Public Health Investments and the Infant Mortality Gap: Evidence from Federal Sanitation Interventions on U.S. Indian Reservations

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Abstract: To what extent do differential levels of investment in various public health inputs explain observed differences in health outcomes across socioeconomic and racial groups? This study investigates the impact of 3700 projects that were part of a widespread Federal initiative to improve sanitation infrastructure on U.S. Indian reservations starting in 1960. Sanitation investment substantially reduced the cost of clean water for households, leading to sharp reductions in both waterborne gastrointestinal disease and infectious respiratory disease among Native American infants. Treating 18 percent of homes in a community with sanitation generated the same reduction in Native American infant mortality as the construction of one Indian Health Service hospital. The sanitation program was quite cost-effective, in part because improvements in the overall disease environment also reduced infectious respiratory disease among nearby white infants. Despite these health externalities, sanitation interventions explain about a third of the remarkable convergence in Native American and white infant mortality rates in reservation counties between 1960 and 1998.

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Public Health Investments and the Infant Mortality Gap: Evidence from Federal Sanitation Interventions on U.S. Indian Reservations

Substantial disparities in health outcomes exist across racial and socioeconomic groups. On average, economically advantaged groups are healthier and populations become healthier as their economies develop.[1] Less clear is the extent to which differential levels of investment in various public and private health inputs explain the observed differences in health. This study investigates the impact of two potentially important health determinants - sanitation and hospitals - by exploiting a series of projects implemented by the Federal government on U.S. Indian reservations starting in 1960. The results show that sanitation investment led to a sizable and cost-effective reduction in the infant mortality rate of the targeted beneficiaries, Native Americans, and an additional, although smaller, reduction in mortality of nearby white infants.[2] Indian Health Service hospitals also contributed to infant mortality declines.

Between 1960 and 1998, the infant mortality of Native American infants in reservation counties fell from 53 to 9 per 1000, while white infant mortality declined from 26 to 6 per 1000 (see Figure 1). Thus, there was a substantial reduction in the Indian-white infant mortality gap in reservation counties and in the country overall.[3] The convergence was particularly dramatic for post-neonatal deaths and for deaths from gastrointestinal diseases (see Figures 2 and 3). Several recent papers have explored the determinants of

[1] A person born in a high-income country can expect to live 19 years longer than a person born in a low-income country on average (World Bank, 2002, based on 2001 data. Low income countries are the 66 countries in income range <$745 GNI per capita and high income countries are the 52 countries in income range >$9206 GNI per capita.) Similarly, disadvantaged groups within countries have inferior health outcomes. In the United States, the white and nonwhite infant mortality rates are 5.7 and 11.4 per 1000, respectively. (National Center for Health Statistics, 2002, Table 34 based on 2000 data.)

[2] In this paper, I will use the terms Native American and Indian interchangeably to describe American Indians and Alaskan Natives.

[3] The fraction of Indian births in urban areas grew from 28 percent to 46 percent, in part due to changing ethnic identification among the population. The infant mortality rate for urban Indians was 21 per 1000 in 1960, lower than the white urban rate of 27 per 1000. In 1998, the Indian and white urban rates were 9 and 6 per 1000, respectively, and similar to the rates in reservation counties.

the black-white infant mortality gap, but virtually no work has yet investigated the impressive reductions in infant mortality among American Indians.[4]

In the 1950s, the American public grew increasingly aware of substandard living conditions on Indian reservations. In 1952, the U.S. government documented that most Indians living on reservations hauled water for household use and drank water from potentially contaminated sources (Department of Health and Human Services, 1999). The 1955 Indian infant mortality rate on reservations was estimated at 63 per 1000, comparable to 1960 rates in Venezuela and Jamaica.[5] These findings, coupled with an administrative change regarding Indian health care at the federal level, prompted Congress to adopt the Sanitation Facilities Construction Act. The 1959 legislation authorized sanitation improvements in Indian country under the auspices of what is now the Indian Health Service. Since 1960, the Sanitation Facilities Construction program has served about 35,000 homes and spent about $105 million (in 2000 dollars) annually.

For the past four decades, the Federal government has provided a wide range of health inputs on Indian reservations.[6] The impacts of these sizable public outlays on the health of Native Americans and neighboring whites have not been previously studied.[7] This paper focuses on 3,699 Federal sanitation interventions implemented as part of the Indian Health Service Sanitation Facilities Construction Program between 1960 and 2001. It also examines the impact of Indian Health Service hospitals constructed during the time

[4] The nonwhite-white gap in infant mortality narrowed substantially in the 1925-1945 period (Collins and Thomasson, 2002). The bulk of the change appears to have been driven by relative improvements in post-neonatal mortality (28 days to 11 months), typically affected by environmental factors such as infectious disease. Since 1965, nonwhite post-neonatal and neonatal mortality have both moved closer to white levels. Chay and Greenstone (2000) and Almond, Chay and Greenstone (2001) argue that Civil Rights-era desegregation of hospitals played a part in this convergence.

