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Ordeal mechanisms, information, and the cost-effectiveness of strategies to provide subsidized eyeglasses☆

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ABSTRACT

The cost-effectiveness of policies providing subsidized health goods is often compromised by limited use of the goods provided. Through a randomized trial involving 251 primary schools in western China, we tested two approaches to improve the cost-effectiveness of a program distributing free eyeglasses to myopic children. Relative to delivery of free eyeglasses to schools, we find that providing vouchers redeemable in local optical shops modestly improved the targeting of eyeglasses to those who would use them without reducing effective coverage. Information provided through a health education campaign increased eyeglass use when eyeglasses were delivered to schools, but had no effect when requiring voucher redemption or when families were only given a prescription for eyeglasses to be purchased on the market. Though most expensive, free delivery to schools with a health education campaign was the most socially cost-effective approach tested and increased effective coverage of eyeglasses by 18.5 percentage points after seven months.

1. Introduction

The World Health Organization estimates that more than 1 billion people globally live with visual impairment that is either fully treatable or could have been prevented (WHO, 2019). More than 90% of these individuals live in developing countries (Bourne et al., 2017). The most common cause of visual impairment is refractive error which, in the vast majority of cases, can be completely corrected by properly-fitted eyeglasses (Steinmetz et al., 2021). The private and social costs of uncorrected refractive error are

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substantial, particularly among children among whom vision impairment is associated with impaired cognitive, language, and socio-emotional development (Warren, 1994); academic achievement (Resnikoff et al., 2008); and self-esteem (Augestad, 2017).

We study alternative approaches to improve the cost-effectiveness of programs providing subsidized eyeglasses to myopic children through schools in rural China. Like programs providing many other types of subsidized health products, a challenge is that ensuring access alone is not enough: Eyeglasses require active use for their benefits to be realized. The effectiveness of programs providing eyeglasses therefore depends not on ownership, but on the effective coverage (rates of eyeglass use) attained. As a result, cost-effectiveness can be undermined if subsidized eyeglasses go unused. Moreover, subsidized eyeglasses may displace existing demand at market prices, further compromising cost-effectiveness.

Given the potential for waste due to non-use, the cost-effectiveness of programs providing subsidized health goods like eyeglasses can be improved by (a) targeting to individuals most likely to use them (on the extensive margin); and (b) increasing usage among those acquiring a good (on the intensive margin). Although it has been argued that charging a positive price (cost-sharing) can improve cost effectiveness through these channels, empirical evidence suggests that – for a variety of preventative health goods – charging even a modest price can significantly dampen demand and screen out a significant number of beneficiaries who would have used these products if provided for free, thus undermining the primary policy goal of increasing usage (Dupas and Miguel, 2017).

Through a randomized trial across 251 primary schools in western China, we test two non-price approaches to improve the cost-effectiveness of distributing fully-subsidized eyeglasses and compare these to providing prescriptions alone. The first approach is to apply an ordeal mechanism by providing families of myopic children with vouchers for free eyeglasses that are only redeemable at designated optometry shops. Relative to providing free eyeglasses directly, the non-monetary cost imposed by requiring voucher redemption may better target eyeglasses to those who will use them. The second approach, providing information about the benefits of eyeglass use through a health education campaign, can improve cost-effectiveness by increasing the rate or intensity of usage among recipients. Because subsidies and information campaigns are commonly implemented simultaneously and are likely to interact in important ways for experience goods like eyeglasses, we also test how the effects of an ordeal and information interact and jointly impact take-up and use.

We use a cross-cutting experimental design to compare these approaches and their interaction to two comparison groups: directly delivering free eyeglasses to myopic children at school and to a "market" condition. All 19,934 fourth- and fifth-grade children in these schools were screened for myopia, and parents of children found to be myopic were notified. We then randomly assigned schools to one of three distribution groups: a "Free Delivery" group, in which eyeglasses were delivered to schools and dispensed directly to the students; a "Voucher" group, in which vouchers were provided for free eyeglasses redeemable at designated optometry shops in the county seat; and a "Market" group, in which caregivers were only given an accurate prescription for eyeglasses which they could use when purchasing eyeglasses in the existing market. Half of the schools within each of these distribution groups were then randomly chosen to receive a "Health Education" campaign for students, parents, and teachers that extolled the benefits of eyeglasses and addressed common types of misinformation. Using this experimental design, we compare the effects of each type of distribution scheme, and their interaction with health education, on acquisition and use of eyeglasses one month and seven months after initial distribution.

We emphasize three main findings. First, the price of eyeglasses, but not a lack of information on the benefits of eyeglass use, appears to be a major barrier to the acquisition of eyeglasses in this context. Relative to the Market group (prescription only), providing vouchers for free eyeglasses increased ownership after seven months by 51 percentage points (a 131% increase from a base of 39%). Providing information through the health education campaign, on the other hand, had little effect on ownership.

Second, we find that, relative to Free Delivery, the ordeal mechanism (voucher redemption) modestly improved targeting efficiency. The ordeal selected out approximately 12% of individuals that would not have used glasses if freely distributed to students at schools. The use of eyeglasses (as measured though unannounced visits to schools) was as high in voucher schools as in the free delivery schools, suggesting that the ordeal did not select-out individuals who would have used eyeglasses if freely delivered (or did not select individuals in a way that reduced overall use rates). Although targeting efficiency was highest in the Market group, "effective coverage" (defined as usage unconditional on ownership) was approximately 12 percentage points higher in the Voucher and Free Delivery groups relative to the Market group after seven months (an increase of nearly 30 percent).

Third, although it was ineffective at increasing ownership in any of the distribution groups, the Health Education campaign was effective in increasing *use* – but only when glasses were freely delivered to schools. Health education had no detectable effect on usage when glasses were distributed through an ordeal mechanism or when individuals needed to purchase eyeglasses in the market. Providing information increased usage in the free distribution group by approximately 19 percentage points after one month and 8 percentage points in the seven-month follow-up (a 21% increase).

Taken together, our results at seven months after the initial distribution show that free delivery with the health education campaign achieved the highest overall rate of effective coverage out of the policy options examined. Moreover, this combination of interventions was the most cost-effective—both in terms of "programmatic" costs (implementation costs) and social costs that account for deadweight loss due to the ordeal imposed by vouchers—relative to only providing prescriptions with no health education. Given the patterns of use that we find, vouchers would have had to screen out approximately 48 percent more individuals without reducing the overall rate of use in order to be as cost-effective as free delivery with information. Requiring an ordeal costly enough achieve this level of screening, though, would impose a deadweight loss large enough to fully offset gains from improved targeting.

Our findings extend the literature on the effects of subsidies and information on the adoption of health goods in developing countries (see Kremer and Glennerster, 2011; Dupas and Miguel, 2017 for reviews). A focus of this literature has been on how pricing (cost-sharing) affects access and the targeting of products to users. Experimental studies randomizing price offers have found that demand for many preventative health products is highly elastic.[1] As a result, higher prices tend to screen out those likely to benefit, reducing cost-effectiveness and undermining the policy goal of increasing coverage.[2] Evidence on whether higher prices effectively target those likely to use products is more mixed. For instance, Ashraf et al. (2010) find that higher prices do screen out those who would use water chlorine less, while Cohen and Dupas (2010) in Kenya find no evidence that cost sharing reduces wastage of bed nets (ITNs).

Existing evidence on whether targeting through inconvenience (such as an ordeal mechanism) is more limited. Although more extensively studied in the context of other social programs,[3] we're aware of only two prior studies with application to health good subsidies. Dupas et al. (2016) conduct a field experiment to examine the effects of a "micro-ordeal" in the distribution of chlorine solution for water treatment, also in Kenya. They find that requiring households to redeem monthly coupons for free chlorine screened out 88 percent of non-users while achieving only slightly lower effective coverage relative to free distribution, suggesting a substantial increase in cost-effectiveness. Though the focus is on a different dimension of targeting, Hoffmann (2018) finds evidence from an experiment measuring willingness-to-pay for water purifiers among households living in slum neighborhoods in Hyperbad, India that non-monetary prices better target poor households than monetary prices.

Our findings contribute to this literature primarily, first, by studying the targeting efficiency of monetary and non-monetary costs for a product with different attributes of those previously studied. Beyond having more or less elastic demand,[4] eyeglasses present a different scope for learning about benefits and costs of product use over time compared to preventative goods like bednets and water treatment. The scope for positive and negative learning can influence the effects of subsidies for experience goods because perceptions of net benefits may change between the time of the take-up/purchase decision and use over time (Fischer et al., 2019). Our findings suggest that market prices screen out a large fraction of potential eyeglass wearers but, in line with Dupas et al. (2016), non-monetary costs imposed by the ordeal do not.

