

**The Impact of Improving Health upon Economic Growth: An Economic Analysis
of the Southern Hookworm Eradication Campaign, 1910-1920**

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ABSTRACT

Southern agricultural productivity dramatically increased during the 1910s after three decades of stagnation. During the same decade an extremely effective health campaign in the American South was directed towards eliminating hookworm disease which infected over 40% of Southerners. The economic evaluation of this successful campaign through the use of economic models captures the gains associated with disease reduction and quantifies the economic impact of each input. In terms of individual agricultural workers, a one-time 29-cent investment increased income by an average of \$40.00 in increased crop output per year thereafter or an incredible annual return of between 11,000 and 16,000%. This estimated annual return while appearing extremely high is consistent with the World Health Organizations recent estimates of parasitic disease eradication in primarily agricultural societies.

Keywords:

Disease Eradication, Economic Growth, Random Effects Modeling,

1. INTRODUCTION

Where mass diseases are brought under control, production tends to increase-through increasing the percentage of adult workers as a proportion of the population, [and] through augmenting their strength and ambition to work. (Stacy May, 1962)

Economists pay slight attention to the impact that changes in health have upon changes in income. The prevailing viewpoint among economists, when addressing the macroeconomic implications of health improvements appears to be that health improvements have occurred as a result of higher incomes. Hence, in an international macroeconomic setting, the citizens of rich countries are healthier as a result of their wealth. Countries whose per capita income is low, on the other hand, are condemned to suffer ill health leaving their citizens with short and relatively unproductive lives. The past macroeconomic emphasis in poor countries has concentrated on increasing income and waiting for the health revolution. This trickle down approach to improving health care in the third world appears to have failed with development specialists now recognizing the need for a different approach.

Causality between ones economic status and ones level of health is not yet fully understood nor is there a generally accepted unidirectional gradient even though a strong correlation has been observed between health and income as early as the mid-19th century. The public health literature abounds in research that has examined the determinates of health inequalities and health levels using economic class as a causal variable while the economics literature has produced studies that predict income without considering the possibility that health itself may determine economic levels. Economists are now challenging the view that health results from higher income and are focusing upon various disease eradication programs to test

this hypothesis. Fortunately, a natural experiment occurred in the United States in the early years of this century allowing for the economic quantification of disease eradication. This disease, a parasitic infection commonly known as hookworm, infected approximately 40% of all southerners.

Numerous scholars have extensively scrutinized the economic fortunes of the southern United States. In particular, much research has been devoted to the dramatic decline in real per capita agricultural output between 1860 and 1880. However, a substantial increase during the 1910s in the value of per capita agricultural income has escaped such close examination. While the annual growth rate of agricultural productivity in the American South between 1880 and 1910 was slightly negative, the growth rate reversed the three decades long trend and increased at an average annual rate of 3.6% between 1910 and 1920 (Brinkley 1994).

SEE TABLE 1 AT END OF DOCUMENT

The interpretation of TABLE 1 is fairly straightforward. This table denotes output per acre and output per person for 1910 and 1920 and compares the change in output per acre between 1910 and 1920 with the change in output per rural population for the same time period. For example, with wheat grown in the South, there were 12.86 bushels produced per acre in 1920 (column 2) and in 1910, there were 12.57 bushels per acre (column 3). 12.86 divided by 12.57 yields 1.0232, the value in column 3 and is the increase in land productivity. In column 5, 6.40 bushels of wheat was produced per rural worker in 1920 and was divided by 2.82 bushels from 1910 production from column 6 to obtain the value of 2.27 in column 7 and is a labor productivity increase of 127%. Column 8 is the value of 2.219 obtained by dividing 2.27 from

column 7 by 1.023 from column 4 and is the greater increase in labor productivity relative to land productivity. The remaining values for the other crops and for the Non-South are similarly derived. The thrust of this table is that for the South, labor productivity showed greater increases than land productivity for all crops while for the Non-south, nearly half the crops exhibited greater increases in land productivity and the others in labor productivity. Apparently, a significant increase in southern labor productivity occurred between 1910 and 1920 which did not occur in either land productivity or in the labor productivity of the non-southern regions of the United States.

What makes the jump in southern agricultural labor productivity even more surprising is that it occurred during the destruction of cotton caused by the spread of the boll weevil. The weevil's sweep through the South began in southern Texas during the mid 1890s and entirely engulfed the South by 1922. At the beginning of 1910 less than half of all southern farmland had suffered the detrimental effects of the weevil infestation but during the decade of the 1910s, the weevil's rapid spread covered nearly 90% of the total arable land area of the South. The real effect of the weevil infestation was to destroy a substantial portion of the cotton crop when cotton production comprised a substantial proportion of the value of the southern agricultural sector. The southern farm laborer increased agricultural output even with the weevil infestation indicating that the actual increase in productivity was higher than the understated estimate in this analysis or in the 1920 census. The 1920 agricultural census indicates that cotton production was reduced overall by 10% from the boll weevil. Robert Higgs (1976) noted that one state, Georgia, suffered a loss of 45% of cotton production during this same period.

