Evaluating Long-Term Impacts of Sustained Mass Deworming: South Korea 1969-1995

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Abstract

South Korea successfully implemented a sustained, nation-wide deworming campaign, jump-started in 1969 with a three-year massive assistance program from the Overseas Technical Cooperation Agency (OTCA), Japan, culminating in the 1995 WHO declaration that the country is essentially worm-free. We propose to study the long-term impacts of this sustained deworming campaign on educational attainment and productivity gains on the part of beneficiaries. For the purpose, we match individual workers from a current longitudinal study of Korean workers from the Korea Labor and Income Panel Study (KLIPS) with the prevailing worm infection rate at the middle school attended by the worker during his/her last year in junior high school attendance, taking advantage of the identification of the middle school attended by the subjects in the KLIPS. A complementary analysis using population census is conducted. The empirical strategy is inspired by the series of investigations by Hoyt Bleakley on the long-term impacts of deworming in the American South. The results suggests that the full exposure to the risk of soil-transmitted helminthes infection during the childhood lowers years of schooling by 1.0~2.4 years, the probability of achieving high school diploma by 20~51%p and adult earning by 5%p. Further, the effect is estimated to be larger for women than for men, which suggests that the STH eradication campaign was more beneficial to the more disadvantaged group of population.

1. Introduction

Deworming is widely recognized as one of the most cost-effective policy interventions in the developing world. The Copenhagen Consensus in 2012 ranks deworming for children in the 4-th position among 16 most desirable investments in terms of the bang for the buck.[1] Miguel and Kremer (2004) report that one additional year of schooling for a child could be bought at around $3.50 under a school-based deworming program such as the one they investigated in Kenya. Bleakley (2007) estimates that roughly 20 percent of the income gap between the northern and southern United States in 1900 can be attributed to hookworm infection prevalent in the South, and close to 50% of the closing of the income gap between the two regions to the worm eradication that took place during the first half of the 20th century.[2]

South Korea successfully implemented a sustained, nation-wide deworming campaign, starting from 1969 with a three-year massive assistance program from the Overseas Technical Cooperation Agency (OTCA), Japan, the precursor to the Japanese International Cooperation Agency (JICA), culminating in the 1995 WHO declaration that the country is essentially worm-free. We propose to study the long-term impacts of this sustained deworming campaign on educational attainment and productivity gains on the part of beneficiaries. For the purpose, we match individual workers from a current longitudinal study of Korean workers from the Korea Labor and Income Panel Study (KLIPS) with the prevailing worm infection rate at the middle school attended by the worker during his/her last year in attendance, taking advantage of the identification of the middle school attended by the subjects in the KLIPS. We deploy various empirical strategies to measure the impacts of the deworming campaign including double differences based on cohort comparison and an empirical strategy inspired by the series of investigations by Hoyt Bleakley on the long-term impacts of deworming in the American South, essentially utilizing the regional variations in pre-eradication infection rates as a source of exogenous variation in the size of the treatment.

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[1] See www.copenhagenconsensus.com.

[2] Many studies that demonstrate significant gains in children's learning outcomes and cognitive functions due to anthelminthic treatment (Simeon et al. 1995; Nokes et al. 1999; Grigorenko et al. 2006).

The results suggests that the full exposure to the risk of soil-transmitted helminthes infection during the childhood lowers years of schooling by 1.0~2.4 years, the probability of achieving high school diploma by 20~51%p and adult earning by 5%p. Further, the effect is estimated to be larger for women than for men, which suggests that the STH eradication campaign was more beneficial to the more disadvantaged group of population.

2. Previous Studies on the Long Term Consequences of Parasitic Infection

Recent studies show that the exposure to risk of parasitic infection during the childhood generates a serious negative effect in the long run. Based on the analysis of data from four countries in the Americas, Bleakley (2010) argues that full exposure to malaria infection over childhood leads to a 50% reduction in earnings in adult life. Bleakley (2007) suggests that full exposure to hookworm infection during the childhood reduces lifetime income by 43%. Lucas (2010) concludes that malaria infection during the childhood hampers education attainment and literacy, analyzing a sample of females in Sri Lanka and Paraguay. Cutler et al. (2009) report that 40 percentage point reduction in the spleen rate experienced in the most malarious states in India is associated with a 2 percent increase in per-capita household expenditure for males.

Whether one would obtain qualitatively similar results from the study of the Korean deworming campaign, however, remains an open question for at least two reasons. The most prevalent types were roundworms and whipworms in Korea during the heyday of worm infection, different from the earlier studies. There is also the possibility that the worm infection-human capital formation nexus might vary from one setting to another.

3. Nation-wide Deworming Campaign in Korea 1969-1995

Infection by the soil-transmitted helminthes (STH) was highly endemic in South Korea until the late1960s. Hunter et al. (1949) reported that the helminth egg positive rate was 94.2% in 1948 using a sample of 919 specimens at the national level. Seo et al. (1969) found that the value of the same measure was 90.5% for the period 1967 to 1969 for a national sample of 40,581 examinees. The status of intestinal helminth infection could be largely explained by the wide-spread use of human feces as fertilizer and the ubiquity of kimchi in the Korean diet, of which the main ingredients are cabbage and radish, often found to be contaminated by worm eggs.

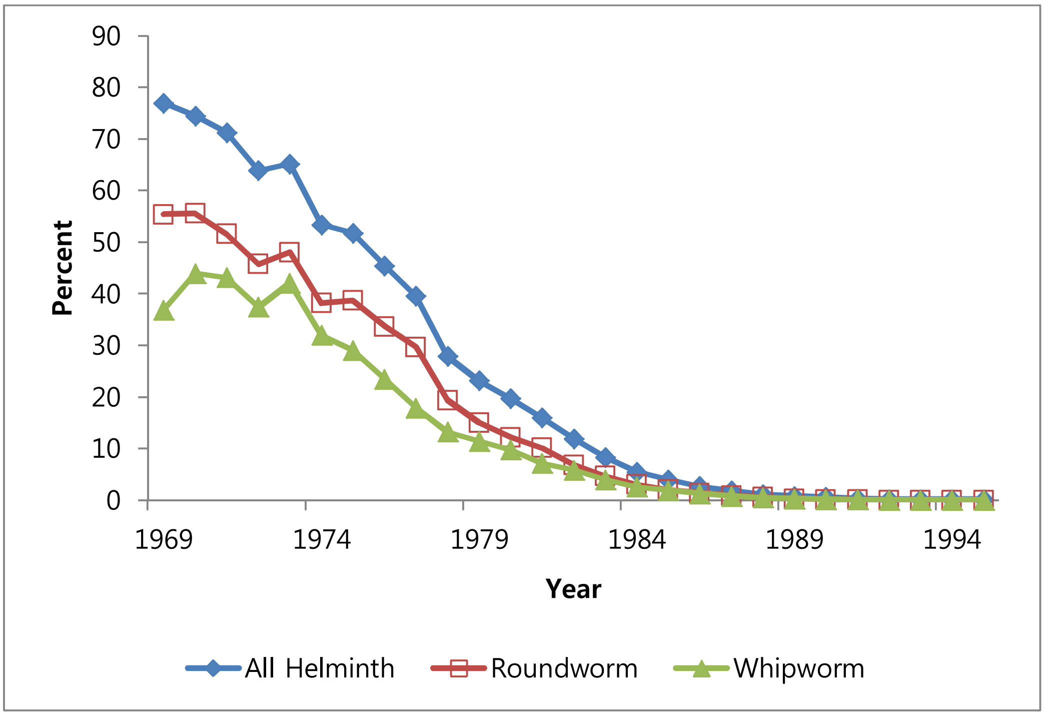
The Korean government initiated mass parasitic control activities in late 1960s. The Parasitic Disease Prevention Act (PDPA) passed by the National Assembly in 1966 mandated worm infection screening of all school children, primary to senior secondary, and administration of treatments to those who tested positive. The Korea Association of Parasite Eradication (KAPE) [3], established in 1963 and put in charge of the implementation of the PDPA, struggled for several years carrying out the mandate due to lack of adequate budgetary support from the government. The nation-wide deworming campaign was effectively kick-started in 1969 with generous support from the OTCA, Japan, precursor agency to today's JICA. The massive aid package included medicine sufficient to treat all infected children for three years, basic set of equipment necessary for screening, and crucially training of technicians to carry out the tests. The deworming aid expired in 1972, but the Korean government overtook financing of the campaign and saw through the sustained implementation till 1995, when the WHO declared Korea worm-free.

