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Nutrition and Educational Performance in Rural China's Elementary Schools: Results of a Randomized Control Trial in Shaanxi Province

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I. Introduction

Although children in both cities and rural areas in China have nearly universal rates of participation between grades 1 and 9, there is still a performance gap between urban and rural students—especially students from poor rural areas. In 2005 over 80% of urban students graduated from academic or vocational high schools (MOE 2006; Wang et al. 2011). However, less than 40% of rural students from poor counties graduated from high school. In China's large municipalities almost 50% of students graduated from college or some other

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tertiary educational institution (henceforth, college). Less than 5% of students from poor rural areas who started grade 1 in the mid-1990s matriculated into a college in the late 2000s (Liu et al. 2011). The high rates of return to higher education in China (e.g., Li et al. 2005; Wang et al. 2007) and the fact that access to higher education facilitates access to formal jobs with benefits mean that the poor performance of rural students is reinforcing inequality trends. It also has been shown in the development literature that there are intrahousehold externalities of education (e.g., Gao 2009). Finally, when poor rural students go to college, there are benefits for those who 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. 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, Business Roundtable, and Council of Chief State School Officers 2005). Although neither competitive high school entrance exam scores (*zhongkao*) nor competitive college entrance exam scores (*gaokao*) are reported publicly by rural and urban cohorts (or any other socioeconomic 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. 2011). There is greater investment per capita in urban students compared to rural students (MOE and NBS 2004; Tsang and Ding 2005). Parents of urban students also have higher educational attainments 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) to 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. Improvements in language and motor development have been observed among preschool-age children in East Africa following increased levels of iron (Stoltzfus et al. 2001). Programs to overcome iron-deficiency anemia also have been shown to increase preschool participation in India (Bobonis, Miguel, and Puri-Sharma 2006). Lower standardized math test scores among school-age children and adolescents in the United States have been attributed to iron deficiency, even to nonsevere iron deficiency (Halterman et al. 2001). School-age children and adolescents deficient in iron register lower scores on various mental performance and educational achievement tests (Nokes, van den Bosch, and Bundy [1998] and references therein). Yet, treating the iron deficiency of school-age children and adolescents can improve and may even reverse the diminished cognitive and educational performance iron deficiency causes (Nokes et al. [1998] and references therein). As shown from a study of adults in Indonesia (using the Indonesia Family Life Survey), treatment of iron deficiency at later stages of the life cycle may also be effective for improving health and human capital; participants were more likely to lose less time because of illness, be more energetic, have better psychosocial health, be working, and earn more. Therefore, to the extent that anemia is a problem in China's poor rural areas, it may be one of the factors that is leading to poor educational performance. We will be concerned with some of these effects in this study.

Poor nutrition, including iron deficiency, in utero and during early childhood also has been shown to have consequences for adult health and human capital (Victora et al. 2008). In some cases, these in utero and early childhood effects are irreversible (Gordon 2003; Lozoff and Georgieff 2006; Harris 2007). While extremely important, these effects of anemia are not the focus of our study.

In almost all countries of the world the prevalence of anemia falls when incomes rise. Indeed, the World Health Organization's (WHO'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 the growing commitment of China's government 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 as anemic. For example, a recent study in Shaanxi Province run by the provincial Center for Disease Control found anemia in as many as 40% 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%–60% (Chen et al. 2005). Although these studies are small-scale and nonrepresentative, 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 a highly unequal distribution of income (Khan and Riskin 2001). If a large share of China's rural population is still suffering from a nutritional deficiency, such as anemia, and only a small share of the urban population is (as is clear from Fu et al. [2003]), 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 article 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 it related to the poor diets of students? Finally, we will analyze if efforts that lower anemia rates lead to better educational performance.

In this article, we report on the results of a randomized control trial (RCT) involving over 3,600 fourth-grade students, mostly aged 9–12 (less than 1% of the sample students were either older than 12 years old, 144 months, or younger than 9 years old, 108 months), from 66 randomly chosen elementary schools in eight of the poorest counties in Shaanxi Province, located in China's poor northwest region, during a single school year over a 7-month period between late October 2008 (the time of the baseline survey) and early June 2009 (the time of the evaluation/end line survey). 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). According to our baseline data (collected before the interventions), 38.3% of the students had Hb levels of below 120 grams per liter (g/L), the WHO's cutoff for being anemic for children who are 9–12 years old (Gleason and Scrimshaw 2007). 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), Hb 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 well as suggesting several courses of action—henceforth, the information treatment) was more mixed.

The rest of the article is organized as follows. Section II 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 III describes the results of the baseline survey, reporting on the severity of anemia and identifying subgroups that may be particularly affected. In Sections IV and V, 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. Section VI presents conclusions.

II. 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. (2011), 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 eight 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 canvass survey by visiting the bureaus of education in each county. In each bureau we obtained a list of all 6-year elementary schools (or elementary schools that had grades 1–6) 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 (i.e., meals for 5 days

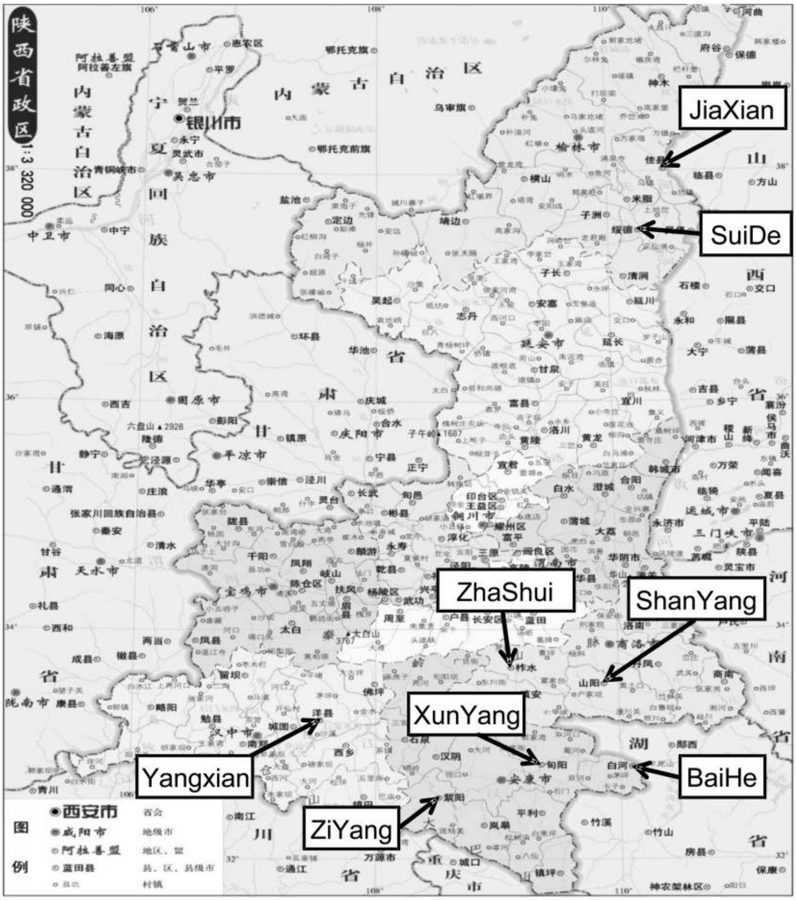

Figure 1. Location of sample counties

out of 7) at school.[1] In total, 116 schools fit these criteria. From this list, we randomly choose 66 schools. There were 3,661 fourth-grade students in these 66 schools, an average of 55 fourth-grade students per school. The list of the counties, the number of schools, the number of students per county, and the average number of students in each fourth-grade class are included in table 1 (rows 2–9).

