if these two estimates are positive and statistically significant from zero.

In order to control for the observed baseline differences between the intervention and control schools, we add to the above model four different sets of variables. First, we control for three different child characteristics, including child's boarding status (boarding at school=1; living at home=0), child's gender (female=1; male=0) and child's age (in months). Second, we control for three different maternal characteristics, including mother's years of education, whether the mother lives at home (living at home=1; if not=0), and mother's working status (self-employed or working for wage=1; if not=0). Third, we control for two different school characteristics, including the number of schoolchildren and the share of boarding children. Finally, in the analysis of the Hb levels and anaemia status, we also control for the Hb tester fixed effects. The model that includes these sets of control variables (three sets for the maths score analysis; four sets for the Hb level and anaemia rate analyses) can be written as:

$$\begin{aligned} Y_{ijk}{}^{endline} &= a_0 + a_1{}^{*}Supplement_{jk} + a_2{}^{*}Parental\ education_{jk} + a_3{}^{*}Y_{ijk}{}^{baseline} \\ &\quad + a_4{}^{*}Z\_Child_{ijk} + a_5{}^{*}Z\_Mother_{ijk} + a_6{}^{*}Z\_School_{jk}\ \left(+a_7{}^{*}Z\_Hbtester_{jk}\right) + \mu_k + e_{ijk} \end{aligned} \tag{2}$$

where Z_Child_{ijk}, Z_Mother_{ijk} , Z_School_{jk} and $Z\_Hb\ tester_{jk}$ are the sets of control variables defined above.[9]

2.4.1 Heterogeneous effects of the supplementation and parental education interventions. As discussed in the introduction, we also make use of our data to examine if the effects of the supplementation and parental education interventions differ by children's gender, anaemia status and boarding status. In order to do so, in three separate sets of regressions we include to the right-hand-side of Equation (2) two interaction variables constructed by multiplying the $Supplement_{jk}$ and $Parental\ education_{jk}$ dummy variables with one of the three child characteristics that we are interested in. The three child characteristics are child's gender (*Female*), child's baseline anaemia status (*Baseline Anaemic*) and child's boarding status (*Boarding*). To illustrate, the setup of the impact heterogeneity analysis in the case of child's gender is presented as follow:

$$\begin{aligned} Y_{ijk}{}^{endline} &= a_0 + a_1{}^{*}Supplement_{jk} + a_2{}^{*}Parental\ education_{jk} + a_{11}{}^{*}Supplement_{jk}{}^{*}Female_{ijk} \\ &\quad + a_{21}{}^{*}Parental\ education_{jk}{}^{*}Female_{ijk} + a_3{}^{*}Y_{ijk}{}^{baseline} + a_4{}^{*}Z\_Child_{ijk} \\ &\quad + a_5{}^{*}Z\_Mother_{ijk} + a_6{}^{*}Z\_School_{jk}\left(+a_7{}^{*}Z\_Hbtester_{jk}\right) + \mu_k + e_{ijk} \end{aligned} \tag{3}$$

The estimates for a_{11} and a_{21} represent the average within-county differences between female and male children in the effects of the two interventions net of other factors. We want to examine the sign and magnitude of the estimates and whether they are statistically different from zero.

3. Average Effects of the Supplementation and Parental Education Interventions

According to our data, anaemia is still prevalent among children in rural areas in North-west China. Based on our baseline testing, the average Hb level of our sample children is 126.9 g/L. The average Hb level of girls is lower than that of boys by 1.5 g/L. The distribution of the Hb levels are close to being normal and the standard deviation is 11.2 g/L. Using an anaemia cutoff of 120 g/L, we find that one out of every four children in our sample (or 26.2%) is anaemic.[10]

3.1 Descriptive Statistics

Somewhat surprisingly, the descriptive statistics show no statistical evidence that the supplementation and parental education interventions improve children's health and educational outcomes (Table 3). While the supplementation intervention raises children's Hb level by 1.77 g/L (panel A, column 3, row 4), the estimate is not statistically different from zero. The estimate for the parental education intervention variable is even slightly negative, though the estimate is statistically insignificant also (–0.66 g/L – panel A, column 3, row 5). Children's anaemia rates in the two intervention groups both drop after the interventions; however, both of the changes are again insignificant statistically (panel B, column 3). Finally, we also find no clear evidence of intervention effects on children's standardised maths scores (panel C, column 3). It seems that, by the descriptive statistics, the two interventions have no effect at all on children's health and educational outcomes.

