The Impact of Eyeglasses on the Academic Performance of Primary School Students: Evidence from a Randomized Trial in Rural China

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Abstract:

About 10% of primary school students in developing countries have poor vision, yet in virtually all of these countries very few children wear glasses. There has been almost no research on the impact of poor vision on school performance in developing countries, and simple OLS estimates are likely to be biased because students who study more often are likely to develop poor vision faster. This paper presents results from the first year of a randomized trial in Western China that began in the summer of 2004. The trial involves over 19,000 students in 165 schools in two counties of Gansu province. The schools were randomly divided (at the township level) into 103 schools that received eyeglasses (for students in grades 3-5) and 62 schools that served as controls. The results from the first year indicate that, after one year, provision of eyeglasses increased test scores by 0.15 to 0.30 standard deviations (of the distribution of the test scores).

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I. Introduction

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II. Background and Literature Review

This section provides an overview of primary education in rural China and a brief literature review of the extent of vision problems among primary school students in developing countries and the impact of those problems on student performance.

A. Primary Education in Rural China. China has achieved nearly universal primary school enrollment. According to the 2000 census, only four percent of adults aged 25 to 29 had not attended any formal schooling (Hannum et al., forthcoming). The Law on Compulsory Education passed in 1986 mandates that all children complete nine years of schooling—six years of primary school and three years of lower secondary school. However, the rural poor and some minority populations continue to face difficulties in meeting this compulsory schooling goal.

In rural areas of Western China, nearly all children attend the nearest public primary school, located in their own village or a nearby village. A typical primary school has one or two classes per grade level. Teachers are allocated to schools within the county by the county educational bureau, and their salaries are paid by the county government. Thus, disparities in primary school quality within counties are generally fairly modest (Li et al, forthcoming). This also helps explain why few students attend schools located away from home.

Each county in China has a Center for Disease Control office, which conducts regular physical exams of all students, including eye exams. If possible, health exams should be conducted every year, but because of budgetary and staff constraints, some schools conduct physical exams only every two or three years **{Albert, is this an accurate statement>]**. The results of the physical exams are given to the school's teachers, who relay information to parents as they feel appropriate.

B. Vision Problems and School Performance. Very little data exist on vision problems among school-age children in developing countries. Bundy et al (2003) report that about 10% of school-age children have refraction errors (myopia, hypermetropia. strabismus, amblyopia, and astigmatism), which account for about 97% of the vision problems among those children. Almost all refraction errors can be corrected with properly fitted eyeglasses, but most children with refraction problems in low income countries do not have glasses. In China, a study by Zhao et al. (2000) in one district in Beijing found that 12.8% of children age 5-15 years had vision problems, of which 90% were due to refraction errors. Only 21% of the children with vision problems had glasses. In rural areas, children with vision problems are even less likely to wear glasses, as will be seen below. In China, a commonly held (but mistaken) view is that wearing eyeglasses causes children's vision to deteriorate faster.

Given the lack of data on vision problems among school-age children in developing countries, there has been very little research on the impact of poor vision on students' academic performance. Only one published study exists; Gomes-Neto et al. (1997) found large impacts of poor vision on primary school children in Northeast Brazil. In particular, they found that children with compromised vision (less than 90 on the Sneller chart) had a 10% higher probability of dropping out of school, an 18% higher probability of repeating a grade, and scored about 0.2 to 0.3 standard deviations lower on achievement tests. Yet these estimates could be biased. First, to the extent that some of these children wore glasses their vision could be correlated with unobserved factors that determine school performance, such as parental preferences for educated children. Second, even if none of these children wore glasses, students' vision can be affected by their home environment and by their daily activities, thus their vision could be correlated with other unobserved factors, leading to biased estimation results.

III. Project Description and Data Available

The lack of rigorous studies on the impact of providing eyeglasses to students with visual impairments in developing countries led to the implementation of the Gansu Vision Intervention Project in 2004 in Gansu province in northwest China. This section describes the project and the data available to evaluate its impact.

A. The Gansu Vision Intervention Project. In 2004, a team of Chinese and international researchers, in cooperation with the Ministries of Health and Education in Gansu province, implemented a randomized trial to examine the impact of providing eyeglasses to primary school students with poor vision in two counties, Yongdeng and Tianzhu. The project covered all students in grades 3-5 in all primary schools from each of these two counties.

Gansu province is located in northwestern China. Its geography is quite diverse, including areas of the flat Loess Plateau, the Gobi desert, mountainous and hilly areas, and vast grasslands. In the year 2000, its population was 25.6 million, 76 percent of whom reside in rural areas (Gansu Bureau of Statistics 2001). The most recent available estimates of rural per capita disposable income place Gansu at a rank of 30 out of 31 provinces, with only Tibet showing lower incomes (National Bureau of Statistics 2004; statistics refer to the first three-quarters of 2003). Using per capita income data and official poverty lines, a recent World Bank report found that 23 percent of the rural population in Gansu is poor, compared to 6.5 percent for China as a whole (World Bank and UNDP 2000).

