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AGRICULTURAL POLICY, MIGRATION, AND MALARIA IN THE 1930S UNITED STATES

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ABSTRACT

The Agricultural Adjustment Act (AAA) caused a population shift in the United States in the 1930s. Evaluating the effects of the AAA on the incidence of malaria can therefore offer important lessons regarding the broader consequences of demographic changes. Using a quasi-first difference model and a robust set of controls, we find a negative association between AAA expenditures and malaria death rates at the county level. Further, we find the AAA caused relatively low-income groups to migrate from counties with high-risk malaria ecologies. These results suggest that the AAA-induced migration played an important role in the reduction of malaria.

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1. Introduction

Despite years of eradication efforts, malaria remains a serious public-health problem in many developing countries. This mosquito-borne disease infects some 300 million and kills nearly one million people every year (WHO 2008). As with many infectious diseases, economic circumstances (e.g. inadequate housing) can affect a population's exposure risk. Thus, a clear understanding of the pathways through which demographic changes impact malaria's incidence can help with the design of effective public-health interventions. Existing studies have yet to convincingly quantify the *causal* impact of demographic changes on malaria.[1] Previous estimates are subject to concerns of omitted variables and reverse causality.[2] Our research design overcomes this empirical challenge by using plausibly random variation in agricultural policy in the United States in the 1930s. Our results offer an important lesson on how demographic changes can help (and hinder) malaria eradication efforts today.

The focus of our study is on the effects of the Agricultural Adjustment Act (AAA) on the incidence of malaria in the South between 1930 and 1940. The AAA was designed to help raise the prices of certain agricultural commodities during the Great Depression by paying farmers to idle land. The AAA was implemented in1933, just prior to a significant decline in malaria death rates, suggesting that further inquiry into the causal significance of the AAA is warranted. As we explain in greater detail below, our hypothesis is that the AAA reduced malaria's incidence by shifting low-income populations (e.g. sharecroppers) away from areas with high-risk malaria ecologies.

With this hypothesis in mind, there are two main components to our study. The first component is to estimate the county-level correlation between AAA expenditures and changes in the malaria death rates between 1930 and 1940. Our identification strategy involves estimating the relationship between the malaria death rate in 1940 and per capita AAA spending during the 1930s. To mitigate concerns of omitted variables bias, we also control for the malaria death rate in 1930, a host of county characteristics in 1930, other New Deal expenditures, and state fixed effects in our main specification.

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[1] There are numerous studies on the association between socioeconomic factors and malaria. See Worrall et al. (2005) for a review of the literature. Fewer studies have explored the role of migration explicitly (Martens and Hall 2000).

[2] Concerns about reverse causality are salient in light of the recent studies examining the impact of malaria on economic outcomes. See Bleakley (2003, 2010), Lucas (2010), Hong (2007), and Barreca (2010), for example.

In short, we find that per capita AAA expenditures have a strong negative association with malaria death rates. For example, compared with a county with no AAA receipts, a county receiving the mean expenditure of $22 per capita had 0.7 fewer malaria deaths per 100,000 inhabitants. Considering that the malaria death rate (per 100,000) fell by 7.0 between 1930 and 1940, the magnitude of the estimated correlation is economically meaningful.

The second component of our study is to investigate the mechanisms through which the AAA expenditures were negatively related with malaria death rates. Malaria is a vector-borne parasite that is transmitted by the bite of the female *Anopheles* mosquito. Given malaria's ecology, there are two potential leading explanations for this negative correlation.

First, the AAA led to changes in land use that potentially reduced the number of mosquito habitats. The AAA encouraged farmers not to grow certain types of crops, which caused farmers to idle land or switch to other crop types. In the case of idled land, there may have been less standing water, and consequently fewer mosquito habitats, since idled land was unlikely to be artificially irrigated. In the case of crop switching, the AAA may have caused the farmers to unknowingly grow crops that hindered malaria transmission.[3]

Second, and our hypothesis, AAA-induced migration redistributed malaria risk throughout the South. AAA reduced the demand for agricultural labor, leading to the out-migration of farm workers and sharecroppers.[4] Conversely, counties where the AAA had little or no presence experienced relatively more in-migration (due to inflows from AAA counties). Out-migration associated with the AAA may have reduced malaria's incidence because farm workers and sharecroppers were in the lower tier of the income distribution and at relatively high-risk of contracting malaria.[5] (In other word, the out-migration of these low-income groups would have lead to a decline in malaria's incidence due to purely compositional reasons.) In counties where the AAA had little or no presence, in-migration of these low-income groups may have led to an increase in malaria's incidence due to imported cases of malaria and increases in the at-risk

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[3] Cotton was an important AAA crop in the South. Since cotton production was relatively labor intensive prior to 1940 (Musoke 1981), idled cotton land may have reduced mosquito-human contact.

[4] Humphreys (2001) appears to be the first scholar to posit that the AAA may have been a key factor in eradicating malaria from the United States since the AAA encouraged migration away from rural farm counties. However, Humphreys did not empirically test her hypothesis.

[5] They tended to live in lower quality housing in less desirable parts of the county and tended to have lower quality diets and health capital, which made them more susceptible to contracting malaria (Humprheys 2001).

population.[6] In both the case of in-migration and out-migration, there may have been an external effect on the non-migrating population due to changes in the probability of contact with an infected mosquito.

Both the out-migration mechanism and the in-migration mechanism described above can explain the observed negative correlation between AAA expenditures and malaria death rates. However, the net causal impact of AAA-induced population shifts depends on whether the out-migration mechanism dominates the in-migration mechanism. That is, the decline in malaria death rates in AAA counties due to out-migration was likely offset to some unknown degree by increases in malaria death rates in non-AAA counties due to in-migration. To the extent that population shifted away from counties with high-risk malaria ecologies, the AAA-induced migration flows likely led to lower malaria rates in the South overall. Although we are constrained by the data, we present suggestive evidence that AAA-induced migration contributed to a net decrease across the South.

While we cannot entirely rule out the land-use mechanism, there are a few pieces of evidence to suggest that the migration mechanisms (both in-migration and out-migration) were the key explanatory factors. In the empirical analysis, there is a strong relationship between AAA expenditures and net-migration (our only measure of migration at the county level) and a relatively weak relationship between AAA expenditures and observable changes in land use. We show that AAA expenditures in neighboring counties are *positively* correlated with the 1940 malaria death rate in the county of interest, which is supportive of the migration mechanism since AAA expenditures in neighboring counties influences migration into the county of interest but has no direct effect on land use. Further, using an alternative empirical strategy and dataset, we present evidence of a sizable negative (positive) correlation between out-migration (in-migration) and the 1940 malaria death rate.

The AAA may have affected the incidence of malaria through other channels, none of which do well to explain the negative correlation. For example, declining agricultural wages may have increased the susceptibility of farm workers to malaria. These groups would have therefore found it more difficult to purchase health capital to prevent and/or treat malaria. In addition,

[6] The risk of migration-related transmission is a real public-health concern (Martens and Hall 2000). The vivax strain of the malaria parasite can survive for years in a human host (Warrell and Gilles 2002). The falciparum strain, which was less common in the United States, can survive only a short period of time in the human host (Warrell and Gilles 2002).

idled land that was poorly maintained may have been prone to standing water and, consequently, actually more hospitable to mosquito breeding. Higher agricultural prices could have adversely affected nutritional intake and overall health capital. However, in all of the aforementioned examples, we would expect to find a positive correlation between AAA expenditures and the malaria death rate, which is not consistent with the empirical findings. Further, we do not consider the fact the AAA was an important source of income support for farm *owners* as a plausible mechanism. The impact of this income-support mechanism was likely to have been small because the AAA funds tended to go to large farm owners (Fishback et al. 2003), who were arguably less at risk of contracting malaria in the first place.[7]

The principal threat to the validity of our research design is policy endogeneity. For example, AAA funds may have been allocated to rural counties experiencing relatively greater economic hardship. To the extent that greater hardship was associated with more malaria, this allocation process would have led to a positive bias, which would imply that the true causal relationship might be larger in absolute value than the estimated negative correlation described above. As a robustness check, we estimate the relationship between AAA expenditures from the 1930s and the changes in the malaria death rate between 1920 and 1930, which was long before the AAA was ever implemented. This placebo estimation finds no negative relationship between AAA spending and the change in the malaria death rate in the 1920s.