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

[1] We decided on the criteria for two reasons. The trend in China is to move more toward 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 who live as boarders. Our criteria ensured that our sample contained boarding school students.

TABLE 1
DISTRIBUTION OF SAMPLE SCHOOLS AND STUDENTS

	Number of Schools (1)	Number of Students (2)	Average Fourth-Grade Class Size in Each School (3)	Percentage of Students (4)
1. Full sample	66	3,661	55	100
By county:				
2. Baihe	7	373	53	10.2
3. Jiaxian	6	226	37	6.2
4. Shanyang	8	460	57	12.6
5. Suide	6	341	56	9.3
6. Xunyang	21	1,192	56	32.6
7. Yangxian	9	546	60	14.9
8. Ziyang	4	296	74	8.1
9. Zhashui	5	227	45	6.2
By treatment:				
10. Supplement	24	1,413	58	38.6
11. Information	12	641	53	17.5
12. Control	30	1,607	53	43.9

Source. Authors' survey.

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.[2] 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 groups are summarized in table 1 (rows 10–12).

[2] The sample size was determined by power calculations performed before the intervention using a software called Optimal Design, which was developed by a group of researchers at the University of Michigan. As discussed in the manual by Spybrook et al. (2008), the power to detect a difference in Hb count between the treatment and control groups in a cluster randomized trial depends on four factors: (*a*) the number of students per school (n), (*b*) the number of schools (J), (*c*) the intraschool correlation in Hb count (ρ), and (*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 the supplement treatment and 0.3 for the information treatment. We assumed that there were 100 fourth graders per school. With the above assumptions on the parameters, in the case of the supplement treatment, we calculated that we could achieve a power equal to 0.8 at conventional significance levels ($\alpha = 0.05$) with about 24 schools for the supplement intervention and 24 schools as controls. In the case of the information treatment, we calculated that we could achieve a power equal to 0.8 at conventional significance levels ($\alpha = 0.05$) with about 12 schools for the information intervention and 12 schools as controls. Since we have two treatment groups (in a single experimental design), to be conservative, we decided to include 30 primary schools as controls in the design.

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 at which 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 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. 2010). In 1999 the Ministry of Education (MOE) launched an aggressive School Merger Policy (Liu et al. 2010). 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 (Wu 2011). 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 nonheated classrooms. The government, however, responded again and began a program to build dormitory facilities. By the mid-2000s, most students who 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. 2009). 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 was 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 who 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 who live in school dormitories (Luo et al. 2009).[3] Therefore, it is important in studying the relationship between nutrition and education that we differentiate between boarding school students and those who live at home.

Outcome Variables of Interest

We used two sets of outcome variables. The most proximate type of outcome variable is hemoglobin. Two trained nurses from 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 on-site (i.e., at schools) using HemoCue Hb 201+ systems. These portable instruments are known to provide rapid, in-the-field measurements of Hb levels with a high degree of accuracy.

The other main outcome variable of our study came from a standardized math test that we administered ourselves. The math test was based on questions drawn from a pool of questions that were originally created for the Trends in International Mathematics and Science Study (TIMSS). Enumerators required students to finish the 29-question test in 30 minutes. No extra time was given. We used the same pool of test questions before and after the intervention, but the questions were rated slightly "more difficult" in the evaluation test (according to the TIMSS rating system). No feedback was

[3] 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 who live at boarding schools were already poorly nourished when they began living at school. This is beside the point for this article. 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.

given after the baseline test. All the test instruments were collected after the baseline survey. In fact, we gave no indication to any of the participants—in either intervention or control schools—that we would be giving them another test, so there was no incentive for any one (i.e., teachers or principals) to try to teach to the test or remember the questions.

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 socioeconomic 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. Students also took a form home to their parents, who filled out information on their levels of education, age, and occupation.

III. Anemia and Test Scores in Shaanxi Province

Although incomes across China have risen, we find that anemia is still widespread (on the basis of our baseline testing of the students in October 2008). Across all of the schools surveyed (combining all eight counties), we found that the average Hb level was 122.6 g/L (table 2, row 1, col. 1). Hemoglobin levels in our sample were normally distributed with a standard deviation of 11.0 g/L. Any student with an Hb level below 120g/L was considered anemic as per WHO guidelines for children between 9 and 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, 1,401 of the 3,661 students we surveyed were anemic, resulting in a prevalence rate of 38.3% (table 2, row 2).

Because we did not prebalance (i.e., 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). The average Hb level in the supplement schools was 121.7, with an anemia rate of 42.5%. The Hb levels in the information (122.6) and control (123.6) schools were slightly higher and anemia rates slightly lower.[4] The standardized math test

[4] Since we did not prebalance 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. When we say that we did "not prebalance," we mean that we randomly selected our 24 vitamin intervention schools, the 12 information intervention schools, and the 30 control schools prior to the time that we did the baseline/intervention. Because of this, it was possible that at the baseline, by chance, there were differences among the intervention and control schools.

TABLE 2

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

					Difference between		
	All Students (1)	Supplement Group (2)	Information Group (3)	Control Group (4)	Supplement and Control Groups (5)	Information and Control Groups (6)	Supplement and Information Groups (7)
1. Hemoglobin level (g/L)	122.6	121.7	122.6	123.6	−1.91	−.92	−.98
					(4.72)***	(1.80)*	(1.94)*
2. Percentage of students who were anemic (%)	38.3	42.5	35.6	35.6	6.94	−.02	6.96
					(3.91)***	(.01)	(2.98)***
3. Standardized math test score	65.3	65.5	63.8	65.7	−.28	−1.83	1.65
					(.50)	(2.71)***	(2.18)**
4. Percentage of boarding students (%)	37.2	38.0	39.9	35.1	2.85	4.82	−1.97
					(1.62)	(2.14)**	(.85)
5. Student's age (in months)	122.0	121.9	121.4	122.4	−.49	−1.03	.54
					(1.24)	(1.99)**	(1.03)
6. Percentage of female students (%)	44.2	43.4	42.9	45.9	−2.44	−2.95	.51
					(1.35)	(1.27)	(.22)
7. Education of mother (years)	7.9	7.9	8.0	7.8	.12	.18	−.06
					(1.24)	(1.76)*	(.76)

Source. Authors' survey.
Note. *t*-values are in parentheses.
* Significantly different from zero at the 10% level.
** Significantly different from zero at the 5% level.
*** Significantly different from zero at the 1% level.

scores in supplement (65.5) and control schools (65.7) were higher than those of information schools (63.8). In control schools, fewer students were boarding at school (35.1%), compared to supplement (38.0%) and information schools (39.9%). The gender distribution is similar, and we find no evidence that female students are less likely to be boarders in supplement, information, or control schools.