3.2 Multivariate Results

The findings in the descriptive statistics may be biased and are at best suggestive, however. This is because potentially there are unobserved time-invariant heterogeneities at the county level and also differences in the baseline characteristics across the three experimental arms. To more accurately estimate the effects of the two interventions, we need to conduct multivariate analysis in order to control for different compounding factors.

Table 3. Haemoglobin levels, anaemia rates and standardised maths scores of fourth-grade children across experimental arms

	Baseline survey (November 2009) (1)	Endline survey (June 2010) (2)	Difference between the baseline and endline surveys (3)
Panel A: Haemoglobin levels (g/L) (N=1,579)			
Supplement group	125.9	130.7	4.81 (1.28)***
Parental education group	127.2	129.6	2.38 (1.44)
Control group	127.3	130.3	3.04 (1.29)**
Difference between the supplement and control groups			1.77 (1.79) [a]
Difference between the parental education and control groups			–0.66 (1.90) [a]
Panel B: Anaemia rates (g/L) (N=1,579)			
Supplement group	27.7	16.7	–11.03 (2.99)***
Parental education group	26.2	18.2	–8.04 (4.06)*
Control group	25.3	18.9	–6.40 (3.15)*
Difference between the supplement and control groups			–4.63 (4.27) [a]
Difference between the parental education and control groups			–1.64 (5.04) [a]
Panel C: Standardised maths scores (units of standard deviation) (N=2,216)			
Supplement group	0.075	0.109	0.033 (0.034)
Parental education group	0.213	0.168	–0.045 (0.035)
Control group	–0.000	–0.000	–0.000 (0.033)
Difference between the supplement and control groups			0.033 (0.047) [a]
Difference between the parental education and control groups			–0.045 (0.048) [a]

Data source: Authors' survey.
Notes: Children with haemoglobin levels below 120 g/L are classified as anaemic. Robust standard errors adjusted for clustering at the school level are reported in parentheses. ***, ** and * indicate statistical significance from zero at the 1, 5 and 10 per cent levels.
[a] Simple difference-in-differences estimates (between the intervention and control groups and between the baseline and endline surveys).

Our multivariate results indeed tell a story that is different from the descriptive statistics (Table 4). Specifically, when we estimate Equation (2) as discussed in Section 2.4 above, we find that the two interventions both raise children's Hb levels. The supplementation intervention raises children's Hb levels by 3.69 g/L (column 2, row 1). The increase is 33 per cent of the sample standard deviation and is significant at the 1 per cent level. The parental education intervention also raises children's Hb levels by a modest 2.22 g/L (column 2, row 2). This increase is still 20 per cent of the sample standard deviation and is significant at the 10 per cent level.[11] The effects of the interventions on children's anaemia status are consistent with the findings above (see Online Appendix, Table A1).

Table 4. Effects of supplementation and parental education interventions on the haemoglobin levels and standardised maths scores of fourth-grade children

	Dependent variable: Endline Hb levels (g/L)		Dependent variable: Endline standardised maths scores (units of standard deviation)	
	(1)	(2)	(3)	(4)
Intervention variables:				
Supplement (1=child in supplement school; 0=not)	4.07***	3.69***	0.09*	0.10*
	(1.26)	(1.22)	(0.05)	(0.05)
Parental education (1=child in parental education school; 0=not)	2.42**	2.22*	0.03	0.02
	(1.13)	(1.30)	(0.05)	(0.05)
Child characteristics:				
Baseline Hb level (g/L)	0.40***	0.39***		
	(0.02)	(0.02)		
Baseline standardised maths scores (units of standard deviation)			0.72***	0.71***
			(0.02)	(0.02)
Boarding dummy (1=yes; 0=no)		1.13*		0.00
		(0.61)		(0.04)
Female dummy (1=yes; 0=no)		–0.49		–0.02
		(0.60)		(0.03)
Age (in months)		0.09***		–0.01***
		(0.02)		(0.00)
Mother characteristics:				
Education of mother (in years)		–0.04		0.01**
		(0.10)		(0.00)
Mother staying at home dummy (1=yes; 0=no)		0.14		0.01
		(0.63)		(0.04)
Mother self-employed or working for wage dummy (1=yes; 0=no)		1.90**		0.02
		(0.94)		(0.05)
Hb tester FE	No	Yes	No	No
School characteristics	No	Yes	No	Yes
County FE	Yes	Yes	Yes	Yes
Constant	76.09***	77.11***	0.02	0.97***
	(3.03)	(3.93)	(0.06)	(0.21)
N	1579	1540	2216	2178
R^2	0.29	0.31	0.55	0.56