Our second main contribution is to test how information and the subsidy distribution method interact in their effect on demand and effective coverage. Similar to Meredith et al. (2013) who experimentally test the effect of providing information on purchase decisions in several contexts, we find little effect of information on total demand (good acquisition). We also find no effect on implied elasticity (difference in acquisition between the market and free arms in our case).[5] In terms of eyeglass *use*, however, information and distribution method do interact. Though effective under free delivery, information does not increase use under the ordeal.[6] As a result, the relative cost-effectiveness of free delivery and the voucher mechanism is switched when information is provided. This is because with information, the amount of waste due to non-use is no longer smaller under the voucher mechanism and it screens out individuals who would have used eyeglasses if freely delivered, while also imposing additional cost on voucher recipients.

The remainder of the paper proceeds as follows. Section 2 provides background on the research context regarding uncorrected refractive errors among school-aged children in rural China. Section 3 describes the experiment and data collection. Section 4 discusses the main results for eyeglass acquisition and usage. Section 5 presents a detailed cost-effectiveness analysis. The final section concludes.

2. Background: uncorrected refractive error among children

Approximately 10–15% of school-aged children in developing countries have vision problems due primarily to myopia (He et al., 2007; Maul et al., 2000; Murthy et al., 2002; Resnikoff et al., 2008). With minor exceptions, visual impairment in children can be fully corrected by the timely and proper fitting of eyeglasses (Esteso et al., 2007; Ma et al., 2015). Numerous studies in developing countries, however, document exceedingly low rates of eyeglass use (Bourne et al., 2004; Ramke et al., 2007). The prevalence of

[1] Preventative health products studied include insecticide-treated mosquito nets (Cohen and Dupas, 2010), chlorine water treatment (Ashraf et al., 2010), improved cookstoves (Mobarak et al., 2012), deworming drugs (Kremer and Miguel, 2007), rubber shoes, soap, and vitamins (Meredith et al., 2013). For insecticide treated bed nets, there is some evidence that credit constraints are an important driver of price elasticity. Giving households more time to purchase, cash, or credit increase demand and reduce price sensitivity (Kremer and Glennerster, 2011).

[2] In addition to screening out those unlikely to use a product, charging a price may increase use through sunk-cost effects (Thaler, 1980) or by signaling that a product is high quality. There is little evidence, however, that cost-sharing increases utilization of health products in developing countries (Cohen and Dupas, 2010; Ashraf et al., 2010).

[3] More traditionally considered in the context of targeting social programs, such as welfare and unemployment (see Nichols et al., 1971; Nichols and Zeckhauser, 1982; Besley and Coate, 1992; Alatas et al., 2016), ordeal mechanisms attempt to encourage targeted individuals to self-select into programs by requiring that applicants undergo an ordeal, such as a time-consuming application procedure or traveling to redeem a voucher.

[4] Evidence on the price elasticity of treatment products in developing countries is more limited but suggests that treatments, such as drugs and curative care, are less elastic. Cohen et al. (2015), for instance, find that demand for malaria treatment (ACTs) in Kenya is relatively price inelastic, particularly between subsidies of 80% and higher. Studying curative care in Sri Lanka, Akin et al. (1998) find relatively inelastic demand.

[5] Ashraf et al. (2013) find that providing information comparing a well-known water purification product to a similar unknown product does not affect total demand for water purification, but does increase the price elasticity of demand for the unknown product. This implies that information about unfamiliar goods may be complementary with subsidies for those goods. The mechanism in this case may differ, however, from the context of providing information about the benefits of more familiar health products without close substitutes.

[6] This corresponds somewhat with a general pattern of findings in the public health literature showing that health promotion campaigns are often more effective when combined with product distribution. In a systematic review of mass media health communication campaigns, for instance, Robinson et al. (2014) note that campaigns appear more effective in promoting healthy behaviors when combined with the distribution of health products such as condoms and smoking cessation aids. Luby et al. (2004, 2005) find that a handwashing promotion campaign that also provided free soap was effective.

uncorrected refractive errors among children in rural China is among the highest in the world (He et al., 2004, 2007). Recent studies show that about 25% of primary school students have myopia, (Yi et al., 2015) but less than one fifth of myopic children own eyeglasses (Ma et al., 2014; Wang et al., 2015).[7] Only half of the children owning glasses regularly wear them (Yi et al., 2015; Wang et al., 2015).

The private and social costs of uncorrected refractive errors in childhood are high. Beyond impairing quality of life, uncorrected refractive errors can reduce productivity and hamper academic performance (Resnikoff et al., 2008). Providing children with eyeglasses through school-based programs has been shown to significantly improve their academic performance, having effects on par with education interventions deemed highly successful (Ma et al., 2014; Glewwe et al., 2016). In a context such as China, where academic performance in early years is critical to gaining access to subsequent higher quality educational opportunities, there are potentially substantial long-term benefits to the early correction of myopia.

Despite these large potential benefits, previous research suggests several factors that contribute to the low utilization of eyeglasses among school children. The absence of vision screening and the affordability of eyeglasses, given liquidity constraints, are likely significant barriers (Resnikoff et al., 2008). In China, many children are unaware that they are visually impaired (Li et al., 2010; Yi et al., 2015), and eyeglasses are a large expense in poor rural areas.[8] The prevalence of misinformation regarding eye health is also likely to limit the adoption of eyeglasses (Li et al., 2010; Yi et al., 2015). There is a common misconception, for example, that wearing eyeglasses, especially when children are in primary school, further deteriorates vision among children. Another misconception is that eye exercises (a daily activity carried out in many rural schools) can prevent and treat myopia, despite any ophthalmological basis or evidence of their efficacy (Li et al., 2015).[9] Among school-aged children, negative peer effects or stigmatization (e.g. teasing) may also be an important factor constraining uptake.

3. Experimental design and data collection

3.1. Sampling

Our experiment took place in two adjoining provinces of Western China: Shaanxi and Gansu.[10] In each of the provinces, one prefecture (each contained a group of seven to ten counties) was included in the study. In each prefecture, we obtained a list of all rural primary schools. To minimize the possibility of inter-school contamination, we first randomly selected 252 townships and then randomly selected one school per township for inclusion in the experiment. For logistical reasons and to ensure sufficient statistical power, schools with fewer than 50 students or more than 150 were excluded from the sampling frame. Within schools, our data collection efforts (discussed below) focused on fourth- and fifth-grade students. From each grade, one class was randomly selected, and surveys and visual acuity examinations were given to all students in these classes.

3.2. Experimental design

Following the baseline survey and vision tests, schools were randomly assigned to one of the six cells in the 3 × 2 experimental design shown in Table 1[11] Schools were first randomized into one of three distribution groups: Market, Voucher, and Free Delivery. Half of the schools assigned to each distribution group were then assigned to receive an additional Health Education Campaign. To improve power, we stratified the randomization by county and by the number of children in the school found to need eyeglasses. In total, this yielded 45 strata. Our analysis takes this randomization procedure into account (Bruhn and McKenzie, 2009).

The three distribution groups were as follows. In the Market group, myopic students were given a letter to their parents that informed them of their child's myopia status and prescription. In the Free Delivery group, each student diagnosed with myopia was given a free pair of eyeglasses as well as a letter to their parents that informed them of their child's prescription.[12] The child was permitted to select a pair of frames, which were then fit to the proper prescription and delivered to the student at school by a team of one optometrist and two enumerators. In the Voucher group, each student diagnosed with myopia was given a voucher for free eyeglasses as well as a letter to their parents that informed them of their child's prescription. Their prescription also was printed in the voucher. This voucher was redeemable for one pair of free glasses at an optical shop in the county seat.[13]

[7] Ma et al. (2014) find that only 16 percent of students in rural public schools in Shaanxi and Gansu who are myopic own glasses; Wang et al. (2015) find a similar rate (18 percent) in Shanghai migrant schools.

[8] Data from our baseline survey showed that, among children who owned glasses, the median price paid was approximately $55. As of 2011, the average monthly income for rural families in China was $130 (China National Statistics Bureau, 2012).

[9] In our baseline survey, around 75% of parents reported that they believe that wearing eyeglasses will deteriorate one's vision. Around 55% believe that eye exercises can effectively treat myopia.

[10] Shaanxi's GDP per capita of USD 6,108 was ranked 14th among China's 31 provincial administrative regions in 2012 and was very similar to that for the country as a whole (USD 6,091) in the same year, while Gansu was the second-poorest province in the country (per capita GDP USD 3,100) (China National Statistics Bureau, 2012).

[11] Consent for participation in the study was obtained from school principals in line with regulations in China. After the baseline survey, one of the 252 schools was found to have no children who required glasses and was excluded from the randomization. Thus, the final sample includes 251 schools.

[12] More than 95% of poor vision is due to myopia. The rest is due to hyperopia and astigmatism. For simplicity, we will use myopia to refer to vision problems more generally.

[13] Program eyeglasses were pre-stocked with one chosen optometrist per county.

Table 1
Experimental design.