When looking at the differences in Hb levels across different types of students, the most striking finding arises with respect to the living arrangements of the students (table 3). Students who live in the school dormitories had significantly lower Hb levels than students who live at home (rows 1–4, cols. 1–3). Our data also demonstrate that students who eat in the school cafeteria had significantly lower Hb levels than students who eat at home or bring lunches from home (not shown in the table). 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. 2009). Luo et al. report that whereas 23% of students who lived in boarding school had height for age Z-scores that were less than -2.00, only 11% of non–boarding school students did.[5] Even after they control for other characteristics (including student age and gender and parental age and education), multiple regression analysis in Luo et al. (2010) revealed two conditional correlations: students who lived at school and students who ate lunch at school had lower Hb levels and higher anemia rates. Table 3 also shows that the other outcome variable—standardized math test scores—is similar between boarding and nonboarding students and across supplement, information, and control schools (rows 5–8).

The Hb levels of male and female students are similar, but we find that male students score higher on the standardized math test than female students in the baseline survey (table 3, cols. 4–6). The difference in Hb levels between male and female students is small and not significant across supplement, information, and control schools (rows 1–4 and cols. 4–6). Similarly to other studies (Leahey and Guo 2001; Levine et al. 2005), we find that male students outperform their female counterparts in sample schools. Male students score about 2 points higher than female students, and this difference is significant in supplement and control schools.

[5] Since stunting is often highly correlated with poor nutrition during the years before attending school, these findings may be evidence that there are also preschooling forces that are at work here. As we mention in several places in the article, we are not trying to say that boarding school residence is causing poor nutrition. The age range of the sample is 60–100 months.

TABLE 3

HEMOGLOBIN LEVEL (GRAMS PER LITER) AND STANDARDIZED MATH TEST SCORE ACROSS TREATMENTS IN BASELINE SURVEY IN OCTOBER 2008 BETWEEN BOARDING AND NONBOARDING STUDENTS

	Boarding Students (1)	Nonboarding Students (2)	Difference between Boarding and Nonboarding Students (3)	Male Students (4)	Female Students (5)	Difference between Male and Female Students (6)
Hemoglobin level (g/L):						
1. Full sample	121.5	123.3	−1.82	122.9	122.3	.62
			(4.91)***			(1.71)*
By treatment:						
2. Supplement	121.7	121.6	.04	122.0	121.3	.76
			(.07)			(1.32)
3. Information	121.6	123.3	−1.77	122.9	122.3	.56
			(2.17)**			(.70)
4. Control	121.3	124.8	3.47	123.8	123.2	.62
			(5.92)***			(1.09)
Standardized math test score:						
5. Full sample	65.8	65.0	.83	66.1	64.0	2.12
			(1.60)			(4.20)***
By treatment:						
6. Supplement	65.7	65.3	.37	66.7	63.6	3.17
			(.44)			(3.81)***
7. Information	63.7	64.1	−.35	64.5	62.9	1.66
			(.30)			(1.44)
8. Control	67.1	65.1	2.09	66.3	64.9	1.42
			(2.55)**			(1.88)*

Source. Authors' survey.
* Significantly different from zero at the 10% level.
** Significantly different from zero at the 5% level.
*** Significantly different from zero at the 1% level.

Interestingly, when we run the correlation coefficient between the Hb levels and math test scores, it is less than 0.10 (although the correlation between anemic status and test scores is higher). In Luo et al. (2010) the coefficient on the Hb level variable also is insignificantly different from zero at a 5% level of significance in a regression that explains math scores (and that holds 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. One reason may be that there is unobserved heterogeneity (i.e., there may be unobserved/unmeasured variables that are correlated with both Hb levels and math scores, e.g., parents' inherent ability, etc.). 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 that was not related to math scores (or other outcome variables). In the next two sections of the article, we first describe our exogenous intervention (implemented as a cluster-level RCT) and then report on the results.

IV. 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 that 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 1–2 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 who 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 classroom) 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.[6]

[6] 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).

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 two multivitamins with mineral supplements to take home for the weekend. They were supposed to take one on Saturday and one on Sunday. Almost all parents whom 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 3-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 parents were then told their own child's Hb level. Their anemia status was given as one of four 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 who 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 who 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 who lived at home and parents of children who lived in boarding schools were both given letters. A translated copy of the letter is in the appendix.

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 reimplemented the hemoglobin tests.

The socioeconomic testing team gave students in sample schools another round of standardized math testing.

After completing our baseline and evaluation survey, we discovered that nonresponses and attrition, while present, do not appear to be serious; nor do they appear to affect the nature of our findings. In total there were 3,821 students enrolled in the 66 schools as fourth graders during the baseline; 3,754 students were surveyed. No survey forms were discarded (since our enumerators checked them all carefully on-site). The 67 nonresponses (25 in the 24 vitamin treatment schools, 14 in the 12 information treatment schools, and 28 in the 30 control schools) were from the 2% of the students absent that day. During the evaluation survey there were 3,759 students enrolled. We were told (by the vice principal in charge of attendance) that 62 students (23 in the 24 vitamin treatment schools, 11 in the 12 information treatment schools, and 29 in the 30 control schools) had dropped out or transferred (for various reasons; most commonly they had moved to the city with their parents). During the evaluation survey 3,694 students were surveyed. Again, no survey forms were discarded. Of all students surveyed during the baseline and evaluation surveys, there were 3,661 surveyed in both time periods. Hence, only 4% of all enrolled students were not part of the baseline evaluation panel. When possible (i.e., in the case of students who filled out a survey form in either the baseline or evaluation survey but not both), we checked those students who were missing (in one but not both of the surveys), and we find no systematic differences in key control variables between the supplement, information, and control schools.