Yongdeng and Tianzhu counties are located in the southwestern end of Gansu. They were selected as study sites because they are typical rural counties in Gansu, are located within several hours drive of the provincial capital (enabling the project to be closely monitored by the provincial Center for Disease Control (CDC) under the Ministry of Health), and have capable county CDC staff to implement the project effectively.

[Let's add short descriptions of each of the 2 counties.]

Yongdeng county is divided into 23 townships, of which 18 participated in the program (the other 5 townships were dropped due to lack of funds to supply eyeglasses). These 18 townships have 155 primary schools. Of the 18 townships in Yongdeng, nine townships were randomly chosen to participate in the eyeglasses intervention in 2004 and the remaining nine were assigned to the control group.

Tianzhu county is divided into 19 townships, all of which participated in the program. These 19 townships have 101 primary schools. Ten of Tianzhu's 19 townships were randomly chosen to participate in the program in 2004, and the remaining nine were assigned to the control group.

The random assignment was done as follows. In each county, all townships in the county were ranked by rural income per capita in 2003, and starting with the first two townships, one township was randomly assigned to be a treatment township while the other was assigned to the control group. For the case of Tianzhu, the 19th township, the poorest, was not paired with any other township; a random draw assigned it to the group that received eyeglasses. The primary schools within each township were either all assigned to the treatment group or all assigned to the control group.[1]

Unfortunately, there were a few cases where control townships were provided with eyeglasses because after providing the eyeglasses in the treatment townships there was money left in the budget to provide more eyeglasses. This occurred two of the control townships in Yongdeng and three control townships in Tianzhu. Also, another of the control townships in Yongdeng was incorporated into a township that received eyeglasses, so that control group was also compromised. **[Also explain the one pair where treatment and control were, in effect, switched]** In all six cases where the control township was provided with eyeglasses, both that township and the treatment township with which it was paired were dropped from the analysis. This leaves six pairs of townships in Yongdeng and six pairs (plus the poorest township, which was randomly assigned to the treatment group) in Tianzhu for which the randomization was carried out according to the plan. All of the regression analysis below is limited to these 25 townships, which together contain about 19,000 students spread across 165 schools (103 of which were received eyeglasses for children in grades 3-5 and 62 of which were controls). **[Reason for more schools in treatment group is primary due to chance; e.g. in Tianzhu the largest township had 13 schools, while no other township had more than 5, and that largest township was randomly put into the treatment group.]**

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[1] Primary schools with less than 100 students were excluded from the project to avoid diseconomies of scale. Students in such schools account for xx percent of primary students in the two counties.

B. Data Used in the Analysis. The data used in the analysis are from three sources: 1. School records on basic student characteristics and academic grades before and after the intervention; 2. Results of health exams, including vision tests, conducted by the county Center for Disease Control in each primary school before eyeglasses were provided; and 3. Information from optometrists' records on students who were fitted for glasses. The basic information in the school records include the grade the student was in during the 2004-05 school year **[no info on whether the child repeated?]**, the students' sex, ethnicity and birthdate, and the occupation and education level of the head of the household (usually the father) in which the student lives. The school academic performance data include scores on exams given at the end of each semester in each grade since the student enrolled at that school (usually grade 1). Separate scores are available for three subjects: Chinese, mathematics and science. For ease of interpretation, all student examination scores were standardized, separately for each grade, by subtracting the mean and dividing by the standard deviation of the scores of students in the control schools.

The school health data include whether the student wears glasses (and if so, the grade the student was in when he or she started to wear glasses), the student's height, weight and hemoglobin count, and **(one?)** measurement of vision for each eye. In China, doctors usually conduct eye exams by asking a patient to read (with the other eye covered) a standard eye chart from 5 meters away. The chart is similar to eye charts used elsewhere. It has 12 rows of the letter E facing in different directions; the top row of the chart has very large E's, and each subsequent row has smaller E's. If the patient can read the 10th row, the normal level, his/her eyesight is coded as 5.0. The first row, corresponding to the worst eyesight, is coded as 4.0, the second row is coded as 4.1, etc. until finally the last row is coded as 5.2. The information from the optometrists include whether the child was fitted for eyeglasses, and if not, the reason eyeglasses were not provided (some students had eye conditions that could not be corrected with eyeglasses, and others declined the offer to receive with eyeglasses). **[Add GSCF-1 and GSCF-2 data if we use it for some analysis.]**

C. Descriptive Statistics. Table 1 presents descriptive statistics on the sample. The data consist of 29,190 students in grades 3-5 in 2004-05 in Tianzhu and Yongdeng counties. Of these students, 3,314 (11.4%) had poor vision in the sense that either the left eye or the right eye (or both) had a visual acuity score of less than 4.8. Only 3.5% of the children in the two counties with vision problems (117 out of 3,314) had eyeglasses before the project began. Students without vision problems had slightly higher test scores than children with vision problems in Chinese (78.9% vs. 78.8%) and mathematics (79.2% vs. 78.9%), but slightly lower scores in science (80.6% vs. 80.8%), at the end of Spring 2004 semester (before the program began).