In the course of the deworming campaign, all school children were screened twice a year for worm infection, and those who tested positive were administered treating medicine until 1988, after which the screening regime relaxed to once a year, reflecting the dramatic decrease in the infection rates nation-wide. Fortunately for the purpose of the current study, the KAPE has preserved the administration data from the school-based deworming campaign, so we can find out the changes in school-by-school infection rates for each year since 1970. The KAPE supplemented the mandatory testing of all school children with a 0.1% sample study of all Korean population once in every five years beginning from 1971. The eradication campaign also included the promotion of flush toilets and chemical fertilizer as well as the education on personal hygiene for both children and adults.

[3] Anthelmintic drugs used for mass chemotherapy in South Korea have changed over time. Santonin-kainic acid was used in 1969 and early 1970s, piperazine from 1971 to 1981, pyrantel pamoate from 1973 to 1988, mebendazole from 1983 to 1993, and albendazole since 1988(Hong et al. 2006).

As a result of the consistent control programs accompanied by the economic development especially in rural communities, the prevalence of soil-transmitted helminthes declined rapidly over the following two decades. The national egg positive rate of overall intestinal helminthes decreased from 84.3% in 1971 to 41.1% in 1981 and further to 3.8% in 1992 (KAPE 2004). As shown in [Figure 1], the infection rate for all school children shows a similar pattern decreasing from 77.0% in 1969 to 0.8% in 1989. The students' egg positive rate of roundworm (Ascaris lumbricoides) and whipworm (Trichuris trichiura), two major parasites in South Korea, recorded 55.4% and 36.9% in 1969, respectively, and both declined to 0.3% in 1989.

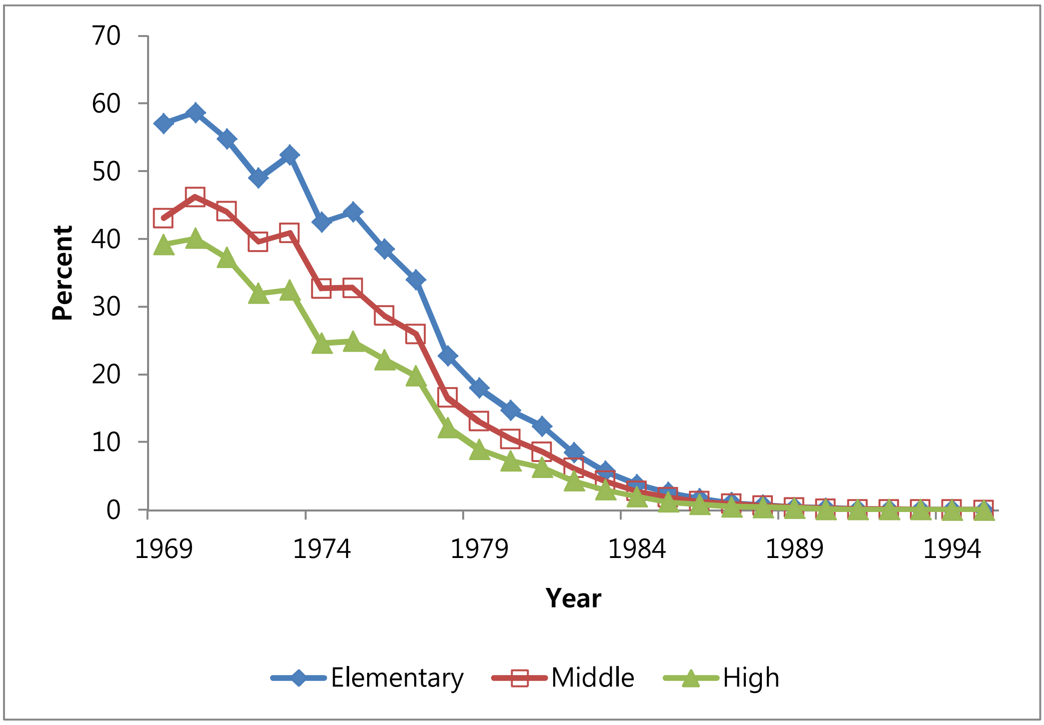
[Figure 1] Soil-transmitted Helminthes Prevalence among Students in Korea



Note: The estimates for the period 1969 to 1988 are the average of the prevalence rates measured in spring and autumn of each year.
Source: Korea Association of Parasite Eradication

Although the trend is similar, the levels of infection rate differed by age of children. [Figure 2] presents the roundworm prevalence over time by school level. The roundworm egg positive rate in 1969 was 57.1% for elementary school children and it was 43.1% for middle school and 39.2% for high school children. The infection rates reached to the level of 0.3~0.4% by 1989 for all levels of school.

<Figure 2> Roundworm Prevalence among Students by School Level in Korea



Note: The estimates for the period 1969 to 1988 are the average of the prevalence rates measured in spring and autumn of each year.
Source: Korea Association of Parasite Eradication

4. Statistical Model and Data Description

For a starter, we employ a standard wage equation in order to estimate the long-run impacts of intestinal worm infection during the childhood as follows.

$$Y_i = \beta X_i + \rho_m E_i^{mid}{}_i + \varepsilon_i \qquad (1)$$

The dependent variable, Y_i , is the log earnings of an individual *i,* or education attainment indicators such as years of schooling and tertiary degree. A set of explanatory variables, X_i , includes observable characteristic such as age, age squared, years of schooling, gender, and job tenure. The exposure to risk of infection over middle school years, denoted by E_i^{mid} , is measured by the average infection rate of the school that the individual attended as a child. Idiosyncratic noise is included as an error term, ε_i .

The main data set for analysis is Korea Labor and Income Panel Survey (KLIPS), a longitudinal study of a representative sample of households and individuals living in urban areas. KLIPS has been conducted annually since 1998 to track the evolution of households and changes in their economic status and activities, including employment and job status, and earned income. The 11^{th} wave of KLIPS contains a supplementary topical module on education history, including the names of junior and senior high schools that each individual entered and graduated. We have incorporated junior high school attendance records into our data set and use the names of junior high, or middle, schools to match school-wide infection rates with individuals.

The measures of intestinal worm infection rate are taken from the bi-annual reports on Intestinal Helminth Examination of Students administered by the KAPE. The KAPE reports provide the helminth egg positive rates for every school during the intervention period. KLIPS and KAPE data are then matched to identify the infection rate of the school during the year of the individual's attendance there.[4]

The empirical model in equation (1) is useful but the coefficient estimates based on the model are potentially biased due to multiple causality. We employ an extensive list of controls to assuage this concern. We also assay a difference in differences exercise based on inter-cohort comparison from different regions of the country, exposed to different levels of worm infection prevalence, partly to address the same concern and also to illustrate how the "big-picture" holds up.