[5] Venezuela and Jamaica had infant mortality rates of and 56 and 58 per 1000 in 1960, respectively (UNICEF, 2002).

[6] In addition to sanitation and hospital care, other services include dental care facilities, health clinics, and substance abuse facilities. The Indian Health Service budget in 2001 was around 2.6 billion dollars, or almost $2000 per Indian eligible for services. The Federal government is heavily involved in many aspects of reservation life. A GAO Report found sixteen Federal programs targeted exclusively to Indian economic development, for example (General Accounting Office, 2001).

[7] Despite the lack of systematic evidence on this point, the Indian Health Service largely takes credit for the gains in Indian health (Rhoades *et al.*, 1987 and Rhoades *et al.*, 1992). Relatively few papers in the economics literature have explored Native American issues. Notable exceptions include work on casinos by Evans and Topoleski (2002), on wages by Gitter and Reagan (2002), and on political economy by Cornell and Kalt (1995). Data limitations are an important reason that the group has not been extensively studied; sample sizes of Native Americans in many surveys are too small to perform meaningful analysis.

period, mainly in the 1960s. I estimate that an additional hospital reduces Indian infant mortality by 1.5 per 1000 births.

How much do improvements in sanitation affect health outcomes? The evidence in the literature is mixed. Galiani *et al.* (2002) find a 5 to 7 percent reduction in child mortality in parts of Argentina that privatized sanitation in the 1990s. Troesken (2001) finds beneficial effects of municipalization on typhoid rates among blacks in early twentieth century America. A review of 17 studies examining the effect of various sanitation interventions finds ten with positive results and seven without (Esrey *et al.*, 1990).[8] In general, studies of large-scale sanitation improvements rely on non-random assignment to the treatment because the decision to invest in sanitation is correlated with economic growth and other factors. It is therefore difficult to differentiate the causal effect of sanitation from a variety of other changes occurring around the same time that could potentially affect health outcomes.

The Sanitation Facilities Construction (SFC) program offers a particularly good opportunity to identify the causal impact of sanitation improvements. The program rules require that sanitation projects are allocated according to a formula based primarily on need, and the total budget is subject to the overall whims of Congressional funding. The exact timing of projects on a given reservation is therefore unlikely to be correlated with other factors that could independently affect infant health. The 3,699 projects in the sample vary widely in size, location, and implementation date. The fact that the interventions are relatively recent also allows one to take advantage of modern micro-data on vital statistics in the United States.[9]

The empirical analysis shows that sanitation interventions have large effects. A 10 percentage point increase in the fraction of homes receiving sanitation improvement reduced Indian infant mortality by 0.84 per 1000 births, or by 4.2 percent. Reductions in infant mortality were concentrated in waterborne gastrointestinal diseases and infectious

[8] The paper reviews studies of various kinds; here I focus on those that considered diarrhea morbidity or mortality as an outcome.
[9] The ability to use population data is important in the study of Indian outcomes because group samples in most surveys are too small to perform meaningful analysis.

respiratory diseases. The Indian infant mortality rate would be about 67 percent higher today in sample areas in the absence of the program. Sanitation investments also appear to have been fairly cost effective. The estimated $214,000 cost of saving an infant is within the range of other interventions targeted at improving infant health.

Smaller but significant benefits of the Sanitation Facilities Construction program accrue to white infants. These benefits arise indirectly from an improved disease environment rather than as a direct result of improved water quality. Despite the spillovers to nearby white infants, the interventions substantially reduced the Indian-white infant mortality gap. In sample areas, the sanitation program can explain 34 percent of the decline in the gap over the period.

The evidence presented here complements a growing literature that evaluates the effect of public health interventions on a variety of outcomes. Bleakley (2002) documents the positive impact of the eradication of hookworm in the American South on schooling and income. Miguel and Kremer (2002) find an effect of deworming medication on school attendance in Kenya. Recent research has also shown that clean air legislation in the 1970s reduced infant mortality (Chay and Greenstone, 2001) and that bans on lead in gasoline reduced crime a generation later (Reyes, 2002). Investments in public health appear to have beneficial effects on economic outcomes, presumably mediated by their impacts on health.

The paper proceeds as follows. Section 1 contains an overview of Native American sanitation and the SFC program. Section 2 presents a simple conceptual framework. Section 3 explains the data and the empirical strategy. Section 4 describes the evidence on the overall effect of sanitation and hospitals on infant mortality and considers the role of health externalities. The implications of the estimates are explored in Section 5, and Section 6 concludes.