In the historical context of the South, our results suggest that the AAA played an important supporting role in malaria's eventual eradication. Namely, the AAA expenditures caused a population shift away from agricultural counties, which also had high-risk malaria ecologies. The AAA may have complicated malaria eradication efforts in areas of in-migration due to the arrival of infected people and ensuing epidemics. However, the epidemics were likely short-lived since the areas of in-migration tended to have low-risk malaria ecologies.

More broadly, our study offers lessons on how demographic transitions, brought about by changes in the agricultural sector, can affect the distribution and overall incidence of malaria. These lessons are applicable to today's world since many malarial developing countries are experiencing rapid rural-to-urban migration (Gallup et al. 1999; White and Lindstrom 2005). Our study suggests that one possible benefit of this urbanization is the redistribution of high-risk

[7] Moreover, the net-increase in income would not have been that large since any increase in AAA income would have been offset by a reduction in crop income.

populations to cities where the risk of malaria transmission is mitigated because of ecological barriers. Of real concern, however, is the possibility that there will be continued epidemics or, worse yet, new endemics in urban areas experiencing in-migration. Efforts to eradicate malaria, therefore, will be more effective when the role of migration is considered.

2. Migration and Malaria's Epidemiology

Malaria is a vector-borne parasite that is transmitted by the bite of the female *Anopheles* mosquito. After an infected mosquito takes a blood meal, the parasite enters a susceptible human host's blood stream, and then develops in the host's liver before returning to the blood stream again. Thereafter, an uninfected mosquito can acquire the parasite by taking a blood meal from an infected human host. Before malaria can be transmitted to another human host, the parasite must incubate in the mosquito's stomach, a process known as "sporogeny." Rainfall and certain land features are important since mosquitoes must lay their eggs in standing water. Also, warm ambient temperatures are necessary for mosquito survival, larval development, and sporogeny (Criag et al 1999). Given the mosquito's flight range is usually less than one mile (O'Malley 1992), transmission is more likely if humans live or work in areas that favor malaria's ecology.

To provide better insight into the relationship between migration and malaria's epidemiology, we introduce a simple model of disease transmission. For simplicity, suppose that there are two groups of people living in the same county: a "low-risk" group and a "high-risk" group. For example, the low-risk group might have less contact with mosquitoes due to better health behaviors. Let $I_C = (1-\alpha)\ I_L + \alpha\ I_H$, where I_C, I_L, and I_H are the equilibrium incidence rates in the entire county, the low-risk group, and the high-risk group, respectively. The α parameter is the share of the county population in the high-risk group. By design, $I_L < I_H$. In order to simplify the discussion, assume the equilibrium incidence rates are unique and stable. Also, we focus on the long-term equilibrium incidence rate, since the comparative statics are simpler than, but qualitatively similar to, the short-term dynamics.

Assuming the two groups do not "mix" (i.e. mosquitoes cannot transmit malaria between the groups), out-migration has a theoretically trivial effect on incidence rates. Out-migration would cause the average incidence rate in the county (I_C) to fall due to a decline in α. If within-group population density affects contact rates, then the people in the high-risk group would also experience a decline in the equilibrium incidence rate. However, the healthy group would experience no change in their equilibrium incidence rate due to the no-mixing assumption. By a similar logic, in-migration would have no effect on the equilibrium incidence rate in the low-risk group, but could increase the equilibrium in the high-risk group via population density.

Given mosquitoes can travel up to one mile, we alter the model to allow for cross-group mixing. That is, we assume that mosquitoes transmit malaria between the two groups and the probability of cross-group mosquito contact increases with the population share of the other group. Thus, I_L is increasing in α and I_H. And, I_H is increasing in α and I_L. Out migration of the high-risk group (a decline in α) will reduce I_L by reducing the probability of contact with mosquitoes transmitting malaria from the high-risk group. Conversely, out-migration will cause I_H to fall since the high-risk group is now also likely to have less contact with mosquitoes from the high-risk group. By a similar logic, *in*-migration of high-risk groups (an increase in α) would cause both I_L and I_H to increase. In other words, out-migration (in-migration) of high-risk groups confers external benefits (costs) to the remaining non-migrating population, even before considering the role of population density. As one contribution of our paper, we seek to quantify the magnitude of the externalities associated with AAA-induced migration of high-risk groups.

Importantly, the net causal impact of migration across counties is uncertain since out-migration and in-migration have competing effects. When out-migration is from relatively high-risk (low-risk) malaria ecologies, the net-causal impact will be a reduction (increase) in the long-term equilibrium incidence rate.[8] In terms of the language used in the model, people may move from being in a high-risk group to a low-risk group, and vice versa, due to purely environmental changes in their living situation. For example, people who move to a colder and drier climate will have less risk of mosquito contact. As we discuss below, the AAA caused a population shift away from counties with high-risk malaria ecologies. Therefore, we expect the AAA caused a net decline in the incidence rate, the magnitude of which is an empirical question we address in the Discussion section below.

3. Historical Background

In order to demonstrate the potential significance of the AAA, some historical background on the United States' experience with malaria is necessary. Malaria was a serious

[8] The short-term dynamics could lead to a different net-effect if areas of in-migration have low immunity or are at an unstable equilibrium of no malaria (Keeling and Rohani 2007).

public-health problem for the American South during the early 20th century. In 1930, for example, over 600 Southern counties had at least one malaria death and about 60 counties had a malaria death rate above 50 deaths per 100,000 inhabitants (see Figure 1). Although statistics on morbidity are not readily available, these death rate data suggest that as many as one in every five individuals contracted malaria each year in the most infected counties.[9] This malaria incidence rate is comparable to modern developing countries that are afflicted by malaria.[10] Consequently, extending the results of our study to areas of the world where malaria is a public health problem today is a worthwhile thought experiment.

Furthermore, the early 20th century South shares other socioeconomic similarities with today's developing countries. The agricultural sector was one of the dominant industries. Public-health institutions were developing slowly. Other diseases, like Typhoid fever and tuberculosis, were a major problem. And, a significant fraction of the population had limited formal schooling. All of these facts reinforce the external validity of our historical study.

Although the last reported case of malaria in America was in 1951 (Humphreys 2001), the root causes of malaria's eradication appear to have origins in the mid-to-late 1930s. As Figure 2 illustrates, malaria death rates were declining throughout most of the early 20th century. Additionally, malaria death rates were highly cyclical. Much of this cyclicality can be explained by fluctuations in the weather (Barreca 2010). After a small drop in 1935, however, the malaria death rate continued to decline throughout the 1940s. Determining the causes of the decline in the late 1930s may offer practical lessons for eradication efforts today.

The AAA, which is the focus of our study, can potentially explain some of the decline in malaria death rates that occurred in the late 1930s. As Figure 2 shows, the acres idled under the AAA grew from 0 in 1932 to 10 million in 1933 and 35 million in 1934. Further, malaria death rates started declining two years after the AAA's implementation (c. 1935), suggesting that the AAA may have had some role in the decline. However, omitted variables, like other malaria eradication efforts, make causal inference highly speculative.

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[9] Historical records suggest an estimated 200 to 400 infections are associated with each death (Humphreys 2001). Public health records in Alabama suggest that the number of malaria cases reported to doctors were roughly 10 times the number of malaria deaths, and officials thought that the number of infections was far higher than the number of cases reported (Kitchens 2011).

[10] For example, the 2002 malaria death rate in Kenya was estimated at approximately 60 deaths per 100,000 inhabitants (WHO 2004).

Public works projects and relief spending, which were part of the New Deal, may have accounted for some of the decline in the late 1930s as well. In particular, the Works Projects Administration's mosquito abatement projects may have directly reduced malaria death rates. Approximately two percent of the WPA budget for the South went towards mosquito eradication projects (Works Progress Administration 1937), but Humphreys (1998) and Kitchens (2011) find that the WPA's efforts had mixed effects. Given the available data, we cannot distinguish the effects of these mosquito eradication projects from the impact of other relief projects, like road construction. Moreover, these public works projects also encouraged migration, which may have indirectly affected malaria death rates. Thus, we control for public works and relief spending in our main specification to avoid omitted variable bias that might arise from correlation of such spending with AAA expenditures.