V. Modeling and Results

When comparing the average Hb levels of all the students in our sample before (122.6; table 2, row 1) and after the intervention (124.5; table 4, row 1, col. 1), we can see that Hb levels rose during the study period. Across all students there was a rise in the average Hb level of 1.9 points (table 4, row 1, col. 4). In turn, the rise in Hb levels translates into a reduction of those students with levels below 120 from 38.3% in October 2008 (table 2, row 2) to 32.1% by June 2009, a reduction of 6.2 percentage points (table 4, row 5, cols. 1 and 4). In other words, in our overall sample there were 6.2% fewer students with anemia at the end of the study than at the beginning of the study. The distributions of the Hb 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 Hb levels and reducing anemia. According to table 4, the rise in the Hb

TABLE 4
DIFFERENCE OF HEMOGLOBIN LEVEL, ANEMIA RATE, AND STANDARDIZED MATH TEST SCORE ACROSS TREATMENTS BETWEEN BOARDING AND NONBOARDING STUDENTS

	Evaluation Survey (June 2009)			Difference between Evaluation Surveys (June 2009) and Baseline (October 2008)		
	All Students (1)	Boarding Students (2)	Nonboarding Students (3)	All Students (4)	Boarding Students (5)	Nonboarding 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	3.00	2.6	3.2
3. Information	123.9	121.6	125.3	1.29	.1	2.1
4. Control	124.7	121.3	125.6	1.13	1.7	.9
Anemia 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.

levels is higher for students in the supplement schools than for students in the control schools. The average change in the Hb level in the supplement schools between October 2008 and June 2009 was 3.00 points (row 2, col. 4). The average change in the control school during the same time period was only 1.13 points (row 4, col. 4). Therefore, while something (perhaps a general rise in income or a natural seasonal effect) caused the Hb levels of the students in the control schools to rise, the rise was nearly three 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 Hb levels between the students in the supplement and control schools are reflected in differences in reductions in anemia rates (or differences in those with Hb levels that are below 120). Anemia rates fell by 10.8 percentage points in supplement schools during the study period (row 6, col. 4). During the same time period, however, anemia rates fell by only 4.0 percentage points in control schools (row 8, col. 4).

In contrast, there is little evidence that the information treatment had an impact on the average Hb levels or anemia rates (table 4, comparing rows 3

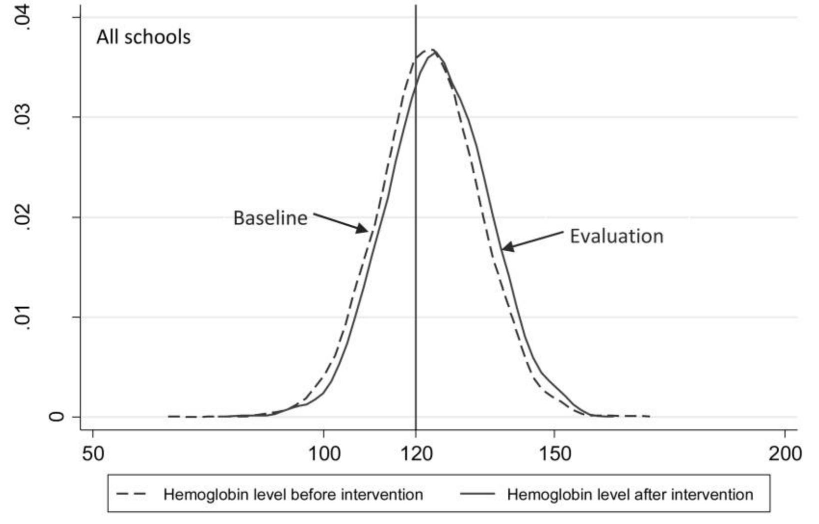

Figure 2. The distributions for all students (in both treatment and control schools) for Hb levels before and after the study intervention, October 2008 to June 2009. Source: Authors' survey.

and 4 and 7 and 8 in col. 4). In fact, although not statistically significant, the rise in the Hb levels (fall in the anemia rates) between October 2008 and June 2009 is smaller in the information schools than in the control schools. The shifting distributions of the Hb 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 who live at home and students who board at school. Table 4 shows that when parents whose children lived at home received a letter, there was a rise in Hb 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 Hb levels fell slightly for those students who lived in boarding facilities. While we cannot explain why the Hb levels of boarding school students fell, it is clear why the effect of the information might be expected to vary between the students who lived at home and the students who lived at school. Even if the parents of the children who 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

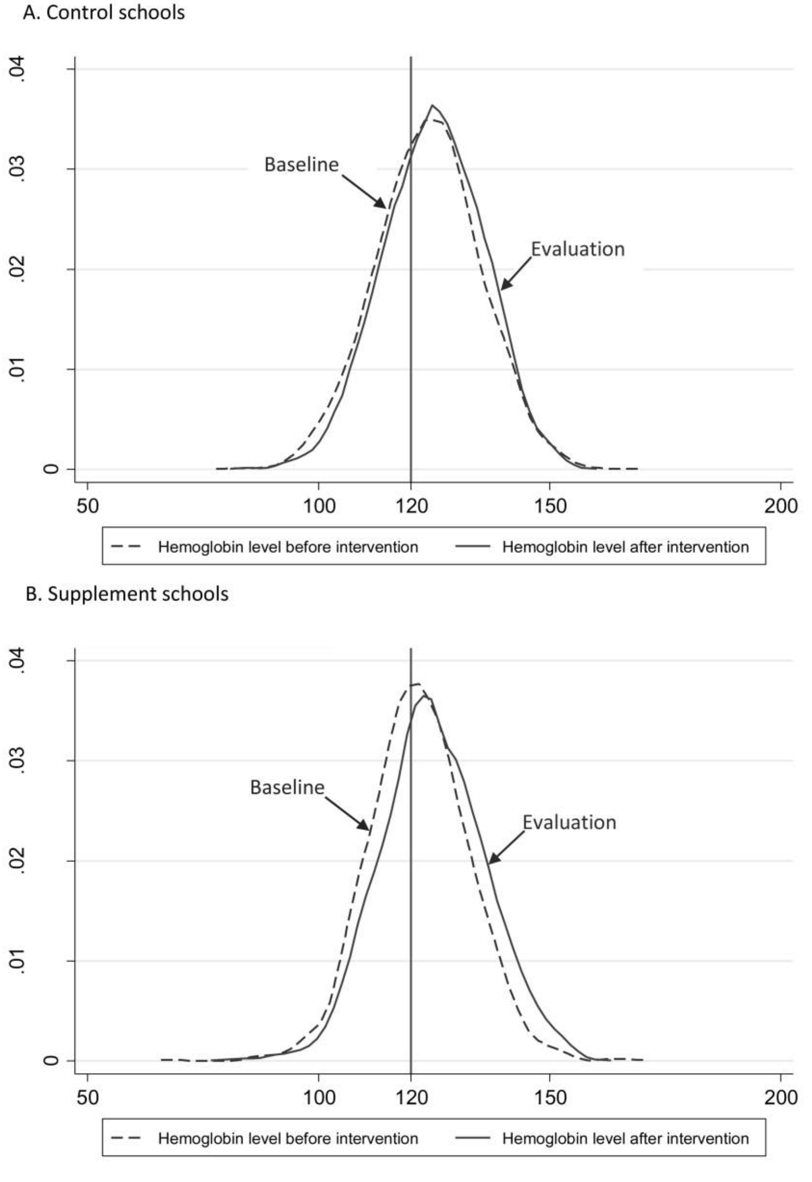

Figure 3. Distributions of Hb levels for students in (*A*) control schools and (*B*) supplement schools before and after the study intervention, October 2008 to June 2009. Source: Authors' survey.