	Distribution Group			Total
	Free Delivery	Voucher	Market	
No Health Education	42 (527)	41 (492)	42 (510)	125 (1,529)
Health Education Campaign	42 (626)	42 (496)	42 (526)	126 (1,648)
Total	84 (1,153)	83 (988)	84 (1,036)	251 (3,177)

Notes: Table shows the distribution of schools (myopic students) across experimental groups. In the Free Delivery group, eyeglasses were delivered to schools; in the Voucher group, vouchers for free eyeglasses were redeemable in the county seat; the Market group only received eyeglass prescriptions. The Health Education Campaign focused on conveying the benefits of eyeglasses and addressing common misconceptions concerning the use of eyeglasses. One school in the Voucher, No Health Education cell was found during the baseline survey to not have any myopic students and was therefore excluded from the randomization.

Compared to free delivery, providing vouchers for free eyeglasses reduces distribution costs. It also imposes an ordeal on the acquisition of eyeglasses in the form of additional transportation and opportunity costs associated with obtaining eyeglasses in the optical shop. This ordeal also may improve cost-effectiveness by screening out those who would not use eyeglasses if freely delivered. The distance from each student's home village and the county seat varied a great deal within our sample, ranging from 1 km to 105 km (measured as the distance from the school), with a mean distance of 33 km. The vouchers were non-transferable and could not be resold. Information that identified the student, including his or her name, school, and county, was printed on each voucher, and students were required to present their identification in person to redeem the voucher. Vouchers expired four months after distribution.

In each of these three distribution groups, half of the schools were randomly assigned to receive health information. The Health Education Campaign included three components. First, a short documentary-type film was shown to students in class. Second, students were given a set of cartoon-based pamphlets in class. Finally, parents and teachers attended a meeting at the school in which they were shown the film, and additional handouts were distributed. Each component of the Health Education Campaign addressed the benefits of wearing glasses and provided information meant to address common misconceptions that lead to inflated perceptions of use costs and contribute to low adoption rates.[14]

3.3. Data collection

Baseline survey and eye examination. A baseline survey was conducted in September 2012. The baseline survey collected detailed information on schools, students, and households. The school survey collected information on school infrastructure and characteristics (including distance to county seat). A student survey was given to all students in selected fourth- and fifth-grade classes. This student survey collected information on basic background characteristics of students and their knowledge of vision health. Students also were asked about their pre-program experience with eyeglasses, including whether they owned eyeglasses, whether they regularly wore their eyeglasses, their experience in wearing eyeglasses if they wore them (e.g., whether they were teased), and their reasons for not wearing eyeglasses if they did not. Household surveys also were given to these same students, which they took home and completed with their parents. The household survey collected information on households (e.g., parents' education levels, value of family assets) that children would likely have difficulty answering as well as information on parents' knowledge and perceptions of eye problems and the use of eyeglasses. This survey was returned by 95.4% of children.

At the same time as the school survey, a two-step eye examination was administered to all students in the randomly selected classes in all sample schools. First, a team of two trained staff members administered visual acuity screenings, using Early Treatment Diabetic Retinopathy Study (ETDRS) eye charts.[15] Students who failed the visual acuity screening test (cutoff is defined by visual acuity of either eye less than or equal to 6/12, or 20/40) were enrolled in a second vision test that was carried out at each school one to two days after the first test. This second vision test was conducted by a team of one optometrist, one nurse, and one staff assistant and involved cycloplegic automated refraction with subjective refinement to determine prescriptions for children who need glasses.[16] After being fitted with eyeglasses, corrected visual acuity (with eyeglasses) was tested again to ensure that both eyes could be improved to 6/12.

[14] The materials used in the Health Education Campaign, including the documentary film, pamphlets, and slides, are posted at http://reap.fsi.stanford.edu/research/vision-care-training-materials. Teachers were included in health education sessions in line with standard practice for school-based health and nutrition programs in China. On average in the Health Education schools, 76% of children had at least one parent or guardian attend an information session.

[15] ETDRS charts are accepted as the worldwide standard for accurate visual acuity measurement (Camparini et al., 2001).

[16] A cycloplegic refraction is a procedure used to determine a person's degree of myopia (refractive error, in stricter terminology) by temporarily paralyzing the muscles that aid in focusing the eye. It is often used for testing the vision of children who sometimes subconsciously accommodate their eyes during the eye examination, making the results invalid.

Acquisition and use of eyeglasses. Our analysis focuses on two key variables: eyeglass ownership and use. Acquisition is defined by ownership, i.e., a binary variable that takes a value of 1 if a student owns a pair of eyeglasses at baseline or acquired a pair during the program (regardless of the source). Acquisition includes both self-purchase and voucher redemption (in the case of the Voucher group). Ownership is 1 for all students in the Free Delivery group.[17]

Use is defined by whether a student wears his or her glasses. Use was measured through unannounced checks to observe whether students were wearing glasses in class. Because observation of whether glasses were worn at a particular point in time may over- or underestimate the level of regular use, however, we supplement this measure with self-reported survey responses of whether children wore eyeglasses and whether they wore them regularly outside of class.

Two rounds of unannounced checks were conducted to collect information on the ownership and use of eyeglasses. A short-term check was conducted in early November 2012 (approximately one month after glasses and vouchers were distributed). In this round, a team of two enumerators made unannounced visits to each of the 251 schools and recorded the number of students in sample classes who were wearing their glasses. To be counted as wearing glasses, the student had to have been observed with his or her glasses on. After this count was finished, students who had been diagnosed with myopia in the baseline eye examination were given a short survey that included questions about whether they owned eyeglasses, how they acquired them, and how often they wore them. To check whether students who said that they owned glasses actually did, we asked to see the glasses (if the glasses were with the student at school, e.g., if they were in his or her desk or backpack). If the glasses were at home, we followed up with a phone call to the parents.

A second, longer-term check was conducted alongside an endline survey in May 2013 (seven months after eyeglasses and vouchers were distributed and training was conducted). In line with the first round of unannounced checks, a team of two enumerators was sent into schools in advance of the rest of the survey team to conduct classroom checks. In this second round of checks, enumerators were given a list of the children diagnosed with myopia to record individual-level information on their usage of glasses.

3.4. Baseline characteristics

Of the 19,934 students given eye examinations at baseline, 3,177 (16%) were found to require eyeglasses. Only these students are included in the analysis sample. The baseline characteristics of these students are shown in Table 2. The first two columns show the mean and standard deviation in the Free Delivery, No Health Education Campaign group. Columns 3–7 show coefficients estimated by regressing each of the baseline characteristics on a vector of indicators for the other treatment arms and indicators for randomization strata. Column 8 provides the *p*-value from the test of a null hypothesis that these coefficients are jointly zero. Only three of the 55 coefficients tested are significantly different from zero, and none of the joint tests is rejected at conventional levels, suggesting a good overall balance across experimental groups.

On average, only 18.9% (601 out of 3,177) of students who needed glasses had them at the time of the baseline. In line with the literature, lack of awareness and misinformation were prevalent and may play a role in explaining this low rate. For example, fewer than half of myopic children knew that they were myopic, and nearly 75% of parents believed that wearing eyeglasses could deteriorate one's vision. This low awareness was despite 63% of children being classified as having moderate or severe visual impairment based on WHO guidelines. Generally, the education level of parents was low: Only 22.6% of children had at least one parent who had attended high school. In addition, 9% of students in the sample had parents who had both migrated elsewhere for work.

Attrition at the short-term and seven month visits was limited (online Appendix Table 1). Only 19 out of 3,177 students could not be followed in the short term, and 127 (4%) could not be followed in the long term. There is slightly higher short-term attrition in the Market, No Health Education Campaign group; however, the magnitude is small (1.7 percentage points).

4. Results: acquisition, ownership, and usage

4.1. Overview of results

Fig. 1 presents a graphical overview of the experimental results. The figure plots the estimates of eyeglass ownership and unconditional usage (effective coverage) based on unannounced checks at one month post-distribution (Fig. 1A) and seven months post-distribution (Fig. 1B).

We find a similar pattern of results at one and seven months post-distribution for eyeglass ownership (top gray bar). Ownership is 100% in the Free Delivery group by design. In the Voucher group, ownership is somewhat lower as the ordeal of redeeming the voucher screens out some children, and increases slightly between the one and seven month waves. Ownership is significantly lower in the Market group, where only eyeglass prescriptions were provided, but increases substantially between one and seven months. Health education appears to have minimal effects on ownership in the Voucher and Market groups.

The lower green bar in the graph shows unconditional usage (effective coverage) based on observations during unannounced checks. The difference between the top gray bar and the bottom green bar therefore represents an estimate of waste: the proportion of eyeglasses that were distributed under the program but not used. The results for unconditional use and waste are also largely similar

[17] We do not adjust ownership for lost or broken eyeglasses during the program because our focus is on cost-effectiveness, and costs for these eyeglasses had already been incurred. By the seven-month follow-up, the reported rate of lost and broken eyeglasses was small (5.6% in the Free Delivery group and 4.6% in the Voucher group; the difference is not significant, i.e., 10% level). The impact of lost or broken glasses is reflected in our estimates of effective coverage as they will not contribute to eyeglass use.