The test score data in Table 1 suggest that vision problems have little effect on students' academic performance. Indeed, simple t-tests show that, for both counties as a whole, none of these differences are significant, although the lower math score for children with poor eyesight in Tianzhu country is significant at the 1% level. But this conclusion is likely to be misleading because school performance can affect eyesight. In particular, medical studies (e.g. Angle and Wissmann, 1980) have shown that doing "near-work", that is spending long amounts of time doing activities with the eyes focused on objects about 1 meter from one's eyes) can cause myopia. This implies that students who spend more time studying are more likely to develop myopia, the most common refractive eye problem.

Indeed, the data available before the Gansu Vision Intervention Program was implemented suggest that studying does harm students' vision. The first thing to realize is that, among this sample of children, very few grade 1 students have vision problems (only 3.1% are classified as having poor vision), but this increases dramatically as children spend more time in school (7.6% of grade 3 students and 16.4% of grade 5 students have poor vision). Thus children's test scores in grade 1 are unlikely to be affected by vision problems but presumably do reflect, in part, time spend studying. OLS regressions of mean (over both eyes) visual acuity on test scores in Chinese in grade 1, controlling for school fixed effects, grade level, parents' education and parental occupation (on the sample children in grades 3-5) show a *negative* impact that is statistically significant at the 1% level. The same holds if one uses math or science test scores in grade 1 instead of Chinese test scores. This suggests that visual acuity is negatively affected by increased study, so that simple comparisons of test scores across students with good vision and students with poor vision are likely to underestimate the negative impact of vision on student performance (because students with good vision, on average, study less). **[Let's check the GSCF-2 data to see if it shows that students who studied more in 2000 are more likely to have bad eyesight in 2004.]**

Table 2 presents information on how the Gansu Vision Intervention Project was implemented for the 3,314 students with poor vision. These statistics exclude the township pairs for which the randomization was not properly implemented. Of these, 1,319 were in the intervention schools and thus were offered eyeglasses, while 750 were in the control group and were not offered glasses. Of the 1,319 students who were offered glasses, 928 (70.4%) accepted them and the other 391 declined. The main reasons for turning down the offer were the objection of household head (92 cases), refusal on the part of the child (69), and problems “getting used to” glasses (55). The main other reason was having eye diseases that cannot be corrected by eyeglasses.

IV. Methodology

Virtually all children of primary school age in Gansu province are enrolled in school **[cite numbers from GSCF-2 to back this up]**. Thus provision of eyeglasses cannot lead to increased school enrollment; the sole impact is on academic performance. The random assignment of schools to participate or not participate in the Gansu Vision Intervention Project allows for straightforward analysis of the impact of the project on students’ scores on academic tests. Because the intervention affected only students who were enrolled in grades 3, 4 and 5 in the 2004-2005 school year and were diagnosed as having poor vision in August of 2004, only students in those grades who were so diagnosed are used in the regression analysis For ease of interpretation, all estimates in the rest of this paper use a standardized test score as the dependent variable; test scores are standardized by subtracting the mean and then dividing by the standard deviation, using the mean and standard deviation of the control group schools.

A. Estimation of the Impact of the Offer of Eyeglasses. The simplest estimate of the impact of the program on children in grades 3, 4 and 5 with poor vision is to compare the mean test scores of those children who were enrolled in the program schools with the mean test scores of those children who were enrolled in the control schools.

Technically speaking, this estimates the impact of the *offer* to receive eyeglasses, not the impact of the eyeglasses themselves, because (as explained above) about one fourth of the children who were offered eyeglasses did not receive them for various reasons.