Data source: Authors' survey.
Notes: Robust standard errors adjusted for clustering at the school level are reported in parentheses. School characteristics include the number of children in school and the share of boarding children. ***, ** and * indicate statistical significance from zero at the 1, 5 and 10 per cent levels.

We also find that the supplementation intervention raises children's maths scores by 10 per cent of the sample standard deviation (significant at the 10% level – column 4, row 1). However, perhaps due to the modest size of impact of the parental education intervention on the Hb levels, the effect of the intervention on the maths scores is nearly zero (0.02 standard deviation, statistically insignificant – column 4, row 2).

Overall, our results are not too different from those reported in another RCT in the same study province by Luo, Shi, Zhang, Liu, et al. (2012). One major difference in the results is that our parental education intervention brought a modest improvement on children's Hb levels, whereas their health information intervention brought no impact at all. This should not be surprising, however. In our intervention we intensively and interactively trained parents about nutrition and anaemia in a special parents meeting; in their intervention they only sent letters to inform parents the anaemia status of their children and provide health information. There was no discussion or interaction in their intervention.

4. Heterogeneous Effects of the Supplementation and Parental Education Interventions

Our multivariate analysis also shows that in some cases there are differences in the effects of the two interventions by children's characteristics.

4.1 Female Children Versus Male Children

First, we compare the intervention effects between boys and girls (Table 5). Our results show that while the supplementation intervention brings nearly the same size of improvements on the Hb levels

Table 5. Heterogeneous effects of supplementation and parental education interventions on the haemoglobin levels and standardised maths scores by children's gender

	Dependent variable: Endline Hb level (g/L)	Dependent variable: Endline standardised maths scores (units of standard deviation)
	(1)	(2)
Supplement (1=child in supplement school; 0=if not)	3.58** (1.72)	0.04 (0.07)
Parental education (1=child in parental education school; 0=if not)	1.07 (1.32)	0.03 (0.08)
Supplement*Female (1=yes; 0=no)	0.26 (1.75)	0.12 (0.08)
Parental education*Female (1=yes; 0=no)	2.53**(1.05)	–0.03 (0.09)
Female dummy (1=yes; 0=no)	–1.26 (0.78)	–0.05 (0.05)
Hb tester FE	Yes	No
Characteristics of child, mother and school	Yes	Yes
County FE and constant term	Yes	Yes
N	1540	2178
R^2	0.31	0.56
F-statistics: Supplement + Supplement*Female=0	10.28***	6.13**
F-statistics: Education + Education*Female=0	5.83**	0.00

Data source: Authors' survey.

Notes: Robust standard errors adjusted for clustering at the school level are reported in parentheses. Child characteristics include child's age (in months), boarding status and baseline Hb level. Mother characteristics include mother's years of education, a dummy variable for mother staying at home and a dummy variable for mother self-employed or working for wage. School characteristics include the number of children in school and the share of boarding children. ***, ** and * indicate statistical significance from zero at the 1, 5 and 10 per cent levels.

of boys and girls (3.58 g/L versus 3.84 g/L – column 1, row 1 and 3), the parental education intervention raises only the Hb levels of girls (3.60 g/L, 1.07+2.53, significant at the 1% level – column 1, row 2 and 4) but not the levels of boys (1.07 g/L, statistically insignificant – column 1, row 2). Following the large effect on the Hb levels of girls, the supplementation intervention also improves the standardised maths scores of girls by 0.16 standard deviation (0.04+0.12, significant at the 5% level – column 2, row 1 and 3). However, the intervention does not seem to improve the maths scores of boys. There is also no impact of the parental education intervention on the maths scores of both boys and girls.

