Impact Evaluation Report 8

Paying for performance in China's battle against anaemia

Linxiu Zhang, Scott Rozelle and Yaojing Shi

October 2013

International Initiative for Impact Evaluation

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Funding for this impact evaluation was provided by 3ie's donors, which include UKaid, the Bill and Melinda Gates Foundation, Hewlett Foundation and 12 other 3ie members that provide institutional support. A complete listing is provided on the 3ie website at http://www.3ieimpact.org/en/about/3ie-affiliates/3ie-members/.

Suggested citation: Zhang, L., Rozelle, S. and Shi, Y., 2013. *Paying for performance in China's battle against anaemia, 3ie Impact Evaluation Report 8*. New Delhi: International Initiative for Impact Evaluation (3ie)

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Paying for performance in China's battle against anaemia

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Abstract

Objectives: To study how misaligned supply-side incentives impede health programmes in developing countries, we tested the impact of performance pay for anaemia reduction in rural China.

Design: A cluster randomised trial of information, subsidies, and incentives for school principals to reduce anaemia among students.

Setting: 72 randomly selected rural primary schools across northwest China.

Participants: 3,553 fourth- and fifth-grade students aged 9 to 11.

Interventions: Sample schools were randomly assigned to a control group with no intervention, or one of three treatment arms: (1) an information arm in which principals received information about anaemia; (2) a subsidy arm in which principals received information and unconditional subsidies; and (3) an incentive arm in which principals received information, subsidies, and financial incentives for reducing anaemia among students. Twenty-seven schools were assigned to the control arm, 15 schools were assigned to the information arm, 15 schools were assigned to the subsidy arm, and 15 schools were assigned to the incentive arm.

Main outcome measures: Student haemoglobin (Hb) concentrations.

Results: Mean student Hb concentration rose by 0.15 g/dL in information schools, 0.08 g/dL in subsidy schools, and 0.24 g/dL in incentive schools relative to the control group. This increase in Hb corresponded to a reduction in anaemia prevalence (Hb < 11.5 g/dL) of 24 per cent in incentive schools. Interactions with pre-existing principal incentives for good test scores may have led to substantially larger gains in the information and incentive arms. In the presence of test score incentives, effects on student Hb concentration were 0.98 g/dL larger in information schools and 0.86 g/dL larger in incentive schools.

Conclusions: Financial incentives for health improvement were modestly effective. Understanding interactions with other motives and pre-existing incentives is critical.

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Abbreviations and acronyms

BMI	body mass index
g/dL	grams per decilitre
HAZ	Height-for-age z-score
Hb	haemoglobin
OLS	ordinary least squares
P4P	pay-for-performance
QOF	Quality and Outcomes Framework
CNY	Chinese yuan

1. Introduction

Inexpensive, highly efficacious technologies and services exist for improving human health in developing countries. However, implementation and coverage are often low. Clear examples include point-of-use water disinfectants, insecticide-treated bed nets, oral rehydration therapy, fortified complementary foods, condoms, improved cookstoves and basic primary health care services. Why have efforts to disseminate these technologies and services not produced greater population health gains? Given tremendous efforts by donors and international organisations in recent years, the answer cannot simply be that they are unavailable or unaffordable.

Misalignment between supplier incentives and the ultimate objective of improving health may be an important part of this puzzle. Building on the logic of performance pay in human resource management, a straightforward solution may be rewarding providers directly for producing socially desirable outcomes. Beyond well-known applications in wealthy countries (such as the British National Health Service's Quality and Outcomes Framework [QOF]), a growing number of aid organisations are also experimenting with pay-for-performance (P4P) incentives under the umbrella of 'results-based financing', rewarding measurable increases in the use of traditionally under-utilised health inputs such as EPI[1]-bundle childhood vaccinations, for example (Loevinsohn and Harding 2005; Doran *et al*. 2006; Soeters *et al*. 2006; Rosenthal and Dudley 2007; Guterman *et al*. 2009; Maynard and Bloor 2010; Montagu and Yarney 2011; Basinga *et al*. 2011).

The full promise of P4P incentives extends far beyond current applications to increase the use of specified technologies and services (Loevinsohn and Harding 2005; Bloom *et al*. 2006). In particular, rewarding the achievement of the ultimate objective – health improvement – without specifying how this should be done can strengthen incentives for creativity and innovation in service delivery. Given broad decision-making authority, local providers are better able to utilise their superior knowledge of what is likely to work (and not work) in local settings. To the best of our knowledge, performance pay for health improvements in a developing country has not previously been tried or evaluated.

The results of our project offer up first evidence on the effectiveness of rewarding providers with better health outcomes. Despite China's rapid economic development, prevalence rates of anaemia among children in rural China range from 20 to 60 per cent – implying more than 10 million affected children (Wang 2005; Chen *et al*. 2005; Wang 2007). In addition to causing debilitating fatigue and retarding growth, childhood anaemia may also impair cognitive development and inhibit human capital accumulation – lowering

[1] The Expanded Program on Immunization (EPI) is a World Health Organization programme that aims to make vaccines available to all children throughout the world. They recommend a fixed bundle of vaccinations that includes polio, measles, neonatal tetanus, diphtheria, pertussis (whooping cough), and tuberculosis vaccines.

socioeconomic status throughout the life course (Halterman *et al*. 2001; Stoltzfus 2001; Yip 2001; Bobonis *et al*. 2006). The high prevalence of childhood anaemia in China and many other developing countries is remarkable, given that it can (in principle) be confronted through simple, low-cost nutrition interventions. We therefore conducted a cluster-randomised field experiment in rural Chinese primary schools, a natural contact point with children (Desai and Alva 1998) to study the impact of information, subsidies and financial incentives for principals to reduce anaemia among students.

2. Methods

2.1 Setting and participants

Through a canvass survey, we first created a sampling universe of all primary schools in 10 nationally-designated poor counties spread across two provinces with high anaemia rates: Ningxia and Qinghai. We then identified all schools having six grades (in other words, 'complete' primary schools, or *wanxiao*) and boarding facilities. These criteria were used because China's government is currently consolidating existing rural schools into new ones with these characteristics. A total of 85 schools met these criteria, and we randomly selected 72 for inclusion in our study.

With the assistance of nursing teams from Xi'an Jiaotong Medical School, we conducted a baseline survey to collect socioeconomic information and haemoglobin (Hb) concentrations from a randomly selected half of fourth and fifth grade students in study schools (sampling 3,944 students in total). Fourth and fifth grade students were chosen because they are old enough for test scores to be relevant, but also young enough not to have reached puberty (at which point nutritional requirements differ more markedly from childhood and vary by gender).

2.2 Randomisation and interventions

Following the baseline survey, our research team randomly assigned study schools to a control arm or one of three experimental arms: 27 to the control arm, 15 to the information arm, 15 to the subsidy arm and 15 to the incentive arm. Figure 1 depicts the flow of participants through each stage of the study, as well as the project timeline. Table 1 shows student characteristics by arm at the time of our baseline survey.