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, col. 4). The difference was significant. As in the case of Hb levels, however, there was no significant difference in the

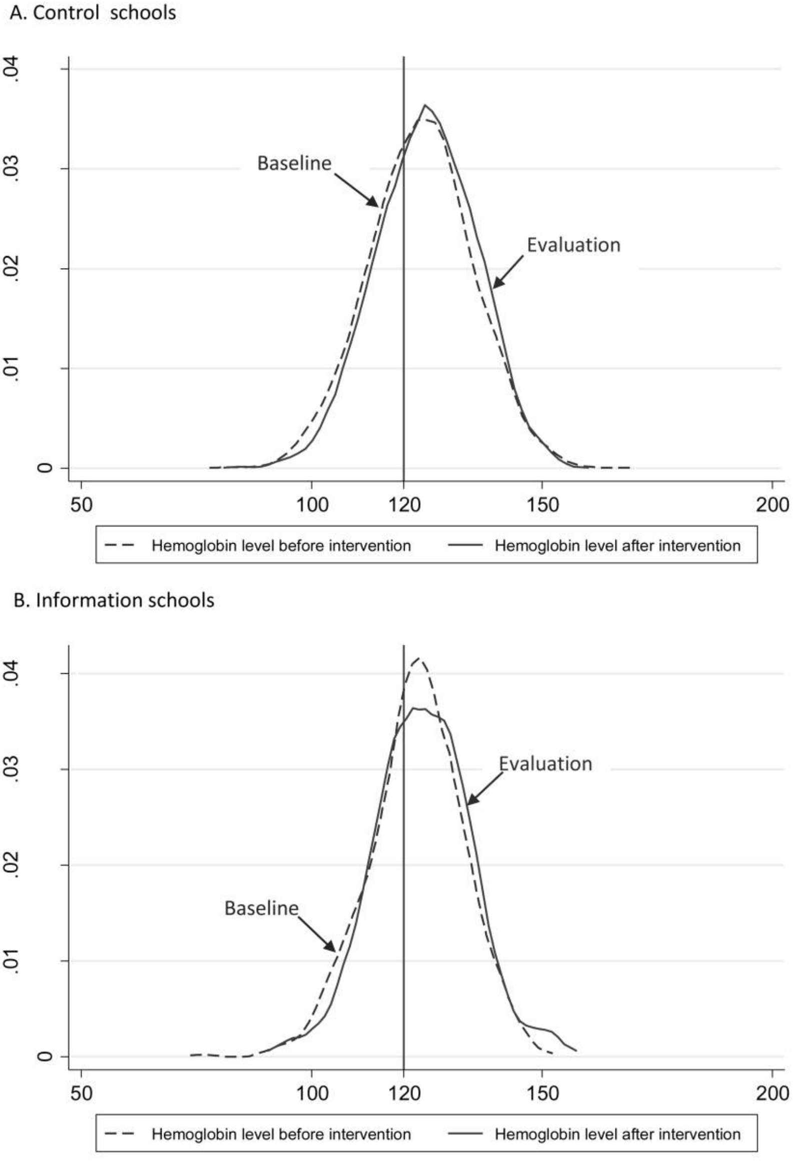

Figure 4. Distributions of Hb levels for students in (*A*) control schools and (*B*) information schools before and after the study intervention, October 2008 to June 2009. Source: Authors' survey.

rise in test scores between students who 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 the boarding students (which was not true in the case of changes in Hb 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 double-differences models in order to estimate the net effect of the treatments on the changes of Hb levels and test scores before and after the treatments. The models (in eqq. [1]–[5] below) are presented in order of increasing comprehensiveness.

The most fundamental model is

$$\Delta Y_{ijk} = a_0 + a_1 \times Supplement\ \ Intervention_{jk} + a_2 \times Information\ \ Intervention_{jk} + e_{ijk}, \tag{1}$$

where ΔY_{ijk} is the change of outcome variable for student i in school j in prefecture k before and after the treatment. In the analysis below, ΔY can be either the change in the Hb level or the change in the standardized test score. The two independent variables, *Supplement Intervention*$_{jk}$ and *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

$$\Delta Y_{ijk} = a_0 + a_1 \times Supplement\ \ Intervention_{jk} + a_2 \times Information\ \ Intervention_{jk} + \mu_k + e_{ijk}, \tag{2}$$

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 who do not live at school, in equation (3) we control for the heterogeneous effects for students who live at school. The model is[7]

[7] As seen in table 3, there are no significant differences in Hb levels between male and female students. We also tried—but do not report for the sake of brevity—to run a model similar to that defined by eq. (3) with interaction terms for gender instead of boarding school status. None of the coefficients on the interaction variables are significant, however. In other words, we do not find that interventions have different effects on male and female students. Complete results are available from the authors on request.

$$\begin{aligned}\Delta Y_{ijk} = {} & a_0 + a_1 \times Supplement\ \ Intervention_{jk} \\ & + a_2 \times Information\ \ Intervention_{jk} \\ & + a_3 \times Boarding\ \ student\ \ dummy_{ijk} \\ & + a_{31} \times Boarding\ \ student\ \ dummy_{ijk} \times Vit\_intervention_{jk} \\ & + a_{32} \times Boarding\ \ student\ \ dummy_{ijk} \times Info\_intervention_{jk} \\ & + \mu_k + e_{ijk},\end{aligned} \tag{3}$$

where all 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 that are designed to measure the differential effects of the supplement and information interventions on boarding school and non–boarding school students.

The final two models are

$$\begin{aligned}\Delta Y_{ijk} = {} & a_0 + a_1 \times Supplement\ \ Intervention_{jk} \\ & + a_2 \times Information\ \ Intervention_{jk} \\ & + a_3 \times Boarding\ \ student\ \ dummy_{ijk} \\ & + a_{31} \times Boarding\ \ student\ \ dummy_{ijk} \times Vit\_intervention_{jk} \\ & + a_{32} \times Boarding\ \ student\ \ dummy_{ijk} \times Info\_intervention_{jk} \\ & + a_4 \times Z\_student_{ijk} + \mu_k + e_{ijk}\end{aligned} \tag{4}$$

and

$$\begin{aligned}\Delta Y_{ijk} = {} & a_0 + a_1 \times Supplement\ \ Intervention_{jk} \\ & + a_2 \times Information\ \ Intervention_{jk} \\ & + a_3 \times Boarding\ \ student\ \ dummy_{ijk} \\ & + a_{31} \times Boarding\ \ student\ \ dummy_{ijk} \times Vit\_intervention_{jk} \\ & + a_{32} \times Boarding\ \ student\ \ dummy_{ijk} \times Info\_intervention_{jk} \\ & + a_4 \times Z\_student_{ijk} + a_5 \times Z\_parent_{ijk} + \mu_k + e_{ijk}.\end{aligned} \tag{5}$$

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 two variables. First, we include the student's *age* in months in October 2008 and, second, we include a *gender* variable that is defined as one 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 stays at home* if the mother lived 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) either if the mother 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 ordinary least squares model (adjusted for clustering), we find that the coefficient on the treatment variables in the Hb level model (1.87; table 5, row 1, col. 1) is exactly 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 − 1.13 = 1.87 from table 4, rows 2 and 4 in col. 4). When we control for other effects, however (in models 2–5), the impact of the supplement treatment on the Hb levels rises somewhat. In summary, providing fourth-grade students with multivitamins with mineral supplements for a 5-month period increased their Hb levels from 2.14 to 2.32 points for students living at home and from 3.17 to 3.58 for boarding students. In other words, the effect of providing fourth-grade students with multivitamins with mineral supplements for a 5-month period will shift the distribution of the Hb count to the right by about 0.2–0.25 standard deviations. Given the distribution of Hb levels in the baseline, this would translate into a reduction of anemia of more than 10 percentage points (or a drop from about 40% to 30%).

