Nutrition and Educational Performance in Rural China's Elementary Schools:

Results of a Randomized Control Trial in Shaanxi Province

Renfu Luo,[1]* Yaojiang Shi,[2] Linxiu Zhang,[1] Chengfang Liu,[1] Scott Rozelle,[3]
Brian Sharbono,[3] Ai Yue,[2] Qiran Zhao[1] and Reynaldo Martorell[4]

***** Corresponding author's mailing address: Center for Chinese Agricultural Policy, CAS, No. 11A, Datun Road, Anwai, Beijing 100101, China
Tel: 86-10-64888990; Fax: 86-10-64856533.
E-mail: luorf.ccap@igsnrr.ac.cn

[1] Center for Chinese Agricultural Policy (CCAP), Institute of Geographic Sciences and Natural Resources Research (IGSNRR), Chinese Academy of Sciences (CAS)
[2] School of Economic Management, Northwest University of Xi'an
[3] Freeman Spogli Institute, Stanford University
[4] Rollins School of Public Health, Emory University

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Abstract

Background. Despite growing wealth and a strengthening commitment from the government to provide quality education, a significant share of students across rural China still have inadequate access to micronutrient-rich regular diets. Such poor diets can lead to nutritional problems, such as iron-deficiency anemia, that can adversely affect attention and learning in school.

Objective. The overall goal of this paper is to test whether simple nutritional interventions lower rates of anemia and to assess whether this leads to improved educational performance among students in poor areas of rural China.

Approach: We report on the results of a randomized control trial (RCT) involving over 3600 fourth grade students, mostly aged 9 to 12, from 66 randomly-chosen elementary schools in 8 of the poorest counties in Shaanxi Province in China's poor northwest region. The design called for random assignment of schools to one of three groups: two different types of treatment/intervention schools; a non-intervention, control group. The two interventions were designed to improve hemoglobin (Hb) levels, which is a measure of iron deficiency. One intervention provided a daily multivitamin with mineral supplements, including 5 milligrams of iron, for 5 months. The other informed the parents of their child's anemia status and suggested several courses of action (henceforth, the information treatment).

Findings: Some 38.3 percent of the students had Hb levels of below 120 g/L, the World Health Organization's cutoff for anemia for children 9 to 12 years old. In the schools that received the multivitamins with mineral supplements, Hb levels rose by more than 2 g/L (about 0.2 standard deviations). The standardized math test scores of the students in the schools that received the multivitamin with mineral supplements also improved significantly. In schools that received the information treatment, only students that lived at home (and not the students that lived in boarding schools and took most of their meals at schools) registered positive improvements in their Hb levels. The reductions in anemia rates and improvements in test scores were greater for students that were anemic at the beginning of the study period. Overall, these results should encourage China's Ministry of Education (MOE) to begin to widen its view of education (beyond teachers, facilities and curriculum) and provide better nutrition and health care for students.

Keywords: anemia, primary school students, randomized control trials, vitamin supplements, mineral supplements, information, educational performance, rural China

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Although children in both cities and rural areas in China have nearly universal rates of participation between grades 1 to 9, there is still a performance gap between urban and rural students—especially students from poor rural areas. In 2005 over 80 percent of urban students graduated from academic or vocational high schools (Wang et al. 2009; Ministry of Education [MOE] 2006). However, less than 40 percent of rural students from poor counties graduated from high school. In China's large municipalities almost 50 percent of students graduated from college or some other tertiary educational institution (henceforth, college). Less than 5 percent of students from poor rural areas who started grade 1 in the mid-1990s matriculated into a college in the late 2000s (Liu, Zhang, Luo and Rozelle 2008). The high rates of return to higher education in China (e.g., Wang et al. 2007; Li et al. 2005) and the fact that access to higher education facilitates access to formal jobs with benefits and other rights mean that the poor performance of rural students is reinforcing inequality trends. It also has been shown in the development literature (e.g., Gao 2008) that there are intra-household externalities of education. In addition, it has been shown that when poor rural students go to college there are benefits for family members and neighbors that remain in the home communities (Zhang et al. 2006).

Why is it that educational outcomes of rural students deteriorate so rapidly after grade 9? One reason may be that after grade 9 matriculation to high school and access to quality educational programs become competitive and dependent on test scores (e.g., fast tracking). If rural students do not perform as well as urban students at the time that they are entering high school, they will naturally fall behind. In fact, there is evidence of statistically significant differences in educational performance between rural and urban students when examining standardized test scores (Young 1998; Webster and Fisher 2000). Mohandas (2000) finds that differences in scores on mathematics achievement tests indicate that students from rural areas are significantly behind students from urban areas in learning mathematics. China's government also recognizes that there are still policy challenges to reducing the rural-urban education gap in student achievement (Asia Society 2005). Although neither competitive high school entrance exam scores (*zhongkao*) nor competitive college entrance exam scores (*gaokao*) is reported publically by rural and urban cohorts (or any other socio-economic factor), it is almost certain that the same differences in standardized tests that are observed between rural and urban students exist in *zhongkao* and *gaokao* exams.

Therefore, an even more fundamental question is why rural students—especially those from poor rural areas—are scoring so much lower than urban students on standardized tests. There are many possible reasons. School facilities and teachers are systematically better in urban areas (World Bank 2001; Wang et al. 2009). There is greater investment per capita in urban students compared to rural students (Tsang and Ding, 2005; Ministry of Education and National Bureau of Statistics [MOE/NBS] 2004). Parents of urban students also have higher education and more time and opportunities to help their children in their studies (Huang and Du 2007).

There is one additional possible factor that may be affecting the educational performance (and scores) of students from poor rural areas: iron deficiency anemia. Iron deficiency anemia is a debilitating health condition that affects hundreds of millions of people worldwide, mostly in developing countries (Yip 2001). Prolonged iron deficiency impairs hemoglobin production, limiting the amount of oxygen that red blood cells carry to the body and brain. As a consequence, anemia leads to lethargy, fatigue, poor attention and prolonged physical impairment. A large body of research links anemia (as well as iron deficiency not serious enough to impair hemoglobin synthesis) with cognitive impairment and altered brain function (Yip 2001). Hence, anemia is doubly burdensome because it also has been shown to have serious implications for the educational performance of those with the disease; indeed, iron deficiency and anemia have been shown to be negatively correlated with educational outcomes, such as grades, attendance and attainment (Halterman et al. 2001; Stoltzfus 2001; Stoltzfus et al. 2001; Bobonis et al. 2006). Poor nutrition, including iron deficiency, in utero and during early childhood has been shown to have consequences for adult health and human capital (Victoria et al. 2008). Therefore, anemia may be one of the factors that are leading to gaps in test scores and ultimately limiting opportunities for social and economic mobility.

In almost all countries of the world the prevalence of anemia falls when incomes rise. Indeed, the World Health Organization's "Global Database on Anemia" and a number of other studies reveal that countries with higher income levels tend to have lower prevalences of iron deficiency anemia (Gwatkin et al. 2007; de Benoist et al. 2008). Incomes across China have risen, even in rural areas. Yet despite growing wealth and China's government's growing commitment to providing quality education, a number of (local, sometimes dated) studies show that a significant share of children across rural China are so severely iron deficient as to be classified anemic. For example, a recent study in Shaanxi Province run by the provincial Center for Disease Control found anemia in as many as 40 percent of freshmen in a rural junior high school (Xue et al. 2007). A study in Guizhou found anemia rates to be as high as 50 to 60 percent (Chen et al. 2005). Although these studies are small-scale and non-representative, they still give rise to concerns that anemia may be a serious problem in rural China, at least for a segment of the population. Such a finding would be important since China in the past has been shown to have highly unequal distribution of income (Khan and Riskin 2001). If large shares of China's population were still suffering from a nutritional deficiency, such as anemia, it would suggest that the efforts of the government in recent years to reduce inequality still have not been sufficient and more effort is needed in targeting nutritional deficiencies.

The overall goal of this paper is to understand if poor nutrition—in particular, anemia—is negatively affecting the educational performance of students in poor areas of rural China. To meet this goal, we pursue three specific objectives. First, we measure whether or not anemia is a widespread problem. Second, we try to understand the source of the problem. Is the anemia related to the poor diets of students? Finally, we will analyze if efforts that lower anemia rates lead to better educational performance.

In this paper we report on the results of a randomized control trial (RCT) involving over 3600 fourth grade students, mostly aged 9 to 12, from 66 randomly chosen elementary schools in 8 of the poorest counties in Shaanxi Province, located in China's poor northwest region. The main two interventions in the RCT (implemented in the 66 sample elementary schools) were focused on improving the nutritional status of students by raising hemoglobin (Hb) levels of students (and reducing the prevalence/severity of their anemia).[5] According to our baseline data (collected before the interventions), 38.3 percent of the students had Hb levels of below 120 g/L, the World Health Organization's cutoff for being anemic for children that are 9 to 12 years old (Gleason and Scrimshaw 2007).[6] When children in 24 of the treatment schools were given one dose (tablet) of iron supplements per day for 5 months (using over-the-counter multivitamins with mineral supplements that include 5 milligrams of iron per tablet in addition to 20 other vitamins and mineral supplements), hemoglobin levels rose by more than 2 points (about 0.2 standard deviations). The standardized math test scores of the students in the schools that received the multivitamins with mineral supplements also improved significantly. The response to the other treatment (which informed the parents of each student their child's anemia status as

[5] We performed the power calculation before intervention using a soft-ware called Optimal Design, which was developed by a group of researchers at the University of Michigan. As discussed in the manual by Spybrook at al. (2008), the power to detect a difference in Hb count between the treatment and control groups in a Cluster Randomized Trials depends on 4 factors: a.) the number of students per school (n); b.) the number of schools (J); c.) the intra-school correlation in hemoglobin count (ρ); d.) the minimum effect size that we would expect to be able to detect (δ). We estimate $\rho = 0.05$. We desire a minimum effect size of 0.2 for supplement treatment and 0.3 for information treatment. We suppose that we have 100 4th graders per school. With above assumption on the parameters, we find that with about 24 school for supplement and 12 schools information treatment, we can achieve power equal to 0.8 at the conventional significance level (α=0.05).

[6] As the cutoff varies for different age group, for conservative we use the 120g/L in our analysis.

well as suggesting several courses of action—henceforth, the information treatment) was more mixed.