Although the AAA and other New Deal policies coincided with declines in malaria death rates in the mid-to-late 1930s, the general decline in malaria death rates throughout the early 20th century can be attributed to many factors. For example, people were becoming more aware of the mosquito's role in malaria's lifecycle (Humphreys 2001). The Rockefeller Foundation and the United States Public Health Service began implementing malaria control projects in the early 1920s (Humphreys 2001). Improved sanitation (Troesken 2004), water purification efforts (Cutler and Miller 2005), improvements in public health education (Fox 2011), and the eradication of hookworm (Bleakley 2007) may have indirectly reduced malaria's incidence by increasing health capital overall. Although analyzing the effects of these factors has important implications for health policy, such an endeavor is outside the scope of this paper and unfeasible given the data available to us. Moreover, these factors do not pose a threat to our identifying assumption since they preceded the 1930s and are, therefore, likely to be uncorrelated with the AAA, particularly after controlling for the other correlates in our analysis.

The Tennessee Valley Authority (TVA), which began construction on six dams between 1933 and 1936 (Tennessee Valley Authority 2010), has often been credited with reducing incidence levels because it concurrently embarked on an anti-malaria program. Humphreys (2001) notes that the TVA relocated residents out of the areas flooded by new reservoirs and was mindful to clear debris from the rivers. However, Carl Kitchens (2011) shows that the TVA created large bodies of standing water that led to a net increase in malaria's incidence. Further, the TVA's impact was confined to areas in Tennessee, Mississippi, and Alabama, while malaria rates declined in many other parts of the South as well.[11]

We can briefly dismiss a few other possible reasons for the decline in malaria death rates in the late 1930s. Public health officials did not begin using the insecticide Dichloro Diphenyl Trichloroethane (DDT) to kill mosquitoes until the early 1940s (Humphreys 1996). Economic growth (or lack thereof) cannot account for the decline since the United States experienced high unemployment rates throughout the 1930s in most parts of the country (Coen 1973). Also, the weather was relatively suitable for malaria transmission during most of the 1930s.[12]

4. Data

a. Malaria Mortality Data

Our key outcome variable is the county's average malaria death rate between 1939 and 1940. We derived this variable from the combined total malaria death counts for 1939 and 1940, from the National Center for Health Statistics. (These death counts were not broken out by individual year.) We calculate death rates by dividing the average number of deaths in 1939 and 1940 by the 1940 county population estimates from the Census (Haines 2004). The sample is restricted to the set of counties in or around the South to limit the analysis to areas where malaria was a concern after 1920 and malaria death records were likely to be more accurate.

In estimating the quasi first-difference model, we control for the malaria death rate circa 1930. This variable is constructed from various historical documents. We have death counts for 1930 from the Virginia Vital Statistics, North Carolina Vital Statistics, Mississippi State Board of Health, and Tennessee Vital Statistics. Death counts for Alabama, Florida, and Georgia come from Hoffman (1932).[13] We use the 1927 death counts for Arkansas and Louisiana from their state boards of health as proxies for deaths in 1930.[14] We constructed death rates from these death counts by dividing by the county population in 1930. We transcribed 1930 malaria

[11] Our estimates are unaffected by including controls for TVA projects in the counties' vicinity (available upon request).
[12] The only observable decline in precipitation occurred in 1938. During the 1930s, there was a general increase in the frequency of days with malaria-ideal temperatures, or temperatures between 22 and 28°C (Barreca 2010).
[13] Fredrick Hoffman was a Consulting Statistician for the Prudential Insurance Company.
[14] Note that the inclusion of state fixed effects will help mitigate any measurement error that is constant within states.

mortality rates for Kentucky, Missouri, Oklahoma, and Texas from a map in Faust (1932).[15] The Faust map reports the malaria death rates only in bins, so we linearly interpolate the malaria death rate in those cases.[16]

In addition, we conduct a placebo check by testing the relationship between AAA expenditures and the change in the malaria death rate between 1920 and 1930. The 1920 malaria death rates come from a table in Maxcy (1923), which reports the county averages of the malaria death rate for the years 1919 through 1921.[17] Maxcy does not report the death rate for counties with fewer than 10 deaths per 100,000 inhabitants, so we assign these counties a death rate of 5.

b. New Deal expenditures

New Deal expenditures by the AAA, relief agencies, and public works agencies were compiled by Price Fishback and Shawn Kantor as part of ongoing research on the New Deal. The New Deal data come from the U.S. Office of Government Reports (1940), which reported total funds distributed by county and by 31 programs for the period 1933 to 1939. The reports did not provide specific spending on mosquito abatement projects, which were one of many types of work relief projects undertaken under the Federal Emergency Relief Administration, Civil Works Administration, Public Works Administration, Works Progress Administration, and Work Projects Administration.

c. County characteristics

In our core specification we control for a number of socioeconomic county characteristics from the 1930 Census (Haines 2004), including log of the population, fraction urban, fraction literate, fraction black, fraction foreign born, fraction of home ownership, farm operators per capita, farm acres per total county acres, crop value per capita, and retail sales per capita. As a robustness test, we have also estimated the model while including information from the 1930 Agricultural Censuses (NHGIS) for the value of output for the following major crop types:

[15] Ernest Carroll Faust was a Professor in the Department of Tropical Medicine at Tulane University. Faust relied on mortality records from state public health offices.

[16] The Faust map illustrates whether the malaria death rate was zero, between 0.1 and 20.0, between 20.1 and 50.0, between 50.1 and 100.0, and between 100.1 and 200.0, respectively. Note that we do not need to interpolate the data for counties with no malaria deaths. Our results are qualitatively similar when we drop counties with interpolated data (approx. 13 percent of the counties in our sample).

[17] Joseph Maxcy was the Assistant Surgeon to the United States Public Health Service. Maxcy drew his data from the United States Public Health Service. For Georgia and Oklahoma, only the 1921 malaria death rate is available.

cereals, hay and forage, cotton and cottonseed, tobacco, potatoes, and vegetables. Our core estimates are similar when controls for crop values, by crop type, are incorporated.

Fishback et al. (2006) provided net-migration rates, which are defined as the net migration per 1,000 people in the county in 1930. They also provided 1930 tax returns per capita, which is a good proxy for the share of people who were in the top 5 to 10 percent of the nationwide income distribution, and an extensive set of geographic controls, including information on the permeability of the soil, number of rivers, number of lakes, number of swamps, and elevation.

Using data from the National Climatic Data Center, we calculated the annual rainfall and the fraction of the year with daily mean temperatures, or the simple average of the daily low and high temperature, in a series of 10°F intervals. The temperature bands are used to capture the nonlinear relationship between temperatures and malaria (Craig, et al. 1999).[18] Not all counties contained weather stations, so the weather information is assigned to counties using inverse-distance weights of the weather stations within 50 miles of the county centroid.[19]

Several counties either merged or split between 1920 and 1940. In addition, some of our key New Deal variables are only available for groups of counties. In order to remain consistent over time, the data are aggregated to the most encompassing unit of observation. This procedure aggregates 96 counties to 40 observations. Information on county boundary changes is from the Atlas of Historical County Boundaries (The Newberry Library 2010). The final dataset consists of 1,205 county units across 14 southern states.[20]

5. Methodology

a. Reduced-form impact of the AAA

To examine the relationship between AAA expenditures and malaria, we estimate the following reduced-form quasi-first-difference model using ordinary least squares:

(1) $Y_{c,\,1940} = b_1 \cdot Y_{c,\,1930} + b_2 \cdot AAA_c + b_3 \cdot X_c + b_4 \cdot W_c + \varphi_s + u_{ct}$,

[18] Specifically, we control for the fraction of the decade with daily temperatures between 50 and 60, 60 and 70, 80 and 90, and more than 90°F, respectively.

[19] Approximately 90 counties did not have a weather station within 50 miles during the 1930-1940 period. We use the weather stations that are within 100 miles in those instances.

[20] The states include Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Missouri, Mississippi, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, and Virginia.

where $Y_{c,\ 1940}$ and $Y_{c,\ 1930}$ are the malaria death rates (or the log of the malaria death rates) in county c in 1940 and 1930, respectively; AAA is the per capita AAA expenditures in county c between 1933 and 1939; X and W are vectors of demographic and geographic characteristics, respectively, that control for a variety of factors that may have been correlated with AAA expenditures and changes in the malaria death rate between 1930 and 1940. State fixed effects (φ_s) are included to account for any omitted variables that affected all counties at the state level, like state laws and public-health expenditures. Heteroskedastic robust standard errors are estimated. For our coefficient of interest (b_2), we also present nonparametric spatially correlated standard errors (Conley and Molinari 2007).[21] The regressions are weighted by the county's 1930 population. Although we rely on equation (1) as our core specification, we show that our estimates are qualitatively similar when we use a Poisson count model, which is often used in situations with low-frequency mortality events.