Table 2
Descriptive statistics and balance check.

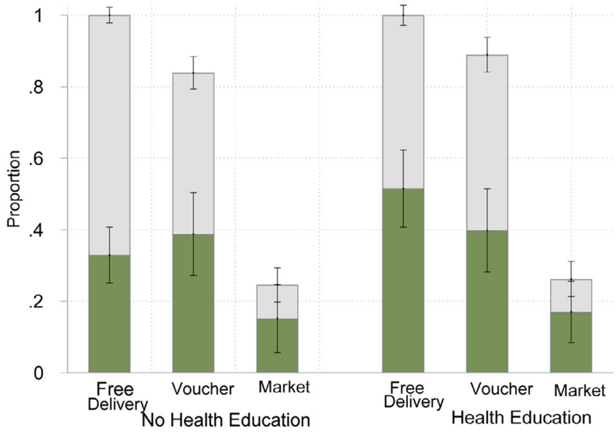
		Free Delivery, No Health Education		Coefficient (standard error) on:						
		Mean	SD	Free Delivery, Health Education	Voucher, No Health Education	Voucher, Health Education	Market, No Health Education	Market, Health Education	Joint Test P-value	Observations
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
(1)	Male (0/1)	0.480	0.500	0.005	0.010	-0.002	0.050	0.001	0.500	3177
				(0.029)	(0.029)	(0.028)	(0.031)	(0.031)		
(2)	Grade 5 (0/1)	0.611	0.488	-0.014	-0.002	-0.004	-0.005	-0.036	0.829	3177
				(0.031)	(0.034)	(0.030)	(0.032)	(0.031)		
(3)	At least one parent has high school education or above (0/1)	0.226	0.419	-0.005	-0.058*	-0.031	-0.017	-0.028	0.451	3163
				(0.025)	(0.031)	(0.028)	(0.027)	(0.030)		
(4)	Both parents out-migrated for work (0/1)	0.092	0.289	0.003	0.022	-0.003	0.009	0.016	0.653	3147
				(0.014)	(0.016)	(0.017)	(0.017)	(0.017)		
(5)	Household assets (Index)	-0.057	1.290	-0.104	-0.173*	-0.118	-0.127	-0.105	0.448	3032
				(0.086)	(0.088)	(0.101)	(0.082)	(0.089)		
(6)	Distance to county seat (km)	33.565	22.433	2.693	0.065	-1.991	5.184	-1.697	0.365	3177
				(4.109)	(4.419)	(4.602)	(3.558)	(4.080)		
(7)	Visual acuity of worse eye (LogMAR)	0.629	0.202	0.002	-0.005	-0.009	-0.003	0.041**	0.172	3177
				(0.016)	(0.021)	(0.016)	(0.016)	(0.019)		
(8)	Moderate or severe myopia (LogMAR>0.5) (0/1)	0.630	0.483	0.002	-0.004	-0.051	-0.000	0.049	0.234	3177
				(0.033)	(0.041)	(0.052)	(0.036)	(0.051)		
(9)	Owns eyeglasses (0/1)	0.188	0.391	0.014	0.025	-0.021	0.021	-0.016	0.169	3177
				(0.023)	(0.023)	(0.022)	(0.024)	(0.019)		
(10)	Aware of own myopia (0/1)	0.473	0.500	-0.015	0.014	-0.011	0.000	-0.025	0.894	3157
				(0.033)	(0.033)	(0.035)	(0.034)	(0.035)		
(11)	Parents believe wearing eyeglasses will harm vision (0/1)	0.747	0.435	-0.002	0.012	0.015	0.002	0.001	0.972	3011
				(0.027)	(0.029)	(0.027)	(0.030)	(0.031)		
(12)	Believes eye exercises treat myopia (0/1)	0.545	0.498	-0.015	-0.016	-0.033	0.017	-0.010	0.812	3177
				(0.035)	(0.038)	(0.036)	(0.039)	(0.036)		

Notes: Data source: baseline survey. The first and second columns show the mean and standard deviation of each baseline characteristic for myopic children in the Free Distribution, No Health Education group. Severity of myopia is measured by the LogMAR of the worse eye. LogMAR takes value from -0.3 (best vision) to 1.6 (worst vision), with an increment of 0.1 corresponding to a one line change on the vision chart; students with normal vision would have value less than or equal to 0.0. Moderate vision impairment is defined as LogMAR >= 0.5 and LogMAR <1.0; severe vision impairment is defined as LogMAR >=1.0. The household asset index was constructed using the first principal competent of variables indicating whether the household owned each of: automobile, truck, motorcycle, tractor, agricultural machine, computer, television, camera, wash machine, air condition, water heater, gas stove, kitchen hood, refrigerator, flush toilet, and access to internet. Distance is the distance from the school to the county seat. Columns 3 through 7 show coefficients and standard errors (in parentheses) from a regression of the characteristic on other five treatment dummies, controlling for randomization strata. Standard errors are clustered at the school level. Column 8 shows the p-value from a Wald test that coefficients are jointly zero. All tests account for clustering at the school level.

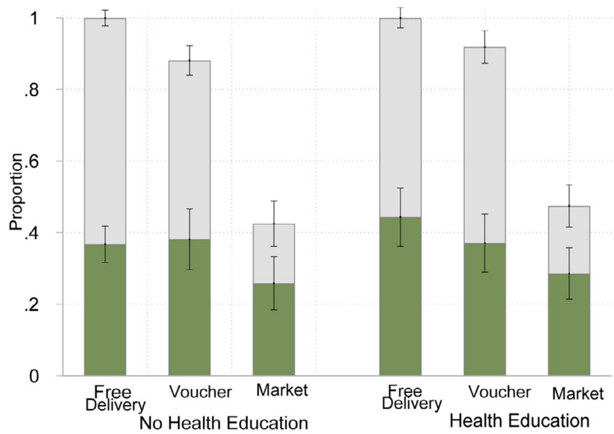
*** Significant at the 1 percent level.

** Significant at the 5 percent level.

* Significant at the 10 percent level.



A. Short-term



B. Long-term

Fig. 1. Acquisition and usage by experimental group.
Note. Gray bars show rate of eyeglass ownership, and green bars show usage rate based on observed use during unannounced visits. Error bars represent 95% confidence intervals. Short-term visits (Fig. 1A) were conducted one month after initial distribution, and longer-term visits (Fig. 1B) were conducted seven months after initial distribution. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.).

in the one and seven-month follow-up rounds. Waste is highest in the Free Delivery only group. Requiring that recipients redeem the voucher reduced waste somewhat as ownership, but not use, decreases. This reduction in waste, however, is only slightly larger than the reduction in waste that comes from increased usage due to adding the Health Education Campaign to Free Delivery. Free Delivery combined with the Health Education Campaign also achieved the highest level of effective coverage of any experimental group. Though it had the smallest amount of waste, the Market group with no health education had the lowest level of effective coverage.

4.2. Ownership

We begin our formal analysis by comparing ownership in the short and long term across the experimental groups. To do so, we use ordinary least squares (OLS) to estimate the regression

$$y_{ij} = \alpha + \beta_I Info_j + \beta_V Voucher_j + \beta_{VI} Voucher_j \times Info_j + \beta_M Market_j + \beta_{MI} Market_j \times Info_j + X_j'\gamma + \varepsilon_{ij}, \quad (1)$$

where y_{ij} is a binary indicator for the eyeglass ownership of child i in school j. We separately estimate the effects on ownership (y_{ij}) at 1 month and 7 months after distribution. $Info_j$ is a dummy variable that indicates that schools receive the Health Education Campaign; $Voucher_j$ is a dummy variable that indicates schools in the Voucher group; and $Market_j$ indicates schools in the Market

Table 3
Eyeglass ownership.