This t-test can be calculated by regressing the (standardized**??**) test score variable (T) on a constant term and a dummy variable that indicates enrollment in a program school (P):

$$T = \alpha + \beta P + u \qquad (1)$$

where u is a residual term that is uncorrelated with P due to the randomized design of the program. Note that children in the same school and the same grade within a school may have common unobserved factors, so random effects should be allowed for at the school and grade level. Yet there is no reason to expect any heteroscedasticity since P is, by the program design, independent of u. **[Actually, there could be variation in the grade random effect across schools, but this is a minor issue.]**

The precision of the random effects estimate of β will depend on the precision of the estimated variance of the random effect. More precise estimates of that variance can be obtained by estimating a model that includes not only students with poor eyesight but also students with good eyesight. This suggests the following econometric model:

$$T = \alpha + \pi PV + \tau P + \beta PV^{*}P + u \qquad (1')$$

where PV is a dummy variable indicating poor vision. In this specification the impact of the program on students with good vision (PV = 0) will be τ, which one would expect to equal zero, and the impact of the program on students with poor vision will $\tau + \beta$, which should equal β since τ should equal zero. The τ coefficient also serves as a check on the random design of the intervention; if the schools that participated in the program were better (worse) than average, then τ would be positive (negative). Finally, the estimate of π is a (biased) estimate of the impact of poor vision on test scores, which one would expect to be negative (ignoring the bias). The bias arises because students who study more are likely to have worse vision, as explained above.

Returning to equation (1), in principle more precise estimates can be obtained by adding additional variables, which leads to:

$$T = \alpha + \beta P + \boldsymbol{\gamma}'\mathbf{x} + u \qquad (2)$$

The econometric intuition is quite simple; in a linear regression model $\mathbf{y} = \mathbf{X}\boldsymbol{\beta} + \mathbf{u}$, the covariance matrix for the estimate of $\boldsymbol{\beta}$ is $\sigma_u^2(\mathbf{X}'\mathbf{X})^{-1}$, and as more variables are added the variance of the unexplained part, σ_u^2, decreases. (Since P is uncorrelated with all other explanatory variables, the plim of the diagonal element of $(\mathbf{X}'\mathbf{X})^{-1}$ that corresponds to the estimated variance of $\hat{\beta}$ is unaffected.) Thus it is useful to add other variables that are likely to be correlated with T to the regression to obtain more precise estimates of β. Of course, adding these variables will not have a significant impact on the estimate of β because P will be uncorrelated with all the added variables.

There are three additional points to note regarding estimation of equation (2). First, it is likely that the variables in **x** are correlated with u, which in this context implies that $\boldsymbol{\gamma}$ does not estimate the causal impact of **x** on student's test scores (although it is still the case that β estimates the causal impact of P because P is uncorrelated with **x** and u). Second, there may be some heteroscedasticity present, so a heterscedasticity-robust estimate covariance matrix should be used, in addition to using a random-effects error structure.

Third, and most important, as in equation (1) more precise estimates can be obtained when using random effects estimation by including both students who have poor vision and students who have good vision. This leads to the following specification:

$$T = \alpha + \pi PV + \tau P + \beta PV^{*}P + \boldsymbol{\gamma}'\mathbf{x} + u \qquad (2')$$

Note that this assumes that the impact of the **x** variables does not vary either by program assignment (P) or by vision status (V). As in equation (1′), if the selection of townships to receive eyeglasses was truly random, then τ should equal zero.

Referring back to equation (2), it is also of interest to see whether the impact of providing eyeglasses varies by different characteristics of the population, which can also be summarized by the variable **x**: This leads to the following regression equation:

$$T = \alpha + \beta P + \boldsymbol{\gamma}'\mathbf{x} + \boldsymbol{\delta}'\mathbf{x}P + u \qquad (3)$$

In this regression model, a consistent estimate of the impact of providing eyeglasses on test scores for a person with characteristics **x** is given by $\beta + \boldsymbol{\delta}'\mathbf{x}$. One variable that should influence the program affect is the student's vision without glasses; students with very poor vision should benefit more than students with only moderately poor vision.

As discussed above, random effects estimation of equation (3) is likely to be more efficient if children with good vision are added to the regression. Doing so yields:

$$T = \alpha + \pi PV + \tau P + \beta PV^*P + \boldsymbol{\gamma}'\mathbf{x} + \boldsymbol{\delta}'\mathbf{x}PV^*P + u \qquad (3')$$

Again, we would expect τ to equal zero. so there is little point in interacting P with **x**. Yet there may be some interactions between PV and **x** (for example, better off parents may be more likely to purchase glasses for their children, which will reduce the impact of PV).

Another estimation method is to consider whether the *change* in students' test scores is affected by being offered eyeglasses. Consider equation (1). Assume that it holds for two time periods, before the program started ($t = 0$) and about one year later, after the program started ($t = 1$). Let T_0 be a student's test score at $t = 0$ and let T_1 be the test score at the end of the first school year in which eyeglasses were offered ($t = 1$). Then the difference in the two test scores is:

$$T_1 - T_0 = (\alpha_1 + \beta_1 P + u_1) - (\alpha_0 + u_0) = (\alpha_1 - \alpha_0) + \beta_1 P + (u_1 - u_0) \qquad (1'')$$

where subscripts on α, β and u allow them to vary over time periods, and there is no $\beta_0 P$ coefficient in the term for T_0 because P = 0 for all observations at time zero. Note that the β_1 in equation (1′) is the same β that is in equation (1).