Figure 1 Trial profile

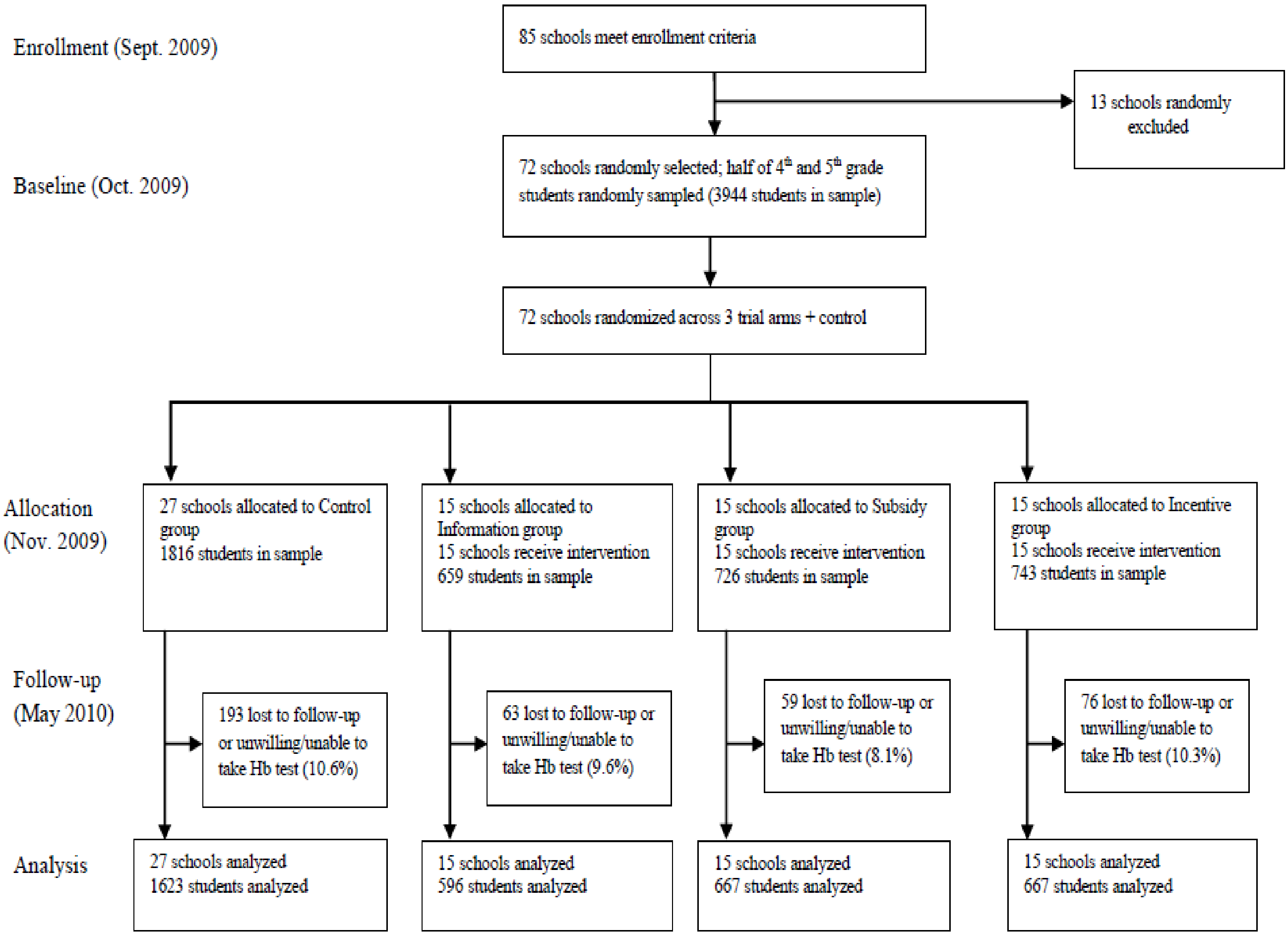


Table 1 Baseline student characteristics by experiment arm

	Control schoo 27 schools 1,623 students	Information schools: 15 schools 596 students	Subsidy schools: 15 schools 667 students	Incentive schools: 15 schools 667 students	P-value: information = control	P-value: subsidy = control	P-value: incentive = control
Hb concentration (altitude adjusted g/dL)	12.6 (12.3–12.8)	12.5 (12.0–12.9)	12.4 (11.9–12.9)	12.4 (11.9–12.9)	0.71	0.59	0.61
Anaemic (Hb<11.5 g/dL)	338, 20.8% (14.4–27.3%)	130, 21.8% (9.9–33.7%)	160, 24.0% (12.4–35.5%)	161, 24.1% (10.3–38.0%)	0.87	0.6	0.63
Sex (female)	778, 47.9% (46.2–49.7%)	281, 47.2% (45.0–49.3%)	317, 47.5% (43.2–51.9%)	319, 47.8% (43.0–52.7%)	0.54	0.85	0.96
Age (months)	123.3 (120.6–125.9)	124.7 (121.8–127.6)	123.4 (118.4–128.3)	120.5 (116.4–124.7)	0.44	0.98	0.22
Boarding student	554, 34.1% (25.5–42.8%)	248, 41.6% (29.3–53.9%)	236, 35.4% (24.1–46.7%)	244, 36.6% (30.5–42.7%)	0.28	0.85	0.62
Migrant mother	386, 23.8% (15.3–32.3%)	156, 26.2% (16.7–35.6%)	158, 23.7% (8.3–39.0%)	165, 24.7% (14.5–35.0%)	0.68	0.99	0.88
Mother has primary school education or less	1403, 86.4% (80.8–92.1%)	545, 91.4% (86.8–96.1%)	572, 85.8% (77.9–93.6%)	569, 85.3% (78.8–91.8%)	0.14	0.88	0.77

Note:
Percentages are of the total number of students in the experiment arm.
95% confidence intervals are in parentheses. Robust standard errors are in brackets.
All standard errors account for clustering at the school level.
*, **, and *** indicate significance at 10%, 5% and 1%, respectively.

All students, nursing teams and enumerators were blind to which schools belonged to which arms of the study.

Our study included a total of four arms: one control group and three intervention groups. Schools in all four groups were located an average of 30 kilometres apart, and because there was only one study school per township, there was no communication among study schools through local school districts. It is therefore unlikely that principals or study participants would have had an opportunity to communicate about the study across study clusters. The experimental groups are:

(0) *Control*. The control group did not receive any intervention. Principals were told that they would be participating in a study on how better nutrition might affect iron deficiency.

(1) *Information* ('information' arm). We provided three types of information to principals: (a) the share of enrolled students who are anaemic; (b) descriptions of efficacious methods for reducing iron-deficiency anaemia (including vitamin supplementation, adding more meat at lunch and other dietary changes, as well as the potential importance of educating parents about anaemia); and (c) details about anaemia's relationship with school attendance, educational performance and cognitive development, as reported in peer-reviewed academic studies (Stoltzfus 2001; Yip 2001; Bobonis *et al*. 2006; Desai and Alva 1998). Principals did not receive financial resources of any kind.

(2) *Information + earmarked operating budget subsidy* ('subsidy' arm). Because purchasing inputs to reduce anaemia may be difficult given current school operating budgets (which are small and allow for little discretion), schools in this arm received earmarked operating budget subsidies. The subsidy schools were given 1.5 Chinese yuan (CNY, approximately USD0.22) per student per day at the time of research, an amount sufficient to buy two to three ounces of red meat. These subsidies were only allowed to be used for nutrition-related expenses (we studied reallocation of school funds as well). In addition, we provided principals with the same information as in 'information' schools. Principals did not receive financial incentives of any kind.

(3) *Information + earmarked operating budget subsidy + anaemia reduction incentive* ('incentive' arm). To test the effectiveness of direct rewards for health improvement, a third group of school principals received performance payments for anaemia reductions among their student bodies. Given the governance structure of Chinese primary schools, school principals make executive decisions about school operations (Basu and Stephenson 2005). Incremental incentive payments were made as salary supplements to principals on a per student basis (CNY150, or approximately USD23, per student who changed from anaemic to non-anaemic over the course of the intervention). This amount was chosen to equal roughly two months of salary (CNY3,000, or about USD438) for successfully reducing the total number of students with anaemia by 50 per cent – a feasible reduction according to our early pilot experience. Principals in 'incentive' schools also received the same information and subsidies as those in 'subsidy' schools.

