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Neglected Rural Public Health Issue: The Case of Intestinal Roundworms

Linxiu Zhang,[a] *Yingping Cai,*[a, b] *Xiaobing Wang,*[a, *]
Xiaochen Ma,[c] *Alexis Medina,*[d] *D. Scott Smith,*[d] *Scott Rozelle*[d]

Abstract

Despite increasing institutional and financial support, certain public health issues are still neglected by the Chinese Government. The present paper examines the soil-transmitted helminth (STH) infection and reinfection rates by conducting a survey on 1724 children in Guizhou Province, China. Our results indicate that 37.5 percent of children had been infected with one or more of the three types of tested STH. However, only 50.4 percent of children reported having taken deworming medicine during the 18-month period before the survey. Of those who reported being dewormed, 34.6 percent tested positive for STH infections. Poverty and number of siblings are significantly and positively correlated with infection and reinfection, and parental education is significantly and negatively correlated with infection and reinfection. Given the ineffectiveness of treatment in these areas to date, for anthelminthic campaigns to actually succeed, China must pay more attention to local-level incentives to improve children's health.

Key words: deworming, intestinal roundworms, poor, reinfection

JEL codes: I14, I15, I18, O10, O53

I. Introduction

The health and education of people in China have improved as a result of the nation's rapid economic growth (Dahlman *et al*., 2007; Wagstaff *et al*., 2009b). The Chinese Government

[a] Center for Chinese Agricultural Policy, Institute for Geographical Sciences and Natural Resource Research, Chinese Academy of Sciences, Beijing, China.

[b] University of Chinese Academy of Sciences, Beijing, China.

*Corresponding author: Email: xbwang.ccap@igsnrr.ac.cn.

[c] Department of Agricultural and Resource Economics, University of California, Davis, USA.

[d] Freeman Spogli Institute for International Studies, Stanford University, Stanford, USA.

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has repeatedly stated its commitment to improving conditions in rural areas (Li, 2010). Since 2003, the government has injected billions of RMB into the rural health-care system, and implemented a complete institutional overhaul (Wagstaff *et al*., 2009c).

Despite the growing institutional and financial support, there are still some public health issues neglected by the Chinese Government. Since the late years of the 20th century China's health officials have focused on controlling high-profile infectious diseases, such as severe acute respiratory syndrome and tuberculosis, and meeting institutional goals for universal health care (Blumenthal and Hsiao, 2005). Although researchers agree that China has achieved progress (Wang *et al*., 2007a; Wagstaff *et al*., 2009a), there are still a number of neglected conditions that plague large sections of the population, including nutritional problems, anemia (Luo *et al*., 2010), mental illnesses, such as depression (Phillips *et al*., 2009), and physical handicaps, such as uncorrected vision (Glewwe *et al*., 2006). Many of these ailments are relatively minor and can be easily treated outside hospitals. However, when treatment does not occur serious side effects can develop and wide swaths of the population can be affected. This a is problem not only in China, but also in other developing countries (Canning *et al*., 2006). When treatment is not administered or is ineffective, diseases may quietly fester, damaging the health of individuals and negatively affecting national productivity.

In the present paper we focus on a neglected disease in China: the soil-transmitted helminth (STH) infection. The main species of soil-transmitted helminths that infect people are *Ascaris lumbricoides* (a roundworm), the hookworms *Necator americanus* and *Ancylostoma duodenale* and the whipworm *Trichuris trichiura*. STH is endemic in more than 130 countries/territories (WHO, 2008). It is estimated that STH prevalence is approximately 26 percent for roundworm, 15 percent for hookworm and 17 percent for whipworm throughout the developing world (de Silva *et al*., 2003). Children are disproportionately vulnerable to STH infections. Globally, there are approximately 800 million children infected with STH, and most of them live in developing countries (Chan, 2011).

The literature on China, although mostly focusing on a single region, seems to support the claim that there has been a resurgence of STH infections in China. High STH prevalence has been observed in various regions of the country, including Yunnan (Steinmann *et al*., 2008), Fujian (Xu *et al*., 2000) and Hunan Provinces (Zhou *et al*., 2007). However, most studies are small, and limited to a single township or village. A parasitological survey of 274 school children, aged 10–12 years, in five villages in Hunan Province shows that the STH infection rate is 37.3 percent in girls and 33.3 percent in boys (Zhou *et al*., 2007). The prevalence of the three main STH (*Ascaris*, hookworm and *Trichuris*) in 215 individuals in

1 village in the southern part of Yunnan Province was above 85 percent.