The rest of the paper is organized as follows. Section I describes the sample, the venue of the study and our main outcome measures (Hb levels; and our education performance indicator—standardized math test scores). Section II describes the results of the baseline survey, reporting on the severity of anemia and identifying subgroups that may be particularly affected. In sections III and IV, we describe the experiment and report on the findings, focusing on whether or not the two interventions reduce anemia and if there is an impact on educational performance. The final section concludes.

I. Data

We collected data on fourth grade elementary school students from 66 schools in eight rural counties in Shaanxi Province. In choosing our sample counties we first obtained a list of all counties in the province. Each of the counties on the list was given a poverty ranking using information from Olivia et al. (2008), who produced a high quality poverty map of Shaanxi. The village-specific poverty indicators from the poverty map were aggregated to produce county-level indicators of poverty. Once each county was assigned a poverty indicator, we chose the 8 poorest counties in Shaanxi. The locations of the study counties are shown in Figure 1.

The next step was to choose the sample elementary schools. To do so we conducted a canvas survey by visiting the bureaus of education in each county. In each bureau we obtained a list of all six-year elementary schools (or elementary schools that had grades 1 to 6) that had at least 200 students. We also required that of the 200 or more students, at least 50 of them lived as boarders in the dormitory and ate most of their meals (that is, meals for 5 days out of 7) at school.[7] In total, 116 schools fit these criteria. From this list, we randomly choose 66 schools. There were 3661 fourth grade students in these 66 schools, an average of 55 students per school. The list of the counties and number of schools and students per county is included in Table 1 (rows 2 to 9).

The RCT was implemented in these sample schools. In simplest terms (the RCT is described in more detail below) the 66 schools (and the students in them) were randomly divided into three sets of schools: in 24 schools, we gave the students multivitamins with mineral supplements, which included iron; in 12 schools, we informed the parents by sending them a letter about the anemia status of their child and suggested approaches to improvement (but did not give multivitamins with mineral supplements); and in 30 schools there were no interventions.[8] Henceforth, these three types of schools are designated (for brevity) as *supplement schools*, *information schools* and *control schools*. The numbers of schools and students in the supplement, information and control schools are summarized in Table 1 (rows 10 to 12).

Venue: Rural Elementary Schools after China's School Merger Program

Demography and increased fiscal capacity (and the government's resolve to try to provide higher quality education to rural students) have triggered a fundamental change in China's rural education policy. Between 1951 and 2000 one of China's main educational goals was to put a school in every village (MOE 1992). In the late 1980s and early 1990s China reached a point where there were almost 700,000 schools in the nation's 800,000 villages (MOE 1992). By the late 1990s, however, fast income growth, the demographic transition and the One

[7] We decided on the criteria for two reasons. The trend in China is to move more towards larger, centralized schools with boarding facilities. Hence, this will be the type of schools that will be most common in the coming years. Second, according to Luo et al. (2009), the most vulnerable students in China's schooling system tend to be those that live as boarders. Our criteria ensured that our sample contained boarding school students.

[8] The sample size was determined by power calculations for our cluster-Randomized Control Trial. Please see section below for details of the calculation.

Child Policy had greatly reduced the number of children in each age cohort in China's villages; enrollment in primary schools in China's rural area dropped (MOE 1999). As a consequence, class sizes in many rural schools fell sharply.

In the late 1990s, at a time when the central government decided it had the fiscal resources (and resolve) to increase the quality of rural education, China's educational leadership changed policy direction (Liu et al., 2009). In 1999 the Ministry of Education launched an aggressive School Merger Policy (Liu et al. 2009). According to the policy, education officials closed down small, remote schools and focused their attention on improving the teaching and facilities in larger, centralized schools. In fact, the merger policy has improved the quality of education—at least in terms of the policy goals of hiring more qualified teachers and improving the infrastructure of schools (Zhuo 2006). The policy also has been widespread. The number of schools fell from around 580,000 in 1999 to 270,000 in 2006 (MOE 1999; 2006).

While the School Merger Policy was successful in a number of dimensions, there were a number of unanticipated consequences that triggered a series of actions, responses and reactions. One of the most notable problems with the School Merger Policy was that the distance between students' homes and schools increased dramatically (Ma 2009). Commuting time increased. In many places commuting itself was dangerous and parents worried about the safety of their children (Xie 2008). In response, school administrators began to let students live at school. Initially, however, boarding facilities were poor, insufficient or nonexistent. Children were known to be sleeping on pulled together desks in non-heated classrooms. The government, however, responded again and began a program to build dormitory facilities. By the mid-2000s most students that needed a place to board had access to dormitory rooms (albeit often quite rudimentary).

There was still another major shortcoming of the program, however. While dormitory facilities improved, boarding—that is, the provision of meals for students—was still far from adequate (Luo et al. 2009a). Dining facilities were built. The government provided a small daily subsidy for boarding students. The amount of the subsidy, however, was often only enough to buy cooking fuel and pay for the dining staff. Students still relied on food brought from home or meager meals (or meal supplements) provided by the schools. The consequence of this boarding policy is that students in many schools in poor areas of rural China were eating 15 or more meals in school. The diets of students in many of these boarding facilities consisted almost entirely of carbohydrates and, at most, of small amounts of pickled vegetables, hot peppers and/or other condiments. In other words, elementary students in rural China's schools—including those that lived at home, but especially those boarded at school—were being provided meals of low dietary quality. A study of 144 boarding schools in northwest China provided convincing evidence that students in rural China suffer from malnutrition, particularly those that live in school dormitories (Luo et al. 2009a).[9] Therefore, it is important in studying the relationship between nutrition and education that we differentiate between boarding school students and those that live at home.

Outcome variables of interest

We have two sets of outcome variables. The most proximate type of outcome variable is hemoglobin. Two trained nurses from the Xi'an Jiaotong University's School of Medicine carried out hemoglobin tests as part of the enumeration activities of each of the survey teams. Hemoglobin levels were measured onsite (that is, at schools) using HemoCue Hb 201+ systems. These portable instruments are known to provide rapid, in-the-field measurements of hemoglobin levels with a high degree of accuracy. The other main outcome variable of our study came from a

[9] It is important to note that in Luo et al. (2009), although it is clear that the levels of malnutrition are significantly worse in the case of boarding students, the paper does not state that boarding school residence is the cause of the poor nutritional status. Indeed, it is possible that students that live at boarding schools were already poorly nourished when they began living at school. This is beside the point for this paper. What is important, however, is that the number of poorly nourished students is concentrated in boarding schools, giving those (policy makers) interested in trying to rectify the problem a well-defined group (that should be fairly easy to target). At the same time, it should be noted that there are also many poorly nourished children living at home.

standardized math test. The math test was based on a sub-set of a test originally created for The Trends in International Mathematics and Science Study (TIMSS).

Four teams of six enumerators (in addition to the nurses) collected the rest of the data set. In each team one enumerator collected data on the school from the principal and the school's fourth-grade homeroom teacher. The other three enumerators executed a short student survey that collected basic socio-economic information about each student. These questions included details about the student's gender, age and family structure. They also asked about where the student lived—at home or in the school's boarding facilities. Each student also took a form home to his/her parents who filled out information on their levels of education, age and occupation.

II. Anemia and Test Scores in Shaanxi Province

Although incomes across China have risen, we find that anemia is still widespread (based on our baseline testing of the students in October 2008). Across all of the schools surveyed (combining all 8 counties), we found the average level of the hemoglobin levels was 122.6 g/L (Table 2, row 1, column 1). Hemoglobin levels were normally distributed with a standard deviation of 11.0 g/L. Any student with hemoglobin levels below 120g/L was considered anemic as per WHO guidelines for children between 9 to 12 (United Nations Children's Fund, World Health Organization, and United Nations University 2001; Gleason and Scrimshaw 2007). Using this cutoff we estimate that across all schools and counties, 1401 of the 3661 students we surveyed were anemic resulting in a prevalence of 38.3% (Table 2, row 2).

Because we did not pre-balance (that is, the schools were assigned as supplement, information and control schools before the baseline survey), the baseline Hb levels, anemia rates and other characteristics in different groups—although close—did differ somewhat (Table 2, rows 1 to 8). The average Hb level in the supplement schools was 121.7, with an anemia rate of

42.5 percent. The Hb levels in the information (122.6) and control (123.6) schools were slightly higher and anemia rates slightly lower.[10]

When looking at the differences between different types of students, the most striking finding arises with respect to the living arrangements of the students (Table 3). Students who lived in the school dormitories had significantly higher anemia rates than students who lived at home. Our data also demonstrate that students who eat in the school cafeteria had significantly higher anemia rates than students who eat at home or bring lunches from home (rows 1-4). This finding is in line with findings from our previous work (and the discussion above), which shows that boarding schools in rural Shaanxi Province are not delivering sufficient nutritional content in school lunches/other meals to their students (Luo et al. 2009a). Luo et al. (2009a) reports that whereas 23% of students that lived in boarding school had height for age (and weight for age) Z-scores that was less than -2.00, only 11% of non-boarding school students did.[11] Even after controlling for other characteristics (including the student's age and gender; and the parents' age and education), multiple regression analysis in Luo et al. (2009b) revealed two conditional correlations: students who lived in boarding school and students that ate lunch at school had lower hemoglobin levels and higher anemia rates. Table 3 also shows that the other outcome variables—standardized math tests are similar across supplement, information and control schools (rows 5-8).

Interestingly, when we run correlation coefficients between the Hb levels and math test scores, it is less than 0.10 (although the correlation between the anemic status and test score is higher). In Luo et al. (2009b) the coefficient on the Hb level variable also is insignificantly different from zero at a 5 percent level of significance in a regression which is explaining math

[10] Since we did not pre-balance before assigning schools to their intervention/control groups, in the multivariate analysis we had to control for the characteristics of students and parents that were collected in the baseline survey.
[11] Since stunting is often highly correlated with poor nutrition during the years before attending school, these findings may be evidence that there are also pre-schooling forces that are at work here. As we mention in several places in the manuscript, we are not trying to say that boarding school residence is causing poor nutrition.

scores (and which is holding student, parent and school characteristics constant). While one may want to jump to the conclusion that anemia is not contributing to the low test scores of rural students in poor areas, we know that there are issues of endogeneity that may be keeping us from being able to identify net causality. It could be that there is unobserved heterogeneity (that is, there may be unobserved/unmeasured variables that are correlated with both Hb levels and math scores—e.g., parents inherent ability; etc.). It could also be that there are negative spillovers within classrooms that are related to the number of students that have anemia. Anemia is known to lead to bad behavior and lack of concentration. Consider a class with a large share of students that are anemic. If a significant share of the students in the class were behaving badly (due to the anemia) it could adversely affect the ability of those students that are not anemic to learn (and thus: no significant measure effect of anemia on math scores). It is precisely for this reason that if we want to understand the effect of anemia on educational performance we need to have some exogenous intervention that could shift anemia which was not related to math scores (or other outcome variables). In the next two sections of the paper, we first describe our exogenous intervention (implemented as a cluster-level RCT) and then report on the results.