Equation (1′) can also be modified by replacing T with $T_1 - T_0$. It is still the case that β will estimate the program impact, since the equation will be:

$$T_1 - T_0 = (\alpha_1 - \alpha_0) + (\pi_1 - \pi_0)PV + \tau_1 P + \beta_1 PV^*P + (u_1 - u_0) \qquad (1''')$$

where again τ_1 should equal zero. If the correlation between the error terms and PV in each time period is primarily due to a fixed effect (the propensity to study does not change) then the coefficient $\pi_1 - \pi_2$ may be a consistent estimate of the effect of poor vision on an additional year of learning.

Similar "differenced" equations can be estimated for equations (2) and (3):

$$\begin{aligned} T_1 - T_0 &= (\alpha_1 + \beta_1 P + \boldsymbol{\gamma}_1'\mathbf{x} + u_1) - (\alpha_0 + \boldsymbol{\gamma}_0'\mathbf{x} + u_0) \\ &= (\alpha_1 - \alpha_0) + \beta_1 P + (\boldsymbol{\gamma}_1 - \boldsymbol{\gamma}_0)'\mathbf{x} + (u_1 - u_0) \qquad (2'') \end{aligned}$$

$$\begin{aligned} T_1 - T_0 &= (\alpha_1 + \beta_1 P + \boldsymbol{\gamma}_1'\mathbf{x} + \boldsymbol{\delta}_1'\mathbf{x}P + u_1) - (\alpha_0 + \boldsymbol{\gamma}_0'\mathbf{x} + u_0) \\ &= (\alpha_1 - \alpha_0) + \beta_1 P + (\boldsymbol{\gamma}_1 - \boldsymbol{\gamma}_0)'\mathbf{x} + \boldsymbol{\delta}_1'\mathbf{x}P + (u_1 - u_0) \qquad (3'') \end{aligned}$$

In the context of a randomized evaluation, the benefit from using this "double difference" estimator is not that it avoids bias or inconsistency, since there is no bias or inconsistency to remedy. Instead, the benefit is that it may yield more precise estimates of the impact of the program. More precisely, it is possible (though not certain) that the variance of ($u_1 - u_0$) in equations (1′), (2′) and (3′) is smaller than the variance of u in equations (1), (2) and (3) because unobserved factors in u that do not change over time are differenced out.

[Write up equations that have both differencing and both good and vision kids, which will be equations (2′′) and (3′′).

B. IV Estimates of the Impact of Providing Eyeglasses. The methods presented in the previous subsection estimate the impact of being offered the eyeglasses, not the impact of receiving eyeglasses. In general, the impact of being offered eyeglasses will be less than the impact of receiving them because, of course, those students who are offered but do not receive glasses do not benefit from the offer. Direct OLS estimation of the benefit of receiving eyeglasses may yield biased estimates because parents and/or students who take up the offer of eyeglasses may differ in unobserved ways from students for whom the offer is turned down. For example, the parents of students who take up the offer may have more favorable attitudes toward education and so may do other things that raise the test scores of their children.

Fortunately, instrumental variable (IV) estimation can be used to obtain consistent estimates. In particular, one can estimate the impact of actually receiving eyeglasses using the same equations presented above, replacing P (the offer to receive eyeglasses) with “G”, actually receiving the eyeglasses. While G is likely to be correlated with residual, P can be used as an instrumental variable for G; P is, by definition, uncorrelated with u and also has strong explanatory power for G. Note that G = 1 not just for students who agreed to accept glasses in the program school but also for students who wear their own glasses, either in the program schools or in the control schools.

While IV estimates for equations for equations (1) and (1″) are straightforward in that one need only replace P with G and use P as an instrument for G, there is one complication with IV estimates of equations (1′) and (1‴). To see the problem, note that automatically replacing P with G in that equation yields $T = \alpha + \pi PV + \tau G + \beta PV*G + u$. Although it is possible to be in a program school if one does not have poor vision, it does not make sense to wear glasses if one does not have poor vision, which implies that $G = 0$ whenever $PV = 0$, and thus G and PV*G are perfectly correlated. While this correlation is not exactly equal to 1 in the data (it is 0.86), this is only due to the fact that there are a very small percentage of students who report wearing classes even though they have good vision. Thus in IV estimates of (1′) and (1‴) the term τG is dropped. **[Also we really don't have a good IV for people who wear glasses and don't reallyneed them.]**

A final point to note about IV estimation is that it is valid even if the randomized trial was not strictly implemented according to the randomized plan. Quite simply, as long as the *plan* was randomized then the instrument is correlated with al possible confounding factors and will be a valid instrument as long as it has explanatory power for the use of eyeglasses (which should be the case as long as the intervention was implemented to some extent according to the randomized plan).