Current economic explanations for higher gross agricultural output per capita focus upon the labor migration out of the South or the economic boom produced by WWI (Wright, 1986).

Approximately 10 percent of the agricultural labor force migrated out of the South in the late 1910s. It is not clear if this migration caused an increase in the average productivity of the remaining labor force. An average increase in productivity as a result of migration would happen only if workers with low productivity left the South while those with high productivities remained. In effect, since one less worker would reduce the denominator of agricultural output per person, at the same time, the numerator would also be reduced as a result of less agricultural output leading to no change in average per capita output unless migrants had a different level of productivity. The crux being that average productivity of migrants must be lower than average productivity of the remaining workers in order for an increase to occur. Even with the large migration of southern workers, population increased by over 10 percent reducing the possibility that marginal productivity increased as a result of fewer workers producing the same total output.

Wright (1986) points out that those workers who migrated out of the South had left the farms before 1910. Since the migrants had already left the farms to temporarily settle in urban areas, the great migration would not have a substantial effect on agricultural labor productivity during the 1910s. Higgs (1976) examined the push (destruction caused by the boll weevil) and the pull (higher northern wages) on the effects of African-American out migration. He concluded that the boll weevil played little role in determining the migration of African-American migration in the 1910s but was substantial in the 1920s.

This paper argues that improving health was an important factor that substantially increased labor productivity during the 1910s thereby raising per capita crop output. The next section of this paper briefly summarizes the hookworm eradication campaign of 1909-1914 and the rise of public health agencies in the American South after 1909. Section 3 summarizes the

scientific evidence demonstrating that hookworm eradication or medical intervention increases the physical capacity of hookworm victims in agricultural occupations. Methodology and the economic model is reported in Section 4. Section 5 statistically evaluates the factor inputs in southern agricultural production to determine the economic effects of each. Section 6 discusses the econometric results while the final section concludes that increases in labor intensity which is mostly overlooked in evaluating the effects of public health programs is actually one of the largest of all economic gains associated with improved health.

2. ROCKEFELLER CAMPAIGN TO ERADICATE HOOKWORM DISEASE

Early this century, a massive public health campaign substantially reduced the incidence of hookworm infestation endemic in the American South. This campaign, lasting between 1909 and 1914, initiated by John D. Rockefeller, enlisted the help of state and local public health agencies by requiring matching funds in order to participate. According to the records of the Rockefeller Sanitary Commission for the Eradication of Hookworm Disease (RSC), the combined private and governmental partnership, covered 1,100 southern counties within 11 southern states, and treated over 700,000 southern hookworm victims out of 1.3 million examined. Much of the two million dollars provided by the RSC was spent on educational activities and not on hookworm treatment itself with the result that millions more sufferers were treated by their personal physicians.

John D. Rockefeller organized the Sanitary Commission on October 26, 1909 with Wickliffe Rose appointed as administrative secretary in December 1909. The Sanitary Commission was incorporated on February 3, 1910 and existed until March of 1914. "The Commission," according to Rose (1910), "had been created for the purpose of eradicating

hookworm disease". The RSC, combining scientific medicine and public education, had three primary objectives: find the geographical distribution of hookworm infection, cure hookworm sufferers, and stop soil pollution in infected areas. Approximately 640,000 Southerners were cured of hookworm disease by RSC personnel with the cost of treatment being twenty-one cents per person and screening costing nine cents per person (John Ettling, 1990). Even though the RSC began operations in 1909, no southerner was cured of hookworm disease until after the 1910 Census counting.

Two techniques the RSC used to accomplish its objectives were education and persuasion. The RSC attempted to win over southern doctors by appealing to their own self interest, e.g., by treating hookworm sufferers, doctors could substantially increase their income since they could charge more than 29 cents for the cure.¹ The dollar amount that patients were willing to pay would have been substantially greater than the cost of testing and treatment allowing a high markup on the part of local physicians. Lectures at conventions and individual visits by the staff of the Sanitary Commission served to educate southern doctors in this procedure.

The RSC was also the major impetus for the formation of local southern public health organizations. In 1909, the best that could be said of local public health was that it was merely inadequate. In most areas of the South, no public health agencies even existed. "Perhaps the

1. The amount of money spent on private testing and cures of hookworm are not included in the estimated two million spent by the RSC or public health agencies since this amount would have been entirely offset by a reduction in the amount spent on potions, nostrums, and patent medicine by hookworm sufferers. The net aggregate effect is to actually decrease the total spend on hookworm eradication in the South and would only serve to boost the economic return. However, southern doctors were able to charge premium prices for cures as a result of a high willingness to pay by those infected by hookworm disease.