III. The Interventions and the RCT

The interventions were designed to be straightforward and easily monitored. Since we were trying to induce from the intervention if poor diet was at least part of the reason behind the high rates of anemia, we wanted to make sure one of our interventions delivered sufficient quantities of easily absorbable iron to students and that compliance was high. Therefore, we decided that the research team itself would be the primary implementer. We worked closely with the principals of the intervention schools (in the case of the supplement and information treatment schools) and the homeroom teachers of all fourth graders (in the case of the supplement schools). Principals in all schools (the two intervention schools and the control schools) and the homeroom teachers of the fourth graders in the supplement schools were given a small honorarium (100 yuan—about the equivalent of 1 to 2 days salary). The research team intermittently (about one time per month) sent out members to undertake unannounced compliance checks. During the checks the inspector interviewed teachers that were dispensing supplements (in the intervention schools), teachers in the supplement schools that were not part of the intervention (e.g., third or fifth grade teachers), students in the supplement schools and their parents. According to our findings, there was almost 100% compliance.

The first intervention, the passing out of multivitamins with mineral supplements in the 24 supplement schools, was the more complicated and time consuming of the two interventions. In each of the supplement schools we trained each homeroom teacher in the supplement intervention protocol and provided a colorful poster (that was hung on the wall of the class room) reminding them of the protocol. The teachers were also given equipment to boil and dispense clean water. Each month we also would supply them with about 5 weeks worth of multivitamins with mineral supplements and disposable paper cups.[12]

The protocol was simple. During the first class period after the first meal of the day (typically lunch) students always first go to their homeroom class. At least one period before the class, the teacher was supposed to boil a large kettle of water and let it cool. As soon as all of the students were in class, the teacher would hand out two disposable paper cups to each student. A multivitamin with mineral supplements was placed in one cup. The other cup was filled with water. The teacher would dispense the multivitamin with mineral supplements and water one student at a time and watch them take it. On each Friday afternoon, students would be given 2 multivitamins with mineral supplements to take home for the weekend. They were supposed to

[12] We delivered vitamins once per month primarily to make sure that the vitamin supply was sufficient. At one point we were concerned that teachers might sell them on the local market. In fact, so few rural residents had ever even heard of multivitamins (with or without minerals) that there was really almost no independent demand. We found no local supermarkets in any of the sample counties that carried multivitamins (with or without minerals).

take one on Saturday and one on Sunday. Almost all parents that we talked to (during the spot checks) knew about the weekend protocol. Multivitamins with mineral supplements were dispensed from November to June. There was about a three-week period during winter break when no multivitamins with mineral supplements were dispensed.

The other intervention was simpler and more focused in terms of the time period of intervention. About 2 weeks after the baseline survey, we assembled a list of the anemia status of each of the students. We then sent one of four letters to the parents, depending on each student's Hb level. The letter was written to describe to each parent what anemia was and its known consequences. The parent was then told their own child's Hb level. Their anemia status was given, as 1 of 4 categories: severely anemic (Hb levels below 115 g/L); moderately anemic (Hb levels between 115 and 120 g/L); not anemic, but borderline (Hb levels between 120 and 130 g/L); or not anemic (Hb levels 130 g/L or higher). The students that were anemic were then told two things. First, they were told that they should consult a doctor. Second, they were told that anemia was often associated with poor diet and that parents should strive to give their children a balanced diet that contained at least 1 ounce of meat per day. The letter was sent home with the student and there was a follow up check by the homeroom teacher that parents received the letter. To be clear, parents that received the letter received no other intervention. Specifically, the students in the information schools were not given multivitamins with mineral supplements. There was no counseling over and above the letter that was sent to them—regardless if the parents were illiterate or not. Parents of children that lived at home and parents of children that lived in boarding schools were both given letters. A translated copy of the letter is in appendix A.

Evaluation Survey

In June 2009 the survey team revisited the 66 sample schools that constituted the two groups of intervention schools and the control schools. The nursing teams re-implemented the hemoglobin tests. The socio-economic testing team gave students in sample schools another round of standardized math testing.

IV. Modeling and Results

When comparing the average hemoglobin levels of all of the students in our sample before (122.6—Table 2, row 1) and after the intervention (124.5—Table 4, row 1 column 1), we can see that hemoglobin levels rose during the study period. Across all students there was a rise in the average hemoglobin of 1.9 points (Table 4, row 1 column 4). In turn, the rise in hemoglobin levels translates into a reduction of those students with levels below 120, from 38.3 percent in October 2008 (Table 2, row 2) to 32.1 percent by June 2009, a reduction of 6.2 percentage points (Table 4, row 5 columns 1 and 4). In other words, in our overall sample there were 6.2 percent fewer students with anemia at the end of the study than at the beginning of the study. The distributions of the hemoglobin levels for the entire sample (including students in both intervention and control schools) before and after the study are shown in Figure 2.

Descriptive statistics provide the initial evidence that providing multivitamins fortified with iron to students each day has an impact on increasing hemoglobin levels and reducing anemia. According to Table 4, the rise in the hemoglobin levels is higher for students in the supplement schools than for students in the control schools. The average change in the hemoglobin level in the supplement schools between October 2008 and June 2009 was 3.0 points (row 2, column 4). The average change in the control school during the same time period was only 1.1 points (row 4, column 4). Therefore, while something (perhaps a general rise in income / or a natural seasonal effect) caused the hemoglobin levels of the students in the control schools to rise, the rise was nearly 3 times greater in the supplement schools and was statistically significant at the 1% level. The changes in the distributions over time for control schools and supplement schools are shown in Figure 3. Differences in shifts in hemoglobin levels between the students in the supplement and control schools are reflected in differences in reductions in anemia rates (or differences in those with hemoglobin levels that are below 120). Anemia rates fell by 10.8 percentage points in supplement schools during the study period (row 6, column 4). During the same time period, however, anemia rates fell by only 4.0 percentage points in control schools (row 8, column 4).

In contrast, there is little evidence that the information treatment had an impact on the average student's hemoglobin levels or anemia rates (Table 4, comparing rows 3 and 4, 7 and 8 in column 4). In fact, although not statistically significant, the rise in the hemoglobin levels (fall in the anemia rates) between October 2008 and June 2009 is less in the information schools than in the control schools. The shifting distributions of the hemoglobin levels in the control and information schools are shown in Figure 4.

While the information treatment appears to have little impact on the average student, a disaggregation of the descriptive statistics suggests that there may be important heterogeneous effects between students that live at home and students that board at school. Table 4 shows that when parents whose children lived at home received a letter, there was a rise in hemoglobin levels that exceeded those in the control schools (rows 3 and 4). The difference is also statistically significant at the 1% level. In contrast, the hemoglobin levels fell slightly for those students that lived in boarding facilities. While we can not explain why the hemoglobin levels of boarding schools students fell, it is clear why the effect of the information might be expected to vary between the students that lived at home and the students that lived at school. Even if the parents of the children that lived at school were told that their child was anemic and that they should improve their diet, because boarding students eat 15 or more (of their 21) meals per week at school, there would be less opportunity for the parents to affect their diet through meals cooked at home.

There is also descriptive evidence that the supplement treatment had a positive effect on standardized math test scores. The test scores in the supplement schools rose on average by 5.6 percentage points from 65.5 in October 2008 to 71.1 in June 2009 (Table 4, row 10). This rise was greater than that achieved by students in the control schools, which rose by only 4.6 percentage points (Table 4, row 12, column 4). The difference was significant. As in the case of hemoglobin levels, there was no significant difference, however, between the rise in test scores of students that received the information treatment and students in control schools. Interestingly, there also is no significant difference in test scores in information schools between the live-at-home students and boarding students (which was not true in the case of changes in hemoglobin levels).

Multivariate Analysis

To improve estimation efficiency and control for any observable differences that existed between the control and treatment schools during the baseline, we also run a series of multivariate models in order to estimate the net effect of the treatments on hemoglobin levels and test scores. The models (in equations 1 to 5 below) are presented in order of increasing comprehensiveness.

The most fundamental model is:

$$Y_{ijk} = a0 + a1*\text{Supplement Intervention}_{jk} + a2*\text{Information Intervention}_{jk} + e_{ijk} \quad (1)$$

where Y_{ijk} is the outcome variable for student *i* in school *j* in prefecture *k*. In the analysis below *Y* can be hemoglobin levels or the standardized test scores. The two independent variables, $\textit{Supplement Intervention}_{jk}$ and $\textit{Information Intervention}_{jk}$, are dummy variables that are equal to one if the student is in a supplement or information school, respectively. The base group in the regression includes students in the control schools. In equation (1) e_{ijk} is an error term that is correlated within schools, given the cluster-RCT design and a_0, a_1 and a_2 are parameters to be estimated. When estimating our equations, we control for school-level clustering in our standard errors.

Because in Shaanxi many of the schooling decisions are carried out by the prefecture education bureau, in equation (2) we control for prefecture effects. The model is:

$$Y_{ijk} = a0 + a1{*}\text{Supplement Intervention}_{jk} + a2{*}\text{Information Intervention}_{jk} + \mu_k + e_{ijk} \qquad (2)$$

where all of the variables and parameters are the same as in equation (1) except we add a set of prefecture dummy variables, μ_k.