V. Estimates of Program Impact

This section presents estimates of the impact of the Gansu Vision Intervention Project on the test scores of students in grades 3-5 in 2005. Thus these results measure the impact of the project after one year (future versions of this paper will examine results after 2 years, once the data are in). For ease of interpretation, all test scores have been normalized separately for each subject and each grade, subtracting each test score by the mean for the control group schools and then dividing by the standard deviation of the control group schools. The first subsection presents OLS estimates of the impact of being offered eyeglasses, and the second subsection presents IV estimates of the impact of receiving eyeglasses.

A. OLS Estimates of the Impact of Being Offered Eyeglasses. Before examining the impact of the Gansu Vision Intervention Project, the data must be examined to see whether the offer of eyeglasses was in fact randomly allocated across townships. This was done my estimating equations (1) and (1′) using test scores from the Spring of 2004, before the project was implemented. These results are shown in Table 3.

The estimates of equation (1) in the top half of Table 3 show no statistically significant difference in spring 2004 test scores across program and control schools, as indicated by the coefficients on the “treatment township” variable. Mean Chinese and science scores are virtually identical, while the mean mathematics score is somewhat lower in the program (treatment) townships, but this difference is far from statistically significant. Averaging across all three scores gives an insignificant difference of -0.066 standard deviations of a test score.

Estimates of equation (1′) in the bottom half of Table 3, which include both students without vision problems and students with vision problems, are more precise, as seen in the lower standard errors of the estimates of β. Comparing students without vision problems (i.e. examining the coefficient on “treatment township”), there is little difference in mean test scores for students without vision problems, and all differences are completely insignificant; the difference of the averaged scores is only -0.018 standard deviations and is also insignificant. Focusing on the (more precise) estimates of differences across students with poor vision (i.e. the coefficient on “poor vision × treatment township), there is no significant difference for Chinese or science, but there is marginally significant (10% level) evidence that math scores were lower in program schools than in the control schools. Yet the difference in math scores is relatively small (0.088 standard deviations of a test score), and when all scores are averaged there is no significant impact. In any case, estimates of test score differences should control for any random selection of schools that resulted in math scores being slightly lower in program townships.

Level (equations (1) and (1′)) and differenced (equations (1″) and (1‴)) results without controlling for covariates are given in Table 4. The first results, those for equation (1), include only children with poor vision. The results show positive impacts for all three subjects, but the impact on science scores is the only one that is statistically significant (5% level). The impacts range from 0.062 (Chinese) to 0.178 (science). The impact on the average score is 0.146, which is not quite significant at standard levels (t-statistic of 1.57).

It is not particularly surprising that the impacts are low, since the program has been in place for only one year, but it would be useful to have more precise estimates of the impact. By adding students with good vision to the regressions analysis, as done in equation (1′), precision is increased. In particular, the standard error of the estimated impact of the program on students with poor vision is cut almost in half, from about 0.09

to about 0.045. This increase in precision produces an estimated impact of 0.10 on Chinese that is statistically significant at the 5% level (t-statistic of 1.92), but the impacts on mathematics and science scores (about 0.07 and 0.06, respectively, are still not statistically significant. Finally, the estimated impact on the average test score is 0.09 and statistically significant at the 5% level.

Some other things to note about these estimates are: 1. For students with good vision, there are only very small (and far from statistically significant) differences across program and control schools, which is consistent with the results in Table 3; and 2. Students with poor vision do not appear to have lower test scores, which probably reflects the endogeneity of this variable, as discussed above.

As explained in Section IV, it is possible that differenced results yield more precise estimates of the impact of the offer of glasses than do level results. The third set of results in Table (4) show estimates of equation (1″), which are based only on students with vision problems. The estimated impacts are somewhat more precise, as indicated by the somewhat smaller standard errors in three out of four cases (compared to the first set of results), and for the math and science tests (but not the Chinese) this impact is significant at the 5% level. The average impact over all three tests is 0.20 standard deviations, which is somewhat higher than of results for equation (1), and it is significant at the 5 level.

The last set of estimates in Table 4 examines differenced results that include both students with good vision and students with poor vision. The impacts are fairly precisely estimated, but not as precisely estimated as the level results that include children with good vision. The estimated impacts are all positive but only the impact of 0.10 for

Chinese is statistically significant at the 5% level. For the average of all tests, the impact of 0.09 is also significant at the 5% level.