4.2 Anaemic Children versus Non-anaemic Children

We find some surprising results in the heterogeneity analysis of the two interventions by children's baseline anaemia status (Table 6). The effect of the supplementation intervention on the Hb levels of anaemic children is smaller than the effect on non-anaemic children (2.19 g/L versus 4.24 g/L – column 1, row 1 and 3). The estimated coefficients of the *Supplement*Anaemia* variable is negative and is significant at the 10 per cent level (−2.05 – column 1, row 3). Somewhat similarly, the parental education intervention also brings a small and insignificant impact to anaemic children and a larger and significant (at the 10% level) impact to non-anaemic children (1.65 g/L versus 2.47 g/L – column 1, row 2 and 4). Therefore, taken all these results together, we find that the effects of both the

Table 6. Heterogeneous effects of supplementation and parental education interventions on the haemoglobin levels and standardised maths scores by children's baseline anaemia status

	Dependent variable: Endline Hb level (g/L)	Dependent variable: Endline standardised maths scores (units of standard deviation)
	(1)	(2)
Supplement (1=child in supplement school; 0=if not)	4.24*** (1.27)	0.13** (0.06)
Parental education (1=child in parental education school; 0=if not)	2.47* (1.39)	–0.05 (0.06)
Supplement*Baseline anaemic (1=yes; 0=no)	–2.05* (1.04)	–0.02 (0.08)
Parental education*Baseline anaemic (1=yes; 0=no)	–0.82 (1.34)	0.19** (0.08)
Baseline Hb level (g/L) [a]	0.39*** (0.04)	–0.04 (0.06)
Hb tester FE	Yes	No
Characteristics of child, mother and school	Yes	Yes
County FE and constant term	Yes	Yes
N	1540	1523
R^2	0.31	0.55
F-statistics: Supplement + Supplement*Baseline anaemic=0	2.60	2.23
F-statistics: Education + Education*Baseline anaemic=0	1.15	3.69*

Data source: Authors' survey.

Notes: Robust standard errors adjusted for clustering at the school level are reported in parentheses. Child characteristics include child's gender, age (in months) and boarding status. Mother characteristics include mother's years of education, a dummy variable for mother staying at home and a dummy variable for mother self-employed or working for wage. School characteristics include the number of children in school and the share of boarding children. ***, ** and * indicate statistical significance from zero at the 1, 5 and 10 per cent levels.

[a] In accordance with our outcome variable, we choose to include the baseline Hb level as the explanatory variable instead of the baseline anaemia status.

supplementation and parental education interventions are weaker among those who are more vulnerable – the anaemic children.

We also find impact heterogeneities on children's standardised maths scores by anaemia status. The supplementation intervention brings a large improvement on the test scores of non-anaemic children (0.13 standard deviation, significant at the 5% level – column 2, row 1) and a slightly smaller impact to anaemic children (0.11 standard deviation, 0.13+ −0.02, statistically insignificant – column 2, row 1 and 3). These results are consistent with the effects found on the Hb levels. In contrast, the parental education intervention actually raises the test scores of anaemic children (0.14 standard deviation, −0.05+0.19, significant at the 10% level – column 2, row 2 and 4) but not those of non-anaemic children (−0.05 standard deviation, statistically insignificant – column 2, row 2). The set of results may appear surprising given the lack of intervention effect on the Hb levels of anaemic children. However, if parents of anaemic children are unable to improve the diet of their children (say, due to lack of extra income to buy red meat), they may instead simply help their children study harder.