Commission's most important legacy in the South," according to Van Woodward, "was the network of state and local public health agencies it left in its wake" (Ettling, 1981). During the four-year operation of the Sanitary Commission, state funding for health programs increased by 81%. State health agencies assumed greater powers and every southern state established a public health department. Five out of the twelve southern states had a statewide agency before the RSC's involvement (Ettling, 1981) and only two southern counties had full time health organizations in 1911, but due to the impact of the RSC over 260 county health operations were in operation by 1924 and every southern state had full time health agency (Rockefeller Archive Center, Rockefeller Collection, Record Group 5, Series 2, Sub-series 200-USA, Box 1, Folder 2A).²

The eradication campaign proved that a substantial reduction in hookworm infection was possible, feasible, and had occurred. The rural population enjoyed improved health and an increased capacity to labor. Lani Stephenson and Celia Holland (1987), two doctors laboring in the third world today to eradicate the same pest, praised the first wide-scale attempt to eradicate this disease.

The Rockefeller Foundation project in the United States showed that debilitating hookworm disease can be controlled and that major benefits accrue to the populations involved. The Rockefeller Foundation subsequently expanded the scope of the RSC to include the rest of the world and ended its efforts to fight hookworm in the southern United States in the early 1920's. The International Health Board, the RSC's offspring, continued the fight against

2. While other newly discovered types of efficacious public health activities were being implemented in the North, very little was extended to the rural South. These activities, for example, were pasteurization, and sanitary systems.

hookworm with infection surveys and eradication campaigns on every continent of the globe during the 1920s.

3. HOOKWORM EFFECTS ON LABOR PRODUCTIVITY

Hookworm infection causes both physical and mental retardation and a reduction in a workers capacity for labor.³ Asa Chandler (1922) noted that “[T]he most characteristic effect of hookworm infestation on the nervous system is a general dulling of the entire system, resulting in the very well-known apathetic, lazy disposition of hookworm patients.” An early study by Waite and Neilson (1919) demonstrated that children with hookworm infection were nearly two years behind mentally. Numerous later studies confirmed this link between mental retardation and hookworm infection (e.g. Smillie and Spencer, 1926). In terms of physical stunting, adults with very mild infections of hookworm that exhibit no clinical symptoms are shorter and weigh less than people not infected with hookworm (Dock and Bass, 1913).

Research in Africa continue to affirm the negative relationship between hookworm and productivity. "The relationship between anaemia, hookworm disease and worker productivity," according to Celia Holland (1987), " is particularly important, especially for families dependent on self-employed subsistence farming. The ability to perform work and the earning capacity of male and female rural workers is seriously reduced "

The mechanism whereby curing a hookworm victim results in an increase in agricultural production resides in the newfound ability to sustain a peak effort. Agriculture is by its very

3 Detailed symptoms of hookworm infections can be found in Dock and Bass (1913) who described hookworm symptoms so well that modern texts have failed to improve the accuracy of the descriptions.

nature a productive activity that is seasonal. This implies that much of the time a farmer has no need to labor in the fields (e. g. winter) and at other times of year must expend great effort (planting and particularly harvest). According to E. B. Hammond (1899), the labor relationship between planting an acre of cotton and harvesting an acre of cotton is about one to ten. Essentially, it takes ten hours to plant an acre of cotton and about one hundred hours to harvest an acre of cotton. In addition, harvest has a time constraint since cotton will deteriorate if left on the boll too long whereas planting can be more leisurely. While a farmer infected with hookworm may have been able to plant several acres of cotton, for example, he would never have been able to harvest the crop because of the physical debilitation caused by hookworm. After being cured, the farmer would have been able to sustain greater efforts in the harvesting of crops thereby dramatically increasing agricultural output.

Scientific studies confirming the increase in worker productivity when hookworm is either eradicated or treated are abundant. Agricultural workers in particular have increased crop output according to studies both recent and in the same period as the RSC's hookworm eradication campaign. Shapiro (1919) demonstrated that in Costa Rican agricultural plantations raising sugar cane, coffee, corn, and beans as export crops, workers increased output between 14.6 percent and 27 percent relative to similar plantations where hookworm infected workers remained untreated. Brooks et al. (1979) demonstrated as late as 1979 that among adult Kenyan road workers, treatment for hookworm symptoms resulted in a decrease of 30 percent in the time required to perform a standard day's task. Similar studies by Edgerton et al. (1979) show increases in work capacity of female tea estate workers in Sri Lanka.

Recent medical studies in Africa demonstrate that treatment for the symptoms of hookworm infection or curing a hook worm victim substantially increases their physical capacity.

Modern day researchers, Stephenson and Holland (1987) note the importance of reducing the harmful effects of hookworm upon unsuspecting hosts in today's agricultural regions infested with hookworm.

Many societies recognize that hookworm is a debilitating disease that causes lethargy, exhaustion, and sometimes death. This was well described in the United States many years ago. Hookworm anaemia reduces physical fitness and lowers worker productivity. This relationship is important because hookworm anaemia is contributing to reduced work output and is hampering development and agricultural productivity in many tropical countries (Stephenson and Holland, 1987).