		School Level		Individual Level	
Owns eyeglasses		One month	Seven Months	One month	Seven Months
		(1)	(2)	(3)	(4)
(1)	Health Education	-0.005	0.002	-0.004	0.001
		(0.018)	(0.018)	(0.014)	(0.014)
(2)	Voucher	-0.149***	-0.097***	-0.164***	-0.119***
		(0.030)	(0.028)	(0.023)	(0.021)
(3)	Voucher × Health Education	0.020	-0.009	0.056	0.036
		(0.051)	(0.047)	(0.034)	(0.031)
(4)	Market	-0.768***	-0.610***	-0.755***	-0.575***
		(0.028)	(0.036)	(0.024)	(0.032)
(5)	Market × Health Education	0.043	0.071	0.021	0.048
		(0.044)	(0.052)	(0.036)	(0.045)
Total Effects					
(6)	Voucher + Health Education	-0.132***	-0.102***	-0.112***	-0.081***
		(0.038)	(0.035)	(0.025)	(0.023)
(7)	Market + Health Education	-0.729***	-0.537***	-0.739***	-0.525***
		(0.033)	(0.038)	(0.025)	(0.030)
(8)	Observations	251	251	3132	3054
(9)	Adjusted R-squared	0.795	0.675	0.537	0.883
(10)	Mean in Free Delivery, No Education Group	1.00		1.00	

Notes: Rows (1) to (5) show coefficients on treatment group indicators estimated by OLS using Eq. (1). Standard errors clustered at school level are reported in parentheses. Rows (6) and (7) report the total treatment effects (relative to Free Distribution only) of the Voucher with Health Education (sum of coefficients from rows 1,2, and 3) and the Market (prescriptions only) with Health Education (sum of 1, 4, and 5). Columns (1) and (2) report school-level estimates and columns (3) and (4) report estimates using individual level data. Columns (1) and (3) report estimates for the short-term follow up one month after initial distribution. Columns (2) and (4) report estimates from seven months after initial distribution. All regressions control for randomization strata indicators. *** Significant at the 1 percent level. ** Significant at the 5 percent level. * Significant at the 10 percent level.

group. The omitted Distribution Group is Free Delivery. We chose to use Free Delivery as the comparison group because the take-up of eyeglasses in this group is 100 percent by design. The coefficient β_I therefore captures the effect of the Health Education Campaign in the Free Delivery group; β_V compares ownership in the Voucher group to that (100% ownership) in the Free Delivery group (i.e. the proportion screened out of ownership by the voucher); and β_M compares ownership in the Market group to that in the Free Delivery group (the proportion not taking up eyeglasses when only provided a prescription). The coefficients on the interaction terms, β_{VI} and β_{MI}, give the additional effect of the Health Education Campaign in the Voucher and Market groups relative to the effect of the Health Education Campaign in the Free Delivery group. X_j is a vector of dummy variables for randomization strata. We adjust standard errors for clustering at the school level, using the cluster-corrected Huber-White estimator.

The results for ownership are shown in Table 3. The first two columns show estimates from Eq. (1), but data are collapsed to the school level. The next two columns show the individual-level results. Odd-numbered columns show results for the short term (approximately one month after initial distribution) and even-numbered columns show seven month results. Note that all of the children in the Free Delivery group have a value of 1 for ownership in both the short and long term; thus, coefficients show estimated percentage point deviations from full ownership.

The table also shows that, in the short term, the ordeal imposed by the voucher screened out approximately 15% of individuals who would have been given eyeglasses under free delivery. By the seven month wave, ownership increased by only 5% in the Voucher group, suggesting that, if individuals were to redeem their voucher, they did so shortly after receiving one. Seven months after the distribution of vouchers, approximately 88% of individuals had redeemed them for free eyeglasses. This high redemption rate is remarkable given the cost of the voucher ordeal (discussed in more detail in the Discussion and Conclusion section). Ownership in the Voucher group was 50% higher than in the Market group, which was approximately 40% at seven months. The Health Education Campaign had no distinguishable effects on ownership in either the Voucher or Market groups.

4.3. Correlates of eyeglass ownership

Table 4 presents the data on correlates of eyeglass ownership in the long term in the Voucher and Market groups. Although not causal, this analysis provides useful information on (a) how redemption rates are correlated with costs imposed by the voucher ordeal and (b) whether more myopic children and children from poorer households are more likely to redeem their voucher (i.e., the degree to which vouchers target based on need), and (c) how these differ from the case when payment is required for eyeglasses. Beyond price effects on who selects into ownership, vouchers may alter determinants relative to the market by affecting salience or strengthen the signal of the importance placed on eyeglass ownership by the school. On the other hand, subsidizing eyeglasses through the voucher could signal a lower value of eyeglasses and increase the relative salience of the indirect costs (time and travel) of obtaining eyeglasses.

Table 4
Correlates of eyeglass ownership seven months after distribution.

		Owns eyeglasses at seven-month follow up			
Sample:		Voucher, No Health Education (1)	Voucher, Health Education (2)	Market, No Health Education (3)	Market, Health Education (4)
(1)	Moderate visual impairment	-0.014	-0.012	0.065*	0.157***
		(0.024)	(0.018)	(0.038)	(0.045)
(2)	Severe visual impairment	-0.012	0.141	0.653***	0.252***
		(0.074)	(0.134)	(0.140)	(0.086)
(3)	Distance to county seat (km)	-0.003***	-0.001	0.002	0.001
		(0.001)	(0.001)	(0.002)	(0.003)
(4)	Household Asset Index	-0.007	0.003	0.018	0.011
		(0.014)	(0.010)	(0.021)	(0.017)
(5)	Owns eyeglasses at baseline (0/1)	0.125***	0.022	0.643***	0.475***
		(0.025)	(0.032)	(0.033)	(0.051)
(6)	Thinks eyeglasses good looking at baseline (0/1)	0.117***	0.038*	0.029	0.096
		(0.026)	(0.019)	(0.105)	(0.141)
(7)	Parents believe wearing eyeglasses will not harm vision (0/1)	0.058**	-0.006	0.013	0.044
		(0.022)	(0.026)	(0.048)	(0.047)
(8)	Male (0/1)	-0.022	-0.023	0.013	0.025
		(0.037)	(0.025)	(0.037)	(0.048)
(9)	Grade 5 (0/1)	0.028	0.007	-0.003	0.053
		(0.031)	(0.024)	(0.040)	(0.051)
(10)	At least one parent has high school education or above (0/1)	-0.035	-0.021	-0.108**	0.048
		(0.038)	(0.031)	(0.043)	(0.048)
(11)	Both parents out-migrated for work (0/1)	0.050	0.024	0.039	-0.071
		(0.030)	(0.021)	(0.063)	(0.060)
(12)	Constant	0.906***	0.988***	0.276**	0.170*
		(0.043)	(0.072)	(0.137)	(0.091)
(13)	Observations	436	447	459	479
(14)	Adjusted R-squared	0.091	0.207	0.340	0.237

Notes: OLS estimates of a linear probability model with a binary dependent variable that is equal to 1 if the student owned eyeglasses seven months after initial distribution by experimental group. The regressors were measured at baseline. Sample sizes are less than the full sample due to observations missing at least one regressor. Severity of myopia is measured by the LogMAR of the worse eye. LogMAR takes value from -0.3 (best vision) to 1.6 (worst vision), with an increment of 0.1 corresponding to a one line change on the vision chart; students with normal vision would have value less than or equal to 0.0. Children with LogMar between 0.5 and 1 are considered to have moderate visual impairment and those with LogMar>1 have severe impairment. Distance is measured as the distance from the school to the county seat. The household asset index was calculated using a list of 13 items and weighting using the first principal component. Regressions also include county fixed effects (not shown).

*** Significant at the 1 percent level.

** Significant at the 5 percent level.

* Significant at the 10 percent level.

In addition, although the Health Education Campaign had no distinguishable effect on the *levels* of redemption and ownership in the Voucher and Market groups, it is possible that providing information affected the selection process; i.e., the composition of those who select into ownership could be different with and without the Health Education Campaign. To analyze these issues, we estimate linear probability models in which the binary dependent variable is equal to 1 if a student owns eyeglasses after seven months. We estimate correlates separately for each of the four experimental groups: Voucher without the Health Education Campaign, Voucher with the Health Education Campaign, Market without the Health Education Campaign, and Market with the Health Education Campaign.

Beginning with the model for the Voucher without Health Education Campaign group (Column 1), we find that, conditional on other covariates, the distance to the county seat (a proxy for the cost of the ordeal) is a significant predictor of ownership. We find little association, however, with proxies for degree of need: Visual acuity and household asset quintile are largely uncorrelated with ownership (although all children in the sample are myopic and in need of eyeglasses). It therefore appears that the cost of going through the ordeal to acquire eyeglasses is the main driver of selection in this group rather than absolute need. We also find a significant relationship with ownership at baseline, whether children think that eyeglasses are attractive, and whether parents believe eyeglasses will harm vision.

The selection process is significantly different when the voucher is combined with the Health Education Campaign (Column 2; Chow test statistic: 17.22, p-value < 0.001). Interestingly, the cost of the ordeal (distance) is no longer a significant predictor of ownership.[18] Bearing in mind that these estimates are not causal, providing health education appears to damper the effect of the ordeal cost on voucher redemption. Ownership at baseline, whether children think that eyeglasses are attractive, and whether parents believe eyeglasses will harm vision also appear to become less significant determinants of voucher redemption.

In the Market groups (Columns 3 and 4), there is a strong relationship between eyeglass acquisition (purchase) and the degree of myopia. Household wealth, in contrast, is still uncorrelated with purchase. Indirectly, this suggests that liquidity constraints may not play a significant role in determining eyeglass demand. Rather, the more important role of subsidies in this context may be to facilitate learning through experience (as discussed in Dupas (2014)).