Unlike a traditional first-difference, our quasi-first-difference model includes the lagged outcome variable, $Y_{c,\ 1930}$, as an explanatory variable. That is, we allow for the rate of decay to depend on the level of the malaria death rate in 1930. This econometric modeling choice is based on epidemiological theory on infectious diseases (Keeling and Rohani 2007). We find strong empirical evidence to support this modeling choice. We can reject the hypothesis that the coefficient on malaria death rates in 1930 (b_1) is equal to one at the one-percent level.

This approach effectively constrains the decay function (in malaria death rates) to be linear and equal across all counties. In one test of this assumption, we control for the cubic malaria death rate in 1930. Also, in an alternative specification, we interact all the explanatory variables in equation (1), including the state fixed effects, with the lagged malaria death rate ($Y_{c,\ 1930}$). This specification allows for the possibility that the decay functions varied by county characteristics. Also, the interactions with the state fixed effects control for biases that may result from the fact that many of the states' 1930 malaria data come from different sources.

The identifying variation for the relationship between malaria and the AAA is the residual variation after controlling for a large set of county characteristics, including controls for crop output, economic activity, geography, weather, other New Deal programs, and the demographic composition of the population. The greatest threat to our identification strategy is that AAA expenditures may have been allocated to counties experiencing relatively greater

[21] We allow the error terms to be correlated for counties within 100 miles of each other.

economic hardship on dimensions that we have not measured. Since greater hardship would have been positively correlated with both malaria death rates and AAA expenditures, holding the correlates constant, the coefficient on AAA expenditures would likely be biased in a positive direction. Given that we find a negative relationship between AAA expenditures and the malaria death rate, this bias is likely to lead to an underestimate of the causal effects of the AAA. As an important placebo check, we also estimate the relationship between AAA expenditures and the change in the malaria death rate between 1920 and 1930, years before the AAA was ever implemented.

There is likely some measurement error in the malaria rates in 1930 and 1940. For example, malaria death rates were sometimes misclassified as other prominent diseases, like Typhoid fever, that shared similar symptoms (Troesken 2004). Further, estimates of the malaria death rate in 1930 from the Faust map have more measurement error because we developed the malaria statistics by interpolating across bins. Since the measurement error is likely to be uncorrelated with the AAA expenditures, we do not anticipate a meaningful bias on the estimated coefficient of interest. Also, we cannot determine the extent to which our estimates are identified by differences in the fatality rate versus differences in the morbidity rate. Nonetheless, our results most likely incorporate some of the morbidity effects of the AAA since the AAA-induced variation in the mortality rate is likely to be positively correlated with the morbidity rate.

b. Identifying the causal mechanisms

A key component of this paper is to test whether changes in land use and/or migration are the causal mechanisms behind our reduced-form estimates. We test the relative importance of these two mechanisms in a few ways. First, we examine how the AAA affected net-migration, the percent black, and several measures of farm activity between 1930 and 1940, using a quasi first-difference model akin to equation (1).

Second, we examine the effects of AAA expenditures in neighboring counties on the malaria death rate in the county of interest. If the AAA caused out-migration of people susceptible to malaria, we might expect that neighboring counties' AAA expenditures would raise both net-migration rates and malaria death rates in the county of interest because most migrations would have been short distances (Boustan et al. 2010). However, neighboring counties' AAA expenditures would not have affected land use *directly* in the county of interest, although migration may have led indirectly to changes in land use.

Third, using the 1940 Census, we estimate a quasi-first-difference model that separately analyzes the roles of in-migration and out-migration. We conduct this analysis at the State Economic Area (SEA) level since the 1940 Census has information only on the migrants' SEA (but not county) of residence both prior to and subsequent to migrating. In addition to providing more support for the migration mechanism, the SEA-level analysis can help resolve the net-causal impact of the AAA (over the entire population) by exploring whether in-migration and out-migration have asymmetric effects.

6. Results

a. *Summary Statistics*

Table 1 summarizes the characteristics of the 1,205 counties in the sample. As an initial comparison, means are calculated for the key covariates for samples stratified on Suk Chul Hong's (2010) measure of malaria risk, which is based on the relationship between environmental factors and malaria morbidity statistics from the 19th century. Hong's measure of malaria risk is a strong predictor of the malaria death rate in 1930 and 1940. There were an average of 5.5 malaria deaths per 100,000 habitants in 1930 in "low-risk" counties (N=420) and an average of 13.8 "high-risk" counties (N=785).

Geography, climate, and socioeconomic status are all associated with malaria risk. High-risk counties were much more likely to contain a lake or swamp. There is a strong negative correlation between malaria risk and elevation, which influences temperature and rainfall. Between 1931 and 1940, low-risk counties had daily mean temperatures between 80 and 90°F only 13 percent of the year, while high-risk counties had these temperatures around 18 percent of the year on average. The fraction illiterate was 7.7 and 9.5 percent in low- and high-risk counties, respectively. Also, high-risk counties had a much higher fraction of black inhabitants and lower rates of home ownership.

The average annual net-migration rate, defined as the inflow of migrants minus the outflow of migrants over the 1930 population in thousands divided by 10 years, was 0.98 for the entire sample. Between 1930 and 1940, high-risk counties experienced a 0.12 percent decline in population, while low-risk counties experienced a 3.47 percent increase in population, both due to net-migration. The standard deviation in annual net-migration rates was approximately 16.

Average annual AAA expenditures per capita were much higher in high-risk counties ($23.30) than low-risk counties ($14.69), an important consideration when evaluating the net impact of the AAA. The standard deviation in per capita AAA expenditures was approximately $20, implying there was substantial heterogeneity across counties in AAA expenditures.

b. Core estimates

The Table 2 results illustrate that AAA expenditures were negatively correlated with the malaria death rate in 1940, controlling for the malaria death rate in 1930. The statistically significant coefficient of -0.033 in the model with all correlates and fixed effects in column (3) indicates that each additional per capita dollar of AAA expenditures was associated with a decline in the malaria death rate. The results suggest that a county with the mean AAA expenditures of $22 per capita was likely to have a malaria death rate that fell by 0.7 deaths per 100,000 people more than a county with no AAA expenditures. Given that malaria death rates fell by approximately 7.0 (from 11.2 to 4.2) between 1930 and 1940, the change in AAA expenditures can account for roughly 10 percent of the average reduction in malaria mortality risk.

It is important to note that the coefficient on AAA expenditures is positive when we do not control for the county characteristics and state fixed effects in column 1 of Table 2. Once controls for the county characteristics are included (columns 2 and 3), the coefficient becomes negative, large in magnitude, and statistically significant. Thus, a failure to add these controls would have led us to conclude that the AAA was associated with higher malaria death rates due to positive omitted variable bias. In unreported estimates we find that counties with a higher number of farm operators per capita received more AAA expenditures, and experienced less of a decline in the malaria death rate. This finding accords with historical accounts that urban areas, which tended to receive fewer AAA grants, were also becoming relatively more effective at controlling malaria over this time period (Humphreys 2001).

We find strong support for using a quasi-first-difference model, as opposed to a traditional first-difference model where b_1 in equation (1) would be set to one. The coefficient on the malaria death rate in 1930 is 0.11 in column (3) and is statistically significantly different from one at conventional levels. Also, AAA expenditures had a stronger negative relationship with malaria death rates than either relief spending or public works spending. The coefficients on relief spending and public works spending were economically small and statistically insignificant.

c. Placebo tests and other robustness checks

Even though we control for numerous observable characteristics that might have influenced the distribution of AAA spending, there may have been omitted variables that were correlated with both AAA spending and malaria death rates. To address this concern, we perform a placebo test and estimate the relationship between AAA expenditures from the 1930s and the malaria death rate in 1930, controlling for the malaria death rate in 1920. These estimates, which are presented in Table 3, mitigate concerns that pre-existing trends or unmeasured variables are causing the AAA coefficient to be negative in our core regressions. The coefficient of the 1930s AAA variable is positive and not statistically significant when we use all of the controls in the model in column (3).