[It may make sense that the strongest impact is on mathematics, since that subject may require looking at the blackboard (which is harder to see for myopic students) than do Chinese and science. Maybe look at GSCF pedagogy data to see if we can find this in the data.]

B. IV Estimates of the Impact of Wearing Eyeglasses. This subsection presents estimates of the impact of wearing eyeglasses for one year on student test scores. (A few of the students have worn eyeglasses for more than one year; of the 1,245 children with glasses, about 199 had purchased them on their own, and of these 94 had purchased them about one year ago, 85 had purchased them two years ago, 18 had purchased them 3 years ago, and 2 had purchased them about 4 years ago, so only 105 out of the 1,245 children had them for more than one year). As explained above, random selection into the treatment school, conditional on having bad eyesight, is the instrumental variable. This IV has strong explanatory power; in the regressions that include only children with poor vision the R^2 of the first stage regression is 0.45 and the F-statistic is 1713.6.

The first set of results in Table 5 show the results for equation 1, except that the sole explanatory variable is wearing eyeglasses, instead of being in a program school. The impacts are larger than the analogous results given in Table 4, yet only the impact is statistically significant only for the science test., with an impact of 0.25 standard deviations. Averaging over all 3 tests, the impact is about 0.21 standard deviations, but this is not quite statistically significant at the 10% level (t-stat. of 1.56).

More precise estimates are obtained by adding students who so not have poor vision and estimating an equation similar to equation (1′), for which there are two explanatory variables, a dummy variable indicating poor vision and a dummy variable indicating that a student has poor vision and wears eyeglasses. These results are shown in the second panel of Table 5. As expected, the standard errors are much lower, but the estimated impacts are also somewhat lower. This time the estimated impact of wearing glasses on Chinese is 0.13 standard deviations, which is significant at the 5% level. In contrast, the estimated impacts of on math and science are lower (0.09 and 0.08) and not statistically significant. The average effect over all three subjects is somewhat smaller than the level regression IV results, 0.13, yet this is statistically significant at the 5% level.

The third set of results in Table 5 uses differences in test scores from 2004 to 2005 as the dependent variable. In two out of three cases the standard errors are lower than they were for the level estimates, and the impact of wearing eyeglasses is large (0.32 and 0.25) statistically significant for math and for science. The average impact is 0.28, which is statistically significant at the 1% level. Finally, differenced results that include children with good vision show results that are somewhat less large (0.22 and 0.18) but still statistically significant for math and science, and an average impact of 0.20, which is statistically significant at the 1% level.

[We should compare our results with results based only on kids from the control group. We could show ordinary OLS estimates as well as IV estimates, perhaps using distance to the nearest place with an ophthalmologist as an IV].

VI. Summary and Conclusion

TO BE WRITTEN

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Table 1: Descriptive Statistics from Tianzhu and Yongdeng Counties

		Tianzhu	Yongdeng	Both Counties
Number of children in grades 3-5 in 2004-05		10,598	18,592	29,190
Children with vision problems		1,216 (11.5%)	2,098 (11.3%)	3,314 (11.4%)
Of which:				
Had glasses already		52 (4.3%)	65 (3.1%)	117 (3.5%)
Did not have glasses		1,164 (95.7%)	2,033 (96.9%)	3,197 (96.5%)
Test scores in spring 2004 (before intervention):				
Students without vision problem				
Chinese		78.7	79.0	78.9
Mathematics		78.9	79.5	79.2
Science		80.4	80.8	80.6
Students with vision problem				
Chinese		78.3	79.2	78.8
Mathematics		77.4	79.7	78.9
Science		80.5	81.1	80.9

Note: Vision problems is defined as a “score” **[explain this]** < 4.8 in one or both eyes.

Table 2: Implementation of Gansu Vision Intervention Project

		Tianzhu	Yongdeng	Both Counties
Students in grades 3-5 in 2004-05 with vision problems				
Of which:				
In control schools		626	124	750
In program schools		786	533	1319
Students in program schools who:				
Accepted the offer to receive glasses		309	619	928
Did not accept the offer to receive glasses:		224	167	391
Reasons given for not accepting glasses				
Household head refused				92
Child refused				69
Cannot adjust to glasses?				55
Eye disease 1				10
Optometrist not available				21
Eye disease 2				62
Eye problem cannot be corrected by glasses				4
Eye disease 3				1
Vision not correctable(?)				19
Child is handicapped				2

Note: These figures are only for townships in which the randomization was correctly implemented.