The coefficient on the information intervention variable in the simple model also is consistent with the descriptive findings (table 5, row 2, col. 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, col. 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, which are effectively triple differences (row 2, cols. 3–5). For example, in the full model (col. 5) the coefficient on the information intervention variable is positive (1.30) and significant at the 5% level. However, the coefficient on the interaction term is negative and significant (−2.76). The interpretation of these two variables is that after a letter was sent to the parents (whose children 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 Hb level compared to students in the control group.

However, the letter did not do as much good for the students who lived at the school. According to the results of the full model, the impact of the letter to the parent on boarding students was only 0.65 (1.30 − 2.76 + 2.11 = 0.65), far less than the impact on nonboarding students of 1.30. One possible explanation is that boarding students eat at home for only 2 days

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				
Independent Variable	(1)	(2)	(3)	(4)	(5)
Treatment variables:					
1. Supplement (1 = student in supplement treatment school, 0 = not)	1.87	2.14	2.32	2.20	2.32
	(4.28)***	(5.08)***	(4.39)***	(4.16)***	(4.30)***
2. Information (1 = student in information treatment school, 0 = not)	.16	.40	1.44	1.23	1.30
	(.11)	(.75)	(2.11)**	(1.79)*	(1.87)*
Student characteristics and interaction terms:					
3. Boarding student dummy (1 = boarding student, 0 = nonboarding student)			1.73	1.75	2.11
			(2.90)***	(2.92)***	(3.43)***
4. Supplement intervention variable × boarding student dummy			−.82	−.78	−.85
			(−.95)	(−.90)	(−.96)
5. Information intervention variable × boarding student dummy			−2.81	−2.51	−2.76
			(−2.57)**	(−2.30)**	(−2.46)**
6. Student's age (in months)				−.03	−.03
				(−1.59)	(−1.68)*
7. Gender (1 = female, 0 = male)				−.64	−.60
				(−1.70)*	(−1.55)
Parent characteristics:					
8. Mother stays at home (1 = yes, 0 = no)					.37
					(.78)
9. Education of mother (years)					−.28
					(−1.01)
10. Mother self-employment or wage-earning job (0 = no, 1 = yes)					1.65
					(2.68)***
Prefecture dummies:					
11. Prefecture dummy 1		−5.18	−5.20	−5.09	−5.13
		(−7.89)***	(−7.89)***	(−7.71)***	(−7.56)***
12. Prefecture dummy 2		−12.11	−12.38	−12.37	−12.52
		(−17.71)***	(−17.90)***	(−17.84)***	(−17.67)***
13. Prefecture dummy 3		−9.12	−9.15	−9.04	−9.22
		(−16.68)***	(−16.66)***	(−16.45)***	(−16.37)***

TABLE 5 (*Continued*)

Independent Variable	Dependent Variable: Change in Hemoglobin Level before and after Intervention				
	(1)	(2)	(3)	(4)	(5)
14. Constant	1.21	8.46	7.92	11.57	11.82
	(4.05)***	(16.83)***	(14.68)***	(5.29)***	(4.86)***
15. Observations	3,661	3,661	3,661	3,661	3,661
16. R^2	.01	.10	.11	.11	.12

Source. Authors' survey.
Note. Clustered standard deviations are used.
* Significantly different from zero at the 10% level.
** Significantly different from zero at the 5% level.
*** Significantly different from zero at the 1% level.

each week (the weekend), and parents cannot provide better nutrition for their children while they are living at school. Alternatively, it could be that the principals of the boarding schools were hoping that the parents would improve nutrition at home, so they did not improve nutrition at school. At the very least, it might be fair to conclude that principals in boarding schools are not taking advantage of the fact that students living in boarding schools (and under the guardianship of principals) for most of the week offer 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 do their anemia rates decline but their test scores also rise (table 6, row 1). Regardless of the model, after the students took multivitamins with mineral supplements for 5 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 (the differences between boarding and nonboarding students are not significant). In other words, the effect of providing fourth-grade students with multivitamins with mineral supplements for a 5-month period is about 0.1 standard deviations. Although the effect is only moderate, it does show that nutrition and health truly are inputs to educational performance in poor rural areas of China.

Unfortunately, while we found that Hb levels rose somewhat for those students who 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.

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 Variable	(1)	(2)	(3)	(4)	(5)
Treatment variables:					
1. Supplement intervention (1 = student in supplement treatment school, 0 = not)	1.05	.99	1.22	1.16	1.09
	(2.32)**	(2.16)**	(2.11)**	(2.01)**	(1.86)*
2. Information intervention (1 = student in information treatment school, 0 = not)	.58	.58	.16	.05	.16
	(1.04)	(1.03)	(.22)	(.07)	(.22)
Student characteristics and interaction terms:					
3. Boarding student dummy (1 = boarding student, 0 = nonboarding student)			.07	.14	.31
			(.11)	(.22)	(.46)
4. Supplement intervention variable × boarding student dummy			−.75	−.74	−.77
			(−.81)	(−.78)	(−.82)
5. Information intervention variable × boarding student dummy			.90	1.02	1.26
			(.78)	(.89)	(1.08)
6. Student's age (in months)				−.05	−.06
				(−2.73)***	(−2.84)***
7. Gender (1 = female, 0 = male)				.34	.46
				(.82)	(1.10)
Parent characteristics:					
8. Mother stays at home (1 = yes, 0 = no)					−.37
					(−.72)
9. Education of mother (years)					.30
					(1.03)
10. Mother self-employment or wage-earning job (0 = no, 1 = yes)					.12
					(.18)
Prefecture dummies:					
11. Prefecture dummy 1		.70	.65	.68	.58
		(.98)	(.90)	(.94)	(.78)
12. Prefecture dummy 2		−.91	−.84	−.77	−.81
		(−1.24)	(−1.13)	(−1.03)	(−1.06)
13. Prefecture dummy 3		1.26	1.29	1.34	1.40
		(2.11)**	(2.15)**	(2.23)**	(2.29)**
14. Constant	4.54	3.93	3.93	10.36	10.43
	(14.47)***	(7.15)***	(6.63)***	(4.18)***	(3.84)***
15. Observations	3,661	3,661	3,661	3,661	3,661
16. R^2	.00	.01	.01	.01	.01

Source. Authors' survey.
Note. Clustered standard deviations are used.
* Significantly different from zero at the 10% level.
** Significantly different from zero at the 5% level.
*** Significantly different from zero at the 1% level.