Within our study areas, the National Ministry of Health survey of helminth prevalence from 2001 to 2004 included 356 629 individuals across China, and encompassed several studies by local Centers for Disease Control and Prevention (CDC), including Guizhou Province (Coordinating Office of the National Survey on the Important Human Parasitic Diseases, 2005). The Guizhou Provincial CDC found an STH prevalence of 53.8 percent among 4091 primary and middle school students, and 48.3 percent among 1748 children of preschool age during the study period of 2001–2004 (Wang *et al*., 2007b). A more localized study in Guizhou shows similar rates of 50.0 percent in 2007 among children aged 2–12 years in a rural, mountainous county in western Guizhou (Chen and Xia, 2010). These rates suggest that STH infections persist at high levels among the rural population in Guizhou Province.

Not only has there been little research on the prevalence of STH infections in China, but there is limited concern regarding the ineffectiveness of recent efforts to control these infections. Ziegelbauer *et al*. (2010) study two schools in Yunnan Province: one student population underwent annual deworming treatment for several years and the other school offered no deworming treatment. They find a significant difference in the prevalence and intensity of infections between the two schools, but no significant difference in the self-rated quality of life or end-of-term grades among students with infections compared to students without infections. They did find that students infected with *Ascaris* had significantly lower measures of self-rated health. Besides the small sample size, one of the main drawbacks of the study is that the two sample schools are quite different. The school offering deworming is bigger and located on the outskirts of a large city, while the other school is a small boarding school located in a remote rural area. These differences could lead to problems in identifying causality.

To our knowledge, there are no large statistical studies that have measured the correlates of the decision to seek deworming treatment. The main purpose of the present paper is to report on the relationship between deworming treatment and STH infection in rural China and to identify the individual and household characteristics correlated with the decision to deworm. To achieve these goals, we adopt a two-pronged approach. We measure STH infection rates among school-aged children in rural Guizhou, then measure reinfection rates among children who have been dewormed in the past, before analyzing the effect of past deworming on current infection status. Furthermore, we identify the factors associated with STH infection, reinfection and participation in deworming activities, and compare the prevalence of STH infection rates and effectiveness of deworming activities between Han and ethnic minorities.

The rest of the paper is organized as follows. Section II describes the data and the methodology. Section III documents the prevalence and intensity of STH infections, the deworming efforts and the subsequent reinfection status in rural Guizhou. Using multivariate analysis, we shed light on: the effectiveness of deworming efforts, who chooses to deworm, and what other factors are associated with infection and reinfection status. We also describe how the prevalence of STH infection, deworming and reinfection rates differ between communities of Han and communities of ethnic minorities. Section IV concludes.

II. Data and Methods

1. Study Setting and Sample Size

This survey of impoverished children in rural settings was carried out in June and September of 2010 in Guizhou Province, located in China's south-west. The high rates of poverty and the humid climate are conducive to STH infection. Guizhou is demographically one of the most ethnically diverse provinces in China, with minority groups representing 35.7 percent of the total population (NBS, 2012).

Six rural counties are randomly selected from the bottom quartile of counties based on average net per capita incomes (NBS, 2010). The average net per capita income in the study areas is US$433/year (NBS, 2011).

We chose two groups of children, those aged 3–5 and those aged 8–10 years, to conduct our research. Each group differs with respect to socialization and exposure to school environments. For the sampling strategy, refer to Wang *et al*. (2012).

In each sample village we randomly sampled 11 preschool-aged children and 11 school-aged children. This led to a total sample size of 844 preschool-aged children and 880 school-aged children, for a total of 1724 students in 48 schools and 94 villages (see Table 1). Because fecal samples were unattainable for some children, some sample villages have

Table 1. Sample Description

County	Survey date	Villages	Schools	Sampled children	Of which:	
					3–5 years	8–10 years
County 1	June 2010	15	8	261	121	140
County 2	June 2010	16	8	267	138	129
County 3	June 2010	16	7	283	122	161
County 4	September 2010	15	8	309	153	156
County 5	September 2010	16	9	323	163	160
County 6	September 2010	16	8	281	147	134
Total		94	48	1724	844	880

Note: Because multiple villages have been merged into 1 administrative village in Counties 1 and 4, our sample includes only 15 villages instead of 16.

fewer than 22 observations with fecal samples. In no case are there fewer than 8 pre-school aged children and 8 school-aged children who provided samples. On average, there are 9.36 (880/94) school-aged children per sample village and 8.98 (844/94) preschool-aged children per sample village.

2. Data Collection, Stool Sample and Laboratory Testing

The primary variable of interest is the stool parasite status of the selected child; that is, whether positive or negative for any of three types of STH, as determined by a single stool sample. In addition, the intensity of every infection according to egg density per gram was measured using World Health Organization (WHO) standard protocols (WHO, 2011). Other variables and characteristics, such as household eating habits and sanitation information, were collected using a socioeconomic survey instrument. The survey contained questions about individual and household characteristics, health and sanitation behavior, and whether the child has taken anti-helminthic medication within the 18-month period prior to the survey. The school-aged children completed the survey themselves under the direct supervision of trained enumerators from the Chinese Academy of Sciences. The preschool-aged children's data is obtained by trained enumerators who interviewed the children's parents or caregivers.