Table 3: Checking for Differences Across Treatment and Control Groups
(Differences in Spring 2004 scores)

	Dependent Variable			
	Chinese	Math	Science	Average
Explanatory Variables				
	Equation (1) *N* = 2,044			
Constant	-0.139* (0.074)	-0.051 (0.082)	-0.112 (0.078)	-0.118 (0.074)
Treatment Township (β)	-0.031 (0.093)	-0.126 (0.103)	-0.007 (0.099)	-0.064 (0.094)
	Equation (1′) *N* = 18,971			
Constant	-0.174*** (0.055)	-0.109* (0.056)	-0.179*** (0.061)	-0.182** (0.059)
Poor Vision (π)	0.037 (0.037)	0.081** (0.037)	0.056 (0.037)	0.068** (0.034)
Treatment Township (τ)	-0.053 (0.069)	-0.070 (0.071)	0.078 (0.077)	-0.018 (0.075)
Poor Vision×Treatment Township (β)	0.024 (0.047)	-0.087* (0.047)	-0.065 (0.046)	-0.050 (0.053)

Notes: 1. All regressions include school random effects

2. Standard errors are in parentheses.

Table 4: Estimated Program Effect: Level and Difference Results, without Covariates

	Dependent Variable			
	Chinese	Math	Science	Average
Explanatory Variables				
	Equation (1) *N* = 2,031			
Constant	-0.157** (0.072)	-0.155** (0.067)	-0.132* (0.072)	-0.190** (0.075)
Treatment Township (β)	0.061 (0.091)	0.091 (0.084)	0.177* (0.091)	0.146 (0.094)
	Equation (1′) *N* = 18,864			
Constant	-0.141** (0.060)	-0.138** (0.060)	-0.112* (0.057)	-0.161** (0.066)
Poor Vision (π)	-0.030 (0.037)	0.005 (0.037)	0.036 (0.037)	0.003 (0.035)
Treatment Township (τ)	-0.009 (0.076)	0.038 (0.077)	0.028 (0.073)	0.023 (0.084)
Poor Vision×Treatment Township (β)	0.097** (0.046)	0.065 (0.046)	0.058 (0.047)	0.093** (0.044)
	Equation (1″) *N* = 2,031			
Constant	-0.011 (0.065)	-0.114 (0.086)	-0.012 (0.063)	-0.065 (0.015)
Treatment Township (β)	0.084 (0.081)	0.225** (0.108)	0.171** (0.079)	0.197*** (0.072)
	Equation (1‴) *N* = 18,863			
Constant	0.033 (0.049)	-0.029 (0.059)	0.066 (0.048)	0.023 (0.046)
Poor Vision (π)	-0.065 (0.043)	-0.077* (0.043)	-0.018 (0.042)	-0.063* (0.034)
Treatment Township (τ)	0.045 (0.062)	0.111 (0.074)	-0.049 (0.061)	0.043 (0.058)
Poor Vision×Treatment Township (β)	0.070 (0.054)	0.146*** (0.054)	0.126** (0.053)	0.0142*** (0.043)

Notes: 1. All regressions include school random effects

2. Standard errors are in parentheses.

Table 5: Effect of Eyeglasses: Level and Differenced IV Results, without Covariates

	Dependent Variable			
	Chinese	Math	Science	Average
Explanatory Variables				
	Equation (1) *N* = 2,031			
Constant	-0.158** (0.073)	-0.158** (0.071)	-0.132* (0.072)	-0.191** (0.075)
Having eyeglasses (β)	0.087 (0.129)	0.133 (0.125)	0.249** (0.127)	0.206 (0.132)
	Equation (1′) *N* = 18,547			
Constant	-0.146*** (0.037)	-0.114*** (0.037)	0.093*** (0.035)	-0.146*** (0.040)
Poor Vision (π)	-0.032 (0.037)	0.003* (0.037)	0.035 (0.037)	0.001 (0.035)
Poor Vision×Having eyeglasses (β)	0.132** (0.065)	0.090 (0.065)	0.081 (0.066)	0.127** (0.061)
	Equation (1’′) *N* = 2,031			
Constant	-0.015 (0.071)	-0.117 (0.087)	-0.017 (0.069)	-0.069 (0.015)
Having Eyeglasses (π)	0.123 (0.125)	0.318** (0.153)	0.248** (0.120)	0.284*** (0.120)
	Equation (1′’) *N* = 18,547			
Constant	0.061** (0.026)	0.039 (0.035)	0.035 (0.026)	0.047* (0.026)
Poor Vision (π)	-0.068 (0.043)	-0.084* (0.044)	-0.017 (0.043)	-0.067* (0.034)
Poor Vision×Having eyeglasses (β)	0.102 (0.076)	0.216*** (0.077)	0.175** (0.075)	0.200*** (0.060)

Notes: 1. All regressions include school random effects

2. Standard errors are in parentheses.

3. The instrumental variable for having eyeglasses is a dummy variable for being selected into the program and having poor vision.