Initial differences in regional infection rates are bound eventually to evaporate as the national infection rate converges ever closer to zero. This means that there is a considerable variation in the extent of reduction in regional infection rates, depending on the initial levels of infection rates. To the extent that this variation is orthogonal to the error term, after a suitable set of controls are adopted, this should permit consistent estimation of the campaign impacts. This is the insight utilized by Bleakley's series of investigations of the impacts of worm eradication in the American South. (Bleakley 2010, for instance)

[4] It is possible to measure the infection rate during the elementary school years, but it could only be estimated at county or province level since KLIPS does not provide the names of one's elementary school.

In the alternative model in equation (2), STH infection rate at the individual's middle school before the intervention (E_i) is interacted with the duration of exposure to the deworming, or eradication program (Exp_j). Given that the serious nation-wide deworming campaign started in 1969, Exp_j is measured by the ratio of years after 1969 over the first 18 years of life(one's age when one graduates from senior high school in Korea), following the specification in Bleakley (2010). The area(i), birth cohort(j) and time(t) specific effects are controlled for in the model.

$$Y_{ijt} = \theta E_i \times Exp_j + \sigma_i + \phi_j + \kappa_t + \mu_{ijt} \quad (2)$$

The statistical model is discussed in more detail in the subsequent section.

5. Empirical Results

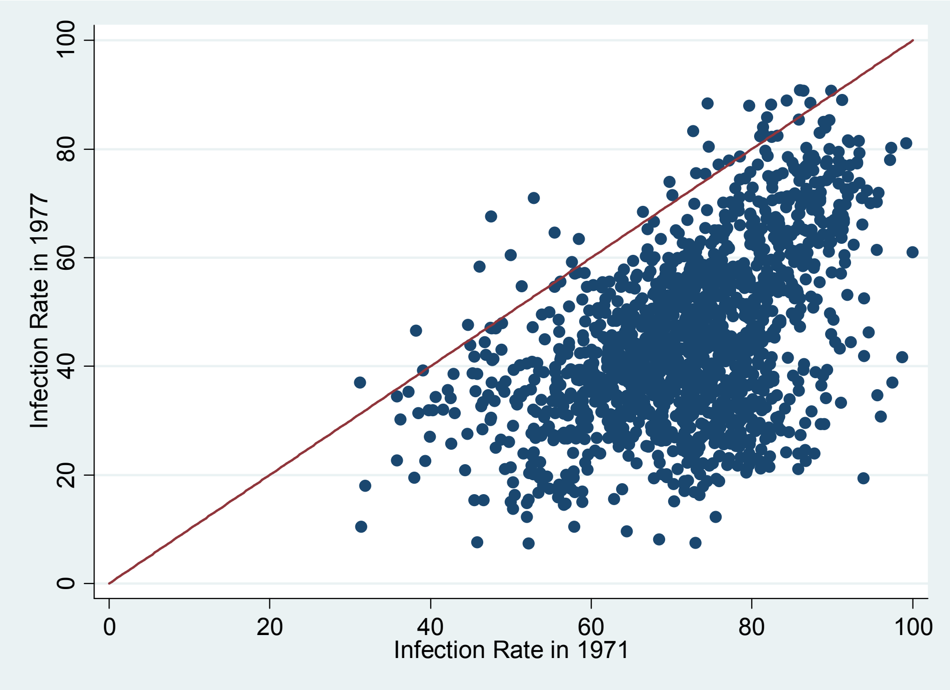
5.1. Exploratory data analysis

The school infection rates from the KAPE reports are available for the period from 1971 to 1977,[5] and [Figure 3] illustrates the changes in the school-level infection rates over the period. Each dot in the figure represents a school, showing the school-wide infection rates at the beginning (1971) and at the end of the period (1977). The national infection rate at middle school level decreased from 44.1% in 1971 to 26.0% in 1977, but these averages hide rather wide variation in the levels and their temporal changes. The egg positive rate decreased for most schools, indicated by the fact that most points are below 45 degree line in [Figure 3]. We note that the extent of the fall in infection rates is not proportional to the initial infection rate, and that the higher the initial infection rate, there is a tendency that the subsequent fall is greater.

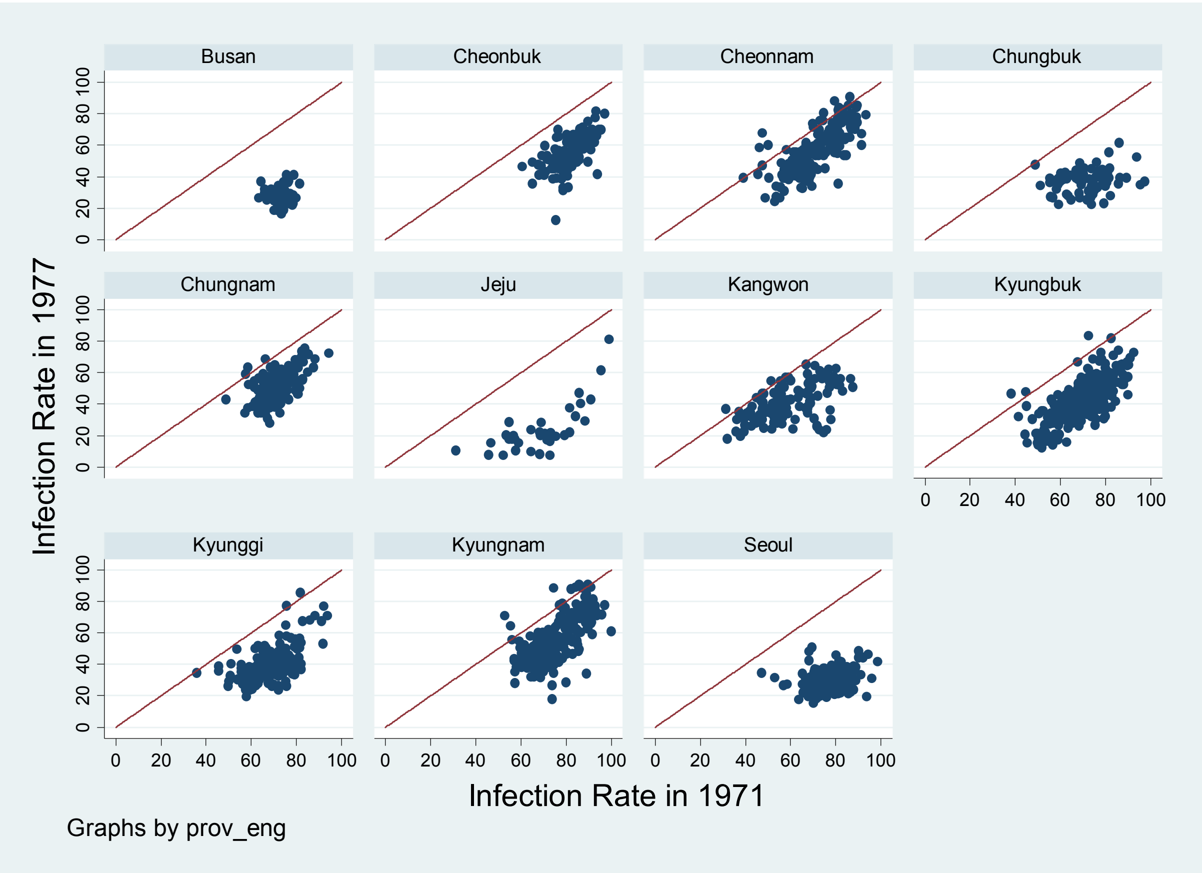
A few other patterns are observed from the illustration of the changes in infection rates when schools are grouped by province in [Figure 4]. First, the infection rates in urban areas like Seoul and Busan are more homogeneous and dropped more than rural areas. Second, although the infection rates decreased for most rural areas by 1977, there was still a large variation in the level within provinces. Roughly speaking, the change in rural provinces was a shift in level rather than the change in the distribution. Third, it is notable that schools in Jeju province experienced the largest drops in infection rates, and the rates in 1977 were similar for most schools except a few. Considering that Jeju province is an island, this suggests that universal deworming program may be more effective for area isolated or for areas with less farming land.