Stool samples of each of the children included in the study are collected once and sent to the county CDC. There is one lab per county, for a total of six labs. The majority of the samples were tested the same day that they were collected. Because of time and labor constraints, a small fraction of samples were tested the day after collection. These samples were stored overnight in the CDC laboratory refrigerator, which is kept at a constant 4°C. The Kato–Katz smear method (CDC, 2008) was used for species-specific identification of parasite eggs: *Ascaris*, hookworm and *Trichuris*. A single smear test was performed on each sample. Samples found to be positive for any of these three parasites underwent egg burden counts to determine the eggs per gram (epg) of feces, using standard WHO protocol. CDC employees at the county level examined the samples and performed the tests. As a quality control, 10 percent of samples were also checked by a parasite expert from the National Institute for Parasitic Disease to verify the initial diagnosis.

3. Hypotheses and Econometric Analysis

To better understand the relationship between deworming treatment and STH infection in rural China, we test three hypotheses using probit models for the different sample sizes:

$$P_i = a + b_i X_i + e_i \,. \qquad (1)$$

The first hypothesis addresses whether deworming is effective for reducing STH infections among school-aged children in rural China. The dependent variable, P_i, is a dummy variable equal to 1 if the child is infected with STH, and 0 otherwise, and i is the number of sampled children (1724). X_i includes a dummy variable to represent the deworming history (following Wang *et al*., 2012). It equals 1 if anyone reported taking deworming medicine within the 18-month period prior to the survey and 0 otherwise; X_i also includes a vector of control variables, comprising household wealth measured by an asset index,[1] individual and household characteristics, and self-reported health and sanitation behavior.

The second hypothesis concerns which factors are significantly correlated with STH reinfection. To test the hypothesis we focus on the subsample of children who have undergone deworming treatment in the past (868). P_i is a dummy variable equal to 1 if tested positive for STH infection, and 0 otherwise for the sampled children whose reported taking deworming medicine within the 18-month period prior to the survey.

The final hypothesis concerns which factors are statistically significantly correlated to the household/individual decision to undergo deworming treatment. The sample size is all of the sampled children (1724). P_i is a dummy variable equal to 1 if individuals report having taken deworming medicine within the 18 months prior to the survey, and 0 otherwise. To test the second and third hypotheses, the independent variables are the same as those used in testing the first hypothesis excluding the dummy variable representing children's deworming history. a represents a constant. β_i are the coefficients of interest.

III. Results

1. Summary Statistics

We collected data on a variety of individual and household characteristics, including age, gender, number of siblings and parental education. In our sample, 45.1 percent of children are female and 54.9 percent are male, a ratio typical of most poor areas in China (NBS, 2010). The average number of siblings is 1.6, which means that, on average, each family has two or three children. Only 31.8 percent of mothers and 48.7 percent of fathers have 9 years of education or more.[2]

Health and sanitation habits include: whether the children wash their hands before eating; whether the children wash their hands after using the toilet; whether the children consume undercooked or raw meat or vegetables; and whether the children drink unboiled water. The results are discouraging. Only 54.4 percent of children report that they wash

[1] The asset index is divided into four quartiles from fewest assets to most assets.

[2] These are from the descriptive statistics of the variables used in estimations, and can be provided by the authors upon request.

their hands before eating, while 49.3 percent report that they wash their hands after using the toilet. Although we do not have data on why hand washing is so infrequent, our field visits and interviews suggest that one possible reason may be a lack of water near the toilet and cooking facilities. Indeed, many families only have a single faucet in the courtyard of their homes, and no indoor plumbing. Our data also show that 20.3 percent of children report consuming uncooked meat, while the rates for consumption of uncooked vegetables and unboiled drinking water are as high as 75.0 and 85.3 percent, respectively.

Infection rates in the study sites are high. Overall, 37.53 percent of the sampled children have been infected with one or more of the three types of STH (see Table 2) at some point. *Ascaris* infection rates are the highest among the three, and infection with hookworm is the lowest. Infection rates were higher in school-aged children (42.27 percent) than in preschool-aged children (32.58 percent), and these differences are statistically significant ($p < 0.01$), indicating that the infection rate of STH is statistically higher for school-aged children than that for preschool-aged children. Statistically significant differences in infection rates between the two age groups were also observed for the three types of STH when compared separately. The high infection rates and the differences between the two age groups are consistent with recent published observations.[3]

The deworming rate in Guizhou is lower than we expected, given the low cost of treatment and the past record of China's deworming initiatives. Only half of the samples (50.35 percent) reported that they had taken deworming medicine within the past 18 months