Motivated by the descriptive statistics and the obvious differences that seem to exist between boarding school students and students that do not live at school, in equation (3) we control for the heterogeneous effects for students that live at school. The model is:

$$\begin{aligned} Y_{ijk} = {} & a0 + a1{*}\text{Supplement Intervention}_{jk} + a2{*}\text{Information Intervention}_{jk} \\ & + a3{*}\text{Boarding student dummy}_{ijk} + a31{*}\text{Boarding student dummy}_{ijk}{*}\text{Vit\_intervention}_{jk} \\ & + a32{*}\text{Boarding student dummy}_{ijk}{*}\text{Info\_intervention}_{jk} + \mu_k + e_{ijk} \qquad (3) \end{aligned}$$

where all of the variables and parameters are the same as in equation (2) except we add a dummy variable to control for the impact of living at school (*Boarding student dummy)* and a set of interaction terms which are designed to measure the differential effects of the supplement and information interventions on boarding and non-boarding school students.

The final two models are:

$$\begin{aligned} Y_{ijk} = {} & a0 + a1{*}\text{Supplement Intervention}_{jk} + a2{*}\text{Information Intervention}_{jk} \\ & + a3{*}\text{Boarding student dummy}_{ijk} + a31{*}\text{Boarding student dummy}_{ijk}{*}\text{Vit\_intervention}_{jk} \\ & + a32{*}\text{Boarding student dummy}_{ijk}{*}\text{Info\_intervention}_{jk} + a4{*}\text{Z\_student}_{ijk} + \mu_k + e_{ijk} \qquad (4) \end{aligned}$$

and:

$$\begin{aligned} Y_{ijk} = {} & a0 + a1{*}\text{Supplement Intervention}_{jk} + a2{*}\text{Information Intervention}_{jk} \\ & + a3{*}\text{Boarding student dummy}_{ijk} + a31{*}\text{Boarding student dummy}_{ijk}{*}\text{Vit\_intervention}_{jk} \\ & + a32{*}\text{Boarding student dummy}_{ijk}{*}\text{Info\_intervention}_{jk} + a4{*}\ \text{Z\_student}_{ijk} + a5{*}\text{Z\_parent}_{ijk} \end{aligned}$$

$+ \mu_k + e_{ijk}$ (5)

In addition to the variables included in equation (3), we also control for the levels of student characteristics, *Z_student*$_{ijk}$, in equation (4) and student characteristics *and* parent characteristics, *Z_parent*$_{ijk}$, in equation (5).

In our analysis *Z_student*$_{ijk}$ is a vector that includes three variables. First, does the *child eat two meals per day* (on a typical day)? This is a dummy variable that equals 1 if the child eats two meals per day in October 2008; and 0 if the child eats three meals per day. Second, we include the student's *age* in months in October 2008. Finally, we include a *gender* variable which is defined as 1 if the student is female.

The vector *Z_parent*$_{ijk}$ includes three variables, specifically the characteristics of the student's mother. First, we define a dummy variable *Mother stay at home* if the mother is living in the village in October 2008 (1=yes; 0=no). Second, we include a variable representing the *Education of the mother* which is measured as years of attainment. Finally, we measure the mother's employment (Mother self employment or wage earning job) if the mother either is part of a household self employed activity or if she has a formal wage earning job (1=yes; 0=no). Since equation (5) controls for the most comprehensive set of variables, we will call this the *full model*.

Results

The results of the multivariate model largely support the descriptive statistics. In fact, in the simple OLS model (adjusted for clustering) we find that the coefficient on the treatment variables in the Hemoglobin level model (1.87—Table 5, row 1, column 1) is nearly the same as the difference between the before-and-after-intervention change in the supplement schools and the change over the same time period in the control schools (3.00-1.1=1.9—from Table 4, rows 2 and 4 in column 4). When we control for other effects, however, (in models 2 to 5), the impact of the supplement treatment on the hemoglobin levels rises somewhat. In summary, providing fourth grade students with multivitamins with mineral supplements for a five month period increased their hemoglobin levels from 2.02 to 2.32 Hb points. In other words, the effect of providing fourth grade students with multivitamins with mineral supplements for a five month period will shift the distribution of the hemoglobin count to the right by about 0.2-0.25 standard deviations. Given the distribution of hemoglobin levels in the baseline, this would translate into a reduction of anemia of more than 10 percentage points (or a drop from about 40 percent to 30 percent).

The coefficient on the information intervention variable in the simple model also is consistent with the descriptive findings (Table 5, row 2, column 1). Our data provide little evidence of any effect of the information treatment on the average student in the information schools. The same result is found when we add prefectural dummy variables (row 2, column 2). Interestingly, however (and also consistent with the descriptive statistics), there is a small and positive impact after we add interaction terms between the information intervention and boarding school dummy (row 2, columns 3 to 5). For example, in the full model (column 5) the coefficient on the information intervention variable is positive (1.39) and significant at the 5 percent level. However, the coefficient on the interaction term is negative and significant (-3.00). The interpretation of these two variables is that after sending a letter to the parents (whose children that live at home), in fact, the parents appear to have taken action in some way that led to a small rise in their child's hemoglobin level compared to students in the control group.

However, the letter did not do any good for the students that lived at school. According to a joint test of significance, the impact of the letter to the parent on the boarding students was negative (1.39-3.00=-1.61) and significant. In fact, we have no definitive explanation of why the effect should be negative. One possible explanation is that parents may have expected the schools to provide better nutrition for the students that lived at school and cut back on their nutrition at home (wanting to free ride on the improved school-provided nutrition) when in fact nutrition did not improve at school (recall: there were no other intervention in the information schools). Alternatively, it could be the principals of the boarding schools that were hoping the parents would improve nutrition at home and cut back on whatever improvements principals as a whole (that is, those in control schools) were making (leading to the negative result). At the very least if we count this as no effect (that is, not positive), it might be fair to conclude that principals in boarding schools are not taking advantage of the fact that students that are living in boarding schools (and that are under the guardianship of principals most of the week) are providing an opportunity to improve student nutrition and health since there is a relatively dense concentration of vulnerable students living and eating together under the control of the education system for most of the year.

Perhaps most policy relevant for the education field in China, our results demonstrate that when students are given multivitamins with mineral supplements, not only does their anemia rates decline, their test scores also rise (Table 6, row 1). Regardless of the model, after taking multivitamins with mineral supplements for five months, ceteris paribus, the standardized math test scores of the students in the supplement treatment schools rose over 1 point more than the scores of the students in the control schools. In other words, the effect of providing fourth grade students with multivitamins with mineral supplements for a five month period is about 0.1 standard deviations. Although the effect is only moderate, it does show that nutrition and health truly is an input to the educational performance in poor rural areas of China.

Unfortunately, while we found that hemoglobin levels rose somewhat for those students that lived at home and were part of the information intervention, we can find no significant impacts on the test scores. The point estimates of the coefficients are positive (Table 6, row 2). However, in all cases, the standard deviations are large and the effect is not significant.

Effects on the Anemic

Perhaps more importantly, the impacts of the intervention on the students that began the study period with low hemoglobin levels are stronger—especially relative to those that began the study period with better iron status. To look at this we divided the sample into two parts—those with hemoglobin levels of below 120 g/L (anemic); and those with hemoglobin levels of above 135 (non-anemic)—and ran the full model (from equation 5). From our results, we can see that the effect of the supplement treatment on the anemic (an increase of 2.49 hemoglobin levels—Table 7, row 1, column 1) was somewhat larger than the impact on the average student (2.21—Table 5, row 1, column 5). There was no significant effect on the non anemic (Table 7, row 1, column 2). However, there was a significant and relatively larger effect (1.79 in Table 7, row 2, column 1 compared to 1.39 in Table 5) of the information treatment on the students that began the study anemic and who lived at home.

The larger impact on the anemic (versus the non-anemic) also shows up when we run equation 5 on the divided sample. In fact, the impact is almost twice as large for the case of the anemic. Whereas in the full sample (Table 6, row 1, column 5) we found that the supplement treatment raised math test scores of the average student by 1.02 points, in the sample of anemic students math test scores went up by 1.95 points, or around 0.2 standard deviations (Table 7, row 1, column 3).

The findings from examining the anemic and non anemic students separately do not provide evidence of positive spillovers. In cross sectional analysis (in Luo et al. 2009b), we found weak or zero relationship between anemia and test scores. One hypothesis was that because anemic students were not only performing poorly in class but also behaving badly (and causing disturbances in schools) that there were negative spillovers on non anemic students. If this were true, we would expect that the supplement intervention might have positive effects on the test scores of the non anemic students. In fact, the analysis reported in Table 7 (row 1, column 4) does not support such an interpretation as we do not see the test scores of the non-anemic rise in supplement schools.

V. Summary and Discussion

We have shown that anemia is epidemic in rural Shaanxi elementary schools. The overall anemia rate was 38.3 percent when using a blood hemoglobin cutoff of below 120 g/L. Moreover the problem is widespread. Although there was significant variation between counties and schools, the data showed that anemia rates were more than 10 percent in almost every single school in the sample. And while anemia is a problem in both subpopulations of students—those that live at home and those that board—the rates are higher for students that are boarding at schools. Although we have no evidence of causality, these findings may imply that poor nutrition from school-provided meals is one possible source of anemia.

The study also produced evidence that demonstrates both the source (or part of the source) of the problem and a solution (or one possible solution). From the results of our randomized control trial (RCT) involving over 3600 fourth grade students from 66 randomly chosen elementary schools in 8 of the poorest counties in Shaanxi Province, we found that the intervention that provided over-the-counter multivitamins with mineral supplements, including iron, to students for 5 months had significant impact in increasing hemoglobin levels and raising standardized math test scores. The supplement intervention raised hemoglobin levels of anemic students by about 0.2 standard deviations and also raised test scores of the anemic by about 0.2 standard deviations. In schools that received the information treatment (that is, their parents received a letter about the anemia status of their child) only students that lived at home (and not the students that lived in boarding schools and took most of their meals at schools) registered higher hemoglobin levels.

Are these large effects? Other studies that have analyzed the impacts on test scores of different interventions have found similar effects and these effects were deemed important. For example, the Tennessee STAR program reduced class size from twenty-two to fifteen and test scores improved by 0.21 standard deviations (Krueger and Whitmore 2001). The Indian Balsakhi Program provided tutoring for under-performing children in grade 3 and 4 and improved test scores by 0.27 standard deviations (Banerjee et al. 2007). A merit scholarship program for girls in Kenya increased test scores by 0.28 standard deviations (Kremer, Miguel, and Thornton, 2009). Hence, the effect of the supplement treatment appears to have an impact that is in the same order of magnitude of other documented effects. This suggests that providing better nutrition in schools (at least in rural elementary schools in poor areas of China's Shaanxi province) may be an effective input into the education process and be part of a strategy to try to reduce the gap in educational performance.