2.3 Outcomes and follow-up

Primary school surveys. We first conducted baseline surveys of principals in all study schools. These surveys collected detailed information about (a) nutritional characteristics of school meals (meat, soybean, fruit and vegetable composition of school meals); (b) use of anaemia-related nutritional supplements (such as iron or multivitamin/mineral supplements); and (c) school characteristics (class size, infrastructure, school budgets and school expenditure records). Because the effectiveness of any incentive scheme depends critically on local context, we also collected administrative information about explicit financial incentives that local education bureaus offer for good test scores.

Performance in response to any set of incentives must be verifiable, so we measured Hb concentrations directly using finger prick blood samples (with HemoCue 201+ point-of-care diagnostic technologies) drawn from a randomly selected half of all fourth and fifth grade students in all study schools. We randomly retested 10 per cent of all sampled students as well; if the second measure differed from the original one by more than 0.3 g/dL among three or more students, we retested all sample students in that school. Short surveys were also administered to students to collect basic information about their ages, socioeconomic characteristics and eating patterns. Specifically, students were asked about their consumption of a variety of different foods over the past week.

During our follow-up school surveys, we also gathered additional information from principals about strategies they pursued to reduce anaemia among students. Total attrition from the baseline survey to the follow-up survey was 9.9 per cent, balanced across the control group and experimental arms. Although the Hb levels of the dropouts were about 0.3 g/dL less than the students that did not drop out, the Hb levels were the same in each arm of the experiment and the control group.

Household surveys. We conducted baseline and follow-up household surveys for each child in our school-based sample. Specifically, we visited each child's home and interviewed his or her parents, collecting information about household socioeconomic characteristics, individual health behaviours and nutritional characteristics of household meals (consumption of meat, beans, fruits and vegetables).

2.4 Statistical analysis

We used altitude-adjusted Hb concentration measured in grams per decilitre (g/dL) as the primary outcome variable. Using estimates from pilot studies, we calculated that we required 55 fourth and fifth grade students per school and 15 schools per arm to detect a standardised effect size for Hb concentration of 0.4 with 80% power at the 5% significance level. We assumed an intra-cluster correlation of 0.25, a pre- and post-intervention correlation of 0.5, and a 10 per cent loss to follow-up.

2.5 Baseline findings

To make sense of our baseline prevalence data, we adopted two distinct statistical methodologies. First, we broke down the altitude-adjusted Hb levels and anaemia rates (using age-specific anaemia cut-offs) by region. Next, we used multivariate probit models with county dummy variables and school dummy variables to more rigorously assess regional variability in anaemia prevalence.

In order to identify individual, household and school-based factors associated with anaemia status at baseline, we first conducted a descriptive analysis of anaemia rates for each potential correlate. Next, we conducted a multivariate linear regression to identify the relationship between each potential correlate and Hb levels.

To show the relationship between anaemia status and measurable outcomes at baseline, we first compared anaemic and non-anaemic students in terms of their physical measurements and their scores on a series of psychological and cognitive tests. We then ran a series of multivariate regressions, using as the dependent variable height for age z-score, a dummy variable equal to one if the student is stunted, body mass index (BMI) z-score, score on a standardised maths exam and score on a psychological exam, respectively, and controlling for a number of individual and household-based characteristics.

2.6 Endline findings

We used unadjusted and adjusted ordinary least squares (OLS) regression analysis to estimate how student Hb concentrations changed in the intervention arms relative to the control arm. Our unadjusted analysis regresses changes in altitude-adjusted Hb concentrations on dummy variables for 'information', 'subsidy' and 'incentive' study arms. We used adjusted analyses as well to improve precision and to test for heterogeneous treatment effects. Specifically, we included county dummy variables, baseline student characteristics (including gender, age in months, baseline Hb concentration and student boarding status), and baseline parent characteristics (including maternal education and whether or not a child's mother is a migrant worker). In all regressions, we accounted for the clustered nature of our sample by constructing Huber-White standard errors corrected for school-level clustering (relaxing the assumption that disturbance terms are independent and identically distributed within schools).

Additionally, we investigated how the impact of treatment arms varied by pre-existing principal incentives for good test scores. Roughly 20 per cent of schools in our sample had explicit test score incentives through the cadre evaluation system (*ganbu kaohe zhidu*). These were balanced across experiment arms and gave principals up to one month of additional salary for mean test scores ranking in their district or county's top decile. In some adjusted regressions, we also included a dummy variable coding whether or not principals had pre-existing financial incentives for good average test scores (henceforth 'test score incentive dummy') and interactions between experiment arms and the test score incentive dummy.

Finally, we analysed behavioural responses to each intervention arm, testing for differences (and differential changes) in (a) principals' strategies to reduce anaemia, (b) principals' efforts to educate parents about good nutrition and anaemia, (c) the composition of students' diets (at home and at school), and (d) types of school expenditures.

The results of all these analyses are shown in the sections on Baseline results and Endline results (sections 3 and 4).

2.7 Theory of change

In addition to our statistical analyses of primary project outcomes, we paid particular attention to identifying why each of the interventions succeeded or failed. We have mapped out the theories of change for the three different interventions:

Target participants → principals → nutritional training (Do they receive the information? Do they understand it?) → change behaviour (Can they afford to change their behaviour? Is the person receiving the information the person who makes decisions about student consumption? Does the person receiving the information have a way of reaching others who can directly affect student nutrition?) → better student health

Target participants → principals → financial Subsidy (Do they receive the subsidy? Is the subsidy large enough to enact meaningful changes? Is the subsidy used for its intended purpose? Do they understand how it can best be used to improve student nutrition? Are there other needs that they perceive as being more important than student nutrition?) → better student health

Target participants → principals → financial incentive (Do they understand how the incentive works? Does the future payoff of the incentive outweigh the potential current payoff of the subsidy payment? Is the incentive large enough to encourage behavioural change?) → better student health

Our survey instruments were designed to capture any gaps in the chain (in other words, whether the interventions were reaching the targeted population and/or having their intended benefits). For example, our endline survey of principals collects detailed records of how they spent their subsidy payment, as well as information on other incentives offered to them by local officials. This will capture any lapses in steps along the theory of change, as well as any substitution away from the intended beneficiary of the implementation.

Our survey instruments will also measure the change in principals' knowledge between the baseline and endline surveys as a way of observing whether they understood the information that was presented to them.

We also took care to sharpen our survey and implementation tools before the project began, so as to minimise any leakages along the causal chain. For example, we conducted extensive pretesting of the survey instruments – especially the test of principal knowledge – to make sure that it asked the questions in a clear straightforward way, and included both easy and difficult questions. This would help ensure that the survey captured an accurate distribution of understanding, rather than underestimating understanding by asking confusing or misleading questions, or overestimating it by asking easy questions.

3. Baseline results

3.1 Anaemia prevalence in Qinghai and Ningxia

Despite the growing wealth in China, our results indicate that anaemia is still prevalent among sample students in Qinghai and Ningxia. Across all of the schools surveyed, we found the average Hb level to be 125.2 grams per litre (g/L), after adjusting for altitude. Hb levels were normally distributed with a standard deviation of 14.5. Using age-specific anaemia cut-offs, we calculated that 24.9 per cent of the students we surveyed were anaemic.

The overall anaemia prevalence disguises geographical variation across counties. To gain a clearer picture of this variation, we conducted a multivariate probit regression of county dummies on anaemia rates, using the following specification:

(1) $Y_{ij} = a_0 + a_1 * Countydummy_j + e_{ij}$

where Y_{ij} is a dummy variable equal to one if student *i* in county *j* is anaemic; $Countydummy_j$ represents a set of nine dummy variables that are equal to one if student *i* is in county *j*; and e_{ij} is an error term that is correlated within counties.