[5] Infection rates data are available only at aggregated levels beyond 1978, but not at the individual school level.

[Figure 3] Infection rates compared school by school in (N=1,497)

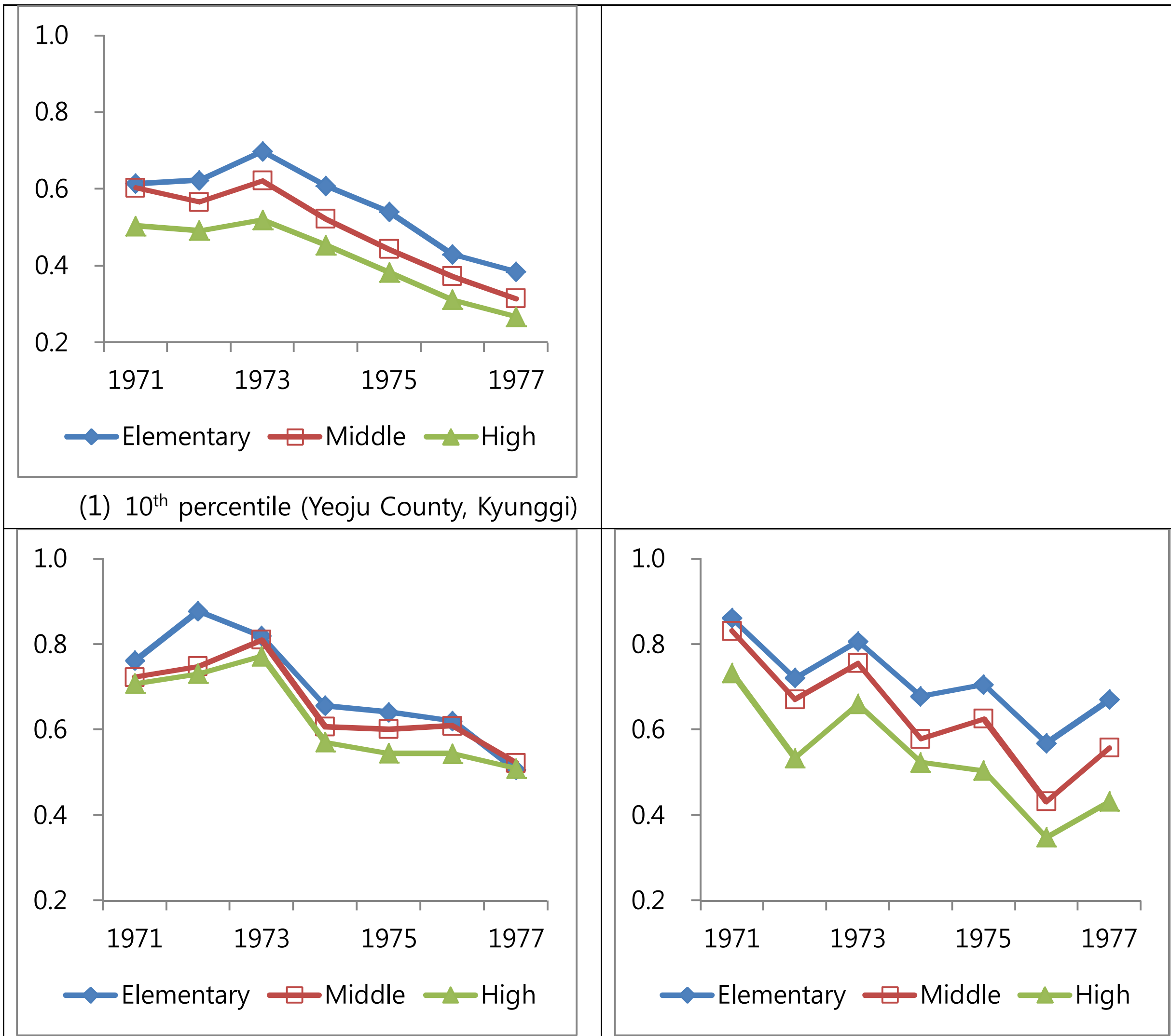


[Figure 4] School-level infection rates in 1971 and 1977 by province



[Figure 5] illustrates the changes in year-to-year school-level infection rates for three selected Counties. The three Counties are Yoeju, Kyunggi Province; Jinju, Kyungnam Province; and Soonchang, Cheonbuk Province. The Counties are located at the 10th, 50th, and 90th percentile, respectively, in the national distribution of infection rates in 1971. Perhaps two patterns are worth noting. First, the egg positive rates at different school levels have the same ordering as those at the national level: with the rates at elementary school being the highest, followed by infection rates at the junior high school, and then by those at the senior high school level. Second, the changes in the infection rates were not necessarily monotonic. The bumpy trajectories suggest the resilience of the worm population to reproduce and revert to the steady state infection rate.

[Figure 5] Changes in infection rates at different school levels: selected counties



(1) 10th percentile (Yeoju County, Kyunggi)

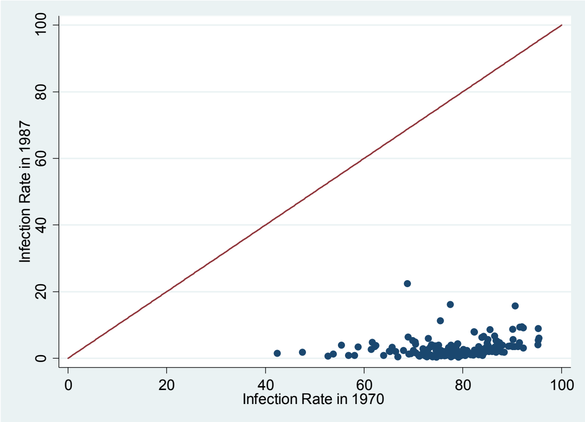
(2) 50th percentile (Jinju, Kyungnam)

(3) 90th percentile (Soonchang County, Cheonbuk)

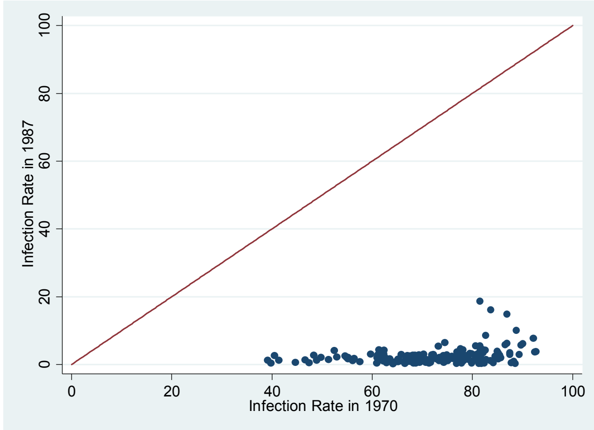
Note: The infection rates at middle school level in the three counties in 1971 are close to the 10th, 50th and 90th percentile in the distribution, respectively.