One testament to the beneficial effects of hookworm treatment during the eradication campaign came from the sufferer, Rufus Stamper, in a letter he wrote to Dr. T. E. Wright of Homer, Louisiana, the Sanitary Commission doctor who cured him:

Some time ago you were here and gave me the hookworm treatment. Before I took it I weighed ninety-six pounds, was 56 ½ inches high, and wore a No. 4 shoe; I was twenty years old, my face was as smooth as a girl's, my hair was apparently dead, I craved something to eat all the time and ate a considerable amount of table salt, somehow it appears that I craved it. Now at the end of four months since taking this treatment which certainly removed a large quantity of hookworms, I weighed [sic] 140 lbs., have grown to 61 inches in height, wear a No. 7 shoe, my face all bearded out, I do not crave salt any more, I feel like a new fellow. Before the treatment I felt bad and stupid all the time, now I can't keep up with myself neither day nor night. I could not have run 50 yards, even slight exertion worried me down, now I am as good as any one. I feel like a new fellow (Rufus Stamper, letter, Rockefeller Foundation, Collection 22, Record Group 95-105, Series 2, Box 4, Folder 96, Item 221, Rockefeller Foundation Archives).

4. METHOD

Data for the statistical analyses were obtained from archival sources providing reports on the rates of hookworm infestation and various census publications. An attempt was made to collect all relevant data on hookworm infestation rates for as many southern counties as possible that were surveyed both in the original hookworm eradication campaign (1909-1914) and again

after 1920. While the data encompasses five southern states (i.e. Alabama, Tennessee, Mississippi, North Carolina, and South Carolina), partial re-surveys for the states of Florida, Kentucky and Georgia were not included in this analysis because of the limited number of counties re-surveyed.

The census reports provided data variables composed of rural population, total acres per county, total agricultural income, total expenditures on fertilizer, total expenditures, total expenditures on hired labor, number of improved acres, number of African-Americans, number of mules, number of farms, number of farms operated by owners, number of tenant farmers, number of acres planted in cotton, and the number of acres planted in tobacco. The above listed variables were collected for the 1910 and 1920 census years. TABLE 2 lists the means, standard deviations, and descriptions for each variable. Fortunately for this analysis, even though the RSC existed as an entity in 1909, eradication efforts by the RSC did not commence until after the 1910 agricultural counting was completed.

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4A. ANALYSES MODELS

Conceptually, the presumed theoretical relationships between the per capita value of all crops and dairy products divided by the rural population (the outcome or dependent measure) and the independent variables (all assumed to be exogenous) consisting of various measures of inputs into the production process are unidirectional. The inputs consist of the normal land, labor, and capital commonly taught in basic economics. However, because reality is rarely so pure as theory, additional variables that modify the inputs are added to the model. Hence, for

example, fertilizer expenditures as a percentage of total expenditures are included to account for the increased quality of land whenever fertilizer is added to increase crop production.

The effect of the percentage of the rural population infected with hookworm on per capita income is expected to be negative (Brinkley 1994, 1997) and is due in part to the studies quoted earlier in this paper. The effect of the percentage of African-Americans in each county on per capita income is ambiguous and, if negative, due to discrimination suffered (Wright, 1986) and, if positive, due to the differential effects of disease (Coelho and McGuire 1997, 1999).

Similarly, the effects of farm tenure have been debated in the literature so that the possible effects are ambiguous (Reid, 1973, 1976, 1976a, 1979; Lee and Passell, 1979). Standard economic theory indicates that increases in land, labor, or capital will raise production. Hence, mules which is a proxy for capital is expected to be positively related to output. Similarly, increases in fertilizer, improved acres, and hired labor should also be positively related to output. A shift in both cotton and tobacco acreage out of other crops should be positive since, at the margin, the value of each would be more profitable, otherwise, no shift would have occurred. A simplifying assumption of independence is made for each of the explanatory variables and a lack of endogeneity is assumed.

In estimating the regressions a pooled regression model, a consistent fixed effects (least squares dummy variables, LSDV) model, and a time series model⁴ with the data transformed to percentage changes or differences, is assumed. Because of the nature of the data set (only two time periods and approximately 350 spatial units) in order to preserve as many degrees of

⁴ In the so called time series model, only two time periods are used so a low R-squared would not be surprising and no auto-correlation will be present.

freedom as possible, the dummy variables are placed upon the unit variables by state rather than upon each county. The equations regressed are as follows:

$$\text{Pooled} \quad Y_{it} = X_{it} \beta + \varepsilon_{it} \quad (1)$$

$$\text{LSDV} \quad Y_{it} = X_{it} \beta + D\alpha_i + \varepsilon: D = \text{unit dummies.} \quad (2)$$

$$\text{Time Series} \quad Y_i = X_i \beta + \varepsilon: Y_i = (Y_{i1920} - Y_{i1910})/Y_{i1920}, X_i = X_{i1920} - X_{i1910} \quad (3)$$

Additional diagnostic tests of each analysis model were conducted to evaluate the extent to which the results were sensitive to influential and/or outlying data points. Previous research using cross-sectional data has suggested that extreme data points have considerable influence on parameter estimates from linear regression models. Cook's distances⁵ were evaluated to locate and screen for outliers and highly leveraged data points (Barrett and Lewis, 1984; Stevens, 1986). None were dropped from this analysis. Finally, an additive model is assumed relating independent measures to the dependent measure.