Various other robustness checks are presented in Table 4. The coefficient on AAA expenditures in 1940 remains negative and statistically significant when we control for: 1) changes in covariates between 1920 and 1930, 2) the cubic of the malaria death rate in 1930, 3) crop types, and 4) interactions between the covariates and state fixed effects and the malaria death rate in 1930. The coefficient ranges from -0.023 to -0.046 across specifications (1) through (4) in Table 4. Column (5) of Table 4 implements a Poisson count model to account for the fact that approximately half the counties have no malaria deaths in 1940. The column (5) coefficient implies that counties with an additional per capita dollar of AAA expenditures tended to have malaria death rates that were 0.9 percent lower. This effect is larger than the negative 0.3 percent effect (0.033 divided by an average malaria death rate of 11) implied by the baseline OLS coefficient in column (3) of Table 2.[22]

[22] Our estimates are also similar when we use a negative binomial model. In results not reported, we stratify our estimates based on some of the observable characteristics of the county. We find similar estimates when we stratify based on Hong’s measure of malaria risk. The estimated effect is larger when we restrict the sample to counties with at least one city, which is defined by having a population of 25,000 people or more. When we stratify on population density, the estimates remain large and negative when we restrict to our sample to high-density counties (i.e. more than 30 people per square mile) and low-density counties (i.e. less than 30 people per square mile), respectively.

d. Changes in observables characteristics

In order to explore the mechanisms by which the AAA influenced malaria death rates, we examine the relationship between county characteristics in 1940 and AAA spending in Table 5. There are three key findings worth mentioning. First, the coefficient of -0.157 on AAA expenditures in column (1) shows that AAA spending was associated with a decline in net-migration. Counties with the mean per capita AAA spending of $22 experienced a 3.5 percent greater decline in population due to net-migration than counties with no AAA spending. This effect is large relative to the average annual net-migration rate of 0.9 and modest compared to the standard deviation in the net-migration rate of 16.0.[23]

Second, AAA funds were negatively associated with the fraction black and the number of farm operators per capita. Brigham Depew (2010) finds that the AAA-induced reduction in farm operators came from a decline in the number of share tenants and croppers. Depew's and our results imply that the AAA induced lower socioeconomic groups to migrate. Thus, AAA spending is likely to have affected the migration decisions of groups most at-risk of contracting malaria.

Third, the AAA had little impact on overall farm acreage or harvested acreage within farms. The coefficients from columns (4) and (5) in Table 5 imply that a $22 increase in per capita AAA expenditures was correlated with a 0.3 percentage point increase in the fraction of land in farms (from a baseline of 58.9 percent) and a 0.3 percentage point decrease in the fraction of farmland harvested (from a baseline of 45.5 percent). In estimates not reported, we verify that the AAA did not impact land acreage in drainage enterprises using a small subsample of counties and novel data.[24]

The finding that the AAA did not drastically decrease farm and harvested acreage can be explained by anecdotal evidence that many southern farmers who took land out of cotton, one of the key AAA crops, began growing "non-cash crops." For example, a survey of AAA recipients in five cotton states (Arkansas, Oklahoma, Texas, Georgia, and South Carolina) showed that only 2 percent of the acreage taken out of cotton production was actually left idle. About three-fourths of the cotton acreage was converted to home food and feed crops, and about one-tenth

[23] These estimates are consistent with previous research on migration and the New Deal that focused on the entire country (Fishback et. al. 2006 and Boustan et. al. 2010).

[24] The drainage variable was only available for 213 counties out of 1,205.

was converted to permanent pasture and meadow crops. About one-eighth went to soil improvement crops to be turned over (Agricultural Adjustment Administration 1936, 48). This anecdotal evidence, coupled with our empirical findings, suggest that land use was not the driving mechanism behind the negative correlation between malaria death rates and AAA expenditures.

e. The Impact of AAA Spending in Neighboring Counties

As a means of corroborating our argument that AAA-induced migration was the mechanism contributing to lower malaria death rates, we estimate our quasi-first-difference model while adding neighboring counties' AAA spending as well as controls for the neighbors' malaria death rate in 1930 and New Deal public works and relief spending (see Table 6). If AAA spending in the county of interest reduced malaria because people susceptible to malaria out-migrated, we might expect to see evidence that neighbors' AAA spending raised malaria rates in the county of interest because neighboring county migrants were more likely to move to a neighboring county. The results in columns (1) and (2) of Table 6 show that neighbors' AAA spending was associated with an increased malaria death rate and higher net-migration rates in the county of interest. The effects of the neighbors' AAA spending are *both* about 40 percent less in absolute magnitude as the AAA coefficients in the county of interest, suggesting that the migration mechanism may be able to explain the majority of the negative correlation between malaria death rates and AAA expenditures. However, we cannot make a strong conclusion in this regard since the coefficients on neighboring county's AAA expenditures in columns (1) and (2) are statistically insignificant.

f. Malaria and Migration Flows Between State Economic Areas

The county-level regressions show that AAA spending was associated with a reduction in *net*-migration rates and also with reductions in malaria, which is consistent with a mechanism in which the AAA lowered (increased) malaria risk through out-migration (in-migration) of people susceptible to malaria. The next step to establishing this chain of reasoning is to estimate the separate relationships between the AAA and out-migration and in-migration, respectively, and malaria death rates and out-migration and in-migration, respectively. The relationship for both migration in-flows and out-flows can be examined using 1940 Census data from the IPUMS, which reports residence in 1935 and 1940 by State Economic Area (SEA), but not by county. Most SEAs contained several counties, so the SEA sample aggregates 1,205 counties into 162 SEAs. Although the aggregation leads to fewer observations, the SEA analysis offers the opportunity to look separately at in-migration and out-migration flows in ways that cannot be done with the county data on net-migration rates.

We replicate the results found in our county-level estimates at the SEA level in columns (1) and (2) in Table 7. In column (1) an additional dollar of AAA grants per capita is associated with 0.0318 fewer malaria deaths per 100,000 inhabitants. This estimate is nearly identical to the coefficient of -0.0333 in our county-level estimates (column 3 of Table 2). The standard error is larger, in part, due to the use of more aggregated data. In column (2) each additional dollar of AAA expenditures was associated with a statistically significant decline of 0.172 net-migrants per 1,000 per year, which is only slightly more than the -0.157 coefficient found in our county-level estimates (column 1 of Table 5), suggesting that the AAA was more likely to induce inter-SEA migration than intra-SEA migration.

The results in Table 7 provide suggestive evidence that the AAA was likely to both increase out-migration and reduce in-migration. Each additional dollar of AAA expenditures was associated with 0.08 additional out-migrants (per 1,000) per year and 0.09 fewer in-migrants per year. The coefficient on AAA is statistically significant at the 10-percent level in the out-migration regression (column 3), but statistically insignificant in the in-migration regression (column 4).

The results in column (5) test the relationship between malaria death rates and out-migration and in-migration, respectively. The negative sign of the out-migration coefficient is consistent with our hypothesis that out-migration of low-income groups (e.g. sharecroppers) contributed to reductions in malaria mortality. The positive sign of the in-migration coefficient also suggests that in-migration was associated with higher malaria mortality. The causal effects of out-migration and in-migration are likely to be larger in magnitude than the estimated coefficients due to endogeneity. For example, people might have been more likely to leave (move to) SEAs with high (low) malaria risk.

In addition, the magnitude of the coefficient on out-migration is twice the size of the coefficient on in-migration, suggesting that out-migration was the more significant causal mechanism. For example, an increase in the annual out-migration rate of 20 (per 1,000), which is the average out-migration rate between 1935 and 1940, is associated with a decline in the malaria death rate of 0.77. An increase in the annual in-migration rate of 20 is only associated with a 0.35 increase in the malaria death rate. In other words, an SEA with an annual out-migration rate of 20, an annual in-migration rate of 20, and a net-migration rate of zero, would experience a sizable decline in the malaria death rate of approximately 0.42. However, we cannot reject that the coefficients on out-migration and in-migration, respectively, are equal in absolute magnitude.

In column (6) we examine the relationship between malaria death rates and migration flows while taking into account differences in malaria mortality risk in the migrants' SEA of origin in 1935. Specifically, we create an in-migrant malaria mortality risk variable that is the weighted average of the malaria death rate in the migrants' sending SEAs with the share of in-migrants from the sending SEA as the weights. We create a similar measure for out-migration by simply interacting the out-migration rate with the malaria death rate in the SEA of interest.

In general, the standard errors on the coefficients in column (6) of Table 7 are large so we cannot put meaningful bounds on our estimates. This caveat aside, the column (6) specification (with interactions) suggests a larger out-migration effect than our column (5) specification. That is, the coefficient on the out-migration rate in column (6) is now -0.0641, or close to twice as large as the column (5) estimates. The coefficient on the out-migration rate interacted with the malaria death rate is close to zero. These column (6) out-migration estimates suggest that the malaria death rate was reduced by 1.3 deaths per 100,000 people in an SEA with 20 additional out-migrants per 1,000 people (-0.64 times 20) regardless of the malaria death rate in 1930.