4.4. Usage

Usage results are presented in Tables 5 and 6. We estimate two types of effects on usage: usage conditional on eyeglass ownership (Table 5) and unconditional usage or "effective coverage" (Table 6). For both types of usage rates, we compare across groups, using the same specification as with ownership (Eq. (1)), but with measures of eyeglass usage as the dependent variable. We examine effects on three different measures of usage: whether a student was observed wearing eyeglasses during unannounced checks, whether a student self-reported using eyeglasses, and whether a student reported that he or she use their eyeglasses regularly, including outside of class.[19] Although the levels of these different measures vary, the observed pattern of results is similar. We therefore focus our discussion on the results based on unannounced checks.

For short-term *conditional* usage after one month (Table 5, Column 1), we find the lowest rates in the Free Delivery without the Health Education Campaign group (32.9 percent). Adding health education to free delivery increases usage substantially (by 18 percentage points, or a 55% increase). Conditional usage is also 14 percentage points higher in the Voucher than in the Free Delivery group. The effects of the health education and of the voucher, however, appear to be substitutes, as there is essentially no effect of the Health Education Campaign in the Voucher group. Conditional usage with the voucher and health education was approximately 44%, or 11.4 percentage points higher than under free delivery. This is significantly less than the 51% rate of conditional usage for Free Delivery with the Health Education Campaign (p-value = 0.02). The highest rate of conditional usage was in the Market group with the Health Education Campaign at 65.1%, although this is not significantly higher than in the Market group without the Health Education Campaign group (60.1%).

The pattern of longer-term results (seven months after initial distribution) is similar to that of the short term, but the gaps in usage between the groups are narrower. After seven months, usage increased slightly in the Free Delivery group (from 32.9% to 36.8%). Longer-term usage in the Free Delivery with the Health Education Campaign group remained significantly higher (by 7.7 percentage points) than in the Free Delivery without the Health Education Campaign group. Usage in the Voucher group, however, decreased slightly by 3.5 percentage points (from 46.8% in the short term to 43.3% in the long term) and was no longer significantly higher than usage in the Free Delivery group. Usage in the Voucher group with the Health Education Campaign also was not significantly different from that of the Free Delivery group. Conditional usage in the Market group remained significantly higher than in the other groups, at 58.5%.

Differences across groups in usage, unconditional on eyeglass ownership (Table 6), provide an indication of the "effective coverage," the total number of children who wear eyeglasses, obtained under each of the treatments. We find the highest rate of effective coverage in the Free Delivery with the Health Education Campaign, both in the short term and after seven months (51.5% at one month and 44.4% at seven months; unconditional usage is the same as conditional usage in the Free Delivery groups, as all students own eyeglasses). This is significantly higher than in the Voucher Groups with and without the Health Education Campaign in the short term but not in the long term (effective coverage was 38–40% in the Voucher group with and without the Health Education

[18] Running a separate linear probability model (pooling the Voucher without the Health Education Campaign and Voucher with Health Education Campaign groups), interacting distance measures with a dummy variable for the Health Education Campaign yields a p-value of 0.003 for a test that coefficients on these interactions are jointly zero. Entering distance linearly yields a similar result.

[19] In the seven-month follow-up, the correlation between the unannounced check and self-reported use is 0.54 and the unannounced check regular use is 0.51.

Table 5
Effects on eyeglass use, conditional on ownership.

		Wearing during unannounced check		Self-reported: Wears eyeglasses		Self-reported: Regularly wears eyeglasses	
		One month (1)	Seven Months (2)	One month (3)	Seven Months (4)	One month (5)	Seven Months (6)
(1)	Health education	0.182***	0.077*	0.113***	0.079***	0.191***	0.083***
		(0.058)	(0.041)	(0.036)	(0.030)	(0.031)	(0.024)
(2)	Voucher	0.139**	0.065	0.065*	0.041	0.070**	0.048
		(0.065)	(0.047)	(0.038)	(0.039)	(0.031)	(0.030)
(3)	Voucher × Health Education	-0.207**	-0.109	-0.085*	-0.051	-0.139***	-0.050
		(0.092)	(0.067)	(0.050)	(0.050)	(0.047)	(0.040)
(4)	Market	0.272***	0.217***	0.142***	0.158***	0.220***	0.150***
		(0.072)	(0.046)	(0.051)	(0.036)	(0.058)	(0.042)
(5)	Market × Health Education	-0.132	-0.115	-0.081	-0.043	-0.113	-0.041
		(0.101)	(0.074)	(0.063)	(0.048)	(0.077)	(0.060)
Total Effects							
(6)	Voucher + Health Education	0.115*	0.034	0.093***	0.069**	0.122***	0.081***
		(0.062)	(0.042)	(0.035)	(0.031)	(0.034)	(0.027)
(7)	Market + Health Education	0.322***	0.178***	0.174***	0.195***	0.298***	0.192***
		(0.068)	(0.055)	(0.041)	(0.035)	(0.051)	(0.042)
(8)	Observations	251	2416	2253	2416	2253	2416
(9)	Adjusted R-squared	0.156	0.095	0.036	0.056	0.087	0.051
(10)	Mean in Free Delivery, No Education Group	0.329	0.368	0.712	0.642	0.139	0.198

Notes: Table shows estimated effects on eyeglass use conditional on eyeglass ownership. Rows (1) to (5) show coefficients on treatment group indicators estimated by OLS using Eq. (1). Standard errors clustered at the school level are reported in parentheses. Rows (6) and (7) report the total treatment effects (relative to Free Distribution only) of the Voucher with Health Education (sum of coefficients from rows 1,2, and 3) and the Market (prescriptions only) with Health Education (sum of 1, 4, and 5). Columns (1) and (2) report results from "unannounced checks" where enumerators visited schools unannounced and noted which children were wearing eyeglasses in class. The protocol used in the short term unannounced check was for enumerators to only count the number of children wearing eyeglasses. As a result, regressions in column (1) are at the school level. Columns (3) and (4) report results for self-reported use and columns (5) and (6) report results for self-reported regular use of eyeglasses. Odd-numbered columns report estimates for the short-term follow up one month after initial distribution. Even-numbered columns report estimates for seven months after initial distribution. All regressions control for randomization strata indicators. *** Significant at the 1 percent level. ** Significant at the 5 percent level. * Significant at the 10 percent level.

Table 6
Effects on effective coverage (unconditional eyeglass use).

		Wearing during unannounced check		Self-reported: Wears eyeglasses		Self-reported: Regularly wears eyeglasses	
		One month (1)	Seven Months (2)	One month (3)	Seven Months (4)	One month (5)	Seven Months (6)
(1)	Health Education	0.186***	0.076*	0.106***	0.079**	0.183***	0.081***
		(0.055)	(0.042)	(0.037)	(0.032)	(0.031)	(0.024)
(2)	Voucher	0.059	0.014	-0.068*	-0.039	0.031	0.019
		(0.059)	(0.043)	(0.039)	(0.038)	(0.028)	(0.027)
(3)	Voucher × Health education	-0.176**	-0.086	-0.033	-0.025	-0.122***	-0.043
		(0.083)	(0.064)	(0.054)	(0.051)	(0.044)	(0.037)
(4)	Market	-0.177***	-0.109***	-0.499***	-0.294***	-0.045*	-0.042
		(0.048)	(0.038)	(0.039)	(0.037)	(0.027)	(0.027)
(5)	Market × Health Education	-0.168**	-0.049	-0.075	-0.020	-0.146***	-0.039
		(0.065)	(0.056)	(0.051)	(0.051)	(0.038)	(0.038)
Total Effects							
(6)	Voucher + Health Education	0.069	0.003	0.005	0.015	0.093***	0.056**
		(0.059)	(0.041)	(0.041)	(0.035)	(0.032)	(0.025)
(7)	Market + Health Education	-0.159***	-0.082**	-0.469***	-0.235***	-0.008	-0.001
		(0.044)	(0.036)	(0.036)	(0.038)	(0.025)	(0.025)
(6)	Observations	251	3054	3132	3054	3132	3054
(7)	Adjusted R-squared	0.295	0.089	0.263	0.121	0.085	0.045
(8)	Mean in Free Delivery, No Education Group	0.329	0.368	0.712	0.642	0.139	0.198

Notes: Table shows estimated effects on eyeglass use, not conditional on ownership. Rows (1) to (5) show coefficients on treatment group indicators estimated by OLS using Eq. (1). Standard errors clustered at the school level are reported in parentheses. Rows (6) and (7) report the total treatment effects (relative to Free Distribution only) of the Voucher with Health Education (sum of coefficients from rows 1,2, and 3) and the Market (prescriptions only) with Health Education (sum of 1, 4, and 5). Columns (1) and (2) report results from "unannounced checks" where enumerators visited schools unannounced and noted which children were wearing eyeglasses in class. The protocol used in the short term unannounced check was for enumerators to only count the number of children wearing eyeglasses. As a result, regressions in column (1) are at the school level. Columns (3) and (4) report results for self-reported use and columns (5) and (6) report results for self-reported regular use of eyeglasses. Odd-numbered columns report estimates for the short-term follow up one month after initial distribution. Even-numbered columns report estimates for seven months after initial distribution. All regressions control for randomization strata indicators. *** Significant at the 1 percent level. ** Significant at the 5 percent level. * Significant at the 10 percent level.