5. RESULTS

The results of the analyses are presented in TABLE 3. The first column indicates the variable while the second column indicates the coefficients from the pooled regression, the third column reports the coefficients from the LSDV model, and the last column represents the coefficients from the time series model. Additional information is reported at the bottom of each

⁵ Cook's distances measures the change in the estimates of the regression coefficients when the largest Cook's value (or the *i*th case) is deleted. Essentially, this distance is a scaled Euclidian distance between the vectors of fitted values. A very large Cook's distance or outlier could unduly influence the parameter values of the regression.

column - the mean of the dependent variable, the number of observations, and the adjusted R-squared values. The value of the t-statistic is given in parenthesis below each coefficient. The coefficients on the constant term or the dummy variables are not reported in TABLE 3.

SEE TABLE 3 AT END OF DOCUMENT

The effect of hookworm is negative and always above the 99% significance level. The effect of owners and tenants have mixed signs but are almost always non-significant. The coefficients for cotton and tobacco acres as a proportion of all improved acres are positive and always significant. The coefficients for mules per acre, the percent improved acres, and fertilizer are all positive and significant except for fertilizer which is negative and non-significant in the time series regression. Hired labor or rather the proportion of farm expenditures for hired labor is generally non-significant but is significant and negative in the time series regression. However, hired labor is negative only in relation to spending on fertilizer and other farm expenditures. The variable hired labor is a proportion of total spending so, even if it declined as a proportion of total farm expenditures, absolute spending on hired labor increased substantially and is positively related to income per person (average spending per county was \$93,288 in 1910 and \$137,113 in 1920). The coefficient of African-American population is positive and always significant.

Generally, the results are supportive of economic theory and of the assertion that hookworm infection has a negative impact upon per capita income. The coefficients in the pooled regression and LSDV regression can be interpreted as a one unit change of the independent variable causing a dollar change in per capita income. In the case of hookworm, a

one percent increase in hookworm infection among the rural population lowers income by \$0.40 in the pooled regression and by \$0.32 in the LSDV regression. The interpretation of the time series regression coefficients is a one unit change in the independent variable causes a percentage change in the dependent variable. Again, using hookworm as the example, a one percentage point increase in hookworm infection causes about a five tenths of a percent reduction in per capita income. Since a one percent increase in per capita income is \$0.85, and a one percentage point decrease in hookworm results in a 0.549 percent increase in per capita income, or as noted above, an increase of \$0.46. However, the effects are at the county level so the income increased on average by \$0.46 for every person in that county when one percent of the population was cured of hookworm. So curing one person of hookworm out of every hundred is an average decrease of 1% for the county. Hence, one persons income increased - the one cured of hookworm - and the other 99 people=s income remained unchanged. This being the case, the individual cured would have had an income increase of \$40.00, \$32.00, or \$46.00 depending upon which regression coefficient is used to calculate the increase. The other coefficients are much more difficult to interpret. Only hookworm infection and the African-American variables have the same denominator as the dependent variable so are easy to interpret. The other independent variables are deflated by total farm spending - Fertilizer and Hired Labor - or by improved acres - Cotton, Tobacco, and Mules - or by unimproved acres - improved acres. As a result care must be taken in these interpretations.

6. DISCUSSION

The strengths of the current models for the explanation of agricultural productivity are substantial. Using three different regression models with consistent results lends confidence in

the robustness of the analyses. The per capita 1920 income composed of both the value of all crops and the value of dairy products is in constant 1910 dollars. Hence, the discussion will always be in real terms and not in nominal price or income changes. The only surprising result in these analyses is the statistically significant negative relationship between hired labor and the percentage change in per capita income in the time series regression. The real spending on hired labor increased by 46% from a county average of \$93,288 in 1910 to \$137,112 in 1920 but since spending on fertilizer increased by 206% and other farm spending increased by 169%, the proportion of spending on hired labor declined relative to other expenditures. Hence, the negative coefficient only indicates that greater profits were obtained by spending on fertilizer and other expenditures, not that spending on hired labor decreased per capita income. Any other coefficients with unexpected signs are not statistically significant.

Even though much has been written addressing the economic organization of farming, in these analyses, farm tenure, whether owners or tenants, is not significant in any of the regressions indicating that how the land is farmed makes little difference in how much is produced. At least between 1910 and 1920, the value of output per person did not appear to depend upon the distribution or property rights of that output.