Effects on the Anemic

Another way to examine if we are truly observing the effect of the intervention is to see if the Hb and learning effects show up only in the anemic students. Since additional iron supplements should have an effect only on those who are anemic, we should see an effect on the anemic in the intervention schools above and beyond any effect on the nonanemic in the same class. In other words, the impacts of the intervention on students who began the study period with low Hb levels are stronger, especially relative to those who began the study period with better iron status.

We did this two ways. First, we divided the sample into two parts—those with Hb levels below 120 g/L (anemic) and those with Hb levels above 135 (nonanemic)—and ran the full model (from eq. [5]).[8] From our results, we can see the effect of the supplement treatment on the anemic. The point estimation is 3.02 Hb points for non–boarding school students (or a shift of 0.27 standard deviations) and 3.02 + 0.92 + 0.15 = 4.09 Hb points for boarding school students (or 0.37 standard deviations; table 7, rows 1, 3, and 4, col. 1). This effect was larger than the impact on the average student (an increase of 2.32 Hb points for nonboarding students and 2.32 + 2.11 − 0.85 = 3.58 Hb points for boarding students; table 5, rows 1, 3, and 4, col. 5). There was no significant effect on the nonanemic who live at home (table 7, row 1, col. 2). Interestingly, there was a significant and relatively larger effect (1.70 in table 7, row 2, col. 1 compared to 1.30 in table 5) of the information treatment on the students who began the study anemic and who lived at home.

The larger impact on the anemic (vs. the nonanemic) 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, col. 5) we found that the supplement treatment raised math test scores of the average student by 1.09 points (the difference between boarding and nonboarding students is not significant), in the sample of anemic students, math test scores went up by 1.64 points, or around 0.2 standard deviations (table 7, row 1, col. 3).

The findings from examining the anemic and nonanemic students separately do not provide evidence of positive spillovers. In the cross-sectional analysis (in Luo et al. 2010), we found a weak or zero relationship between

[8] We recognize that our choice of 135 for nonanemic students is arbitrary. In order to see if our results are robust to the assumptions, we have tried several different specifications under different assumptions. Specifically, although we do not report the results, we also repeated the analysis in table 7 using 130 and 140 as alternative cutoffs. We find the same insignificant results for the nonanemic students when using these alternative cutoffs, showing that the results are robust to this assumption.

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 SUBSAMPLE

	Change in Hb Level (g/L) before and after Intervention: Hb Level in October 2008		Change in Standardized Math Scores before and after Intervention: Hb Level in October 2008	
Independent Variable	< 120 g/L (1)	> 135 g/L (2)	< 120 g/L (3)	> 135 g/L (4)
Treatment variables:				
1. Supplement intervention (1 = student in supplement treatment school, 0 = not)	3.02	−.72	1.64	−.54
	(3.92)***	(−.54)	(1.71)*	(−1.15)
2. Information intervention (1 = student in information treatment school, 0 = not)	1.70	.62	−.74	−.01
	(1.67)*	(.34)	(−.59)	(−.02)
Student characteristics and interaction terms:				
3. Boarding student dummy (1 = boarding student, 0 = nonboarding student)	.92	−1.74	.76	.59
	(1.13)	(−1.00)	(.72)	(.93)
4. Supplement intervention variable × boarding student dummy	.15	5.04	−1.20	.39
	(.12)	(2.00)**	(−.81)	(.43)
5. Information intervention variable × boarding student dummy	−3.14	−.71	1.50	−.99
	(−2.04)**	(−.21)	(.80)	(−.88)
6. Student's age (in months)	−.00	−.06	−.05	−.02
	(−.13)	(−1.45)	(−1.63)	(−.95)
7. Gender (1 = female, 0 = male)	−.21	−1.98	.41	.51
	(−.40)	(−1.95)*	(.63)	(1.41)
Parent characteristics:				
8. Mother stays at home (1 = yes, 0 = no)	−.07	1.24	1.00	−.42
	(−.10)	(1.10)	(1.22)	(−1.06)
9. Education of mother (years)	.09	.55	.22	.20
	(.24)	(.79)	(.46)	(.84)
10. Mother self-employment or wage-earning job (0 = no, 1 = yes)	.01	1.40	.23	.09
	(.01)	(.90)	(.22)	(.16)
Prefecture dummies:				
11. Prefecture dummy 1	−5.59	−4.32	1.05	−.09
	(−5.56)***	(−2.59)***	(.81)	(−.15)
12. Prefecture dummy 2	−13.67	−12.15	−.48	−.25
	(−13.51)***	(−6.53)***	(−.37)	(−.39)
13. Prefecture dummy 3	−9.47	−10.71	1.31	.29
	(−11.84)***	(−7.31)***	(1.27)	(.58)
14. Constant	16.26	5.90	9.18	3.14
	(4.62)***	(1.00)	(2.07)**	(1.35)
15. Observations	1,401	408	1,401	408
16. R^2	.18	.20	.01	.03

Source. Authors' survey.
Note. Clustered standard deviations are used.
* Significantly different from zero at the 10% level.
** Significantly different from zero at the 5% level.
*** Significantly different from zero at the 1% level.

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), there were negative spillovers on nonanemic students. If this were true, we would expect that the supplement intervention might have positive effects on the test scores of the nonanemic students. In fact, the analysis reported in table 7 (row 1, col. 4) does not support such an interpretation as we do not see the test scores of the nonanemic rise in supplement schools.

In addition, we can also implement a triple-difference estimation procedure. In this article, we can do so by using the students in the supplement intervention group with Hb levels above 135g/L (in October 2008 during the baseline) as an additional "control group" against which we compare those students in the supplement intervention class that start (also in October 2008) at Hb levels below 120g/L and estimate the additional effect in a single regression (in contrast to table 7). The results of this triple-difference estimator (between supplement intervention and control, before and after the intervention, and between the anemic and nonanemic in the supplement intervention class) are reported in table 8. The results are consistent with the results reported in table 7. The impacts of supplement intervention on Hb levels and standardized test scores are still positive and significant in both columns (table 8, row 7).

Searching for Alternative Sources of Change and Robustness

While are results are fairly robust (up to this point), we still need to consider if anything else might have changed above and beyond our intervention that may have (in part) led to the observed changes in Hb levels and test scores. There are several ways to think about this and address this question. For example, is it possible that there was a Hawthorne effect? It is our research group's practice to visit control schools every time we visit treatment schools (including during the compliance checks to the treatment schools), a step that we take explicitly to eliminate any Hawthorne effect.