The column (6) coefficient on the in-migration rate is now negative, which is the opposite sign of the column (5) estimate and contrary to our hypothesis. However, the effect of in-migration appears to be strongly influenced by the malaria death rates in the sending SEAs, which is consistent with our hypothesis. The statistically significant coefficient of 0.0060 on the interaction term between the in-migration rate and the in-migrant malaria risk measure suggests that increases in in-migration from areas with higher malaria risk raised the malaria death rate in the SEA of interest. If the in-migrants had an average malaria mortality risk of 11 per 100,000, the 1940 malaria death rate in the SEA of interest would be approximately 0.9 higher if the annual in-migration rate was 20 (-0.02 times 20 plus 0.006 times 20 times 11). Like out-migration, the effect of in-migration appears to be larger in the column (6) specification than the column (5) specification. Nonetheless, out-migration appears to have a larger effect than in-migration in absolute value in both specifications.

On the whole, the Table 7 estimates suggest that both the out-migration mechanism and the in-migration mechanism contributed to the AAA's negative association with malaria death rates. However, the fact that out-migration has a larger association with malaria death rates than in-migration is consistent with our hypothesis that the AAA-induced migration caused a net-decrease in malaria death rates. Given the imprecision of these estimates and the endogeneity surrounding migration decisions, we should not draw strong conclusions from these SEA estimates.

7. Discussion

The *net* causal effect of the AAA depends on the mechanism by which the AAA was associated with lower malaria death rates. If the lower malaria death rates came from changes in land use that helped reduce mosquito habitats, then the AAA can be said to have contributed to a decline of malaria where the AAA monies were spent. Similarly, if the AAA lowered malaria in the county of interest through out-migration in the areas where the AAA spent more money, the AAA would have contributed to a decline in those counties. However, the benefit may have been offset by out-migrants who helped spread infections to counties receiving fewer AAA grants.

To get an upper-bound estimate of the impact of the AAA, assume that the AAA coefficient in column (3) of Table 2 is a causal effect, and the AAA expenditures exclusively reduced the malaria death rate. Under these strong assumptions, this AAA coefficient implies that the AAA reduced malaria death rates throughout the South by 0.7 deaths per 100,000 people, which accounts for roughly 10 percent of the decline in the malaria death rate between 1930 and 1940. This indicates that the AAA may have played an important supporting role in malaria's eradication from the South.

Although our SEA-level estimates suggest that in-migration might have increased malaria death rates, there is empirical support for the use of the upper-bound estimates when considering the *long-term* implications of the AAA through the 1940s. As Table 1 illustrates, AAA funds disproportionately went to counties with high-risk malaria ecologies. Thus, when migrants moved to counties where the AAA had little or no presence, any migration-related epidemics were likely to have been short lived due to ecological barriers to transmission. Moreover, the

United States Public Health Service and other agencies had already invested heavily in eradicating malaria from cities, which received less AAA money, so new epidemics may have been relatively easier to contain in urban areas (Humphreys 2001).

Our estimates also speak to the externalities associated with migration. To provide an approximation of these externalities, we utilize the simple model in Section 2. Specifically, we define the change in the malaria death rate in a typical county C between 1940 and 1930 as Y_{C1940} - Y_{C1930}. Here, Y is the malaria death rate (instead of I for the incidence level like before) and we have subscripts for the year (1930 or 1940). The term (Y_{C1940} - Y_{C1930}) can be decomposed into $[(1-\alpha_{1940})\ Y_{L1940} + \alpha_{1940}\ Y_{H1940}] - [(1-\alpha_{1930})\ Y_{L1930} + \alpha_{1930}\ Y_{H1930}]$, where the α parameter is the fraction of the population in the high-risk group in a given year. In order to approximate the magnitude of the externalities (i.e. the effect of changes in α on changes in Y_L), we must make four simplifying assumptions. First, assume that the high-risk group makes up 5 percent of the population in a given county in 1930 (i.e. α_{1930} equals 0.05). Second, the entire high-risk group out-migrates between 1930 and 1940 (i.e. α_{1940} equals 0). The first and second assumptions imply that the out-migration rate is 5. Third, the effects of the AAA are entirely due to out-migration. The third assumption implies that a net out-migration rate of 5 per 1,000 people per year results in approximately 1.0 fewer malaria deaths per 100,000 in 1940 (-0.033 divided by -0.157 times 5).[25] Relying on the first three assumptions, we have that $-1.0 = Y_{L1940} - 0.95\ Y_{L1930} - 0.05\ Y_{H1930}$ or $-1.0 = (Y_{L1940} - Y_{L1930}) + 0.05\ (Y_{L1930} - Y_{H1930})$. Thus, to uncover the magnitude of the externalities (Y_{L1940} - Y_{L1930}) we need only know the difference in malaria death rates between the low-risk and high-risk groups (Y_{L1930} - Y_{H1930}). Thus, our fourth assumption is that the high-risk group has 10 more malaria deaths per 100,000 inhabitants than the low-risk group ($Y_{L1930} - Y_{H1930} = 10$). Under these four assumptions, the change in the malaria death rate in the low-risk group (Y_{L1940} - Y_{L1930}) is -0.5, suggesting modest external benefits to out-migration.

It is important to note that our approximation of the externalities is sensitive to changes to the fourth assumption. For example, if we assume the malaria death rate in the high-risk group was 20 higher than the low-risk group, the external benefits to the non-migrating population

[25] The -0.033 and -0.157 come from column (3) in Table 2 and column (1) in Table 5, respectively.

would be nil.[26] As an additional caveat, this calculation also ignores the real possibility of heterogeneous impacts by population density.

These caveats notwithstanding, this thought experiment suggests that a reduction in the high-risk population may confer some, albeit limited, external benefits to the rest of the population. Thus, public-health interventions that reduce malaria risk (e.g. providing free bed nets) are likely to be undervalued when these externalities are ignored.

8. Conclusion

The upper-bound estimates here suggest that the AAA played an important supporting role in malaria's eradication from the United States. We cannot rule out the possibility that part of the gain may have come through changes in land use that helped reduce mosquito populations. However, much of the evidence here shows that a key mechanism through which the AAA was associated with reductions in malaria mortality was through a population shift away from counties with high-risk malaria ecologies to counties with low-risk ecologies. Further, the reduction in malaria mortality is a positive outcome that helps offset the negative features of the AAA, such as reduced sharecropper wages, that contributed to increased migration.

The South's experience with the AAA in the 1930s illustrates a case where migration flows, driven in part by policy shifts, can improve health conditions overall. However, the results also suggest that there are very realistic cases where in-migration of at-risk groups can undermine malaria eradication efforts. If, as in some developing countries, urban centers have high transmission rates, then rural-to-urban migration could be an important mechanism complicating malaria eradication efforts. The inability of public-health institutions to keep pace with rapid urbanization may be one explanation for the persistently high incidence levels in some of today's developing countries.

[26] The first and second assumptions are a matter of mathematical convenience, mostly since we do not need to know how changes in α affect Y_{H1940}. Relaxing the third assumption changes the interpretation, but does not materially affect the magnitude of the externalities. That is, assuming some of the effects of the AAA are due to in-migration, an increase in the at-risk population confers an external cost to other groups as well.