A positive relationship exists between the proportion of land improved relative to total acreage and per capita income. Increasing the proportion of improved acres to total acreage by one percent would raise average per capita income by about \$1.30. An interesting result is that as a greater percentage of improved acres are devoted to cotton or tobacco, the value of output per person increases. This result is most likely due to the increase in prices for tobacco from 1910 to 1920 being greater than the average price increase. Since tobacco prices increased by 227%, this is possibly a real effect from a nominal event. The proportion of acreage devoted to

cotton declined and resulted in a reduction in per capita income. However, considering the spread and the effects of the boll weevil, this action of shifting out of cotton production would reduce risk for the farmer and so is unsurprising. The number of mules per acre are always statistically significant and positively associated with increased output. These results unsurprisingly conform to economic theory.

The proportion of the rural population that was African-American was significant and positively related to per capita income indicating that perhaps the theories of Coelho and McGuire (1997, 1999) are closer to the truth than other explanations asserting discrimination. Between 1910 and 1920, per capita income declined when the proportion of African-Americans in the rural labor force population declined. This result confirms earlier work showing the same relationship between county income and race for 1870, 1880, 1890, and 1900 census years using only cross-sectional data (Brinkley, 1994). Contemporary studies by the RSC showed that African-Americans had lower rates of hookworm infection but, most importantly, the detrimental effects of hookworm infection was less burdensome than on European-Americans (Dock and Bass, 1910; Chandler, 1929). As a result, even adjusting for the prevalence rates of hookworm, the intensity of the wormload is not accounted for in these analyses. Essentially, if ten African-Americans were infected with hookworm, their production would have been higher than if ten European-Americans had been infected.

Finally, the last independent variable in these analyses is the proportion of the population infected with hookworm disease. The coefficients in each regression are negative and statistically significant at the 99% level of significance supporting the central assertion in this paper. Productivity measured as per capita income is lower where ever hookworm disease rates are high and per capita income increases when hookworm rates fall.

Dividing the coefficient by the required investment to increase that variable by one and then multiplying by one hundred for the pooled and LSDV regressions denotes the rate of return. The same can be calculated for the time series regression results but is slightly more complicated. For this economic model, the total dollar impact can be calculated by multiplying the coefficient by the mean difference and then by \$0.84 which is the dollar value of one percent.

Using the coefficient values for hookworm will clarify the calculations on the rate of return. The mean difference from TABLE 2 is -26.32 or the average county decline in hookworm infection rates. This value multiplied by the coefficient values from TABLE 3 gives \$10.55, \$8.37, and \$12.26 for the Pooled, LSDV, and Time Series regressions respectively. These dollar figures are the increase in per capita income for a per capita decrease of 26% of hookworm. Since the cost for a single person to be cured of hookworm (or to have their hookworm reduced by 100 percent) was \$0.29, the per capita cost would have been \$0.076 to lower infection rates by 26.32 percent (\$0.29 divided by 100 times 26.32) since on average each persons rate of infection declined by 26 percent (from 32 to 13 percent). The economic return on reducing hookworm is therefore 13,881 percent according to the pooled regression results, 11,013 for the LSDV regression results, and 16,131 percent for the time series results (e.g. \$10.55 divided by 0.076 times 100 equals 13,881 percent).

However, the percentage of the rural population that was African-American don't have associated investments or returns unless, for example, a dollar amount could be estimated to prevent the migration of African-Americans. Since the regression results indicate that income per capita was higher for African-Americans, preventing their migration would have increased per capita income by about \$0.72 to \$0.97 per person.

The economic return for hired labor was negative but significant. However, this return is in relation to that proportion of total farm expenditures not included in the regression analysis. Expenditures on hired labor and fertilizer were approximately 75 percent of total expenditures in 1910 and 69 percent in 1920. So the coefficient values only indicate their impact upon per capita income relative to the 25 percent and 30 percent expenditures not included in the regressions. This is evident since both were never significant in the same regression; when one was significant, the other was not. However, these results do seem to indicate that factor constraints were probably present. As noted earlier in this paper, approximately 10% of the rural labor force migrated out of the South during the 1910s. Since hired labor tended towards young men who are the most productive and most likely to migrate and to be absent, there would likely not have been enough to hire causing a disequilibrium at the margin. While land is not mobile, and clearly did not migrate, a lack of farmers to farm the land would also have created disequilibrium in this factor. Since agriculture tends towards a Leontief type production, the similarities in return for hired labor and improved acres tend to support this supposition. Mules per acre apparently have a high rate of return but since the values were multiplied by 100 prior to estimation, the actual one unit impact should be read as one hundredth the size shown and is a very small return, but still positive and worth making to many farmers.