The results also have implications for China's overall education policy. In the recent past there has been increasing support in the Ministry of Education (MOE) for greater investment into rural education. However, many of the most influential voices have insisted that the MOE's job should be limited to providing better teachers, books and classrooms, the traditional purview of educators. Our results suggest that China's top educators may want to begin to rethink their role and consider adding the provision of better health and nutrition as an additional way to improve education. According to our findings, even if students have better teachers and more modern classrooms, when students are anemic, their test scores will be lower. Therefore, we hope that our paper helps encourage China's MOE to begin to broaden its view of education (beyond teachers, facilities and curriculum) and provide better nutrition and health care for students.

References

Asia Society. 2005. Education in China: Lessons for U.S. Educators. Asia Society, Business Roundtable, Council of Chief State School Officers, November, 2005. Retrieved January, 20, 2010, from: http://www.asiasociety.org/files/ChinaDelegationReport120105b.pdf.

Banerjee, A., C. Shawn, D. Esther, L. Leigh. 2007. Remedying Education: Evidence from Two Randomized Experiments in India. *Quarterly Journal of Economics* 122(3): 1235-1264.

Bobonis, G., E. Miguel, and C. Puri-Sharma. 2006. "Anemia and School Participation." *Journal of Human Resources*, 41(4): 692-721.

Chen, J., X. Zhao, X. Zhang, S. Yin, J. Piao, J. Huo, B. Yu, N. Qu, Q. Lu, and Wang, S. 2005. "Studies on the Effectiveness of NaFeEDTA-fortified Soy Sauce in Controlling Iron Deficiency: a Population-based Intervention Trial." *Food and Nutrition Bulletin*, 26:177-186. PMID: 16060219.

de Benoist, B., E. McLean, I. Egli, and M. Cogswell. 2008. *Global Prevalence of Anemia 1993-2005: WHO Global Database on Anemia.* Geneva: World Health Organization Press.

Gao, Y. 2008. "Schooling Education Investment, Intra-Household Externality of Literacy and Return on Peasant's Family Income: Theory and Evidence from the North Rural of China's Jiangsu Province." Retrieved January, 20,2010, from SSRN: http://ssrn.com/abstract=1310221.

Gleason, G. and Scrimshaw, N.S. 2007, " An overview of the functional significance of iron deficiency" in Nutritional Anemia, ed. Kraemer, K. and Zimmermann, M. B. Sight and Life Press. Switzerland: 45-58.

Gwatkin, D., S. Rutstein, K. Johnson, E. Suliman, A. Wagstaff, and A. Amouzou. 2007. Socio-economic Differences in Health, Nutrition, and Population within Developing Countries. Washington, DC, World Bank.

Halterman, J., J. Kaczorowski, C. Aligne, P. Auinger, and P. Szilagyi. 2001. "Iron Deficiency and Cognitive Achievement among School-aged Children and Adolescents in the United States." *Pediatrics*, 107:1381-1386.

Huang, A. and X. Du. 2007. "Comparative Analysis of Urban and Rural Difference in Family Education in China." *Journal of Yibing University*(in Chinese), 1: 107-110.

Khan. A.R. and C. Riskin. 2001. *Inequality and Poverty in China in the Age of Globalization*. Oxford: Oxford University Press.

Kremer, M., E. Miguel, and R. Thornton. 2009. "Incentives to learn." *Review of Economics and Statistics*, 91(3): 437-456.

Krueger, A. B., and D. M. Whitmore. 2001. "The Effect of Attending a Small Class in Early Grades on College-Test Taking and Middle School Test Results: Evidence from Project STAR." *Economic Journal* 111:1-28.

Li, H. P.W. Liu, N. Ma, and J. Zhang. 2005. “Does Education Pay in Urban China? Estimating Returns to Education Using Twins" Discussion Papers, Chinese University of Hong Kong, Department of Economics. Retrieved Feburary 8, 2010, from http://www.gsm.pku.edu.cn/store/object/2006824194540611.pdf.

Liu, C., L. Zhang, R. Luo, and S. Rozelle. 2008. "Early Commitment on Financial Aid and College Decision Making of Poor Students: Evidence from a Randomized Evaluation in Rural China." Retrieved September 28, 2009, from http://stanfordreap.win.aplus.net/doc/pdf/207_Liu%20et%20al_ECFA%20and%20college%20decision%20of%20poor%20students%20in%20rural%20China.pdf.

Liu, C., L. Zhang, R. Luo, and S. Rozelle. 2009. "The Effect of Primary School Mergers on Academic Performance of Students in Rural China." Retrieved September 28, 2009, from

http://stanfordreap.win.aplus.net/doc/pdf/204_Liu%20et%20al_Feb2009_Impact%20of%20school%20merger%20on%20performance.pdf.
Luo, R., Y. Shi, L. Zhang, C. Liu, S. Rozelle, and B. Sharbono. 2009a. "Malnutrition in China's Rural Boarding Schools: the Case of Primary Schools in Shaanxi Province." *Asia Pacific Journal of Education*, 29(4):481-501.
Luo, R., Kleiman-Weiner, M., Rozelle, S., Sharbono, B., Zhang, L., Liu, C., Shi, Y., Yue, A., Martorell, R. and Lee, M. 2009b." Anemia in Rural China's Elementary Schools: Prevalence and Correlates in Shaanxi Province's Poor Counties." Retrieved January 10, 2010, from: http://iis-db.stanford.edu/pubs/22724/211_Anemia_in_Rural_Chinas_Elementary_Schools.pdf.
Ma, Y. 2009. "The Rebound of Dropout Rate after School Merging Program in Rural China." Retrieved January 10, 2010, from: http://news.xinhuanet.com/edu/2009-11/12/content_12440098.htm.
MOE (Ministry of Education). 1992. *Educational Statistics Yearbook of China*. Beijing: People's education press.
———. 1999. Educational statistics yearbook of China. Beijing: People's Education Press.
———. (2006). Educational statistics yearbook of China. Beijing: People's Education Press.
MOE and NBS (Ministry of Education and National Bureau of Statistics). 2004. *China Educational Finance Statistical Yearbook*. Beijing: China Statistics Press.
Mohandas, R. 2000. *Report on the Third International Mathematics and Science Study* (TIMSS), National Institute for Research and Development, Ministry of National Education. Retrieved January 10, 2010, from: http://www.apecneted.org/resources/downloads/timssresults.pdf.
Olivia, S., J. Gibson, S. Rozelle, J. Huang, and X. Deng. 2008. "Mapping Poverty in Rural China:How Much Does the Environment Matter?" Working Paper in Economics 14/08, University of Waikato, Hamilton, New Zealand. Available from: http://www.chinapovmap.org/NR/rdonlyres/etzxjiensoxkc2ictj3cmm2liyp5qpvxx3hs4ywh3ejdwjmzozfa74n6o4ifpbmg45j7dkcwrh653a/0814.pdf.
Stoltzfus, R. 2001. "Defining Iron-Deficiency Anemia in Public Health Terms: A Time for Reflection." *The Journal of nutrition*, 131(2):565S-567S.
Stoltzfus, R., J. Kvalsvig, H. Chwaya, A. Montresor, M. Albonico, J. Tielsch, L. Savioli, and E. Pollitt. 2001. "Effects of Iron Supplementation and Anthelmintic Treatment on Motor and Language Development of Preschool Children in Zanzibar: Double Blind, Placebo Controlled Study." *British Medical Journal*, 323:1389,1-8.
Spybrook, J. Raudenbush, S. W., Liu, X., Congdon, R. and Martínez, A. 2008, Optimal Design for Longitudinal and Multilevel Research: Documentation for the "Optimal Design" Software, Retrieved January 28, 2010, from http://sitemaker.umich.edu/group-based/files/od-manual-v200-20090722.pdf.
Tsang, M.C., and Y. Ding. 2005. "Resource Utilization and Disparities in Compulsory Education in China." *Education and Economy* (In Chinese), 2: 34-40.
United Nations Children's Fund, World Health Organization and United Nations University. 2001. Iron Deficiency Anemia: Assessment, Prevention, and Control, A Guide for Programme Managers. Geneva, World Health Organization.
Victora, C., L. Adair, C. Fall, P. Hallal, R. Martorell, L. Richter, H. Sachdev. 2008. "Maternal and child undernutrition: consequences for adult health and human capital." *The Lancet*, 371(9609): 340-357.
Wang, X., C. Liu, L. Zhang, R. Luo, Y. Shi, S. Rozelle, and B. Sharbono. 2009. "What is Keeping the Poor out of College? Enrollment Rates, Educational Barriers and College Matriculation in China." Retrieved January 28, 2010, from

http://reap.stanford.edu/publications/what_is_keeping_the_poor_out_of_college_enrollment_rates_educational_barriers_and_college_matriculation_in_china/
Wang, X., B. Fleisher, H. Li, S. Li. 2007. "Access to Higher Education and Inequality: The Chinese Experiment." IZA Discussion Paper No. 4030. Available at SSRN: http://ssrn.com/abstract=996402
Webster B.J., and D. L. Fisher. 2000. "Accounting for Variation in Science and Mathematics Achievement: A Multilevel Analysis of Australian Data Third International Mathematics and Science Study (TIMSS)." *School Effectiveness and School Improvement*, 11(3): 339-360.
World Bank. 2001. *China: Challenges of Secondary Education*. Second Education Series 22856. Washington D.C., World Bank.
Xie, M. 2008. The Increasing Burden on Rural Family after School Merging Program in Rural China, Retrieved January 10, 2010, from http://www.gd.xinhuanet.com/newscenter/2008-09/03/content_14298403.htm.
Xue, J., Z. Wang, J. Zhang, Y. Han, C. Huang, Y. Zhang, and Z. He. 2007. "Study on Current Situation of Anemia and Intelligence of Country Adolescents in Shaanxi." *Modern Preventive Medicine* (In Chinese), 34(9): 1800-1801.
Yip, R. 2001. "Iron Deficiency and Anemia." In *Nutrition and Health in Developing Countries*, ed. Semba, R.D. and Bloem, M.W. Humana Press. New York: 327-342.
Young, D.J. 1998. "Ambition, Self-concept and Achievement: A Structural Equation Model for Comparing Rural and Urban Students." *Journal of Research in Rural Education*, 14(1): 34-44.
Zhang, L., R. Luo, C. Liu, and S. Rozelle. 2006. "Investing in Rural China: Tracking China's Commitment to Modernization." *The Chinese Economy*, 39(4): 57-84.
Zhuo, M. 2006. "Primary School Consolidation in Rural China: Advantages, Disadvantages and Solutions." Education Forum, The Education Department of Fujian Province. Retrieved January 10, 2010, from: http://218.85.72.34/newsInfo.aspx?pkId=10103.