Table 2. Prevalence of Soil-transmitted Helminth Infections in Guizhou Province, 2010

	All sampled children (%)	3–5 year-old (%)	8–10 year-old (%)	*p*-value of difference
Infected	37.53	32.58	42.27	0.0000
Ascaris	32.71	28.79	36.48	0.0007
Hookworm	1.39	0.47	2.27	0.0014
Trichuris	10.85	6.64	14.89	0.0000
Not infected	62.47	67.42	57.73	NA
Total	100.0	100.0	100.0	NA
Sample size	1724	844	880	NA

Notes: Because some students have multiple infections, the sum of the by-species infection rates is larger than the total infection rate. The last column shows the *p*-value of the *t*-statistic of the difference in infection rates between the two age groups. NA, not available.

[3] Wang *et al*. (2012) conduct a survey on three counties in Sichuan Province and three counties in Guizhou Province in 2009–2010. During the study they found that the overall prevalence of intestinal infections was 40.1 percent for school-aged children and 33.9 percent for preschool-aged children. The sample studied in the present paper include three Guizhou counties studied by Wang *et al*. (2012). In the present paper, we add three Guizhou counties with minority populations.

Table 3. Deworming Rates in Guizhou Province, 2010

	All sampled children		3–5–year-old children		8–10–year-old children		*p*-value of difference
	Number	Dewormed (%)	Number	Dewormed (%)	Number	Dewormed (%)	
County 1	261	59.77	121	76.03	140	45.71	0.0000
County 2	267	55.43	138	70.29	129	39.53	0.0000
County 3	283	34.63	122	49.18	161	23.60	0.0000
County 4	309	43.69	153	54.90	156	32.69	0.0001
County 5	323	49.54	163	68.71	160	30.00	0.0000
County 6	281	60.85	147	72.11	134	48.51	0.0000
Total	1724	50.35	844	65.28	880	36.02	0.0000

Notes: Percent dewormed indicates whether the child reported taking deworming medication within the past 18 months. The last column shows the *p*-value of *t*-statistic of the difference in deworming rates between the two age groups.

(see Table 3). Preschool-aged children had significantly higher deworming rates than school-aged children ($p < 0.01$). The lower rate of deworming among school-aged children seems counterintuitive because schools are a natural contact place for an at-risk population, and it would be easier to treat children when they are together in a single place rather than when they are spread out, as the preschool-aged children are.

A total of 34.56 percent of dewormed children had been reinfected with one or more of the three types of STH by the time of our survey; reinfection rates were significantly higher ($p < 0.05$) among school-aged children (39.75 percent) than among preschool-aged children (31.58 percent, see Table 4). Table 5, column 2 focuses on reinfection rates for *Ascaris*, because prevalence was highest for this species. Although we do find significantly lower rates of *Ascaris* infection among dewormed children ($p < 0.05$), 29.95 percent of dewormed children had been reinfected by the time of our survey. These high reinfection rates raise concern that the deworming efforts underway in Guizhou are not adequate to curb the STH problem.

While prevalence data describe the proportion of individuals infected, they do not provide an indication of the intensity of infection, which is also a central determinant of

Table 4. Reinfection Rates in Guizhou Province, 2010

	All sampled children (%)	3–5-year-old children (%)	8–10-year-old children (%)	*p*-value of difference
Infected	34.56	31.58	39.75	0.0148
Ascaris	29.95	27.22	34.70	0.0206
Hookworm	0.81	0.54	1.26	0.2557
Trichuris	8.87	6.35	13.75	0.0006
Not infected	65.44	68.42	60.25	NA
Total	100.0	100.0	100.0	NA
Sample size	868	551	317	NA

Notes: All sampled children are those who reported taking deworming medication within the 18 months prior to the survey. The last column shows the *p*-value of the *t*-statistic of the difference in reinfection rates between the two age groups. NA, not available.

Table 5. *Ascaris* Burden for Non-dewormed and Dewormed Children by Age Cohort in Guizhou Province, 2010

	Sample size	*Ascaris* infection rates (%)	If infected, mean *Ascaris* burden (epg)	If infected, percentage with worm burden that is:		
				Light	Moderate	Heavy
All sample children	1724	32.71	11 142	59.22	36.70	4.08
Not dewormed	856	35.51	10 882	59.87	36.51	3.62
Dewormed	868	29.95	11 446	58.46	39.92	4.62
p-value of difference		0.0132	0.7672	0.7352	0.9200	0.5515
3–5–year old children	844	28.79	12 538	58.02	36.21	5.77
Not dewormed	293	31.84	14 573	54.84	37.63	7.52
Dewormed	551	27.22	11 276	60.00	35.33	4.67
p-value of difference		0.1586	0.3349	0.4302	0.7181	0.3544
8–10–year old children	880	36.48	10 085	60.12	37.07	2.81
Not dewormed	563	37.47	9255	62.08	36.02	1.90
Dewormed	317	34.70	11 677	56.36	39.09	4.53
p-value of difference		0.4118	0.2939	0.3219	0.5900	0.1733

Notes: The severity of *Ascaris* burden is defined by the number of *Ascaris* eggs per gram (epg) of feces. Light infection is defined as <4999 epg; moderate infection is defined as 4999–49 999 epg, and heavy infection is defined as >49 999 epg. The *p*-value of *t*-statistics of difference is reported.