The economic returns generated by reducing the prevalence rate of hookworm infection is absolutely stunning. The rates of return are nearly impossible to believe and certainly appear to be wildly incorrect since one would expect returns of this magnitude to be the captured immediately and to be widespread. However, other very recent studies support the magnitude of the returns generated within this analysis. The World Health Organization (1998) estimates similar returns for infectious diseases, other parasitic diseases and nutritional supplements. A

Yellow Fever vaccine costing \$72 in the United States will save \$381 to \$763 per case averted and from \$1904 to \$3817 for each death averted in developing nations where Yellow Fever has a mortality rate of approximately 50%. The vaccine returns between 5 and 53 times the investment or a return of 500 to 5000 percent annually. Treatment for Lymphatic Filariasis costs between \$0.05 and \$0.10 annually for five years per person with 120 million people infected. The economic return to eliminate this disease is estimated by the World Health Organization at \$4 billion per year. The economic rate of return is 33,000 to 66,000 percent (4 billion divided by [120 million times 0.05 or 0.10] times 100). Controlling Chagas disease (American trypanosomiasis) costs approximately \$19 to \$35 million per year in the Southern Cone countries but the estimated return is over \$3.5 billion per year. The annual rate of return is 10,000 to 18,200 percent. Iron fortification costing \$0.20 per year per person returns an increase of \$10 per year per person or a ratio of 50 (5000%). However, later World Bank ratio estimates for iron fortification go as high as 500 for an economic return of 50,000 percent.

The economic returns generated by the RSC campaign to eradicate hookworm are not out of line with current estimates to reduce the global burden of disease in developing countries. In fact, the economy of the Southern States in 1910 was remarkably similar to current developing nations with such a high agricultural sector and low levels of education.

7. CONCLUSION

The hookworm eradication campaign conducted by the RSC in the southern United States was a natural experiment that allows a quantification of economic returns from public health efforts. The bottom line in these analyses and using conservative numbers is that spending to cure a person of hookworm during the eradication campaign of the early 1910s

generated a far greater return than any other investment in southern agriculture during the 1910s. The overlooked economic value of the hookworm eradication campaign in the early years of this century encourages a look hard look at other instances of macroeconomic fluctuations in the American economy. The public health literature of the past abounds in descriptions and data collections of diseases (e.g. Tuberculosis, Yellow Fever, Influenza, Malaria, and Pellagra) that have afflicted the American people and the subsequent eradications of these same diseases but without evaluating any resultant economic benefit. An interesting future study, for example, would be to examine the relationship between the great worldwide influenza epidemic of the late 1910s and the subsequent worldwide Great Depression. While hookworm infestation is still rampant worldwide today, little economic analysis is being directed to the economic benefits of eradication. In addition, the positive economic impact of reducing other diseases such as malaria is supported by the results obtained from this study. Numerous researchers are examining the economic impact of malaria eradication without benefit of a natural experiment such as that of the hookworm eradication campaign in the southern United States in the early years of this century. However, the conclusions reached in this paper can certainly be applied to the elimination of other diseases and the resultant economic benefit to be derived.

This analysis is very crude in attempting to estimate the effect on economic development of the first major partnership between the public and private sectors in improving health in the United States. There is considerably more research to be undertaken in this area. Dr. Nelson (1990) probably stated the need best by proclaiming,

The greatest need in macroepidemiology is for the application of the highest-quality epidemiological research for evaluation of the role of hookworms in relation to the overall well being and survival of people in the endemic areas. In the past all the emphasis has been on the deleterious effects of the parasites. We certainly need more information on morbidity and the economic consequences of hookworm disease"

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TABLE 1
CHANGES IN AGRICULTURAL OUTPUT PER ACRE
AND PER PERSON, 1910-1920

(1)	(2)	(3)	(4)		(5)	(6)	(7)	(8)	
CROP	Q/T ₂₀	Q/T ₁₀	Q/T ₂₀ /Q/T ₁₀		Q/L ₂₀	Q/L ₁₀	Q/L ₂₀ /Q/L ₁₀		(Q/L)/(Q/T)
WHEAT									
South		12.86	12.57	1.023		6.40	2.82	2.27	2.219
Non-South	12.95	15.81	0.818		28.74	22.89	1.255		1.534
OATS									
South		27.86	22.57	1.23		5.92	3.49	1.38	1.122
Non-South	27.76	29.32	0.947		33.14	34.31	0.892		0.94
CORN									
South		20.64	20.91	0.79		31.07	34.56	0.89	1.126
Non-South	30.92	29.05	1.06		58.21	65.28	0.83		0.78
IRISH POTATO									
South		86.94	124.86	0.69		1.91	2.61	0.73	1.057
Non-South	89.71	103.27	0.87		9.03	12.19	0.74		0.85
SWEET POTATO									
South		94.66	90.55	1.04		2.95	2.31	1.27	1.21
Non-South	128.24	112.02	1.14		0.27	0.24	1.15		1.01
TOBACCO									
South		862.3	688.8	1.25		31.25	14.97	1.27	1.016
Non-South	849.5	1064.5	0.79		7.02	9.65	0.72		0.911
COTTON									
South		0.39	0.38	1.00		0.54	0.47	1.13	1.13
Non-South	0.64	0.62	1.35		0.01	0.008	1.17		0.866
HAY									
South		1.33	1.08	1.22		0.70	0.41	1.68	1.37
Non-South	1.24	1.09	1.13		3.10	2.57	1.21		1.07

Notes: The South is composed of the South Atlantic, East South Central, and the West South Central geographic divisions while the Non-South (US) is composed of New England, Middle Atlantic, E. North Central, W. North Central, Mountain, and Pacific geographic divisions according to the Census. The value Q/T is calculated by taking the sum of the

output of each crop divided by the total number of acres used to grow that crop in 1920 and dividing by the same ratio from 1910 values. Q/L is similarly determined and $(Q/L)/(Q/T)$ is calculated by dividing Q/L by Q/T or column 3 by column 2.