The STH infection rate at county level is available for a longer time span. [Figure 6] plots the infection rates in 1970 and 1987 for different school levels. Although there is a wide variation in STH prevalence across counties in 1970, the infection rate converges to zero in most of areas by 1987. This tendency is observed in all levels of school.

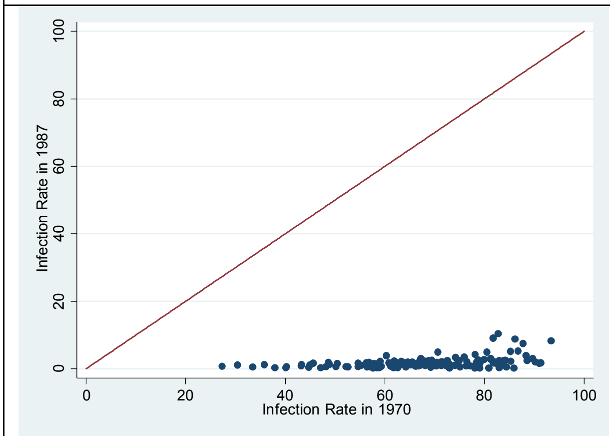
[Figure 6] STH Infection Rates at County in 1970 and 1987(N=179)



(1) Elementary School



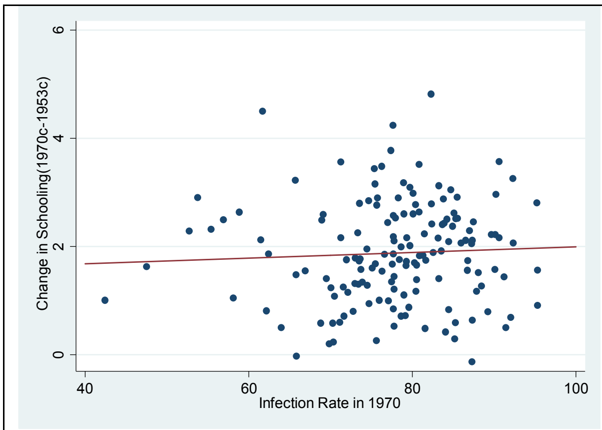
(2) Middle School



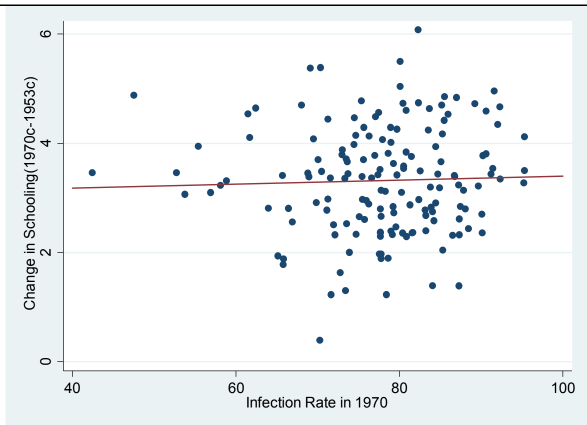
(3) High School

Given that those areas with high STH prevalence before the intervention experienced a larger drop in infection rate during the campaign, the outcome measure would increase more in high prevalence areas compared to low prevalence areas if the campaign had any positive impact. [Figure 7] exhibits the correlation between pre-intervention STH prevalence and change in education measure across cohorts. The education measure by birth cohort and birth county is constructed from the Korean Population Census in 2000. The vertical axis in panel (1) in [Figure 7] indicates the change in the completed years of schooling between 1970 birth cohort and 1953 birth cohort in the same county, whereas the horizontal axis measures the STH infection rate in 1970. Panel (1) and (2) in [Figure 7] show that the high prevalence areas experienced a larger increase in the completed years of schooling during the campaign period for both male and female population. The same correlation is observed when the high school graduation is considered as an education measure.

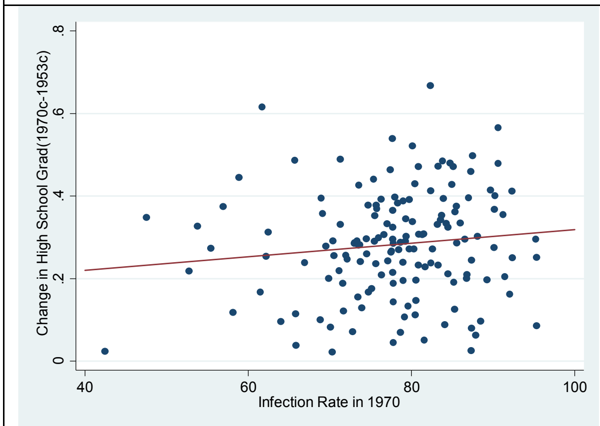
[Figure 7] Change in Education between Birth Cohort(1970-1953) and Pre-intervention STH Prevalence



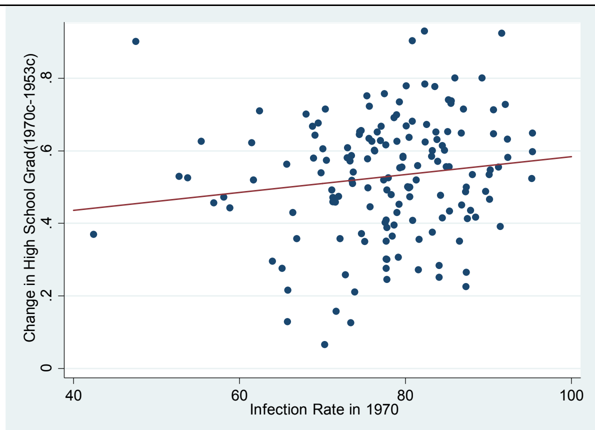
(1) Male, Years of Schooling



(2) Female, Years of Schooling



(3) Male, High School Graduation

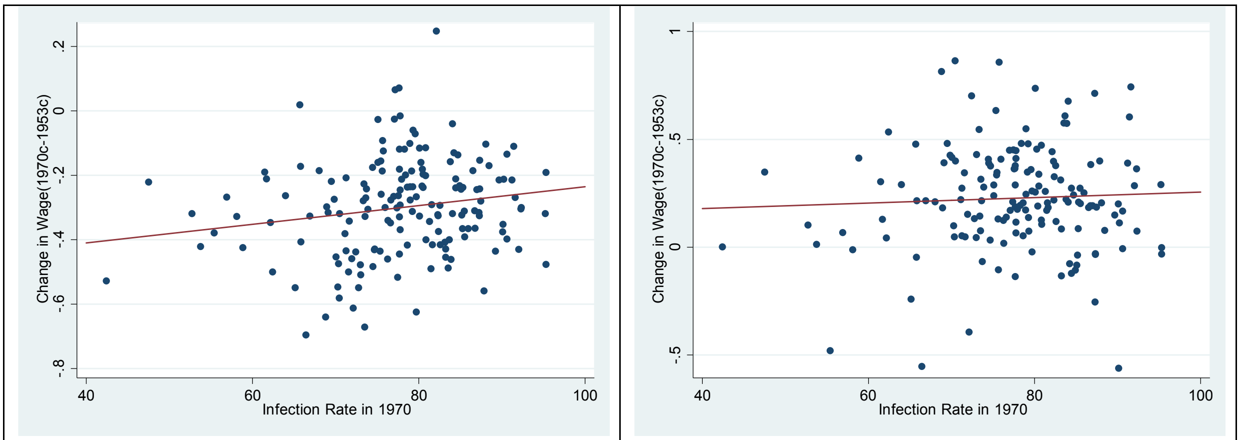


(4) Female, High School Graduation

Next, wage is taken as an outcome variable. The population census in 2000 does not include the information on earnings, but it does have the employment status and industry and occupation code for workers. First, a wage equation is estimated using the 2000 Wage Structure Survey in Korea. The Wage Structure Survey is annually conducted for a representative sample of workplaces and has information on working hours and compensation of individual employees.[6] Then, the coefficients are utilized to predict the wage for the employees in the population census.[7]

[Figure 8] presents a scatter plot of the change in the wage between 1970 birth cohort and 1953 birth cohort who were born in the sample county and the STH infection rate in 1970. As in the case of education measure, it is observed that high prevalence areas faced a larger increase in the wage level than low prevalence areas. It is also found that the correlation is stronger among male employees than among female counterparts.