TABLE 1.

THE DISTRIBUTION OF SAMPLE SCHOOLS AND STUDENTS

	Number of schools (1)	Number of students (2)	Percentage of students (3)
1. Full sample	66	3661	100
By County			
2. Baihe	7	373	10.2
3. Jiaxian	6	226	6.2
4. Shanyang	8	460	12.6
5. Suide	6	341	9.3
6. Xunyang	21	1,192	32.6
7. Yangxian	9	546	14.9
8. Ziyang	4	296	8.1
9. Zhashui	5	227	6.2
By treatment			
10. Supplement	24	1413	38.6
11. Information	12	641	17.5
12. Control	30	1607	43.9

Source. Authors' survey

TABLE 2.

THE DISTRIBUTION OF SAMPLE SCHOOLS AND STUDENTS ACROSS TREATMENTS FROM BASELINE SURVEY IN OCTOBER 2008.

	All students	Control group	Difference between supplement and control groups	Difference between information and control groups	Difference between supplement and information groups
Baseline Survey (October 2008)					
1. Hemoglobin level (g/L)	122.6	123.6	-1.91 (4.72)***	-0.92 (1.80)*	-0.98 (1.94)*
2. Percentage of students that were anemic (%)	38.3	35.6	6.94 (3.91)***	-0.02 (0.01)	6.96 (2.98)***
3. Standardized math test score	65.3	65.8	-0.3 (0.65)	-1.8 (2.61)***	1.5 (1.95)*
4. Percentage of boarding students (%)	37.2	35.1	2.85 (1.62)	4.82 (2.14)**	-1.97 (0.85)
5. Percentage of students eating two meals a day	43.1	51.8	-21.05 (11.85)***	-3.23 (1.37)	-17.81 (7.81)***
6. Student's age (in months)	122.0	122.4	-0.49 (1.24)	-1.03 (1.99)**	0.54 (1.03)
7. Percentage of girl students (%)	44.2	45.9	-2.44 (1.35)	-2.95 (1.27)	0.51 (0.22)
8. Education of mother (years)	7.9	7.8	0.12 (1.24)	0.18 (1.76)*	-0.06 (0.76)

Source: Authors' survey

Note: t values in parentheses; ***, ** and * indicate significantly different from zero at the 1, 5 and 10 percent levels, respectively.

TABLE 3.

THE ANEMIA RATE AND STANDARDIZED MATH TEST SCORE ACROSS TREATMENTS IN BASELINE SURVEY IN OCTOBER 2008 BETWEEN BOARDING AND NON-BOARDING STUDENTS

	All students (1)	Boarding students (2)	Difference between boarding and non-boarding students (3)
Anemia rate (%)			
1. Full sample	38.3	41.6	5.32 (3.19)***
By treatment			
2. Supplement	42.5	42.5	-0.17 (0.10)
3. Information	35.6	39.8	7.04 (1.82)*
4. Control	35.6	41.7	9.45 (3.77)***
	Standardized math test score		
5. Full sample	65.3	65.8	0.87 (1.69)*
By treatment			
6. Supplement	65.5	65.7	0.37 (0.45)
7. Information	64.0	63.7	-0.38 (0.32)
8. Control	65.8	67.1	2.09 (2.66)***

Data source: Authors' survey
Note: t value in parentheses; ***, ** and * indicate significantly different from zero at the 1, 5 and 10 percent levels, respectively.

TABLE 4.
THE DIFFERENCE OF HEMOGLOBIN LEVEL, ANEMIA RATE AND STANDARDIZED MATH TEST SCORE ACROSS TREATMENTS BETWEEN BOARDING AND NON-BOARDING STUDENTS

	Evaluation Survey (June 2009)			**Difference between Evaluation Surveys (June 2009 and Baseline (October 2008))**		
	All students (1)	Boarding students (2)	Non-boarding students (3)	All students (4)	Boarding students (5)	Non-boarding students (6)
Hemoglobin level (g/L)						
1. Full sample	124.5	123.3	125.3	1.9	1.8	2.0
By treatment						
2. Supplement	124.7	124.7	124.8	3.0	2.6	3.2
3. Information	123.9	121.6	125.3	1.3	0.1	2.1
4. Control	124.7	121.3	125.6	1.1	1.7	0.9
Anemic rate (%)						
5. Full sample	32.1	36.1	29.7	-6.2	-5.5	-6.6
By treatment						
6. Supplement	31.7	33.0	31.2	-10.8	-9.5	-11.4
7. Information	33.6	42.1	28.3	-2.0	2.3	-4.4
8. Control	31.6	36.3	29.0	-4.0	-5.4	-3.2
Standardized math test score						
9. Full sample	70.4	70.8	70.0	5.1	5.0	5.1
By treatment						
10. Supplement	71.1	70.7	71.3	5.6	5.0	6.0
11. Information	69.1	69.4	68.9	5.1	5.6	4.7
12. Control	70.4	71.6	69.7	4.6	4.5	4.6

Source. Authors' survey

TABLE 5.

EFFECTS OF SUPPLEMENT AND INFORMATION INTERVENTIONS ON THE CHANGE IN HEMOGLOBIN LEVELS BETWEEN OCTOBER 2008 AND JUNE 2009 IN FOURTH GRADE SAMPLE SCHOOLS IN SHAANXI PROVINCE.

	Dependent variable: Change in Hemoglobin level before and after intervention				
	(1)	(2)	(3)	(4)	(5)
Treatment variables					
1. Supplement (1=student in supplement treatment school); 0=not)	1.87	2.14	2.32	2.02	2.21
	(4.28)***	(5.08)***	(4.39)***	(3.75)***	(4.03)***
2. Information (1=student in information treatment school; 0=not)	0.06	0.40	1.44	1.29	1.39
	(0.11)	(0.75)	(2.11)**	(1.88)*	(1.99)**
Student characteristics and interaction terms					
3. Boarding student dummy (1=boarding student; 0=non-boarding student)			1.73	1.77	2.15
			(2.90)***	(2.94)***	(3.48)***
4. Supplement intervention variable * Boarding student dummy			-0.82	-0.71	-0.85
			(-0.95)	(-0.82)	(-0.96)
5. Information intervention variable * Boarding student dummy			-2.81	-2.70	-3.00
			(-2.57)**	(-2.46)**	(-2.66)***
6. Two meals a day or not (1=yes, 0=no)				-0.82	-0.79
				(-1.95)*	(-1.84)*
7. Student's age (in months)				-0.03	-0.03
				(-1.65)*	(-1.74)*
8. Gender (1=female; 0=male)				-0.52	-0.47
				(-1.36)	(-1.21)
Parent characteristics					
9. Mother stays at home (1=yes,0=no)					0.35
					(0.74)
10. Education of mother (year)					-0.30
					(-1.09)
11. Mother self-employment or wage earning job (0=no, 1=yes)					1.58
					(2.56)**
Prefecture dummies					
12. Prefecture dummy 1		-5.18	-5.20	-5.40	-5.45
		(-7.89)***	(-7.89)***	(-7.93)***	(-7.81)***
13. Prefecture dummy 2		-12.11	-12.38	-12.97	-13.11
		(-17.71)***	(-17.90)***	(-17.34)***	(-17.16)***
14. Prefecture dummy 3		-9.12	-9.15	-9.44	-9.61
		(-16.68)***	(-16.66)***	(-16.46)***	(-16.34)***
15. Constant	1.21	8.46	7.92	12.38	12.67
	(4.05)***	(16.83)***	(14.68)***	(5.51)***	(5.07)***
16. Observations	3661	3661	3661	3661	3661
17. R-squared	0.01	0.10	0.11	0.11	0.12

Source: Authors' survey

Note: ***, ** and * indicate significantly different from zero at the 1, 5 and 10 percent levels, respectively.

TABLE 6.

EFFECTS OF THE STUDY'S SUPPLEMENT AND INFORMATION INTERVENTIONS ON THE CHANGE IN STANDARDIZED MATH SCORES BETWEEN OCTOBER 2008 AND JUNE 2009 IN FOURTH GRADE SAMPLE SCHOOLS IN SHAANXI PROVINCE.

	Dependent variable: Change in standardized math test scores before and after interventions				
Independent variables	(1)	(2)	(3)	(4)	(5)
Treatment variables					
1. Supplement intervention (1=student in supplement treatment school); 0=not)	1.05	0.99	1.22	1.07	1.02
	(2.32)**	(2.16)**	(2.11)**	(1.80)*	(1.72)*
2. Information intervention (1=student in information treatment school; 0=not)	0.58	0.58	0.16	0.06	0.18
	(1.04)	(1.03)	(0.22)	(0.08)	(0.25)
Student characteristics and interaction terms					
3. Boarding student dummy (1=boarding student; 0=non-boarding student)			0.07	0.26	0.45
			(0.11)	(0.39)	(0.66)
4. Supplement intervention variable * Boarding student dummy			-0.75	-0.85	-0.93
			(-0.81)	(-0.90)	(-0.98)
5. Information intervention variable * Boarding student dummy			0.90	1.01	1.22
			(0.78)	(0.87)	(1.03)
6. Two meals a day or not (1=yes, 0=no)				-0.39	-0.29
				(-0.85)	(-0.62)
7. Student's age (in months)				-0.05	-0.06
				(-2.71)***	(-2.85)***
8. Gender (1=female; 0=male)				0.33	0.42
				(0.79)	(1.00)
Parent characteristics					
9. Mother stays at home (1=yes,0=no)					-0.41
					(-0.80)
10. Education of mother (year)					0.29
					(0.99)
11. Mother self-employment or wage earning job (0=no, 1=yes)					0.06
					(0.09)
Prefecture dummies					
12. Prefecture dummy 1		0.70	0.65	0.61	0.54
		(0.98)	(0.90)	(0.81)	(0.71)
13. Prefecture dummy 2		-0.91	-0.84	-1.02	-1.01
		(-1.24)	(-1.13)	(-1.25)	(-1.23)
14. Prefecture dummy 3		1.26	1.29	1.19	1.25
		(2.11)**	(2.15)**	(1.90)*	(1.97)**
15. Constant	4.54	3.93	3.93	10.71	10.84
	(14.47)***	(7.15)***	(6.63)***	(4.20)***	(3.87)***
16. Observations	3661	3661	3661	3661	3661
17. R-squared	0.00	0.01	0.01	0.01	0.01

Source: Authors' survey

Note: ***, ** and * indicate significantly different from zero at the 1, 5 and 10 percent levels, respectively.