Although for brevity the full results of this model are not presented here, the p-value of the test (an F-test of the joint significance of the dummies) shows a significant county effect ($p < 0.001$). Haiyuan county in Ningxia had the lowest average anaemia rate at 8.2%; Xunhua county in Qinghai the highest at 75.4%.

Beyond the variation observed among counties, we also conducted a multivariate regression of school dummies on anaemia rates, to determine whether school-level variation was a significant factor. The model specification was identical to that used in equation (1), but substituting a set of 75 school dummy variables for the county dummies. The p-value of the test shows a significant school effect ($p < 0.001$), indicating significant variation across schools. The anaemia rate ranged from 5.9% to 100%.

3.2 Individual-, household- and school-based correlates of anaemia

In considering which factors may be correlated with anaemia status, we identified three general categories: individual-based factors (such as age and gender); household-based factors (such as parental education and occupation); and school-based factors (such as whether a student boards or eats at school). In this section, we first consider each factor separately. In the second part of the section, we conduct a multivariate analysis to determine which factors are significantly associated with anaemia status.

In the first category, males and females did not appear to differ in their anaemia rate – as shown in Table 2. Pre-pubescent children are unlikely to show the large gender differences common during adolescence and adulthood, when females are more likely to be iron deficient due to blood loss during menstruation. Younger children seem to have lower rates of anaemia, and these rates appear to increase as children age (Table 2).

Household characteristics we identified as being potentially correlated with anaemia include parental education and parental employment. In terms of employment, rural parents may work full-time on the farm ('full-time farmer'), part-time on the farm and part-time in an off-farm job ('part-time farmer'), or full-time off the farm ('off-farm worker'). China's large migrant labour force also means that some rural parents may be working in a different town, county or province; we attempt to assess parental migrant status by asking whether the parent lives at home for most of the year, or away from home for most of the year.

Some household characteristics also appear to be correlated with anaemia (Table 2). For example, higher levels of parental education seem to be associated with lower anaemia rates. A number of demographic studies support this result (Desai and Alva 1998); however, the causal relationship has yet to be defined (Desai and Alva 1998; Basu and Stephenson 2005; Hobcraft 1993).

Parental employment – especially that of the father – also appears to be correlated with anaemia rates among children (Table 2). Children whose fathers were involved in off-farm labour had lower anaemia rates than those whose fathers were full-time farmers. While the causality of this relationship and the mechanisms behind it cannot be determined from this analysis, one possible explanation is that parental employment is acting as a proxy for socioeconomic status, which is known to be inversely associated with anaemia and general nutritional status of children (Yip *et al*. 1987; World Bank 2007). In China, farming income is lower than off-farm income (de Janvry *et al*. 2005), so full-time farmers are likely to have lower household incomes than part-time farmers or off-farm workers.

In terms of school-based characteristics, our data indicate that students who live in the school dormitories had higher anaemia rates than students who live at home. Furthermore, students who eat in the school cafeteria had higher anaemia rates than students who eat at home or bring lunches from home (Table 2).

Table 2 Individual-, household- and school-based characteristics that may correlate with anaemia

Item	With anaemia (%)	Who board (%)	Percentage of total students
Gender			
Female	24.6	37.5	48.1
Male	25.5	39.6	51.9
Age group			
Age group: below 9	21.6	29.7	38.1
Age group: (9, 10]	24.8	37.9	27.9
Age group: (10, 11]	27.1	46.9	21.6
Age group: above 11	30.2	51.7	12.7
Father's education			
Illiterate	28.8	44.1	20.1
Primary school	26.4	42.4	41.3
Junior high school	22.1	33.6	29.3
High school	19.8	25.7	8.2
College or above	18.9	18.9	1.1
Mother's education			
Illiterate	27.3	41.8	48.3
Primary school	24.2	39.9	34.8
Junior high school	19.8	27.4	13.7
High school or above	17.2	21.5	3.2
Father's employment			
Full-time farmer	27.5	43.5	33.3
Part-time farmer	24.8	37.9	50.0
Off-farm worker	21.2	30.7	16.7
Mother's employment			
Full-time farmer	24.9	41.2	51.3
Part-time farmer	24.6	38.1	38.1
Off-farm worker	25.3	27.2	10.6
Father's residence			
Lives at home	24.7	39.2	61.0
Lives away from home	25.5	37.5	39.0
Mother's residence			
Lives at home	24.4	38.1	86.9
Lives away from home	27.9	41.6	13.1
Boarding status			
Does not board	23.2		61.4
Boards	27.5		38.6
Lunch			
Eats at home or brings lunch from home	23.6		54.0
Eats at school cafeteria	26.4		46.0

Data source: Authors' survey.

To more rigorously examine the relationship between anaemia status and the individual-, household- and school-based factors described above, we conducted a multivariate linear regression Table 3, using the following specification:

$$(2)\ Y_{ij} = a_0 + a_1 * Boarding_{ij} + e_{ij}$$

where Y_{ij} is the Hb level for student *i* in school *j* and $Boarding_{ij}$ is a dummy variable that is equal to one if student *i* is boarding in school *j*.

As many non-boarding students still eat lunch at school, in equation (3) we control for the heterogeneous effects of students who eat lunch at school. The model is:

$$(3)\ Y_{ij} = a_0 + a_1 * Boarding_{ij} + a_2 * Lunch_{ij} + e_{ij}$$

where $Lunch_{ij}$ is a dummy variable that is equal to one if student *i* eats lunch at school *j*. Motivated by the descriptive statistics and the differences that seem to exist between different gender and age groups, in equation (4) we control for individual-based characteristics:

$$(4)\ Y_{ij} = a_0 + a_1 * Boarding_{ij} + a_2 * Lunch_{ij} + a_3 * Z\_student_{ij} + e_{ij}$$

where $Z\_student_{ij}$ represents a set of controls for age and gender. In our final model, we also control for parental characteristics:

$$(5)\ Y_{ij} = a_0 + a_1 * Boarding_{ij} + a_2 * Lunch_{ij} + a_3 * Z\_student_{ij} + a_4 * Z\_parent_{ij} + e_{ij}$$

where Z_parent_{ij} represents a series of controls for parental education, employment and residency.

Consistent with the descriptive analysis, the results of the multivariate analyses show a significant correlation between students' boarding status and Hb levels in Table 3. A number of other results from our descriptive analysis were also confirmed, including a significant positive correlation between age and Hb levels. The data also show that children of fathers with a junior or senior high school education have significantly higher Hb levels than other children. Moreover, paternal employment also matters: children of fathers who worked either part-time or full-time off the farm had significantly higher Hb levels than children of fathers who were full-time farmers.

3.3 Correlations between anaemia and tests of physical, psychological and cognitive outcomes

Having shown the anaemia prevalence in the study areas and identified factors significantly correlated with anaemia status, we now examine the relationship between anaemia status and student performance on tests of physical, psychological and cognitive outcomes. According to our data, anaemia is strongly correlated with students' height and weight as evident in Table 4. Although the body mass index (BMI) z-scores of all students were below normal, students with anaemia had lower BMI than non-anaemic students. Furthermore, only 14% of non-anaemic students had stunted growth (as determined by a height-for-age z-score [HAZ] under –2.0), compared with 27.4% of anaemic students. Thus in this population, anaemia is associated with students that have impaired physiological development.