[Figure 8] Change in Log Wage between Birth Cohort(1970-1953) and Pre-intervention STH Prevalence



(1) Male (2) Female

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[6] The population is all the workplaces with more than 4 employees except those in the industries of public administration, military, social security, domestic service, international and other foreign organizations. The sample in year 2000 consists of 5,400 workplaces and 495,315 employees.

[7] The prediction is made separately for male and female workers. The explanatory variables in a wage equation include age, gender, education, marital status, tenure, industry dummies (35 groups), occupation dummies (44 groups) and province dummies (16 groups).

5.2. STH prevalence in childhood, education and wage

The sample analyzed in this subsection first culls 1,367 individuals from the KLIPS who entered middle school between 1971 and 1977. We were able to match the school infection rate in the year of entrance for 1,008 individuals among them. <Table 1> presents summary descriptive statistics for this sample. The respondents in the sample were born between 1955 and 1967, and 49% of them are female. The average years of schooling are 12.6 years. The average STH infection rate in the 1^{st} year of middle school is 56% ranging from 9% to 96%.

<Table 2> presents the results of estimation of the model in equation (1) for the completed years of schooling as a measure of educational attainment. All equations are estimated controlling for dummies for birth years and dummies for provinces and gender. The main variable of interest on the right hand side is the infection rate at school attended in age 13 (year of entrance in middle school).

According to column (1) in <Table 2>, the reduction in school STH infection rate at age 13 from 100% to zero is associated with one year increase in years of schooling. The coefficient estimate is statistically significant at 10% level. Column (2) and (3) suggests that the correlation is stronger for male respondents(1.2 years) than female counterparts(0.9 year), but neither of the point estimates is statistically significant at conventional level of significance.

Given that the STH infection rate at school at age 13 should be interpreted as a summary measure of STH prevalence experienced by each individual, the magnitude of the association is rather small. One possible explanation for this is the sample selection. That is, the current analysis is based on the sample of respondents whose middle school is identified. If the middle school graduation rate increased over time, those who went to middle school would be a more selected group among early cohorts than among later cohorts. Indeed, the proportion of those who graduated middle school is 70% for the birth cohort of 1953, and it increased monotonically to 98% for the birth cohort of 1967.

As discussed earlier, it is difficult to interpret the results in <Table 2> as a causal effect since the change in STH prevalence is also correlated with various factors in development including social infrastructure and return to education, which are not controlled properly.

Nevertheless, we believe that it is informative to compare the results in <Table 2> with those under other empirical strategies.

<Table 1> Summary Statistics (N=1,008)

Variable	Mean	Std. Dev.	Min	Max
Birth Year	1961.10	2.06	1955	1967
Female	0.49	0.50	0	1
Completed years of schooling	12.57	2.32	9	21
School infection rate at age 13	0.56	0.17	0.09	0.96

<Table 2> Effects of Infection Rate in Childhood on Schooling

Dependent variable: completed years of schooling	(1) All	(2) Male	(3) Female
Infection Rate at Age 13	-1.0343	-1.2048	-0.8658
	(0.6033)*	(0.9772)	(0.7636)
Female	-1.1408		
	(0.1392)***		
R^2	0.13	0.08	0.08
No. of Obs	1,008	517	491

Note: The results are from OLS. In all models, birth year dummies and province (at age 13) dummies are controlled. The values in parentheses are robust standard errors. Statistical significance: * = 10%,** = 5%, *** = 1%.

Since KLIPS is a panel data, the wage is observed for multiple years for the same individual. The first 11 waves of KLIPS (1998~2008) are used for the analysis. The final sample consists of wage observations of those with middle school identified. <Table 3> provides summary statistics. The mean wage is 9,390 won, and the mean age is 42 years. The proportion of females is 35%, which is lower than that of the sample for the analysis on education. The average respondent has 12.7 years of schooling and a working experience for 7 years. The infection rate at his or her school at age 13 is 56% on average.

<Table 4> presents results from OLS estimation of the model in equation (1), where the dependent variable is log of real wage. Column (1) is the results based on the standard Mincer wage equation with a measure of childhood expose to STH infection. When taken seriously, the results in column (1) imply that the decrease in the school infection rate at age 13 from 100% to zero would increase the real wage by 21.8%p. The point estimate is statistically significant at 1% level. According to column (2) and (3), the wage gain associated with the STH eradication in a full risk environment is 28.1%p for men and 9.8%p for women, respectively, although the latter is not statistically significant. .This estimated effect is almost certainly biased due to multiple causality. It is worth noting, however, that this estimate is lower than that of Bleakley (2010), who suggests that the increase in the risk from zero to 100% during the childhood leads to 50% less in adult earning.

The effects of other explanatory variables on wage are roughly consistent with those found in other studies. The wage of female is 35% lower than that of male when other things are equal. One additional year of schooling increases the wage roughly by 7.8%, and one year of tenure increases the wage by 3.4%.

<Table 3> Summary Statistics (N=4,366)

Variable	Mean	Std. Dev.	Min	Max
Real wage(1,000 won)	9.39	5.99	1.66	32.39
Log real wage	2.05	0.61	0.51	3.48
Age	42.00	3.77	32	53
Birth year	1961.24	2.01	1955	1966
Female	0.35	0.48	0	1
Completed years of schooling	12.70	2.38	7	21
Tenure	6.97	6.79	0	31
Year	2003.24	3.17	1998	2008
School infection rate at age 13	0.56	0.17	0.09	0.96

Note: Real wages are in terms of 1,000 won in 2008.

<Table 4> Effects of Infection Rate in Childhood on Log Wage

	(1)	(2)	(3)
Dependent variable: Log of real wage	All	Male	Female
School Infection Rate at Age 13	-0.2181	-0.2807	-0.0977
	(0.0478)***	(0.0559)***	(0.0859)
Age	0.0713	0.1301	-0.0410
	(0.0386)*	(0.0455)***	(0.0704)
Age squared	-0.0007	-0.0014	0.0007
	(0.0005)	(0.0005)**	(0.0008)
Female	-0.3525		
	(0.0148)***		
Schooling	0.0776	0.0720	0.0886
	(0.0031)***	(0.0034)***	(0.0070)***
Tenure(yr)	0.0344	0.0313	0.0432
	(0.0010)***	(0.0012)***	(0.0022)***
R^2	0.55	0.45	0.43
No. of Obs	4,366	2,844	1,522

Note: The results are from OLS. In all models, the year dummies(when the wage is measured) and current province dummies are controlled. The values in parentheses are robust standard errors. Statistical significance: * = 10%,** = 5%, *** = 1%.