STH transmission dynamics (Bundy and de Silva, 1998). Worm burden provides an estimate of the number of roundworms in the intestines, a commonly used indicator of intensity of infection. A successful anthelminthic treatment should reduce both the prevalence of STH in the population and the intensity of infection, and can typically be observed as a change in the distribution of worm burden (i.e. shifts from heavy to light worm burden). Table 5 shows data on worm burden separately for children who have been dewormed in the past 18 months and children who have not been dewormed in the past 18 months. As prevalence rates are highest for *Ascaris*, we focus on worm burden measurements for children infected with *Ascaris*.

Our analysis of the worm burden data, like our analysis of the prevalence data, casts some suspicion on the effectiveness of the deworming programs in the sample villages and schools. In particular, the data show that there is no difference in mean *Ascaris* burden between children who have been dewormed and those who have not (p = 0.7672, see Table 5). There is also no significant change in the distribution of *Ascaris* burden between children who have been dewormed and those who have not. This holds true for both preschool-aged children and school-aged children (see Table 5).

Why do the infection rates remain so high among children who have received deworming treatment? In addition, why are infection intensities unchanged among children who have received treatment? One possibility is that individuals who take deworming medicine may be taking an insufficient dose. National guidelines released by the CDC (2010) recommend the annual administration of only 200 mg of albendazole for children aged 2–12 years, only half of the 400-mg dose recommended by the WHO (2006).

A second reason may be related to the frequency of treatment. The WHO treatment guidelines recommend that in communities with infection rates of 20–50 percent (the rate observed in our study area), school-aged children should be treated once a year. However, our survey asked individuals about their deworming history over the past 18 months. It is possible that many of them did not undergo deworming treatment once a year as recommended, which would mean that they are not receiving treatment with sufficient regularity for it to be effective.

2. Multivariate Results

To more precisely estimate the relationship between deworming treatment and infection rates among children in rural Guizhou, we use a probit estimator to regress deworming history on infection status while controlling for different sets of control variables. The results of the regression estimates are shown in columns 1–3 of Table 6. The first column includes only controls for household wealth as measured by an asset index. Models 2 and 3 include additional control variables (individual characteristics and healthy habits). According to our analysis, there is no significant correlation between deworming and infection status (row 1 in Table 6). Although there appears to be a significant negative correlation in column 1, the correlation fades in terms of magnitude and statistical significance as we refine the model by adding additional control variables (models 2 and 3 in Table 6).

What factors are associated with infection? In all three specifications (models 1–3 in Table 6), household wealth is significantly correlated with infection. The poorer a household is, the more likely it is that the children who live there will be infected. We also find that the number of siblings is significantly and positively correlated with infection, and that living in a family with one additional sibling increases the probability of being infected by approximately 8 percent (see models 2 and 3 in Table 6). Parents' educational background is also associated with the likelihood of children being infected. If a father has 9 years of education or more, the probability of his children being infected with STH is 20 percent lower than that of children whose fathers have less than 9 years of education (see models 2 and 3 in Table 6). We find no significant correlation between STH infection and hand washing behavior or the consumption of uncooked meat or unboiled water.