Table 3 Individual-, household- and school-based correlates of Hb levels

Dependent variable	Hb levels (g/L)			
	(1)	**(2)**	**(3)**	**(4)**
Boarding status (0=non-boarder, 1=boarder)	−1.21 (−2.65)***	−1.42 (−2.57)**	−1.47 (−2.65)***	−1.02 (−1.69)*
Lunch (0=Lunch prepared at home, 1=Lunch prepared at school)		0.37 (0.68)	0.34 (0.63)	0.45 (0.76)
Age of student (months)			0.03 (2.36)**	0.04 (2.80)***
Gender (0=male, 1=female)			−0.61 (−1.35)	−0.9 (−1.86)*
Education of father				
(0=illiterate, 1=primary school)				−0.3 (−0.45)
(0=illiterate, 1=junior high school)				1.28 (1.74)*
(0=illiterate, 1=senior high school)				2.57 (2.44)**
(0=illiterate, 1=college or above)				−0.4 (−0.17)
Father's employment				
(0=full-time farmer, 1=part-time farmer)				1.16 (1.98)**
(0=full-time farmer, 1=off-farm worker)				2.34 (2.82)***
Education of mother				
(0=illiterate, 1=primary school)				−0.2 (−0.37)
(0=illiterate, 1=junior high school)				1.48 (1.91)*
(0=illiterate, 1=senior high school or above)				0.43 (0.30)
Mother's employment				
(0=full-time farmer, 1=part-time farmer)				−0.47 (−0.82)
(0=full-time farmer, 1=off-farm worker)				−1.5 (−1.77)*
Residence of father (0=lives at home, 1=lives away from home)				0.98 (1.85)*
Residence of mother (0=lives at home, 1=lives away from home)				−0.8 (−1.05)
Constant	125.64 (441.7)***	125.55 (402.3)***	122.23 (79.05)***	120.85 (57.75)***
Observations	4,130	4,130	4,130	4,130
R-squared	0.002	0.002	0.002	0.01

Data source: Authors' survey.
Note:
T statistics in parentheses.
*** means $p < 0.01$, **means $p < 0.05$, * means $p < 0.1$.

Table 4 Physical, psychological and cognitive test scores, by anaemia status

Correlates	Anaemic students	Non-anaemic students
BMI z-score[a]	−0.64	−0.49
HAZ score[b]	−1.12	−0.55
Percentage with stunted growth[c]	27.4%	14.0%
Aggregate mental health test (max=90, where lower scores indicate better mental health)	41.7	39.3
Grade 4 maths test—distance from mean (standardised test score, with mean=0 and standard deviation=1)	−0.39	0.15
Grade 5 maths test—distance from mean (standardised test score, with mean=0 and standard deviation=1)	−0.33	0.09

Data source: Authors' survey.
Note:
In this table, we report anaemia rates based on the cut-off of 115 g/L for children aged 11 and under, and a cut-off of 120 g/L for children aged 12 and over. The WHO recommends a Hb level cut-off of 115 g/L for children aged 5–11 and 120 g/L for children aged 12–14. The age range of the majority of our sample population is 9–12 years.
[a] BMI z-scores (kg/m2) are defined based on the WHO Reference 2007 for both genders, aged between 5 and 19.
[b] HAZ scores (height in centimetres) are defined based on the WHO Reference 2007 for both genders, aged between 5 and 19.
[c] In this paper, stunting is defined based on the WHO Reference 2007 for HAZ, where any student with a HAZ score lower than −2 is considered to be stunted.

Through the Zhou Mental Health Test, we were able to measure by self-report how students were able to cope with different stressors as shown in Table 4. Anaemic students had worse average test scores than non-anaemic students, suggesting a possible link between anaemia and mental health.

Students with anaemia also performed worse than students without anaemia on the standardised maths test. In both the fourth and fifth grades, non-anaemic students scored above the mean, on average, while anaemic students scored below the mean. Descriptive statistics indicate a difference of 0.54 standard deviation for fourth grade students and of 0.42 standard deviation for fifth grade students.

Table 5 Correlations between anaemia and physical, psychological and cognitive outcomes

Dependent variable	Standardised maths test score (mean=0, sd=1)	Psycholog-ical test score (max=90)	Height for age z-Score	Student is stunted (0=no, 1=yes)	BMI z-score
Anaemia status (0=not anaemic, 1=anaemic)	−0.39	1.75	−0.40	0.11	−0.09
	(−10.54)***	(3.52)***	(−8.52)***	(7.81)***	(−2.43)**
Boarding status (0=non-boarder, 1=boarder)	−0.14	1.38	0.055	0.0034	0.14
	(−3.50)***	(2.62)***	(1.11)	(0.23)	(3.40)***
School lunch (0=eats lunch prepared at home, 1= school lunch)	0.01	−0.37	0.02	−0.01	0.07
	(0.19)	(−0.71)	(0.51)	(−0.52)	(1.89)*
Age of student (months)	−0.002	0.01	−0.05	0.01	−0.02
	(−2.33)**	−1.06	(−46.1)***	(23.4)***	(−17.3)***
Gender (0=male, 1=female)	−0.07	1.54	0.03	−0.002	−0.06
	(−2.20)**	(3.63)***	(0.83)	(−0.21)	(−1.81)*
Education of father (0=Illiterate, 1=Primary school)	−0.05	0.16	−0.07	0.03	−0.05
	(−1.03)	(0.27)	(−1.33)	(2.04)**	(−1.05)
Education of father (0=Illiterate, 1=Junior high school)	0.09	−0.52	−0.19	0.02	−0.13
	(1.94)*	(−0.80)	(−3.19)***	(1.34)	(−2.56)**
Education of father (0=Illiterate, 1=Senior high school)	0.23	−0.32	−0.18	0.004	−0.03
	(3.32)***	(−0.35)	(−2.05)**	(0.15)	(−0.48)
Education of father (0=Illiterate, 1=College or above)	−0.16	2.19	−0.38	0.02	−0.06
	(−1.01)	(1.06)	(−1.98)**	(0.29)	(−0.35)
Father's employment (0=Full-time farmer, 1=Part-time farmer)	0.11	−0.15	−0.02	−0.01	0.01
	(2.74)***	(−0.29)	(−0.46)	(−0.54)	(0.16)
Father's employment (0=Full-time farmer, 1=Off-farm worker)	0.08	0.24	0.19	−0.05	0.1
	(1.43)	(0.32)	(2.81)***	(−2.49)**	(1.80)*
Education of mother (0=Illiterate, 1=Primary school)	0.08	−0.79	−0.002	0.01	0.06
	(2.18)**	(−1.64)	(−0.04)	(−0.48)	(1.53)
Education of mother (0=Illiterate, 1=Junior high school)	0.26	−2.41	−0.02	−0.02	0.07
	(5.15)***	(−3.55)***	(−0.27)	(−1.01)	(1.33)
Education of mother (0=Illiterate, 1=Senior high school or above)	0.2	−2.98	0.02	−0.02	0.17
	(2.10)**	(−2.36)**	(0.13)	(−0.50)	(1.73)*
Mother's employment (0=Full-time farmer, 1=Part-time farmer)	−0.06	−0.03	0.09	−0.003	0.01
	(−1.61)	(−0.06)	(1.93)*	(−0.19)	(0.20)
Mother's employment (0=Full-time farmer, 1=Off–farm worker)	−0.07	0.54	−0.07	0.03	−0.05
	(−1.19)	(0.73)	(−1.05)	(1.67)*	(−0.95)
Residence of father (0=Lives at home, 1=Lives away from home)	0.19	−0.73	0.07	−0.01	−0.01
	(5.50)***	(−1.57)	(1.58)	(−0.76)	(−0.40)
Residence of mother (0=Lives at home, 1=Lives away from home)	−0.07	0.6	−0.03	0.02	−0.09
	(−1.41)	(0.89)	(−0.44)	(1.10)	(−1.70)*
Constant	0.31	38.52	5.65	−0.82	1.48
	(2.19)**	(19.96)***	(31.15)***	(−15.20)***	(9.85)***
Observations	4130	4130	4130	4130	4130
R-squared	0.08	0.02	0.41	0.17	0.09

Data source: Authors' survey.
T statistics in parentheses. *** means $p < 0.01$, ** means $p < 0.05$, * means $p < 0.1$. SD: standard deviation.
Note: In this table, we calculate anaemia rates based on the cut-off of 115 g/L for children aged 11 and under, and 120 g/L for children aged 12 and over. WHO recommends a Hb level cut-off of 115 g/L for children aged 5–11 and 120 g/L for children aged 12–14. The age range of the majority of our sample population is 9–12.