5.3. Estimating the impacts of infection rate using cohort variations(KLIPS)

Bleakley (2010) estimated the long-term consequences of malaria eradication taking advantage of the variations with respect to birthplace and cohort. He hypothesized that those born after the campaign in high prevalence area will benefit more than those born in low prevalence area. In this subsection, we employ the idea to estimate the impacts of infection rates on education and wage using two data sets: KLIPS and Population Census. One advantage of using KLIPS is that the County of middle school location is identified for each respondent. KLIPS also has a direct measure of individual earning. However, it has a shortcoming that the sample size is relatively small and that the sample is selected upon the middle school graduation. Population census, on the other hand, covers a representative sample of Korean population, but does not have direct information on earning. Therefore, two analyses are likely to complement each other. Specifically, the population census in year 2000 is used.

The measure of exposure to deworming campaign is constructed as in Bleakley(2010). Although the intervention of deworming was implemented through the regular school system, it was accompanied by the occasional deworming campaign for adult residents. Therefore, the level of the exposure is measured with the ratio of the number of years after 1969 to the first 18 years of life.[8] [Figure 9] displays the exposure level by different birth cohort. In the analysis below, it is assumed that people lived in the same County since birth to the age 18.

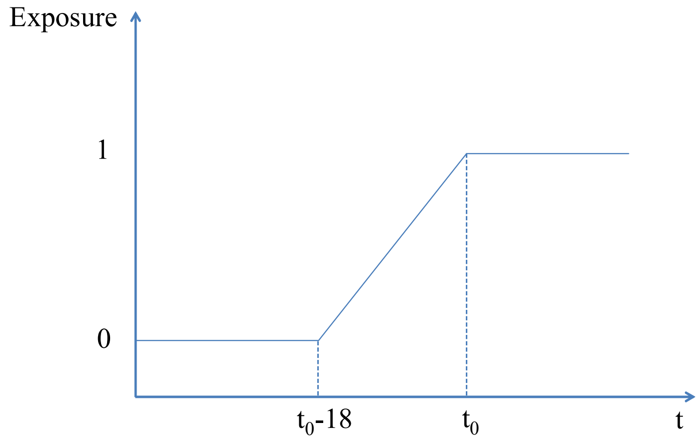
In the statistical model, the initial prevalence is measured with STH infection rate at county level in 1969 (E_i), and it is interacted with a measure of exposure to the eradication program(Exp_j), which is the ratio of years spent after 1969 over the first 18 years in life. The area(i), cohort(j) and time(t) specific effects are controlled for in the model.[9]

$$Y_{ijt} = \theta E_i \times Exp_j + X_{ijt}\beta + \sigma_i + \phi_j + \kappa_t + \mu_{ijt} \quad (3)$$

[8] In the actual estimation, the first year of campaign is set to be year 1970 because the information on STH infection rate is available only since 1970 in KAPE.

[9] In equation (3), time dummies are included only for the case of estimating the effect of STH exposure on wage using KLIPS, in which there are multiple observations of wage for an individual.

[Figure 9] Measuring the Duration of Exposure to the Nation-wide Deworming Campaign



Note: The time along the horizontal axis indicates the year of birth. The first year of campaign t_0 is 1969.

The first part of the analysis using KLIPS estimates the impact of exposure to campaign on educational outcome. The final sample consists of 4,384 respondents who were born between 1942 and 1975 and whose middle school is identified. <Table 5> shows the summary statistics of the sample. The mean of birth year is 1960, and 46% of the sample is female. The mean completed years of schooling is 12.7 years and the proportion of those with high school diploma is 82%. The pre-intervention STH infection rate at county in 1970 is 77% ranging from 42% to 95%.

<Table 6> reports the estimation results of equation (3). Column (1) indicates that the full exposure to the campaign during the childhood compared to zero exposure increases schooling by 2.4 years. The point estimate is statistically significant at 10% significance level. The effect of full exposure on schooling is estimated to be larger in a male sample than in a female sample. According to Column (2) and (3), the full exposure during the childhood increases schooling by 2.9 years for men and by 1.1 years for women, but the latter is not precisely estimated.

On the other hand, the effect of the exposure to the campaign on high school graduation estimated to be quite substantial. Based on column (4) in <Table 6>, the full exposure during the childhood increases the probability of achieving high school diploma by 51.1%p, and the coefficient estimate is statistically significant at 5% level. Unlike the case of years of schooling, this effect is estimated to be larger for a female sample. Column (5) and (6) indicate that the effect of full exposure is 69.2%p for women and 23.1%p for men, and that only the former is statistically significant at conventional level of significance. The overall results in <Table 6> suggest that the STH eradication is likely to have a positive and nonlinear effect on education.

<Table 5> Summary Statistics (N=4,384)

	Mean	Std. Dev.	Min	Max
Birth Year	1960.83	7.91	1942	1975
Female	0.46	0.50	0	1
Completed years of schooling	12.66	2.47	6	21
Index of high school graduation	0.82	0.38	0	1
Exposure to Campaign	0.52	0.36	0	1
County Infection rate in 1970	0.77	0.09	0.42	0.95

<Table 6> Effects of Exposure to the Deworming Campaign on Education(KLIPS)

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent Variable:	Completed Years of Schooling			Index of High School Graduation		
	All	Male	Female	All	Male	Female
Exposure	2.4485	2.9094	1.1094	0.5110	0.2306	0.6919
× Infection Rate	(1.3032)*	(1.5960)*	(2.0439)	(0.2305)**	(0.2412)	(0.3385)**
Female	-0.8363			-0.0688		
	(0.0654)***			(0.0124)***		
R^2	0.12	0.08	0.16	0.10	0.08	0.15
No. of Obs	4,384	2,370	2,014	4,384	2,370	2,014

Note: The values in parentheses are robust standard errors. Statistical significance: * = 10%,** = 5%, *** = 1%. Other explanatory variables include dummies for birth years and counties.

Next, the analysis of the consequence of STH infection risk on wage is presented. The final sample size of wage observation is 16,560, and the summary statistics is shown in <Table 7>. The sample consists of individuals who were born between 1943 and 1975, and the mean age is 40.3 years. The mean real wage is 9,380 won. The mean exposure is 60%, and the mean value of the initial STH prevalence at county level is 0.77. The share of female is 30% in the sample. The mean years of schooling and work experience are 12.9 years and 6.7 years, respectively. The proportion of individuals in a firm with a union is 25%.

The estimation results are displayed in <Table 8>. Column (1) suggests that the full exposure to the campaign during the childhood increases the wage rate by 17.4%p, but the point estimate is imprecisely estimated. Column (2) and (3) further imply that the effect is larger for men than for women, but again neither estimate is precisely estimated. The coefficients on other explanatory variables are estimated to consistent with <Table 4>.

The results might mean that the deworming campaign mainly affected educational attainment, and apart from the indirect impacts on earnings there is no separate, direct impact on earnings. The departure of these results from the findings of Bleakley(2010) might reflect the different types of worms prevalent in the two settings. Alternatively the differences might derive from several limitations in the implementation of the strategy in the current investigation. First, the assumption of continued residence in the same County may be too strong and untenable. Second, the number of middle school students in each County cell may be too small in our sample.