Source: All values were taken from Volume V of the 1920 Agricultural Census from Tables 5, 6, 12, and 13. Population was taken from Table 5. Prices were derived from Table 6. Acreage was taken from Table 12, and the value of each crop was taken from Table 13. All crops from Table 12 were used whenever prices could be obtained.

TABLE 2
Definitions of Variables
with Means and Standard Deviations

VARIABLE	1910	1920	DEFINITION OF VARIABLE
INCOME PER PERSON	\$84.90 (39.96)	\$217.23 (106.53)	Value of all crops plus the value of dairy products divided by the rural population
AFRICAN-AMERICAN POPULATION	35.31 (24.55)	33.42 (24.05)	Number of African-Americans divided by the rural population
OWNERS	51.76 (20.56)	51.78 (20.72)	Number of owned farms divided by the total number of farms
TENANTS	48.30 (20.74)	47.68 (20.94)	Number of tenant farms divided by the total number of farms
FERTILIZER	33.82 (22.13)	40.38 (25.54)	Fertilizer expenditures in current \$ divided by total expenditures.
HIRED LABOR	41.63 (15.32)	28.85 (14.87)	Expenditures on hired labor in current \$ divided by total expenditures.
IMPROVED ACRES	45.89 (14.34)	48.56 (14.30)	Number of improved acres divided by total acres.
MULES	2.4 (0.008)	3.17 (0.009)	Number of mules X 100 divided by improved acres.
COTTON ACRES	22.46 (18.22)	20.21 (16.83)	Number of acres planted in cotton divided by improved acres.
TOBACCO ACRES	0.70 (1.89)	1.70 (4.16)	Number of acres planted in tobacco divided by improved acres.
HOOKWORM	39.63 (21.18)	13.31 (13.91)	Number of people infected with hookworm divided by the rural population.

Notes: The 1920 values are in current dollars where appropriate but are deflated to 1910 constant dollars according to the 1920 census calculations when used in the statistical analyses.

Source: US Census records for population and agricultural output by county for 1910 and 1920 for the five states of Alabama, Mississippi, North Carolina, South Carolina, and Tennessee. The second data source was the five annual reports of the Rockefeller Sanitary Commission and various reports. Rural population is the total population of each county minus urban populations. Income per person for 1910 is line 2 from TABLE 4 plus line 11 of TABLE 3 from the 1910 Agricultural Census reports divided by the rural population. The income calculations above are in current dollars but the regression values for per capita income are in constant 1910 dollars. 1920 income per person is line 2 of TABLE 4 plus line 59 of TABLE 2 from the 1920 Agricultural Census reports divided by the rural population. The other variables are similarly constructed.

TABLE 3

Determinants of Gross Agricultural Income Per Capita
for five Southern States by County for 1910-1920.

Variable Name	POOLED	LSDV	TIME SERIES
Hookworm	-0.401 (-3.989)	-0.318 (-3.107)	-0.549 (-4.407)
Owners	0.548 (1.626)	0.315 (0.942)	-0.308 (-0.866)
Tenants	-0.003 (-0.010)	-0.085 (-0.255)	0.303 (0.896)
Cotton Acres	2.017 (4.931)	1.873 (4.544)	1.051 (2.746)
Tobacco Acres	14.03 (11.33)	12.605 (9.608)	2.403 (2.953)
Mules	19.72 (8.252)	19.223 (7.924)	3.152 (0.788)
Improved Acres	1.319 (6.690)	1.304 (6.069)	1.601 (3.308)
Fertilizer	0.773 (5.586)	0.68 (3.814)	-0.228 (-0.905)
Hired Labor	0.129 (0.625)	-0.182 (-0.845)	-0.752 (-3.308)
African-American Population	0.379 (3.096)	0.419 (3.183)	0.606 (1.827)
Mean of Dependent Variable	112.9	112.9	0.33
Number of Observations	552	552	239
Adjusted R-Squared	.64	.66	.16

The t-statistics are in parenthesis. A t-statistic value over 1.645 indicates a significance level over 90%, a value over 1.96 indicates a level over 95%, a value over 2.576 indicates a level over 99%, and a value over 3.291 indicates a significance level over 99.9%. TSP version 4.2 was used to run the regressions.