Second, we considered the possibility that teachers took the vitamins and as a result became less malnourished and were able to teach more effectively. We do not believe that this is the case. First, in rural China, while not overpaid, teachers are paid fairly well. Most young teachers are graduates of college or professional teaching schools. Teachers, as a professional class, are relatively well off. Hence, it is unlikely that they were malnourished (anemic) in the same way as their students. Therefore, even if they were taking vitamin supplements from the stock that was provided to the school, it is unlikely that this dramatically improved their teaching ability. In this study,

TABLE 8

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 SUBSAMPLE AND USING DIFFERENCE IN DIFFERENCE IN DIFFERENCE METHOD

	Difference in Difference in Difference Estimation	
Independent Variable	Change in Hb Level (g/L) before and after Intervention	Change in Standardized Math Scores before and after Intervention
Treatment variables:		
1. Supplement intervention (1 = student in supplement treatment school, 0 = not)	.48	−1.03
	(.44)	(−.75)
2. Information intervention (1 = student in information treatment school, 0 = not)	1.40	−1.41
	(.95)	(−.78)
Student characteristics and interaction terms:		
3. Boarding student dummy (1 = boarding student, 0 = nonboarding student)	.26	1.04
	(.35)	(1.10)
4. Supplement intervention variable × boarding student dummy	1.96	−.76
	(1.82)*	(−.57)
5. Information intervention variable × boarding student dummy	−1.79	.59
	(−1.28)	(.35)
Hb level in October 2008 and interaction terms:		
6. Hb level dummy in October 2008 (1 = Hb level in October 2008 below 120, 0 = Hb level in October 2008 above 135)	17.77	−.72
	(23.00)***	(−.72)
7. Supplement intervention variable × Hb level dummy	2.10	2.54
	(1.72)*	(1.65)*
8. Information intervention variable × Hb level dummy	−.02	1.10
	(−.01)	(.55)
9. Student's age (in months)	−.02	−.06
	(−.94)	(−2.10)**
10. Gender (1 = female, 0 = male)	−.73	.72
	(−1.54)	(1.25)
Parent characteristics:		
11. Mother stays at home (1 = yes, 0 = no)	.21	.37
	(.37)	(.53)
12. Education of mother (years)	.42	.35
	(1.25)	(.86)
13. Mother self-employment or wage-earning job (0 = no, 1 = yes)	.59	.22
	(.82)	(.24)
Prefecture dummies:		
14. Prefecture dummy 1	−5.10	.68
	(−5.99)***	(.63)
15. Prefecture dummy 2	−13.31	−.48
	(−15.07)***	(−.43)

TABLE 8 (*Continued*)

Independent Variable	Difference in Difference in Difference Estimation: Change in Hb Level (g/L) before and after Intervention	Change in Standardized Math Scores before and after Intervention
16. Prefecture dummy 3	−9.84	1.18
	(−14.16)***	(1.34)
17. Constant	.49	10.84
	(.16)	(2.74)***
18. Observations	1,809	1,809
19. R^2	.49	.01

Source. Authors' survey.
Note. Clustered standard deviations are used.
* Significantly different from zero at the 10% level.
** Significantly different from zero at the 5% level.
*** Significantly different from zero at the 1% level.

unfortunately, we did not test teachers for anemia. In another study that we conducted in another poor province in northwest China, we did test teachers for anemia and found that no teachers were severely anemic.

Third, it should be recognized that while the actions of teachers may be able to affect test scores in a number of ways (e.g., from teaching harder or teaching with more confidence), there is no way that Hb levels could rise except by the ingestion of additional iron. Therefore, the fact that the Hb levels went up for the most anemic students shows that at the very least the teachers in the intervention classes were giving their students vitamins and doing so effectively.

VI. Summary and Discussion

We have shown that anemia is epidemic in rural Shaanxi elementary schools. The overall anemia rate was 38.3% when using a blood Hb cutoff of below 120 g/L.[9] Moreover, the problem is widespread. Although there was significant variation between counties and schools, the data showed that anemia rates were more than 10% in almost every single school in the sample. And while anemia is a problem in both subpopulations of students—those who

[9] The reader should recall that this is not a study that can be considered representative of all students in Shaanxi Province's poor areas. In developing our sampling frame, we identified 116 schools that fit the criteria of having minimum size and boarders. There were other schools that did not fit these criteria (though in most counties most of the students in the poor towns attended schools that met our criteria). While we do not have definitive information on the schools that were excluded, they were often smaller schools that were more rural and less developed. Hence, to the extent that anemia is correlated with more rural and less developed areas, the anemia rates among students in schools that we did not survey could be even higher.

live at home and those who board—the rates are higher for students who 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 involving over 3,600 fourth-grade students from 66 randomly chosen elementary schools in eight 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 a significant impact on increasing Hb levels and raising standardized math test scores. The supplement intervention raised the Hb levels of anemic students by about 0.2 standard deviations and also raised the test scores of anemic students by about 0.2 standard deviations. In schools that received the information treatment (i.e., their parents received a letter about the anemia status of their child), only students who lived at home (and not the students who lived in boarding schools and took most of their meals at school) registered higher Hb levels.

The program also seems to be affordable from a cost-benefit point of view. At current wholesale prices, the vitamins cost about 0.2 yuan per dose (or 0.2 yuan per student per day). It is likely that this price could be lowered if the government ordered them in bulk. Currently, the government provides boarding/lodging subsidies of up to 2.50 yuan per day to students in poor areas. This would mean that an increase of this subsidy of 10% (0.2 yuan per student per day) could lead to reductions of anemia and higher test scores. The staff time is estimated to be between 10 and 30 minutes (depending on whether the teacher needs to boil the water himself/herself). If this were thought to be too much, chewable supplements could be distributed without dispensing water (however, the cost of chewable supplements is likely to be a bit higher—around 0.3–0.4 yuan per dose).

Can the effects found in our study be considered large? 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 Student/Teacher Achievement Ratio program reduced class size from 22 to 15, and test scores improved by 0.21 standard deviations (Krueger and Whitmore 2001). The Indian Balsakhi Program provided tutoring for underperforming children in grades 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 has the same order of magnitude as 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 can be part of a strategy to try to reduce the gap in educational performance.

Any effort to scale up our intervention, however, perhaps should proceed carefully since it is difficult to judge the external validity of a study that was implemented by the research team itself. If the vitamins were distributed and managed fully by the officials, principals, and teachers in the school system, it is unclear whether compliance would be complete or the program would be implemented rigorously. Providing a vitamin a day does have the advantage of being a fairly observable activity, making monitoring relatively easy. Efforts would have to be made to ensure that high-quality vitamin supplements were provided. However, at least in the short term, as long as the initial distribution of supplements to local school districts was managed carefully, given the absence of secondary markets for vitamin supplements, there would not be a great incentive for local actors to engage in actions (e.g., selling the supplements on the market and pocketing the money) that might undermine the program.

Nevertheless, the results of this study have implications for China's overall education policy. In the recent past there has been increasing support in the MOE for greater investment in 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 rethinking 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 study 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.

Appendix

Sample Letter to Parents in Information Treatment School: Health Evaluation Report on Anemia

Dear ____ (student name)'s parents:

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

According to World Health Organization 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 possibly 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 affect 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) possibly 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, deworming medication is available) and to keep physically fit.

Regarding your child's moderate anemia, we strongly recommend that you see 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, and 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

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