Table 6. Probit Estimates of Infection and Reinfection in Guizhou Province, 2010

Dependent Variable	Full sample (1 = infected, 0 = otherwise)			Dewormed sample (1 = infected, 0 = otherwise)		
	(1)	(2)	(3)	(4)	(5)	(6)
Reported taking deworming medicine in past 18 months (1 = yes, 0 = no)	–0.151*	–0.087	–0.080			
	(2.44)	(1.32)	(1.21)			
Household wealth						
Quartile 2	–0.157	–0.148	–0.146	–0.121	–0.101	–0.100
	(1.80)	(1.66)	(1.64)	(0.98)	(0.79)	(0.77)
Quartile 3	–0.226**	–0.170	–0.140	–0.272*	–0.203	–0.195
	(2.67)	(1.95)	(1.59)	(2.22)	(1.59)	(1.52)
Quartile 4	–0.349***	–0.238**	–0.192*	–0.311*	–0.171	–0.150
	(4.07)	(2.62)	(2.04)	(2.56)	(1.31)	(1.11)
Individual characteristics						
Student status (1 = school-aged child, 0 = preschool-aged child)		–0.512	-0.582		–0.224	–0.310
		(0.81)	(0.92)		(0.21)	(0.29)
Age		0.0802	0.0784		0.125	0.126
		(1.38)	(1.35)		(1.69)	(1.70)
Student × age		0.025	0.034		–0.034	–0.028
		(0.29)	(0.40)		(0.25)	(0.21)
Gender (1 = male, 0 = female)		0.006	–0.001		–0.061	–0.062
		(0.10)	(0.01)		(0.67)	(0.68)
Number of siblings		0.085**	0.082**		0.094*	0.090*
		(3.07)	(2.94)		(2.39)	(2.27)
Mother finished secondary school or above (1 = yes, 0 = no)		–0.088	–0.082		–0.222*	–0.211*
		(1.19)	(1.09)		(2.10)	(1.98)
Father finished secondary school or above (1 = yes, 0 = no)		–0.202**	–0.201**		–0.174	–0.169
		(2.96)	(2.93)		(1.76)	(1.70)
Health and sanitation habits						
Wash hands before dinner (1 = yes, 0 = no)			–0.035			–0.093
			(0.45)			(0.83)
Wash hands after using toilet (1 = yes, 0 = no)			–0.125			0.056
			(1.59)			(0.48)
Eat uncooked vegetables (1 = never, 0 otherwise)			0.192**			0.159
			(2.61)			(1.42)
Eat uncooked meat (1 = never, 0 otherwise)			–0.010			–0.040
			(0.13)			(0.33)
Drink un-boiled water (1= never, 0 otherwise)			–0.063			–0.158
			(0.68)			(1.11)
Constant	–0.0666	–0.550*	–0.517*	–0.224**	–0.775*	–0.737*
	(1.03)	(2.26)	(2.00)	(2.66)	(2.48)	(2.16)
Sample size	1724	1724	1724	868	868	868

Notes: Marginal effects of the probit regressions are reported in the table. *t*-statistics are in parentheses. ***, ** and * denote statistical significance at the 1, 5 and 10-percent level, respeectively. The first quartile represents households with the fewest assets and the fourth quartile represents households with the most assets. Quartile 1 is used as the reference group, so it is not included in the table.

3. What Causes Reinfection?

When we limit our sample to children who reported having taken deworming medication in the 18 months prior to our survey, we find similar results: household wealth, number of siblings and parents' education all predict risk of reinfection. Household wealth is significantly correlated with the likelihood of reinfection. The poorer one is, the higher the likelihood of reinfection (see model 4 in Table 6). However, the significant correlation disappears when we control for additional individual characteristics and healthy habits (see models 5 and 6 in Table 6). We also find that the number of siblings is significantly and positively correlated with the likelihood of reinfection. Living in a family with more than one sibling increases the probability of reinfection by approximately 9 percent (see models 5 and 6 in Table 6). For the subsample of children who have undergone deworming treatment, it is mother's education rather than father's that is negatively and significantly correlated with reinfection. When a mother has 9 years of education or more, the probability of her treated children becoming reinfected is approximately 22 percent lower than that of children whose mothers have less than 9 years of education (see models 5 and 6 in Table 6). Consistent with the results of our other models, we find no statistically significant results linking reinfection status with the child's health or sanitation habits. This may be the result of the low variance in sanitation habits across the sampled population.

4. Who Received Treatment?

Our analyses indicate that there are few correlates of the decision to seek deworming treatment. According to our results (see Table 7), treatment status is not linked to household wealth. The coefficients on the asset variable (rows 1–3 in Table 7) are statistically insignificant (from zero, at the 10-percent level), indicating that there is no correlation between receiving treatment and household wealth. In fact, none of the variables we examine are significantly correlated with the decision to be treated. It seems that individuals in our sample either do not have a clear strategy for being treated for STH infections, or are not participating in a system that seeks out at-risk children and provides them with treatment.

This is consistent with the structure and organization of the rural Chinese health-care system, in which local health-care providers have little or no incentive to provide or even promote community treatment of low cost and low-profit diseases. Rather, the decision to seek care is left to the discretion of individuals and their families, who are likely uninformed about both the health risks of STH infection and the benefits of treatment.