4.3 Boarding Children versus Non-boarding Children

Finally, our results show that the effects of the two interventions differ by whether children live at home or board at school (Table 7).[12] Specifically, the supplementation intervention raises the Hb levels of non-boarding children by 4.94 g/L (significant at the 1% level – column 1, row 1) but raises the levels of boarding children by only 1.67 g/L (4.94+ −3.27, statistically insignificant – column 1, row 1 and 3). Similarly, the parental education intervention brings a large impact on non-boarding children (3.54 g/L, significant at the 5 per cent level – column 1, row 2) but not boarding children (0.78 g/L,

Table 7. Heterogeneous effects of supplementation and parental education interventions on the haemoglobin levels and standardised maths scores by children's boarding status

	Dependent variable: Endline Hb level (g/L)	Dependent variable: Endline standardised maths scores (units of standard deviation)
	(1)	(2)
Supplement (1=child in supplement school; 0=if not)	4.94*** (1.32)	0.12* (0.06)
Parental education (1=child in parental education school; 0=if not)	3.54** (1.44)	–0.03 (0.07)
Supplement*Boarding (1=yes; 0=no)	–3.27** (1.42)	–0.06 (0.09)
Parental education*Boarding (1=yes; 0=no)	–2.76** (1.19)	0.10 (0.09)
Boarding dummy (1=yes; 0=no)	2.68*** (0.81)	–0.01 (0.05)
Hb tester FE	Yes	No
Characteristics of child, mother and school	Yes	Yes
County FE and constant term	Yes	Yes
N	1540	2178
R^2	0.31	0.56
F-statistics: Supplement + Supplement*Boarding=0	1.21	0.58
F-statistics: Education + Education*Boarding=0	0.30	0.97

Data source: Authors' survey.

Notes: Robust standard errors adjusted for clustering at the school level are reported in parentheses. Child characteristics include child's gender, age (in months) and baseline Hb level. Mother characteristics include mother's years of education, a dummy variable for mother staying at home and a dummy variable for mother self-employed or working for wage. School characteristics include the number of children in school and the share of boarding children. ***, ** and * indicate statistical significance from zero at the 1, 5 and 10 per cent levels.

3.54+ −3.76, statistically insignificant – column 1, row 2 and 4). In other words, boarding children do not seem to benefit from these two interventions.

On whether the effects on health carry forward to educational outcomes, we only found that the supplementation intervention also brings a positive effect on the standardised maths scores of non-boarding children (0.12 standard deviation, significant at the 10% level – column 2, row 1). We find no impact of the supplementation intervention on the maths scores of boarding children and also no impact of the parental education intervention on both boarding and non-boarding children. Therefore, in sum, our results here show that health-promoting interventions can bring positive impacts on children's education outcomes when their benefits on the health outcomes are large.

5. Discussion and Conclusion

In this article we document that, despite China's rapid economic growth, anaemia is still widespread among elementary schoolchildren in China's rural areas. Using the WHO-recommended anaemia cutoff of 120 g/L in the Hb level, we find that 26 per cent of the sample children in China's Shaanxi Province are anaemic. The results from our RCT show that providing children with daily iron supplement tablets for a period of six months increases children's Hb levels by 3.69 g/L (or 33% of the sample standard deviation). The intervention also raises children's standardised maths scores by 10 per cent of the sample standard deviation. The impact of educating parents about nutrition and anaemia intensively and interactively in one single parents meeting is somewhat weaker. Children's Hb levels, on average, increase by a modest 2.22 g/L (or 20% of the standard deviation) and their maths scores do not show improvement. Our heterogeneity analyses further show that the effects of the two interventions also differ by children's gender, their anaemia status and whether they live at home or board at school (which affects the nutritional content of their daily meals).

Overall, our results let us draw four sets of conclusions. The first one is that carefully implemented health education programmes can indeed produce positive effects on health outcomes. In this study, we design our parental education programme to be both intensive and interactive. We present to parents the same set of information about nutrition and anaemia three times in three different formats (PowerPoint, video and colourful booklet) and answer their questions afterward. We put in effort to help parents fully understand the health information we provide, and the effort is shown to be rewarding. It is important to note that our health education programme is different from the health information programme conducted in Luo, Shi, Zhang, Liu, et al. (2012). In that study, parents were simply informed in letters about their children's anaemia status and several courses of action to treat anaemia. Their programme, while also carefully designed and implemented, unfortunately brought no impact to children's Hb levels. Overall, there are clear evidences that for health education programmes to be effective the level of intensity and interactivity of how health information is passed on to the targeted audience is crucial.