<Table 7> Summary Statistics (N=16,560)

Variable	Mean	Std. Dev.	Min	Max
Birth Year	1962.78	6.56	1943	1975
Age	40.33	6.76	25	55
Calendar year	2003.11	3.17	1998	2008
Female	0.30	0.46	0	1
Real wage(1,000won)	9.38	5.67	1.66	32.39
log real wage	2.07	0.58	0.50	3.48
Exposure	0.60	0.33	0	1
County infection rate in 1970	0.77	0.09	0.42	0.95
Schooling	12.88	2.51	6	21
Tenure(yr)	6.71	7.07	0	36
Union	0.25	0.44	0	1

<Table 8> Effects of Exposure to the Deworming Campaign on Log Wage(KLIPS)

Dependent variable: log real wage	(1) All	(2) Male	(3) Female
Exposure × Infection Rate	0.1743	0.3502	-0.2707
	(0.1901)	(0.2540)	(0.3947)
Female	-0.3038		
	(0.0163)***		
Schooling	0.0794	0.0757	0.0880
	(0.0028)***	(0.0032)***	(0.0070)***
Tenure(yr)	0.0274	0.0239	0.0363
	(0.0010)***	(0.0012)***	(0.0022)***
Union	0.1224	0.0981	0.1927
	(0.0139)***	(0.0154)***	(0.0209)***
R^2	0.48	0.41	0.42
No. of Obs	16,560	11,606	4,954

Note: The values in parentheses are robust standard errors. Statistical significance: * = 10%,** = 5%, *** = 1%. Other explanatory variables include dummies for birth years, calendar years, and provinces.

5.4. Estimating the impacts of infection rate using cohort variations(Census)

As a complementary analysis, the effect of STH eradication is estimated using the 2000 Population Census data. The birth county is identified for each individual, and it is assumed that the respondents lived in the birth county throughout their childhood. The final sample consists of 541,184 individuals who were born between 1930 and 1979. <Table 9> reports sample statistics. The mean age in year 2000 is 41 years and about half of the sample is female. The mean years of schooling are 11.3 years and the proportion of those with high school diploma is 69%. On average, the exposure level is 0.48 and the STH infection rate in 1970 is 78%.

The estimate results in <Table 10> suggest that the exposure to deworming campaign had a positive impact on education. To be specific, the full exposure to the campaign during the childhood increases schooling by 0.95 year and the probability of graduating high school by 19.6%p. Both estimates are statistically significant at 1% level. The magnitude of the effect is smaller compared to those from KLIPS in <Table 6>. This suggests that the effect of the STH eradication on education is larger for population conditional on middle school education than for the general population. It is also found that the consequence of STH infection risk is larger for female group than for male group. According to <Table 10>, the full exposure during the childhood increases schooling by 0.6 year for men and by 1.3 years for women, and the probability of high school graduation by 12.2%p for men and by 26.2%p for women.

<Table 9> Summary Statistics(N=541,184)

Variable	Mean	Std. Dev.	Min	Max
Year of Schooling	11.29	3.92	0	21
Index of high school graduation	0.69	0.46	0	1
Birth year	1958.89	12.70	1930	1979
Female	0.51	0.50	0	1
Exposure	0.48	0.41	0	1
County Infection rate in 1970	0.78	0.09	0.42	0.95

<Table 10> Effects of Exposure to the Deworming Campaign on Education(Census)

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent Variable	Completed Years of Schooling			Index of High School Graduation		
	All	Male	Female	All	Male	Female
Exposure	0.9460	0.5685	1.3104	0.1956	0.1221	0.2622
× Infection Rate	(0.1162)***	(0.1711)***	(0.1510)***	(0.0141)***	(0.0207)***	(0.0188)***
Female	-1.4221			-0.1266		
	(0.0082)***			(0.0010)***		
R^2	0.36	0.19	0.48	0.33	0.21	0.42
No. of Obs	541,184	263,770	277,414	541,184	263,770	277,414

Note: The values in parentheses are robust standard errors. Statistical significance: * = 10%,** = 5%, *** = 1%. Other explanatory variables include dummies for birth years and counties.

Next, the consequence of risk of STH infection during the childhood in terms of wage is estimated. The final sample is composed of 185,526 employees who were born between 1940 and 1979. The sample statistics is summarized in <Table 11>. The mean age in 2000 is 36 years and the ratio of the female is 36%. The mean value of exposure is 62% and the initial STH infection rate is 78%. The mean predicted log wage is 8.84.

The estimation results are reported in <Table 12>. Column (1) indicates that the full exposure to the deworming campaign under age 18 increases the wage by 5%p. The magnitude of the effect is smaller compared to those suggested by recent studies(Bleakley, 2010; Lucas, 2010). The difference in wage gain due to eradication may stem from the difference in species of parasite or in the institution. Further, column (2) and (3) suggest that the effect of STH eradication is larger for female sample than for male sample. The effect of full exposure during childhood is estimated to increase wage by 2.3%p for men and by 18.7%p for women, and the former is not statistically significant. This results is consistent with those regarding education outcome in <Table 10>. These results suggest that the STH eradication is beneficial to more disadvantaged group of the population.

<Table 11> Summary Statistics(N=185,526)

Variable	Mean	Std. Dev.	Min	Max
Birth year	1963.69	9.42	1940	1979
Female	0.36	0.48	0	1
Exposure	0.62	0.37	0	1
County Infection Rate	0.78	0.09	0.42	0.95
Log wage	8.84	0.45	7.51	10.39

<Table 12> Effects of Exposure to the Deworming Campaign on Log Wage(Census)

Dependent variable: log real wage	(1) All	(2) Male	(3) Female
Exposure × Infection Rate	0.0496	0.0230	0.1872
	(0.0273)*	(0.0309)	(0.0449)***
Female	-0.3582		
	(0.0019)***		
R^2	0.27	0.29	0.06
No. of Obs	185,526	118,838	66,688

Note: The values in parentheses are robust standard errors. Statistical significance: * = 10%,** = 5%, *** = 1%. Other explanatory variables include dummies for birth years and counties.

6. Concluding Remark

The paper investigates the long-term impacts of STH infection during childhood on educational attainment of workers and their productivity in Korea. The Korean experience presents a successful case of a sustained, nation-wide school-based deworming campaign from 1969 till 1995. For the purpose, we match a current longitudinal study of Korean workers from the Korea Labor and Income Panel Study (KLIPS) and the annual administration data on school-by-school infection rates taking advantage of the identification of the middle school attended of the respondents in the KLIPS. A complementary analysis is conducted using the 2000 Korean Population Census.

The empirical results based on a simple model suggest that an increase from zero to full risk to STH infection during the childhood is associated with a decrease in years of schooling by 1.0~2.4 years, a decrease in the chance of achieving high school diploma by 20~51%p and a reduction of adult earning by 5%p. It is found that the consequence of the exposure to the risk of infection is larger conditional on entering middle school than otherwise. They indicate a smaller but still significant productivity impact compared to Bleakley's estimated for the American South. Further, the effect of exposure to STH infection risk is estimated to be larger for women than for men, which suggests that the STH eradication was more beneficial to the more disadvantaged group of population.

This partial divergence of our results from previous studies might reflect the differences in the infection-productivity nexus due to differences in prevalent worm types or differences in institution. Our results suggest that the consequence of the risk of parasite infection should be understood in the context of biological, geological and socioeconomic conditions of the population under study.

There are a couple of caveats in the analysis. The analysis based on cohort variation requires the assumptions that individuals lived in the same county throughout their childhood. The exposure to the deworming campaign may be correlated with other factors of economic development. The robustness of the analysis regarding these issues needs to be addressed.

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