TABLE 7.

EFFECT OF THE STUDY'S SUPPLEMENT AND INFORMATION INTERVENTIONS ON THE CHANGE OF HEMOGLOBIN LEVELS AND STANDARDIZED MATH SCORES BETWEEN OCTOBER 2008 AND JUNE 2009 IN FOURTH GRADE SAMPLE SCHOOLS IN SHAANXI PROVINCE, BY SUB-SAMPLE.

Independent variables	Change in Hb level (g/L) before and after intervention		Change in standardized math scores before and after intervention	
	Hb level in Oct. 2008 <120 g/L (1)	Hb level in Oct. 2008 >135 g/L (2)	Hb level in Oct. 2008 <120 g/L (3)	Hb level in Oct. 2008 >135 g/L (4)
Treatment variables				
1. Supplement intervention (1=student in supplement treatment school; 0=not)	2.49 (3.17)***	-0.77 (-0.57)	1.95 (2.00)**	-0.55 (-1.15)
2. Information intervention (1=student in information treatment school; 0=not)	1.79 (1.74)*	0.61 (0.33)	-0.67 (-0.54)	-0.01 (-0.02)
Student characteristics and interaction terms				
3. Boarding student dummy (1=boarding student; 0=non-boarding student)	1.03 (1.24)	-1.62 (-0.93)	0.90 (0.84)	0.59 (0.93)
4. Supplement intervention variable * Boarding student dummy	-0.32 (-0.27)	4.89 (1.94)*	-1.33 (-0.90)	0.38 (0.43)
5. Information intervention variable * Boarding student dummy	-3.52 (-2.24)**	-0.78 (-0.23)	1.30 (0.69)	-0.99 (-0.88)
6. Two meals a day or not (1=yes, 0=no)	0.23 (0.38)	-1.12 (-1.03)	0.85 (1.17)	-0.02 (-0.04)
7. Student's age (in months)	-0.01 (-0.24)	-0.07 (-1.52)	-0.05 (-1.47)	-0.02 (-0.95)
8. Gender (1=female; 0=male)	-0.08 (-0.14)	-1.98 (-1.94)*	0.34 (0.52)	0.51 (1.41)
Parent characteristics				
9. Mother stays at home (1=yes,0=no)	-0.06 (-0.09)	1.34 (1.18)	0.99 (1.21)	-0.42 (-1.05)
10. Education of mother (year)	-0.01 (-0.03)	0.49 (0.71)	0.24 (0.49)	0.20 (0.83)
11. Mother self-employment or wage earning job (0=no, 1=yes)	0.14 (0.16)	1.24 (0.80)	0.15 (0.15)	0.08 (0.15)
Prefecture dummies				
12. Prefecture dummy 1	-5.23 (-5.03)***	-4.58 (-2.72)***	1.47 (1.11)	-0.09 (-0.15)
13. Prefecture dummy 2	-13.76 (-12.73)***	-12.85 (-6.49)***	0.10 (0.07)	-0.26 (-0.38)
14. Prefecture dummy 3	-9.75 (-11.67)***	-11.12 (-7.32)***	1.72 (1.61)	0.29 (0.55)
15. Constant	16.61 (4.57)***	7.27 (1.21)	7.89 (1.70)*	3.16 (1.32)
16. Observations	1401	408	1401	408
17. R-squared	0.17	0.20	0.01	0.03

Note: ***, ** and * indicate significantly different from zero at the 1, 5 and 10 percent levels, respectively.
Data source: Authors' survey

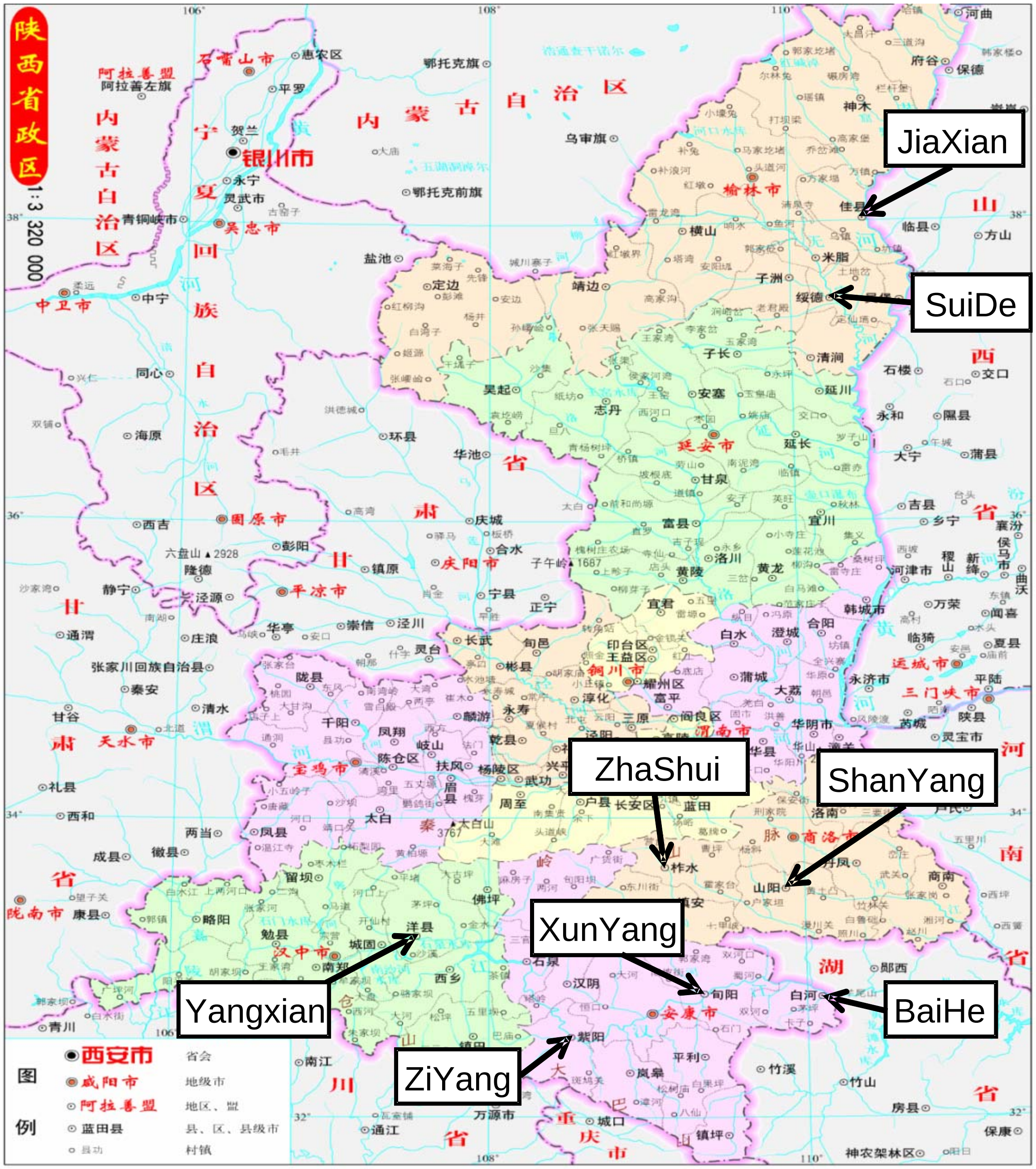

Figure 1. Location of Sample Counties

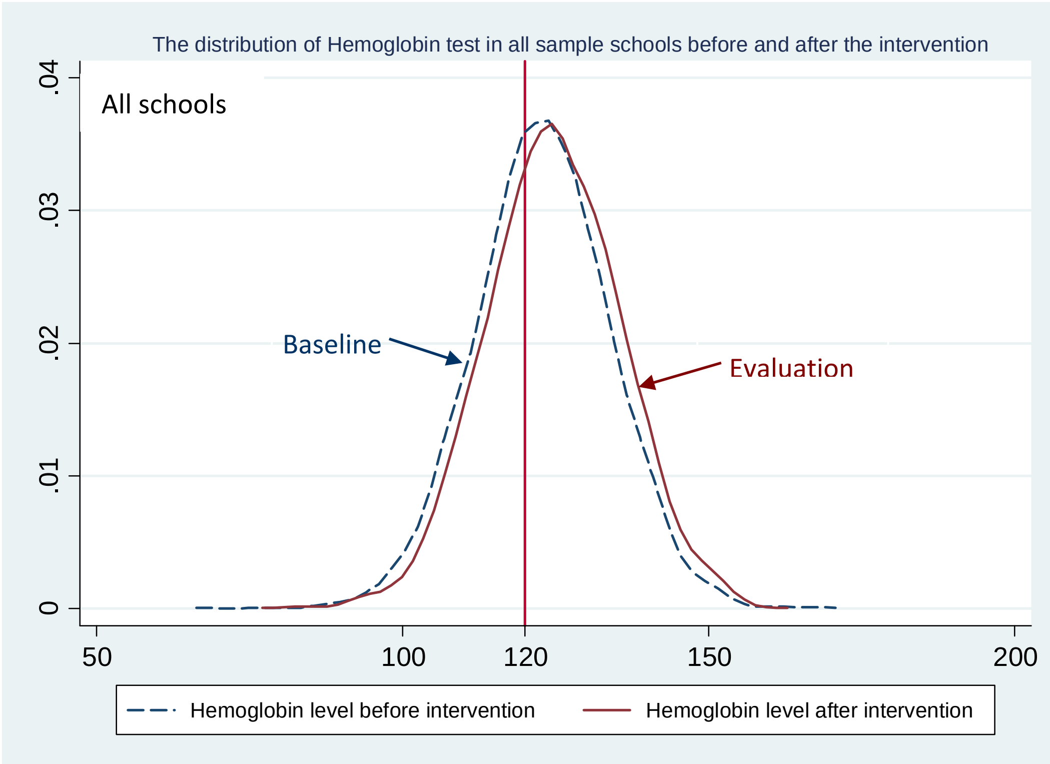

Figure 2. The distributions for all students (in both treatment + control schools) for Hemoglobin levels before and after the study intervention, October 2008 to June 2009.