5. Heterogeneity between Han Chinese and Minority Chinese

In this subsection we examine whether ethnicity is a determinant of infection, deworming status and reinfection after deworming. We collected data on minority status for three of six sample counties. In these areas, the share of minorities is 80.9, 45.5 and 5.7 percent, respectively. We use this data to explore whether there are any systematic differences

Table 7. Probit Estimates of Treatment Status in Guizhou Province, 2010

Dependent variable	Full sample (1 = dewormed, 0 = not)		
	(1)	(2)	(3)
Household wealth			
Quartile 2	0.107	0.152	0.163
	(1.24)	(1.69)	(1.81)
Quartile 3	0.052	0.119	0.123
	(0.63)	(1.36)	(1.38)
Quartile 4	0.119	0.139	0.156
	(1.43)	(1.54)	(1.67)
Individual characteristics			
Student status (1 = school-aged child, 0 = preschool-aged child)		–0.646	–0.528
		(1.02)	(0.83)
Age		0.065	0.070
		(1.13)	(1.22)
Student × age		–0.050	–0.063
		(0.59)	(0.74)
Gender (1 = male, 0 = female)		0.016	0.020
		(0.25)	(0.31)
Number of siblings		0.019	0.017
		(0.67)	(0.61)
Mother finished secondary school or above (1= yes, 0 = no)		0.049	0.060
		(0.67)	(0.82)
Father finished secondary school or above (1= yes, 0 = no)		0.046	0.046
		(0.67)	(0.67)
Health and sanitation habits			
Wash hands before dinner (1 = yes, 0 = no)			–0.046
			(0.60)
Wash hands after using toilet (1 = yes, 0 = no)			0.054
			(0.69)
Eat uncooked vegetables (1 = never, 0 otherwise)			–0.127
			(1.72)
Eat uncooked meat (1 = never, 0 otherwise)			0.068
			(0.84)
Drink un-boiled water (1 = never, 0 otherwise)			–0.125
			(1.38)
Constant	–0.058	–0.023	–0.074
	(1.01)	(0.10)	(0.29)
Sample size	1724	1707	1707

Notes: Marginal effects of the probit regressions are reported in the table. *t*-statistics are in parentheses. The first quartile represents households with the fewest assets and the fourth quartile represents households with the most assets. Quartile 1 is used as the reference group, so it is not included in the table.

between Han and other ethnic minorities in terms of STH prevalence, treatment status and reinfection rates.

Table 8 reports ethnicity-specific infection rates in the three sampled counties for which we have data on minority status. Infection rates among the Han community are 11.86, 46.02 and 48.86 percent in each of the three counties. In contrast, infection rates among the non-Han community are 24.40, 44.22 and 62.50 percent, respectively. Overall, the infection rates among ethnic minorities are approximately 13 percent higher than those among Han (in two of three sampled counties). These differences imply that STH infections are more severe among China’s minority groups.

The ethnicity-specific deworming rates in the three samples counties are shown in

Table 8. Infection Rate by Minority Status and County in Guizhou Province, 2010

	County 4		County 5		County 6	
	Sample size	Infection rate	Sample size	Infection rate	Sample size	Infection rate
All	309	22.01 (%)	323	45.20 (%)	281	49.64 (%)
Han	59	11.86 (%)	176	46.02 (%)	265	48.86 (%)
Non-Han	250	24.40 (%)	147	44.22 (%)	16	62.50 (%)
p-value of difference		0.0367		0.7464		0.2911

Note: *p*-value of *t*-statistics of difference is reported.

Table 9. Deworming rates among the Han communities range from 43.18 to 59.09 percent. The deworming activities of the non-Han communities range from 42.0 to 93.75 percent. In two of the three counties, the deworming rates of minority Chinese were significantly higher than those of Han (approximately 14 and 35 percent higher, respectively, with both significant at the 1-percent level). Hence, the evidence shows that deworming efforts are actually more common in minority communities.

Do the higher treatment rates among minority populations result in lower reinfection rates compared to Han communities? The results in Table 10 suggest the opposite. The reinfection rates among Han Chinese are 13.33, 35.53 and 44.87 percent, respectively, in each of the three counties. The reinfection rates among non-Han Chinese are 26.67, 38.09 and 60.0 percent. In all three counties, the reinfection rates of minority Chinese are higher than those of Han (13.3, 2.6 and 15.1 percent). However, the difference is not statistically significant in any of the three counties, suggesting that there is no evidence on the difference

Table 9. Deworming Rate by Minority Status and County in Guizhou Province, 2010

	County 4		County 5		County 6	
	Sample size	Deworming rate	Sample size	Deworming rate	Sample size	Deworming rate
All	309	43.69 (%)	323	49.54 (%)	281	60.85 (%)
Han	59	50.85 (%)	176	43.18 (%)	265	59.09 (%)
Non-Han	250	42.00 (%)	147	57.14 (%)	16	93.75 (%)
p-value of difference		0.2191		0.0124		0.0056

Note: *p*-value of *t*-statistics of difference is reported.