Second, while the effect of health education is weaker than that of iron supplementation, health education should still be promoted given its low cost and simple implementation. Although the effect size of our parental education intervention on children's Hb levels is only about 60 per cent of the effect size of our supplementation intervention, the cost of the parental education intervention is much lower. The per-child cost of the training and deployment of nutritionists is about 10 yuan (or 1.6 dollars). The per-child cost of providing children with iron supplement tablets every day for a period of six months is 45 yuan (or about 7.3 dollars). The preparation of the parental education intervention is also much simpler and only needs one single day in each of the intervention schools. The supplementation programme, in contrast, requires much effort and collaboration of the principals and school teachers on the distribution of supplement tablets, drinking water and paper cups. The distribution also takes time from class periods every day and the programme has to last for a few months. In terms of overall cost effectiveness, the parental education programme definitely has its advantages.

Third, investments that substantially improve children's health outcomes are also proved to improve children's educational outcomes. The evidence can be found in the results of our supplementation intervention. In this intervention, children's Hb levels increase by 33 per cent of the sample standard deviation and their maths scores by 10 per cent of the sample standard deviation. The magnitude of the maths score increase is actually not small. We do not observe a similar cause–effect relationship in our parental education intervention, however. Due to its modest effect on children's Hb levels, the maths scores of children in our parental education schools do not appear to improve.

Finally, the two interventions actually bring different effects on different groups of children. In some cases, the observed heterogeneous effects might appear somewhat surprising – effects of the supplementation intervention on children's Hb levels and standardised maths scores, though positive, are weaker among anaemic children than among non-anaemic children. It should not be surprising that iron supplementation improves the health and educational outcomes of children who are not anaemic per se, however. The anaemia cutoff is in some sense artificial, and there is other work showing that providing iron to those with Hb levels above the cutoff can have a positive effect (Halterman et al., 2001; United Nations Children's Fund et al., 2001). Still, the larger impact of the supplementation intervention on non-anaemic children is somewhat unexpected. While our paper is not set up to provide scientific explanations for the results, we offer two possible explanations.

First, it is possible that anaemia is a health condition and also a learning barrier that co-exists with other health conditions and learning barriers. While iron supplementation attempts to treat anaemia, others health conditions and learning barriers may remain effective among the most vulnerable children. It is possible that iron supplementation would perform better among vulnerable children when some other complementary inputs on children's health are present (such as meals with better nutritional values). Second, reducing anaemia to the more anaemic children may lead to positive spillovers on the less anaemic or non-anaemic children. For example, if bad behaviour declines and good behaviour improves (e.g., focus and participation) for the class overall because of the intervention, it may be that non-anaemic children are the ones that take more advantage of the better learning environment.

With our findings, one question may arise about whether iron supplementation is a desirable policy if it helps the less vulnerable children more. It is true that interventions and policy measures would better target and help the most vulnerable children. It does not mean, however, that interventions that help the less vulnerable children should not be implemented. What it does mean is that in poor areas of rural China iron supplementation alone is not sufficient to improve health and education of the most vulnerable children. Further research on how these vulnerable children can be aided is still much needed.

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Notes

1. The national government, in fact, recently has taken the first steps to alleviate this problem. In late 2011, officials allocated 16 billion yuan per year for school lunches. This study, however, predates the school lunch programme (*Xinhua News*, 2011).
2. Using the estimates from pilot studies and the Optimal Design software, we calculated that we would need 15 schools per intervention group to detect an effect size for the outcome variables of 20 per cent of the standard deviation with 80 per cent power at the 5 per cent significance level (two-tail test). We assumed an intra-cluster correlation of 0.15, a pre- and post-intervention correlation of 0.6, and a 10 per cent loss to follow-up.