Source: Authors' survey.

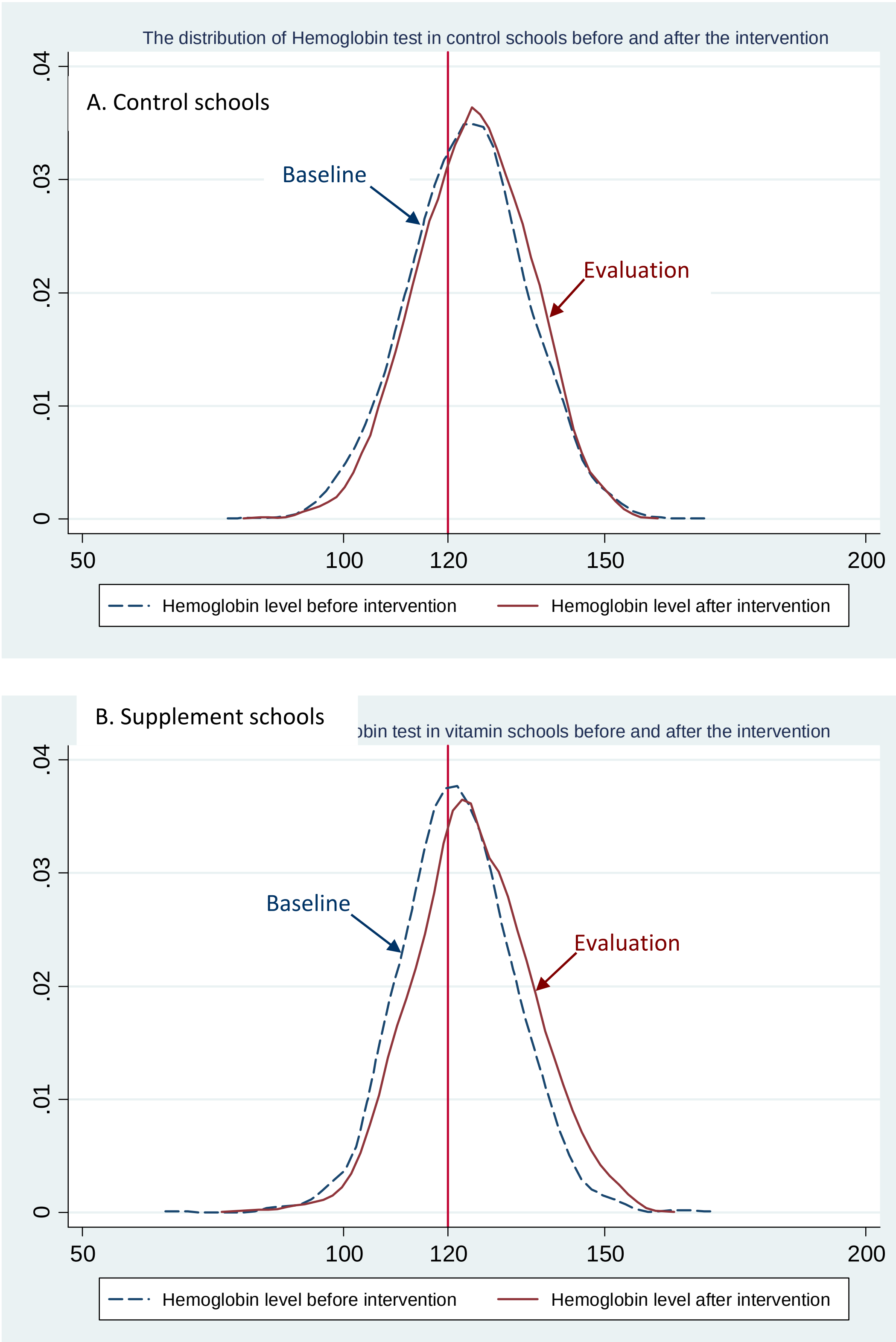

Figure 3. Distributions of Hemoglobin levels for all students (in both treatment + control schools) before and after the study intervention, October 2008 to June 2009.

Source: Authors' survey.

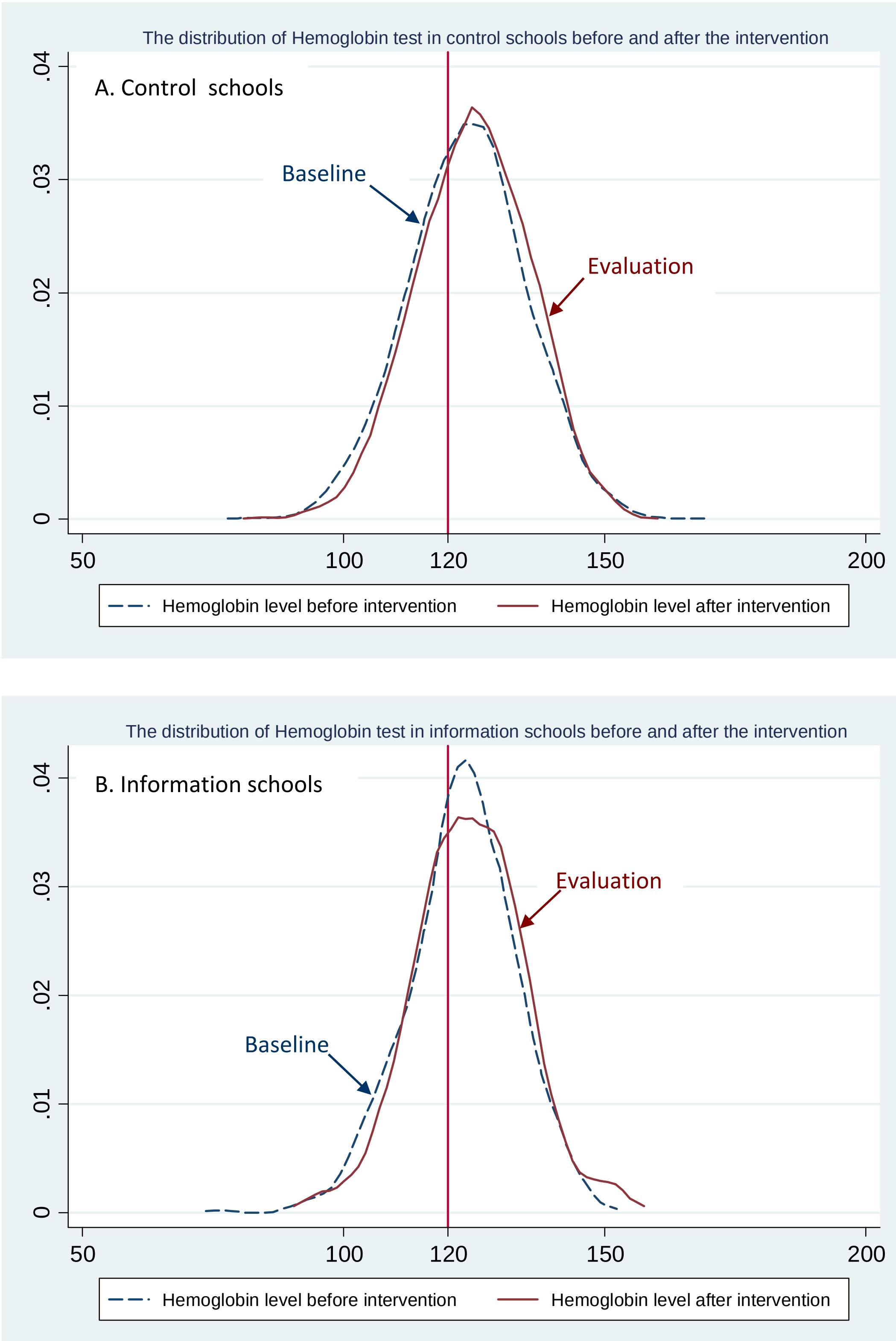

Figure 4. Distributions of Hemoglobin levels for students in information treatment and for students in control schools before and after the study intervention, October 2008 to June 2009.

Source: Authors' survey.

Appendix 1: Sample letter to parent in information treatment school.

Health Evaluation Report on Anemia

Dear ______________________ (student name)'s parents!

As researchers from the Xi'an Jiaotong University, whom have recently conducted a study ("Child Nutrition and Education") at your child's school, we would like to firstly thank you for supporting our work! As part of this study, we tested your child for anemia, and are including the results below:

According World Health Organization (WHO) standards, hemoglobin levels lower than 120 g/L indicate anemia. Based on our test results, your child's hemoglobin levels are ____________________g/L, which indicates that your child possible has serious/mild/no anemia, borderline/no anemia. Anemia can negatively affect a child's development, physical strength and endurance, attention span, cognitive thinking and memory, which all impact educational effectiveness and academic achievement. Anemia also can affect disease susceptibility and spread. Therefore, parents should be particularly attentive about their child's health, especially anemia – early identification of anemia allows faster prevention.

Since (though) your child is (not) possible anemic, we suggest you pay close attention to his/her eating habits: 1) give your child iron-rich foods, including liver (pig, cow, sheep, etc.); animal blood; lean meats (pork, beef, lamb, etc.); fish and shrimp; and bean products (tofu, soy milk, etc) (ideally make sure your child eats one bowl of meat, an egg or an equivalent amount of bean products), and also use iron-fortified soy sauce. 2) Simultaneously, consume fresh vegetables and fruits for sufficient Vitamin C (every day, your child should eat an apple or the equivalent of another fruit). 3) Schedule accordingly three meals per day, and correct bad habits of eating imbalanced meals. Also, it is important to prevent intestinal worm infections (if necessary, de-worming medication is available), and to keep physically fit.

Regarding your child's moderate anemia, we strongly recommend you seek your doctor for medical assistance as soon as possible, to raise your child's hemoglobin levels and ensure your child's health! Currently, common iron supplements include: LiuSuanYa iron, FuMaSuan iron, PuTaoTangSuanYa iron, LiFeiNeng (if there are side effects, please seek medical attention). Best wishes for your child's healthy development!

Respectfully yours,

Xi'an Jiaotong University Medical Center

12.10.2008