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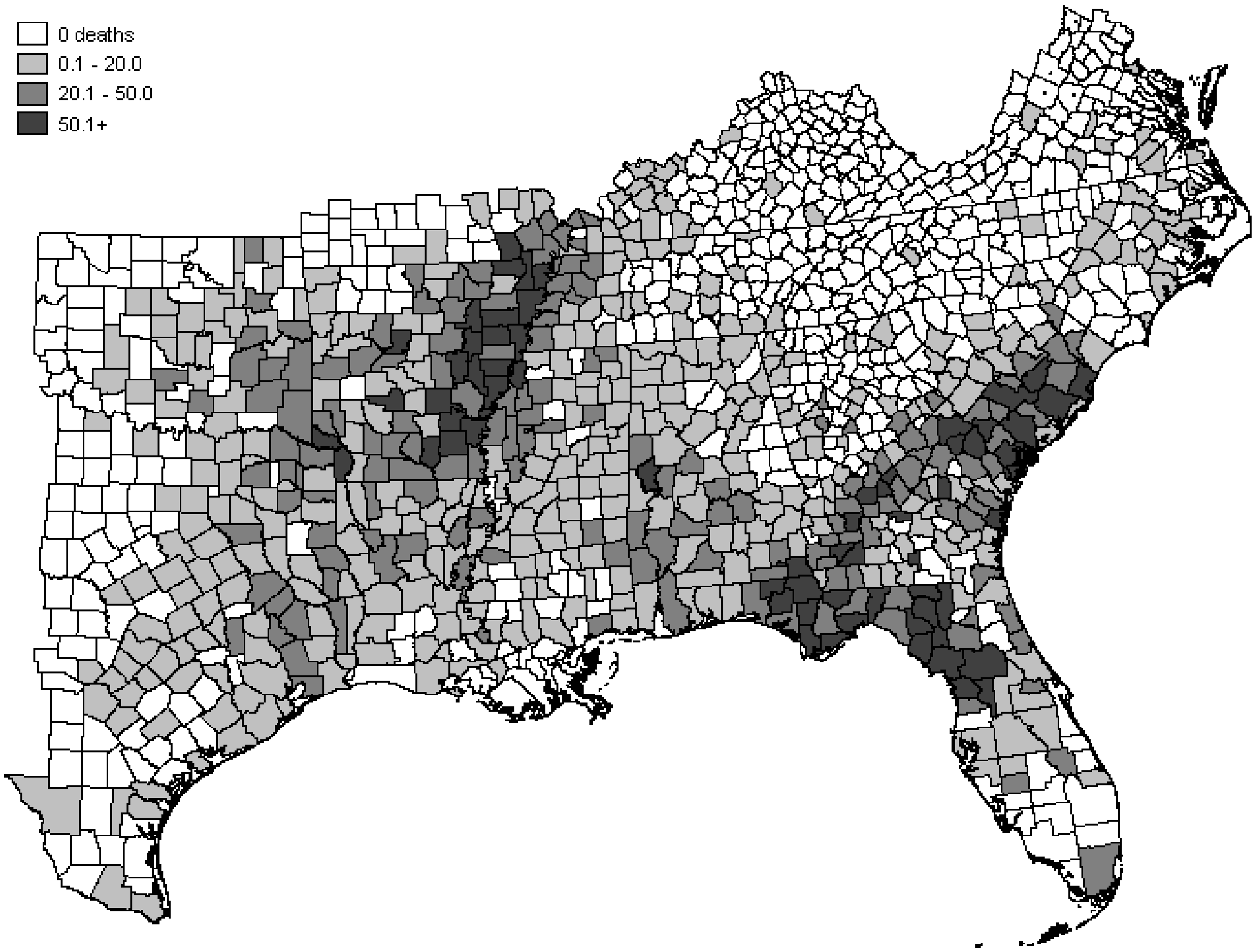
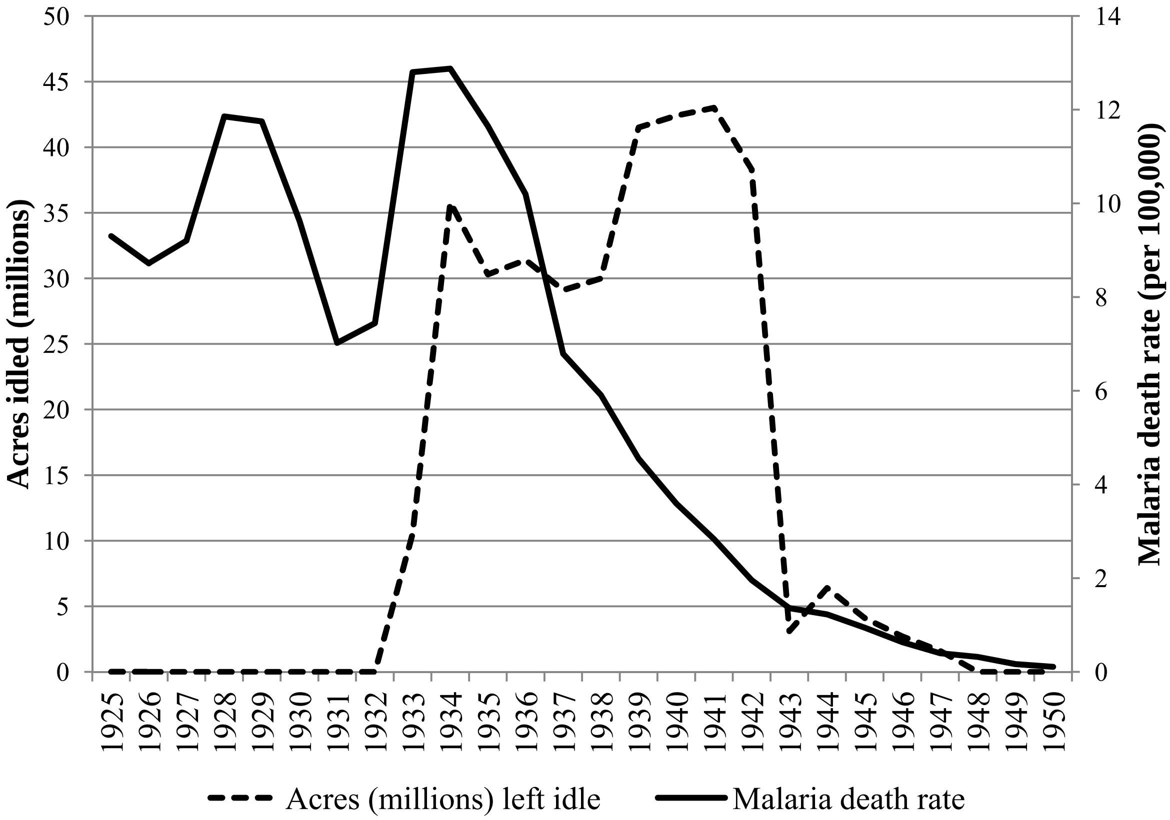
Figure 1: Malaria death rates, by county, 1930



Source: Faust (1932)

Figure 2: Acreage left idle (in millions) under the Agricultural Adjustment Act and the average malaria death rate in the Southern states



Source: AAA data come from Sumner (2006). The malaria death rates come from the Vital Statistics of the United States (various years). The malaria death rate is a simple average of Alabama, Florida, Kentucky, Louisiana, Missouri, Mississippi, North Carolina, South Carolina, Tennessee, and Virginia, or the states that reported malaria deaths over the entire period.

Table 1: Summary statistics

	Year(s)	All	Malaria risk	
			Low	High
Malaria data				
Malaria death rate in 1940	1939-1940	4.2	1.8	5.2
Malaria death rate in 1930	1927/1930*	11.2	5.5	13.8
County characteristics				
Permeability of soil	-	2.24	2.78	2.00
Presence of lake	-	0.82	0.74	0.85
Presence of swamp	-	0.41	0.32	0.45
Presence of major river	-	0.13	0.19	0.11
Lowest elevation	-	298	427	241
Fraction days <50F per year x 100	1931-1939	22.6	26.4	20.9
Fraction days 50-60F per year x100	1931-1940	16.9	16.4	17.2
Fraction days 60-70F per year x100	1931-1940	19.1	18.9	19.3
Fraction days 70-80F per year x100	1931-1940	24.2	24.8	24.0
Fraction days 80-90F per year x100	1931-1940	16.6	13.0	18.2
Fraction days 90+F per year x100	1931-1940	0.5	0.5	0.5
Inches precipitation per year	1931-1940	44.6	43.2	45.3
Illiterate population over age 10 x100	1930	8.97	7.71	9.53
Tax returns per 1,000 inhabitants	1930	12.55	14.23	11.80
Log of total population	1930	10.65	10.61	10.67
Urban x100	1930	31.77	35.63	30.05
Black x100	1930	26.35	14.85	31.46
Crop value per capita	1930	69.12	58.92	73.64
Farm acres per total acres x100	1930	58.89	54.21	60.96
Farm operators per capita x100	1930	9.24	7.47	10.03
Fraction w/ own homes x100	1930	41.00	47.84	37.97
Retail sales per capita	1930	3.02	3.10	2.99
Annual net-migration per 1,000	1930-1940	0.98	3.47	-0.12
New Deal variables				
AAA expenditures per capita	1933-1939	20.66	14.69	23.30
Relief spending per capita	1933-1939	53.25	66.70	47.28
Public works spending per capita	1933-1939	36.98	58.42	27.46
Number of counties	-	1,205	420	785

Notes: *For Arkansas and Louisiana, we rely on malaria deaths from 1927. These statistics are weighted by 1930 county population. The dollar values are current. The malaria risk data was generously provided by Suk Chul Hong (2010).