However, as shown in the previous section, there are many correlates of anaemia, and thus multiple regression is required to assess the causal effect of anaemia on academic and cognitive performance. To examine the correlation between anaemia status and these performance measures we conducted a set of multivariate regressions as shown in Table 5), based on the following model:

(6) $Y_{ij} = a_0 + a_1 \text{*}Anaemia_{ij} + a_2 \text{*}Boarding_{ij} + a_3 \text{*}Lunch_{ij} + a_4 \text{*}Z\_student_{ij} + a_5 \text{*}Z\_parent_{ij} + e_{ij}$

where Y_{ij} can be the standardised math test score, the psychological health test score or physical outcome measures (HAZ score, stunting status and BMI index); $Anaemia_{ij}$ is a dummy variable equal to one if the child is anaemic according to age-specific and altitude-adjusted Hb levels; $Boarding_{ij}$ is a dummy variable equal to one if the student boards at school; $Lunch_{ij}$ is a dummy variable equal to one if the student eats lunch at school; $Z\_student_{ij}$ represents a set of controls for age and gender; and Z_parent_{ij} represents a series of controls for parental education, employment and residency.

We found that anaemia was significantly correlated with reduced scores on all measures of physical, psychological and cognitive performance. This finding supports the work of another study of more than 40,000 school-aged children in Gansu Province, which found academic achievement (measured by normalised test scores in Chinese, maths and science) to be negatively affected by iron deficiency (20). Our findings are consistent with a hypothesis that the rash of anaemia in rural Qinghai and Ningxia schools may (in part) underlie the reduced academic achievement of students from rural areas.

4. Endline results

4.1 Changes in haemoglobin concentrations and complementarity with test score incentives

Figure 2 shows the distribution of student Hb concentration (g/dL) both at baseline and follow-up in each study arm (in separate panels). Each distribution, including the control group, shifted right over time between the baseline and follow-up survey. Larger shifts occurred in intervention schools relative to control schools. The small increase in Hb in the control group presumably reflects a well-documented seasonal effect (Luo *et al*. 2010).

To make the relative magnitude of these shifts more apparent, Figure 3 graphs the difference (vertical distance) between follow-up and baseline distributions relative to the control group by intervention arm. In general, the effect of the interventions was to shift the mass in the distribution of Hb concentration from below 12 g/dL to higher ranges (relative to the control arm).

Figure 4 considers how changes within each arm vary according to pre-existing principal incentives (bonus pay) for good average test scores. Specifically, Figure 4 presents separate panels for each arm, showing changes from baseline to follow-up between schools with and without test score incentives. The variance of these distributions suggests the presence of some random measurement error as commonly reported by others (Alderman *et al*. 2001; Babu and Hallam 1989), but this idiosyncratic variation is uncorrelated with experiment arm or other covariates. Although there is little differential change between schools with and without test score incentives in the control group, schools with test score incentives in the intervention arms experienced larger Hb gains than did their counterparts without them.

Figure 2 Distribution of student haemoglobin concentrations at baseline and follow-up by experiment arm

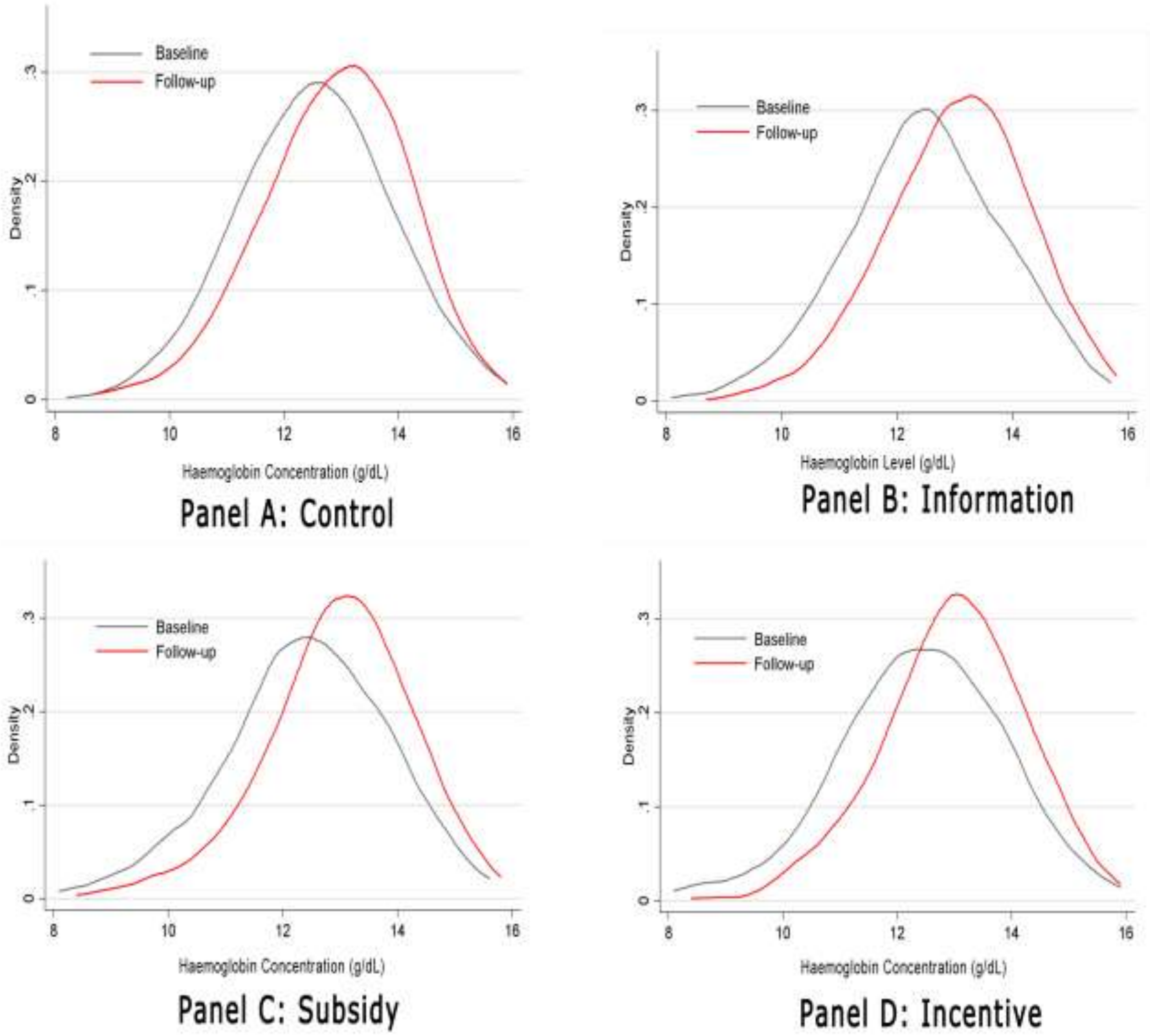
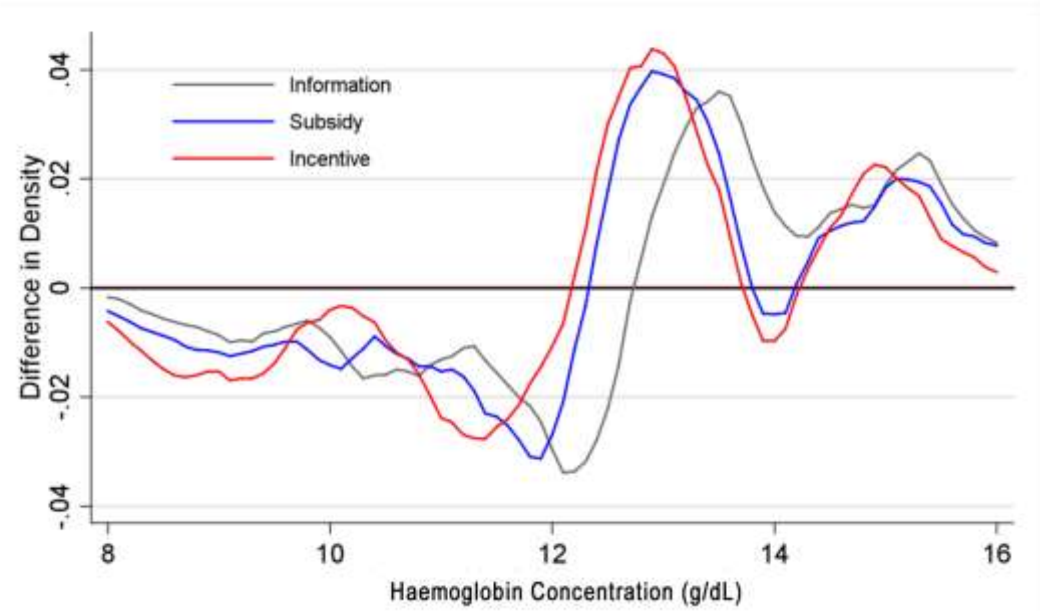