3. Only in the case of one variable (whether the mother lives at home or not) there is a statistical difference (significant at the 5% level). For the sake of brevity, results from the attrition analysis are not shown but are available from the authors upon request.
4. The baseline characteristics of the children and their parents of the maths and Hb samples are basically the same. For the sake of brevity, we mainly report the summary statistics of the maths sample.
5. To check if any specific county drives the baseline differences in the child and parent characteristics across experimental arms, we first checked the descriptive statistics using only counties that have schools randomised to all of the three experimental arms (that is, using counties 1–5 but not counties 6–10). The baseline differences in the observables remain. We have also checked the descriptive statistics by dropping one of the 10 counties at a time. We found that in some of the 10 tables of descriptive statistics the baseline imbalance becomes slightly weaker. Unfortunately, in none of these 10 tables does the observed imbalance goes fully away (results of the 10 tables unreported for the sake of brevity but are available from the authors upon request). We made further attempts and found that the imbalance could be reduced substantially by dropping two selected counties (although some minor imbalance remains). So the question is: should we use the full sample; or should we use the reduced 8 sample counties? For three reasons, we believe it would be better not dropping at the same time the two selected counties from our analysis. First, by dropping these two counties, the sample size would fall. This would reduce the power of the study and it is possible that the precision of the estimates would be reduced. Second, in our trial, we have worked carefully to make sure that our randomisation procedures were performed correctly. Selectively dropping counties ex post would cast doubts on the overall experimental design. This might also somewhat reduce the external validity of the study. Finally, and most persuasively, it really does not matter materially to our results. If we drop any one county or if we drop the two selected counties, the overall results remain largely unchanged (results are available from the authors upon request). Given these findings, therefore, we believe the baseline differences in the observables are not driven by any specific county or (specific set of counties).
6. In designing our RCT we have calculated that we had a large enough sample of schools and enough children per school that the power of the RCT design was high. Therefore, in allocating the 60 schools to the three experimental arms (supplement, parental education or control), we randomised the schools without conditioning on county or pre-balancing the sample. This is because we wanted to make the randomisation strategy very simple and transparent for our government collaborating partners to understand. We agree that if we had randomised the schools conditioning on county or pre-balancing the sample the power of the RCT design would have increased even more. But while the balance of the RCT sample could have been improved, given the random school assignment, the size of the sample and that we control for a large number of baseline characteristics in our adjusted model, we can account for most baseline differences.
7. In an earlier study (Luo et al., 2012), the provision of iron supplements for five months was shown to be already enough for the intervention to have an effect on children's Hb level and anaemia status in rural China.
8. To ensure that the results from both the baseline and endline tests were not influenced by intentional preparation, we made no announcement before the tests and gave no feedback after the tests. We also allowed no extra time for the tests and collected all test instruments immediately right after the tests.
9. Our estimation models do not account for time-varying trends across counties. However, given the random assignment of sample schools to the three experimental arms, this unlikely will bias our estimates.
10. When comparing our baseline data with those in Luo, Shi, Zhang, Liu, et al. (2012) – an RCT study conducted in a different set of rural counties in the same province as in this study – we find that the average baseline Hb level of our children sample, 126.9 g/L, is higher than Luo, Shi, Zhang, Liu, et al.'s average findings, 122.6 g/L. Using an anaemia cutoff of 120 g/L, the anaemia rate in our sample, 26.2 per cent, is also lower than the rate in Luo, Shi, Zhang, Liu, et al., 38.3 per cent. We believe these differences are caused by the ways counties were sampled. In Luo, Shi, Zhang, Liu, et al., their sampling frame gave them a set of counties that was relatively poorer. Children in their sample were also less healthy.
11. The results reported in the paragraph are consistent with the ones in Luo, Shi, Zhang, Zhang, et al. (2012b). They evaluate three different RCTs/datasets in rural China. They conclude that providing daily iron supplement tablets improves children's Hb levels and providing health education/information appears to have no impact. In fact, one of the three RCTs/datasets in Luo, Shi, Zhang, Zhang, et al. is the same as the one studied in this article. The results (or more precisely the discussions of the results) in this article and Luo, Shi, Zhang, Zhang, et al. differ because we report statistical significance at the 10 per cent level (whereas they do not).
12. Since children's boarding status is not a random variable, we conduct a probit analysis of boarding status. The results are presented in Table A2 of the Online Appendix. Overall, there are clear evidences that the two samples of children are different.

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