Table 2: Core estimates, outcome = malaria mortality rate per 100,000

Independent variable	(1) No controls	(2) Controls	(3) Controls + fixed effects
Annual AAA expenditures per capita	0.0383	-0.0309	-0.0333
	(0.0091)***	(0.0123)**	(0.0115)***
	[0.0214]+	[0.0179]+	[0.0159]++
Annual relief spending per capita	-0.0077	0.0002	-0.0011
	(0.0033)**	(0.0022)	(0.0022)
Annual public works spending per capita	0.0003	-0.0008	-0.0004
	(0.0004)	(0.0004)**	(0.0003)
Malaria death rate in 1930	0.1994	0.1302	0.1151
	(0.0185)***	(0.0182)***	(0.0180)***
County characteristics in 1930	No	Yes	Yes
State fixed effects	No	No	Yes
R-squared	0.36	0.54	0.57
Number of counties	1,205	1,205	1,205

Notes: * or + p<0.10, ** or ++ p<0.05, *** or +++ p<0.01. Heteroskedastic robust standard errors are in (parentheses) and nonparametric spatially robust errors are in [brackets]. The regression is weighted by the 1930 county population. The county characteristics include all the variables listed in Table 1 as well as a cubic in elevation and a cubic in precipitation. We omit temperatures below 50°F due to colinearity issues.

Table 3: Placebo estimates, outcome: malaria death rate in 1930

Independent variable	(1) No controls	(2) Controls	(3) Controls + fixed effects
AAA expenditures per capita	0.0527 (0.0228)** [0.0528]	0.0215 (0.0306) [0.0569]	0.0113 (0.0303) [0.0425]
Relief spending per capita	0.0024 (0.0077)	0.0020 (0.0105)	-0.0120 (0.0082)
Public works spending per capita	-0.0029 (0.0017)*	-0.0034 (0.0021)	-0.0004 (0.0011)
Malaria death rate in 1920	0.459 (0.0468)***	0.361 (0.0503)***	0.352 (0.0485)***
County characteristics in 1920	No	Yes	Yes
State fixed effects	No	No	Yes
R-squared	0.32	0.39	0.51
Number of counties	1,205	1,205	1,205

Notes: * or + p<0.10, ** or ++ p<0.05, *** or +++ p<0.01. Heteroskedastic robust standard errors are in (parentheses) and nonparametric spatially robust errors are in [brackets]. We control for the county characteristics in 1920 and the weather conditions between 1921-1930. The regression is weighted by the 1920 county population.

Table 4: Other robustness checks, outcome: malaria death rate in 1940

Independent variable	(1) Trends	(2) Cubic	(3) Crop types	(4) Interactions	(5) Poisson
AAA expenditures per capita	-0.023	-0.028	-0.037	-0.039	-0.0095
	(0.0115)**	(0.0113)**	(0.0126)***	(0.0115)***	(0.0040)**
	[0.0159]	[0.0157]+	[0.0166]++	[0.0136]+++	
Malaria death rate in 1930	Yes	Yes	Yes	Yes	Yes
Trends in malaria death rate 1920-1930	**Yes**	No	No	No	No
Trends in characteristics 1920-1930	**Yes**	No	No	No	No
Cubic of malaria death rate 1930	No	**Yes**	No	No	No
Crop types	No	No	**Yes**	No	No
Controls interacted w/ 1930 malaria death rate	No	No	No	**Yes**	No
Relief spending per capita	Yes	Yes	Yes	Yes	Yes
Public works spending per capita	Yes	Yes	Yes	Yes	Yes
County characteristics in 1930	Yes	Yes	Yes	Yes	Yes
State fixed effects	Yes	Yes	Yes	Yes	Yes
Number of counties	1,205	1,205	1,205	1,205	1,205

Notes: * or + p<0.10, ** or ++ p<0.05, *** or +++ p<0.01. Heteroskedastic robust standard errors are in (parentheses) and nonparametric spatially robust errors are in [brackets]. The regression is weighted by the 1930 county population. The trends in characteristics includes the trends in fraction illiterate, per capita tax returns, fraction urban, fraction black, per capita crop values, fraction of land in farms, fraction farmers, and fraction home ownership. The crop type variables include the fraction of crop value in cereals, hay, cotton, tobacco, and vegetables, respectively. The model with interactions allows county characteristics and state fixed effects to vary linearly with the 1930 malaria death rate.

Table 5: Effects of the AAA on Net-Migration (1930-1940), Percent Black (1940), and Farm Activity (1940)

Outcome / Independent variable	(1) Net-migration rate per 1,000	(2) Black x100	(3) Farm operators per capita x100	(4) Farm acres per total acres x100	(5) Harvested acres per farm acre x 100
AAA expenditures per capita	-0.1570	-0.0153	-0.0145	0.0139	-0.0169
	(0.0513)***	(0.0050)***	(0.0036)***	(0.0251)	(0.0182)
	[0.0506]+++	[0.0061]++	[0.0068]++	[0.0225]	[0.0204]
Mean of outcome in 1930	0.98	26.35	9.24	58.89	45.52
Crop types	No	No	No	No	No
Relief spending per capita	Yes	Yes	Yes	Yes	Yes
Public works spending per capita	Yes	Yes	Yes	Yes	Yes
Malaria death rate in 1930	Yes	Yes	Yes	Yes	Yes
Outcome variable in 1930	Yes	Yes	Yes	Yes	Yes
County characteristics in 1930	Yes	Yes	Yes	Yes	Yes
State fixed effects	Yes	Yes	Yes	Yes	Yes
R-squared	0.49	0.99	0.95	0.90	0.89
Number of counties	1,205	1,205	1,205	1,205	1,205

Notes: * or + p<0.10, ** or ++ p<0.05, *** or +++ p<0.01. Heteroskedastic robust standard errors are in (parentheses) and nonparametric spatially robust errors are in [brackets]. The regression is weighted by the 1930 county population.

Table 6: The Effect of AAA Spending in Neighboring Counties

Outcome / Independent variable	Malaria death rate	Net-migration
AAA expenditures per capita in own county	-0.042 (0.0131)*** [0.0167]++	-0.157 (0.0513)*** [0.0506]+++
AAA expenditures per capita in neighboring counties	0.012 (0.0118) [0.0156]	0.060 (0.0456) [0.0425]
Malaria death rate in 1930	Yes	Yes
Malaria death rate in neighboring counties in 1930	Yes	Yes
Relief expenditures	Yes	Yes
Public works expenditures	Yes	Yes
County characteristics in 1930	Yes	Yes
State fixed effects	Yes	Yes
R-squared	0.59	0.49
Number of counties	1,205	1,205

Notes: Heteroskedastic robust standard errors are in (parentheses) and nonparametric spatially robust errors are in [brackets]. The regression is weighted by the 1930 county population.

Table 7: SEA-level estimates, outcome: malaria death rate in 1940

Outcome Independent variable	(1) Malaria death rate in 1940	(2) Net-migration rate	(3) Out-migration rate	(4) In-migration rate	(5) Malaria death rate	(6) Malaria death rate
AAA expenditures per capita	-0.0318 (0.0196)	-0.1721 (0.0876)*	0.0811 (0.0429)*	-0.0909 (0.0812)		
Out-migration rate per 1,000 1935-1940					-0.0384 (0.0427)	-0.0641 (0.0560)
In-migration rate per 1,000 1935-1940					0.0177 (0.0238)	-0.0207 (0.0202)
Out-migration rate x 1930 malaria death rate in migrant's home SEA						0.0001 (0.0043)
In-migration rate x 1930 malaria death rate in migrant's home SEA						0.0060 (0.0026)**
Malaria death rate in 1930	Yes	Yes	Yes	Yes	Yes	Yes
Relief spending	Yes	Yes	Yes	Yes	Yes	Yes
Public works spending	Yes	Yes	Yes	Yes	Yes	Yes
SEA characteristics in 1930	Yes	Yes	Yes	Yes	Yes	Yes
State fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Number of SEAs	162	162	162	162	162	162

Notes: * p<0.10, ** p<0.05, *** p<0.01. Heteroskedastic robust standard errors are in (parentheses). Note that the mean annual out-migration rate (per 1,000) was approximately 20, and the mean annual in-migration rate (per 1,000) was approximately 18. These regressions are weighted by the SEA population in 1935. The list of SEA characteristics is the same as in the county-level regressions.