Figure 3 Difference in the distributions of haemoglobin concentrations between baseline and follow-up by experiment arm relative to control



Note: Each line in the figure represents the change between the baseline and follow-up Hb distributions in the indicated intervention arm relative to the change in the control group. By construction, this difference is zero across the Hb concentration distribution, thus the control group is represented by the horizontal axis.

Figure 4 Distribution of changes in haemoglobin concentrations among schools with and without test score incentives by experiment arm

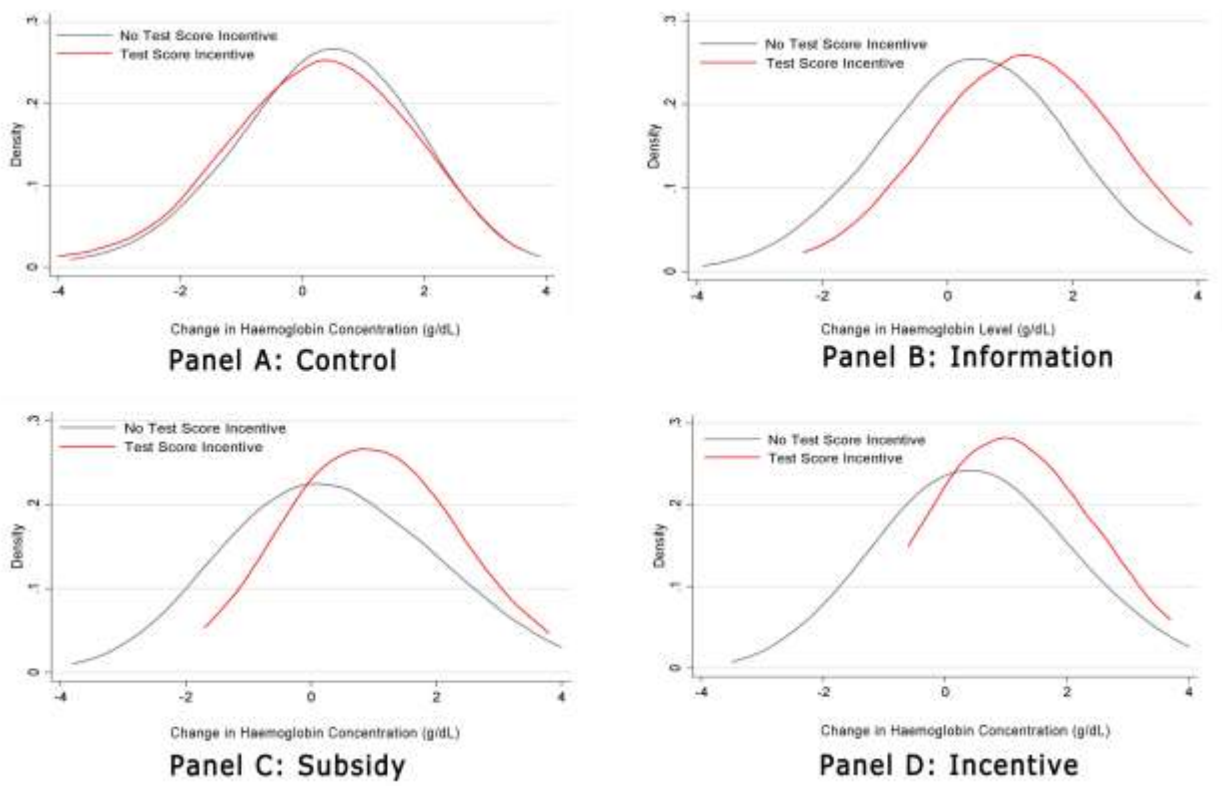


Table 6 Changes in haemoglobin concentration and anaemia prevalence by experiment arm

	Dependent variable			
	Change in Hb concentration (g/dL)[a]		Anaemic (Hb <11.5 g/dL) after intervention[b]	
	(1)	(2)	(3)	(4)
Experiment arm dummy variables				
Student in information treatment school	0.24 (0.19)[c]	0.13 (0.10)	−0.02 (0.03)	−0.01 (0.02)
Student in subsidy treatment school	0.22 (0.25)	0.08 (0.10)	−0.01 (0.04)	−0.02 (0.02)
Student in incentive treatment school	0.23 (0.22)	0.19**[d] (0.09)	−0.02 (0.04)	−0.05*** (0.02)
Control variables				
County fixed effects	no	yes	No	yes
Other controls[e]	no	yes	No	yes
Observations	3,553	3,553	3,553	3,553
R-squared	0.007	0.405	–	–
P-value[f]: incentive=subsidy	0.99	0.30	0.88	0.09*
P-value: subsidy=information	0.95	0.61	0.86	0.78
P-value: incentive=information	0.95	0.60	0.99	0.09*

Note:
[a] Columns 1 and 2 report co-efficient estimates from OLS regressions.
[b] Columns 3 and 4 report marginal probabilities for being anaemic (Hb <11.5 g/dL) calculated as averages over the sample values using probit estimates obtained by maximum likelihood estimation.
[c] Standard errors in parentheses account for clustering at the school level.
[d] *, **, and *** indicate significance at 10%, 5% and 1%.
[e] Other controls include student age (in months), baseline Hb concentration, student gender, whether or not the student boards, whether the student's mother has migrated, whether the student's mother's educational attainment is primary school or less and whether the school principal has a financial incentive for good test scores.
[f] The last three rows report p-values for tests of equality between the coefficients for treatment effect estimates.