Table 10. Reinfection Rate by Minority Status and County in Guizhou Province, 2010

	County 4		County 5		County 6	
	Sample size	Infection rate	Sample size	Infection rate	Sample size	Infection rate
All	135	23.70 (%)	160	36.88 (%)	171	46.20 (%)
Han	30	13.33 (%)	76	35.53 (%)	156	44.87 (%)
Non-Han	195	26.67 (%)	84	38.09 (%)	15	60.00 (%)
p-value of difference		0.1319		0.7386		0.2643

Notes: *p*-values of *t*-statistics of difference are reported. Children are tested positive for infection among those who reported taking deworming medication within the 18 months prior to the survey.

of reinfection rate between Han and non-Han Chinese.

Overall, in the three counties for which we have information about minority infection rates, the prevalence of STH infections is higher among minority groups than among Han groups. However, the difference is only statistically significant in one county. Deworming efforts are also more common in minority communities. In two of the three counties, the deworming rates of minorities are significantly higher than those of Han communities. Unfortunately, the higher deworming rates among minority groups do not translate to lower rates of reinfection.

To better explore the heterogeneity in the effectiveness of deworming treatment between Han and minorities, and to identify the factors correlated with deworming decisions and subsequent reinfection status, we conduct multivariate regression analysis using the subsample of the three counties with minority information. We use the same models that are used in the main results section, adding minority dummies to control for unobserved differences in minority cultures and county fixed effects to control for large observed differences in percent minority across the three counties. We do not find any statistically significant evidence that minority status is a determinant of infection. Minority status is not associated with deworming decisions or reinfection status.

IV. Conclusions

In the present paper we document the prevalence and intensity of STH infections among 1724 children in rural, impoverished and minority areas of Guizhou Province in south-west China. According to our data, 37.5 percent of the sample children are infected with one or more of the three types of STH. The high prevalence of STH infections found in Guizhou is consistent with findings from other regions of China (Zhou *et al*., 2007; Wang *et al*., 2012). Of the three types of STH, infection with *Ascaris* is most common. Hookworm is the least prevalent roundworm in the study areas. Overall infection rates are higher in school-aged children, and slightly lower in preschool-aged children.

Because only a single stool sample is collected for each child in this study, infection rates are likely underestimated. A single stool sample can underreport infection in an individual because of the temporal variation in egg excretion over hours and days (Wang *et al*., 2013). Obtaining only a single sample for *Ascaris* and *Trichuris* could lead to underestimated infection rates of up to 50 percent (Knopp, 2008). Therefore, the real infection rate is likely to be even higher than what our data indicate.

We next investigated the relationship between deworming and infection. We find low self-reported deworming rates (50.35 percent, see Table 3) and a high overall reinfection rate of 34.56 percent (see Table 4). In addition, we find no evidence of reduction in the worm burden. These findings raise the concern that the deworming efforts currently employed in the study areas are ineffective. This hypothesis is supported by the results of the multivariate analysis, which shows no significant correlation between deworming treatment and STH infections when we control for multiple variables.

We find few correlates of deworming decisions. It seems that individuals in our sample either do not have a clear treatment-seeking strategy, or are not part of a system that can correctly identify at-risk children and provide them with treatment. These findings underscore the importance of a long-term, systematic and consistent deworming regimen.

It is important to note that a potential limitation of this study is its reliance on a self-reported variable: “Did you (your child) take deworming medication within the past 18 months?” Given that no medical records exist of deworming activities in our study areas, recall is the next best method of obtaining treatment history.

Our study explores other factors associated with infection and reinfection. We identify number of siblings as significantly and positively correlated with infection and reinfection, and find household wealth and years of parental education to be significantly and negatively correlated with infection and reinfection.

Based on our findings, we suggest that China should consider launching a deworming treatment strategy that is consistent with the recommendations of the WHO (2005). According to WHO treatment guidelines, the implementation of STH control programs at the country level requires strong links with existing interventions. For example, in Cambodia, the government has developed a health package that delivers deworming drugs together with vitamin A, which has reduced delivery costs and enabled remote communities to be included in the program (WHO, 2005). We believe that it is entirely possible for China to use this “hitching a lift” strategy. Our previous research has shown that as many as 39 percent of rural Chinese children suffer from iron deficiency anemia, which, in turn, can be caused by STH infections (Luo *et al.*, 2012). Therefore, it may be of interest to consider the possible “bundling” of deworming medication with iron and other micronutrient supplementation programs (WHO, 2005).

Future research is required to determine the reasons for the ineffectiveness of deworming efforts in our sample areas. Certain aspects of China’s current health system are not compatible with the immediate launch of regular deworming strategies. China’s local officials have incentives that are poorly aligned with ultimate social objectives. Hospitals have little motive to deliver public health programs. The profit-motivated health-care providers in rural China have little to gain from implementing a low-cost STH treatment program. Teachers and principals often avoid taking responsibility for basic health interventions. Because no single actor is incentivized to take responsibility for STH infections, deworming efforts are condemned before they even begin. For anthelminthic campaigns to actually succeed, China will need to pay close attention to local-level incentives to improve child health.

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