Table 7
Cost effectiveness calculations.

		Incremental Amount Relative to Market, No Health Education Group				
		Market, Health Education (1)	Voucher, No Health Education (2)	Voucher, Health Education (3)	Free Delivery, No Health Education (4)	Free Delivery, Health Education (5)
Panel A. Costs						
Programmatic Costs						
(1)	Health Education Campaign	14,154	–	14,154	–	14,154
(2)	Eyeglasses	–	151,536	159,191	184,450	219,100
(3)	Eyeglass Distribution	–	–	–	16,800	16,800
Costs to Households						
(4)	Voucher Redemption	–	54,691	56,036	–	–
(5)	Self-Purchase	6,340	(78,112)	(87,372)	(70,248)	(65,507)
Cost of Public Funds						
(6)	Cost of Taxation	2,831	30,307	34,669	40,250	50,011
Total Costs						
(7)	Programmatic	14,154	151,536	173,345	201,250	250,054
(8)	Social	23,325	158,422	176,678	171,252	234,558
(9)	Social - Excluding Eyeglass Costs for Wearers	23,325	94,708	115,918	103,006	138,154
Panel B. Benefits						
(10)	Number of Additional Children Wearing Eyeglasses	N.S.	56	52	62	146
(11)	Total Lines of Visual Acuity Improvement (LogMAR)	N.S.	29	29	36	80
Panel C. Cost Effectiveness						
Number of Children Wearing Eyeglasses (RMB/Child)						
(12)	Programmatic	N.S.	2,713	3,307	3,254	1,714
(13)	*% Draws Most Cost-Effective*		6%	1%	0%	92%
(14)	Social	N.S.	2,836	3,370	2,769	1,608
(15)	*% Draws Most Cost-Effective*		3%	0%	1%	95%
(16)	Social - Excluding Eyeglass Costs for Wearers	N.S.	1,696	2,211	1,666	947
(17)	*% Draws Most Cost-Effective*		3%	0%	1%	95%
Lines of Visual Acuity (RMB/LogMAR units)						
(18)	Programmatic	N.S.	5,225	5,977	5,590	3,126
(19)	*% Draws Most Cost-Effective*		3%	1%	1%	95%
(20)	Social	N.S.	5,463	6,092	4,757	2,932
(21)	*% Draws Most Cost-Effective*		2%	0%	2%	96%
(22)	Social - Excluding Eyeglass Costs for Wearers	N.S.	3,266	3,997	2,861	1,727
(23)	*% Draws Most Cost-Effective*		2%	0%	2%	96%

Notes. All costs in renminbi (exchange rate as of Sept. 2012 was 6.3 RMB/USD). In the Market, No Health Education group, the cost of providing eye exams was 130,050 yuan total (3,096 yuan per school) and the total cost to those self-purchashing eyeglasses was 110,823 yuan. The cost of the information campaign was approximately 337 yuan per school excluding fixed costs of producing campaign materials. As eyeglasses were donated for the program, we use the market cost of eyeglasses (following Dhaliwal et al., 2013) as measured in the baseline survey (350 yuan per pair). The cost of delivering eyeglasses was around 400 yuan per school (costs variable with the number of eyeglasses delivered was relatively small). Voucher redemption costs to households include transportation costs to and from county seat (assumed to be 1 yuan per km traveled) and the time costs incurred. Time costs are calculated based on a daily adult wage of 120 yuan for eight hours of work and calculating total time spent as two-way travel time (assuming an average travel speed of 20 km/hour) plus one hour spent recieving eyeglasses. The cost of self-purchase is calculated as the sum of travel costs to the county seat, time costs (calculated as for voucher redemption), and the cost of eyeglasses (also assumed to be 350 yuan). In the absence of good estimates for China, we use a deadweight loss from taxation of 20% of programmatic costs (Auriol and Warlters, 2012). Lines of visual acuity improvement are calculated as the difference between corrected visual acuity (vision wearing correctly fit eyeglasses) and presenting visual acuity (vision wihtout eyeglasses). Effects not significant (N.S.) for the information campaign in the market group. Rows 13, 15, 17, 19, 21 and 23 show the percentage of 100,000 simulation draws for which each policy is the most cost effective. Simulations draw values for the impact of each policy on unconditional use (effective coverage), voucher redemption (ownership in the ordeal groups), and self-purchase of eyeglasses in the market from normal distributions with means and standard deviations of original impact estimates.

Campaign in both the short and long term). Usage in the Free Delivery without the Health Education Campaign group is less than unconditional usage in the Voucher group but not significantly so. The lowest effective coverage was in the Market groups (25.9% without the Health Education Campaign in the long term and 28.6% with the Health Education Campaign in the long term; the difference was not significant).[20]

5. Cost-effectiveness

In this section, we compare cost-effectiveness under the different combinations of distribution methods with and without the Health Education Campaign, following largely the methodologies discussed in McEwan (2012) and Dhaliwal et al. (2013). In doing so, we consider effectiveness both in terms of the number of children who wear eyeglasses and total vision gain, or gains summed over all children found to be wearing eyeglasses.[21] We also present both "programmatic" cost-effectiveness (using the direct monetary program costs to the implementing organization) and social cost-effectiveness calculations. We calculate social costs as the sum of: (a) programmatic costs, (b) the cost of public funds, and (c) costs incurred by households in responding to the policies (including the costs to households in undertaking the ordeal).

In calculating social cost-effectiveness, one issue is whether the cost of eyeglasses should be counted. On the one hand, the cost of transfers such as this represents a cost to the implementing organization, but not to society as a whole (except for the cost of public funds), because the cost to the implementer is offset by the benefit to those who receive the transfer (Dhaliwal et al., 2013). On the other hand, beneficiaries may not value eyeglasses at the cost incurred by the implementer (but their average valuation still will not be zero). Indeed, this is the main motivation for subsidizing goods in the first place. As a compromise, we present social cost-effectiveness calculations, including the cost of eyeglasses as well as calculations that exclude the cost of eyeglasses for those found to be wearing eyeglasses (but still including the cost of public funds that corresponds to programmatic eyeglass purchases).[22]

To account for estimation errors, we use Monte Carlo simulations to calculate how often each policy (combination of distribution methods and the Health Education Campaign) is likely to be the most cost-effective of those examined (an approach proposed by Evans and Popova, 2016). We use this approach to simultaneously take into account errors for three different effect estimates that serve as inputs to the cost-effectiveness analysis: unconditional use (effective coverage), voucher redemption in the voucher groups, and self-purchase of eyeglasses. Each simulation draw randomly selects simulated values for each effect from normal distributions with means and standard deviations from the original coefficient estimates. For each type of cost-effectiveness calculation, we report the percentage of 100,000 draws for which each policy is the most cost-effective.

Table 7 presents the results in regard to the costs and benefits of each experimental group relative to the Market group without the Health Education Campaign.[23] The key finding is that the combination of Free Delivery with the Health Education Campaign is the most cost-effective in terms of both programmatic and social costs (and both including and excluding full eyeglass costs). In this group, we calculate the programmatic cost of one additional bespectacled child to be 1,714 yuan (or USD 272 at an exchange rate of 6.3 RMB/USD; Column 5). The point estimate for the relative social cost is 1,608 yuan (USD 255) per child, including full eyeglass costs and 947 yuan (USD 150), excluding eyeglass costs for wearers (Column 5). For each of these three types of costs, Free Delivery with the Health Education Campaign was the most cost-effective policy in more than 90% of simulation draws.

The second most cost-effective policy (based on the simulation) is the Voucher *without* the Health Education Campaign. We calculate programmatic costs for this group to be 2,713 yuan (USD 431) per additional child (Column 2), or 58% higher than the Free Delivery with the Health Education Campaign group. In terms of relative social costs, which take into account costs incurred by households in undergoing the ordeal, the Voucher group without the Health Education Campaign is even less cost-effective (the cost per additional child (Column 2) is 76% higher than the Free Delivery group with the Health Education Campaign). The results are similar, including and excluding full eyeglass costs (Column 2).

Accounting for the gain in visual acuity of those who ultimately wear eyeglasses (calculated as the difference between corrected visual acuity—vision with eyeglasses—and presenting visual acuity—vision without eyeglasses), the differences between the cost-effectiveness of the Free Delivery with the Health Education Campaign and that of the Voucher without the Health Education Campaign become even larger. Programmatic costs are 3,126 yuan (USD 496) per line of visual acuity improvement (measured in LogMAR units) in the Free Delivery with the Health Education Campaign group (Column 5) and 67% higher in the Voucher without the Health Education Campaign group (5,225 yuan (USD 829)) (Column 2). Social costs per line of improvement are more than 86% more expensive in the Voucher without the Health Education Campaign group compared to Free Delivery with the Health Education Campaign group.