To quantify these changes more precisely, the first column of Table 6 shows unadjusted estimates of Hb changes in each of the intervention arms relative to the control arm. The mean increase in all three groups was roughly 0.2 g/dL. However, the increases are not statistically different from zero at conventional significance levels. The second column then shows that adjusting for additional covariates improves their precision. The adjusted incentive estimate is now statistically different from zero (0.19, 95% CI 0.01–0.38). Moreover, although this estimate (for change in Hb) is not statistically distinguishable from the information and subsidy estimates, the impact of the incentive arm on anaemia prevalence is significantly greater than the impact of the information and subsidy arms (Table 6, column 4). The corresponding reduction in anaemia (Hb < 11.5 g/dL) in the incentive arm is 9–23% (2–5 percentage point reduction from Table 2 divided by 22 per cent baseline prevalence).

Table 7 Changes in haemoglobin concentration and anaemia prevalence by experiment arm and pre-existing test score incentives

	Dependent variable			
	Change in Hb concentration (g/dL)[a]		Anaemic (Hb < 11.5 g/dL) after intervention[b]	
	(1)	(2)	(3)	(4)
Experiment arm dummy variables				
Student in information treatment school	0.05 (0.20)[c]	−0.07 (0.10)	0.01 (0.03)	0.03 (0.02)
Student in subsidy treatment school	0.02 (0.27)	−0.02 (0.11)	0.02 (0.05)	0.00 (0.02)
Student in incentive treatment school	0.15 (0.23)	0.09 (0.09)	−0.00 (0.04)	−0.03*[d] (0.02)
Interactions between experiment arm and test score incentive dummy variables				
Principal has test score incentive[e]	−0.15 (0.31)	−0.18 (0.18)	0.05 (0.05)	0.04 (0.03)
Information school * test score incentive	0.89** (0.38)	0.93*** (0.24)	−0.25*** (0.07)	−0.26*** (0.06)
Subsidy school * test score incentive	0.74 (0.49)	0.36 (0.24)	−0.14 (0.10)	−0.05 (0.05)
Incentive school * test score incentive	0.76* (0.39)	0.91*** (0.22)	−0.22*** (0.07)	−0.19*** (0.07)
Control variables				
County fixed effects	no	yes	no	yes
Other controls[f]	no	yes	no	yes
Observations	3,553	3,553	3,553	3,553
R-squared	0.025	0.414	–	–
P-value[g]: incentive=subsidy	0.96	0.005***	0.47	0.06*
P-value: subsidy=information	0.74	0.008***	0.32	0.002***
P-value: incentive=information	0.70	0.94	0.66	0.40

Note:
[a] Columns 1 and 2 report co-efficient estimates from OLS regressions.
[b] Columns 3 and 4 report marginal probabilities for being anaemic (Hb < 11.5 g/dL) calculated as averages over the sample values using probit estimates obtained by maximum likelihood estimation.
[c] Standard errors in parentheses account for clustering at the school level.
[d] *, **, and *** indicate significance at 10%, 5% and 1%.
[e] The test incentive variable is an indicator for whether the principal has a financial incentive for good test scores.
[f] Other controls include student age (in months), baseline Hb concentration, student gender, whether or not the student boards, whether the student's mother has migrated, and whether the student's mother's educational attainment is primary school or less.
[g] The last three rows report p-values for tests of equality between the coefficients for treatment effect estimates.

Because of our careful attention to the causal chain, we noticed from our data that some principals faced pre-existing incentives for good test scores. We decided to analyse how the impact of each intervention varied with pre-existing principal incentives for good test scores. Table 7 (columns 1 and 2) shows estimates for interactions between information, subsidy and incentive interventions (separately) and a test score incentive dummy variable. Both columns suggest that all three interventions were complementary with incentives for good test scores, though this synergy is less pronounced in the subsidy arm. Relative to the control group, test score incentives were associated with mean Hb gains of 0.89–0.93 g/dL in information schools Table 7 (columns 3 and 4) also reports analogous marginal probabilities for being anaemic obtained by maximum likelihood estimation using probit models. Relative to baseline anaemia prevalence rates, these estimates imply an 85–86% reduction in information schools, a 5–32% reduction in subsidy schools, and a 77–81% reduction in incentive schools with pre-existing principal test score incentives.

4.2 Behavioural responses to interventions

In order to capture any lapses in the causal chain, we next present analyses of how principals and parents responded to the study's interventions – both to reduce anaemia and in potentially unintended ways.

4.3 Principals' strategies to reduce anaemia

Three stylised facts characterise principals' major strategies to reduce anaemia in response to study interventions (Loevinsohn and Harding 2005). Relative to subsidy schools, incentive school principals were more likely to use their subsidies to pursue iron supplementation strategies that increased only students' multi-micronutrient intake and not their caloric intake (for example, with vitamins/minerals and iron-fortified wheat) – and less likely to pursue broad feeding strategies that increased both multi-micronutrient intake and caloric intake (for example, with meat and other food added to school lunches) – to reduce anaemia. This response is in line with their more focused incentive to raise iron levels (as opposed to overall nutritional status) (Doran *et al*. 2006). Consistent with research linking broader nutritional gains to school performance (Alderman *et al*. 2001), principals with test score incentives focused relatively more on feeding (Soeters *et al*. 2006). Relative to control schools, principals in all intervention schools provided nutritional information to parents to reduce anaemia. However, information arm principals with test score incentives appear to have done so most vigorously. This is presumably because these principals understood the link between anaemia and school performance (an explicit part of the information they received) and also had incentives to improve test scores; however, they lacked the resources to intervene in ways other than through parents. Because the parents of boarding students are responsible for sending food to school for their children, they can directly influence dietary quality, as can parents of students who do not board.

4.4 Unintended behavioural responses by parents and principals

We also investigated the possibility of unintended (perverse) behavioural responses to the study's interventions. First, we examined if there were offsetting reductions in dietary quality at home in response to improvements in school meals (Babu and Hallam 1989; Jacoby 2002). Second, we estimated if school spending on functions other than nutrition (on administration or teaching, for example) was diverted to reduce anaemia. We found little evidence of either type of behavioural response.

5. Policy recommendations

On balance, our findings suggest that incentives were moderately effective in reducing anaemia rates among school children in rural China. Importantly, we also find that analyses failing to recognise their interactions with other incentives may miss important population health gains attributable to them. Primary school principals with incentives for good test scores made more effective use of subsidies to reduce anaemia – and performance pay for anaemia reduction nearly doubled their impact. Moreover, although the provision of information about anaemia to school principals was ineffective on its own, it was as effective as the entire bundle of information, subsidies and anaemia reduction incentives when combined with test score incentives. Information arm principals with test score incentives had strong incentives to reduce anaemia, but because they lacked resources to do so through schools, they pursued innovative strategies to educate parents in ways that ultimately proved highly effective. Considerably more research is needed, but our findings broadly suggest that policymakers may be able to exploit synergies between financial incentives and other motives/pre-existing incentives (often embedded in local institutions and cultural context) to produce substantial population health gains.

Further research is needed to understand several important dimensions of performance pay for health improvement. These include: (1) understanding how to structure performance pay in multi-tasking environments – in particular for providers with broader clinical responsibility (Holmstrom and Milgrom 1991); (2) identifying optimal combinations of fixed (unconditional) and variable (performance-based) compensation (research on executive compensation suggests that smaller unconditional components may be appropriate but this varies with the degree to which agents can influence the rewarded outcome) (Jensen and Murphy 1990; Hall and Liebman 1998; Raith 2008); (3) examining the relative merits of performance pay at different staff levels within organisations; and (4) documenting the comparative effectiveness and cost-effectiveness of financial and non-financial incentives (given that financial incentives can be costly).

Overall, our paper suggests that performance incentives – and direct rewards for health improvement in particular – may hold promise for promoting a broad class of puzzlingly underutilised health technologies more effectively. However, it offers a cautionary tale against introducing incentives naively without understanding the local institutions within which they are applied. Failing to do so may seriously hamper their effectiveness, while harmonising them with other motives and incentives can amplify their impact.

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