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[20] Analyses comparing acquisition and use results for children with mild myopia and those with moderate and sever myopia are shown in Appendix Tables 4–6. A notable difference is that among children with more mild myopia, the voucher group yields a lower amount of waste and has comparable rates of effective coverage to Free Distribution because education has little effect outside of the market group. Whether vouchers are more cost-effective than Free Distribution for mildly myopic children depends on whether the resources saved by waste reduction outweigh the cost imposed on these households to redeem vouchers.

[21] In our calculations, we use the number of children found to be wearing eyeglasses in the long-term unannounced check.

[22] Another issue is how to handle pre-stocking, which was necessary to facilitate coordination with optometrists participating in the program. The costs of pre-stocking optometrists were, however, not included under the assumption that coordination costs of ex-post transfers to optometrists based on the number of vouchers redeemed (either payments or tax credits) would be negligible if implemented by the government.

[23] See table notes for further detail about these calculations.

Would the Voucher policy could have been more cost-effective than the Free Delivery with the Health Education Campaign policy if it had screened out more non-users? Given the effects that we find, vouchers would have needed to screen out around 48% of all myopic children, without reducing the number or composition of children using glasses, to achieve the same cost-effectiveness as Free Delivery with the Health Education Campaign.[24] Our estimates of how redemption falls with distance to the county seat imply that requiring a travel distance of 181 km would be needed to achieve that amount of screening. This would impose a cost on households of around 648 yuan, more than if they traveled to the county seat and purchased their own. Of course, this calculation makes several assumptions, but the point is to illustrate that, in our context, the amount of deadweight loss that would need to be imposed to screen out enough individuals is likely so large that the Voucher policy could never be more (socially) cost-effective than the Free Delivery with the Health Education Campaign policy.

These analyses are, of course, subject to a number of potentially important underlying assumptions. First, because eyeglasses were donated for the purposes of this program, we use the market cost of eyeglasses (350 yuan) collected as part of the baseline survey. If the program were scaled up, however, eyeglasses could conceivably be purchased more inexpensively if bought in bulk. We calculate that, if the programmatic cost of eyeglasses could be reduced to 124 yuan per pair (but the cost of eyeglasses purchased in the market remained at 350 yuan), the Free Delivery without the Health Education Campaign policy would be as cost-effective as Free Delivery with the Health Education Campaign policy (but the usage rate would still be lower).

Two other potentially important assumptions are 1) that families redeeming the voucher incur the full costs of an independent trip to the county seat, although some may redeem vouchers when traveling to the county for other purposes and 2) that the benefits to children are linear in lines of visual acuity gained. Nevertheless, additional analyses suggest that these assumptions have no effect on the relative cost effectiveness of the different policies. Setting redemption costs to zero does not change the relative cost-effectiveness of the alternative policies on average, but this assumption does meaningfully increase the proportion of simulation draws in which the Voucher, No Health Education policy is most cost effective (Appendix Table 2). Assuming only moderately or severely myopic children (LogMAR>0.5) benefit has little effect on relative cost-effectiveness (Appendix Table 3).

6. Discussion and conclusion

This paper provides new evidence to inform the design of policies for the distribution of subsidized goods in low- and middle-income countries. In the context of a program that distributes subsidized eyeglasses to myopic children in rural China, we compare alternative distribution policies in terms of cost-effectiveness and in terms of the overall rate of use achieved. The distribution of subsidized eyeglasses is a useful setting to study the questions that we address for at least four reasons. First, uncorrected refractive errors (such as myopia) represent a substantial burden in developing countries, generally, and in China, in particular (Maul et al., 2000; Murthy et al., 2002; He et al., 2007; Resnikoff et al., 2008; Ma et al., 2014). Second, even though eyeglasses can fully correct vision loss due to myopia, they are utilized at low rates in developing countries—likely due to a lack of information (Li et al., 2010; Yi et al., 2015), misinformation (Congdon et al., 2008; Li et al., 2010), or stigma (Holguin et al., 2006). Third, like many health products, eyeglasses are an experience good whose use is subject to both positive and negative learning. Experiential learning may be particularly important in determining demand in places where the quality of medical advice is low, such as rural China (Fischer et al., 2019; Bai et al., 2014; Sylvia et al., 2014). Finally, from a policy perspective, eyeglasses are costly to provide at scale, warranting the development of strategies to improve the cost-effectiveness of their provision.

We find that an ordeal mechanism (voucher) that requires beneficiaries to travel to their county seat to redeem vouchers for free eyeglasses improved cost-effectiveness relative to a policy of free delivery by screening out individuals who would not have used eyeglasses if freely delivered. The ordeal also did not reduce the overall rate of usage of eyeglasses compared to free delivery. This finding echoes research by Dupas et al. (2016), who find a similar result for a program that distributes water treatment in Kenya. In contrast to Dupas et al. (2016) however, vouchers screen out a smaller fraction of non-users, possibly due to less scope for negative learning to affect subsequent voucher redemption (Dupas and Miguel, 2017).

We also find, however, that, when combined with a health education campaign designed to provide information on the benefits of eyeglasses and address misinformation about the use of eyeglasses, free delivery outperforms the voucher (with and without health education), both in terms of cost-effectiveness and the overall rate of use achieved. One reason for this is that the health education campaign increased eyeglass use under free delivery but not under the ordeal (voucher) mechanism (or under unsubsidized market prices). Although we're unable to identify the exact mechanism for why the effects of information differ, a possible explanation is that information can offset any negative signal of the value of eyeglasses that may be conveyed by the subsidy. In the case of free delivery, this negative signal may be stronger than with the voucher or at market prices, increasing the marginal effect of information on use. This explanation is in line with that provided by Ashraf et al. (2013) for their finding that information comparing an unknown water purification product relative to a known substitute increases price elasticity for that good by reducing the product quality signal of prices. Another plausible explanation is that vouchers and market prices may simply select out individuals whose use would be most responsive to health education.

Taken together, our results imply that directly providing eyeglasses to children in schools while also conducting a relatively intense health education campaign is an effective approach to increase the number of myopic children wearing eyeglasses in our setting. It is

[24] The total cost of eyeglasses in the Voucher group would need to be reduced to 90,375 yuan, which corresponds to a redemption rate of 52.5%, given a cost of 350 yuan for one pair of eyeglasses, for social cost-effectiveness in terms of total visual acuity improvement to be the same as in the Free Delivery with the Health Education Campaign group. Excluding the direct cost of eyeglasses for wearers (counting eyeglasses as a transfer), the Voucher policy would need to screen out 33.6%.

also more cost-effective than the other approaches tested. Given the size of existing estimates of the cost uncorrected refractive error due to productivity loss alone, there are likely very high returns to programs that effectively increase the number of bespectacled children (Smith et al., 2009).

In presenting these results, we emphasize that, as with related studies, our particular findings are likely specific to context. For example, an ordeal mechanism would likely perform better in contexts in which the elasticity of voucher redemption to time costs is higher. The effects of the health education campaign, and how these effects vary under free delivery or an ordeal mechanism, also likely depend on whether the target population is initially more or less informed about a good. Results also will likely differ for goods with different attributes, in particular, goods with different potential for positive and negative learning over time.

Another potential limitation of this study is that we only collected information on eyeglass use through unannounced checks after seven months. It is possible that rates of use (accounting for the need for new prescriptions, replacements for lost/broken eyeglasses, etc) may evolve differently across the experimental groups over time. Though another round of unannounced checks was infeasible, we did collect self-reported information on self-purchase, ownership, and regular use two years after initial distribution. The results (shown in Appendix Table 7) confirm the main conclusions from the seven month data: The Free Delivery + Health Education intervention achieved the highest rate of effective coverage and was the most cost effective. Moreover, the health education campaign was effective under free delivery but not under the voucher mechanism.[25]

Overall, our results show that there is substantial room for the effectiveness and cost-effectiveness of policies to distribute subsidized goods to be improved by adjusting additional design features, such as distribution modes and accompanying information or social marketing campaigns, in addition to (or in combination with) adjusting subsidy levels.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.jhealeco.2022.102594.

CRediT authorship contribution statement

Sean Sylvia: Conceptualization, Data curation, Formal analysis, Methodology, Writing – original draft, Writing – review & editing. **Xiaochen Ma:** Conceptualization, Data curation, Formal analysis, Writing – original draft, Writing – review & editing, Project administration. **Yaojiang Shi:** Project administration, Funding acquisition, Investigation, Supervision. **Scott Rozelle:** Funding acquisition, Investigation, Project administration, Writing – review & editing, Supervision.

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