1. Background on Native American Health and Federal Health Interventions

Native Americans are among the most economically disadvantaged groups in American society. As of 1990, almost 35 percent of adults lacked a high school degree, and less than 10 percent had a bachelor's degree.[10] Unemployment rates are high, and on reservations often exceed 50 percent. Poverty rates of 26 percent make Native Americans as poor as any major racial group.[11] Other social indicators also reflect hardship: Native Americans are more likely than any other group to be the victim of violent crime,[12] and the age-adjusted mortality rate is 39 percent higher than that of the population at large.[13]

By treaty obligation in some cases and historical precedent in others, the Federal government has assumed long-standing responsibility for Indian health care. Until 1955, the health care burden fell on Bureau of Indian Affairs (BIA, part of the Department of War until 1949), which failed to achieve an acceptable level of health among the Indian population during its tenure. A 1952 survey of Native American households on selected reservations reported that more than 80 percent carried water for household use, and most drank water from potentially contaminated sources (Department of Health and Human Services, 1999). In 1955, when responsibility for Indian health care was transferred to the Department of Health, Education and Welfare, infectious diseases such as dysentery and influenza were endemic. More than five percent of Native American children died in their first year of life.

Along with the transfer of Federal responsibility for Indian health care came a new commitment to Indian health. Hospital facilities were deemed inadequate, and Congress appropriated funds to upgrade existing facilities starting in 1956. Federal appropriations allowed for twelve major hospital projects in the 1960s, half of which represented new construction. Most of the new hospitals had less than 50 beds and were located in isolated, previously underserved communities.

The Federal government also sought to improve sanitation in an effort to raise health levels and quality of life. In 1960, 28 percent of all rural Native American households lacked access to a water system or well, compared to 4 percent of rural white households.

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[10] Author's analysis of 1990 data from Integrated Public Use Microdata System (IPUMS).
[11] U.S. Census Bureau (2001a), based on 1998-2000 data.
[12] U.S. Census Bureau (2001b), Table 307.
[13] Department of Health and Human Services (2002) based on 1998-1999 data, p. 53.

More than half of rural Native American households lacked access to a sewer system or septic tank. Around the same time, the so-called "Kentucky study" published by the Public Health Service showed a cross-sectional relationship between sanitation facilities and gastrointestinal illness.[14] In 1959, Congress authorized the Sanitation Facilities Construction (SFC) Act to enable the provision of water and sewer systems for Indian homes on and near reservations. Largely as a result of this program, sanitation levels improved substantially over time, both absolutely and relative to white households (See Figure 4).[15] Figure 5 shows the overall pattern of total funding and homes served by the SFC Program.[16]

Why does sanitation matter? Sanitation improvements can be viewed as reductions in the cost of obtaining clean water. Households without access to a water system typically must carry water from a central cistern or natural water source. Household water consumption in these circumstances is quite costly, leading to less hand-washing and lower levels of cleanliness of the household and its members.[17] This, in turn, promotes the spread of infectious diseases.

In addition, water itself may be contaminated by chemical toxins or infectious organisms, particularly in the absence of a sewer system. Inadequate sewerage is associated with the transmission of a number of infectious gastrointestinal diseases through the fecal-oral pathway. Young children are particularly susceptible to many of these illnesses (Chin, 2000). Gastrointestinal disease can be fatal or can lower a child's resistance to other potentially fatal diseases like pneumonia. Although the impacts of water and sewer

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[14] U.S. Department of Health, Education and Welfare (1958).

[15] Figure 4 reflects analysis of data from the Integrated Public Use Microdata System (IPUMS). I exclude residents of metropolitan areas. The question is only asked of residents of places with less than 50,000 residents.

[16] The large increase in funding in 1976 was due to the passage of the Indian Health Care Improvement Act, which, for the first time, articulated the Federal goal of raising the health status of Indians "to the highest possible level" and appropriated over $1 billion to the Indian Health Service accordingly (Bergman *et al.*, 1999).

[17] The 1952 Survey found water usage of one gallon per person per day to be common, compared to an average of 50 to 60 gallons in urban areas at the time.

investments are somewhat distinct, they are highly complementary, and are most appropriately considered components of one unified sanitation system.[18]

Table 1 summarizes the characteristics of the sanitation projects examined in the analysis. A typical project serves 100 homes and costs $450,000 (in 2000 dollars). On average, projects take two years from the appropriation year to the completion year. The range of activities funded includes digging wells, providing latrines or septic tanks, building or improving water or sewer treatment plants, extending water and sewer lines, and connecting individual homes to those lines.

How are projects allocated across reservations? The answer to this question is important to the validity of the empirical strategy. The Indian Health Service (IHS) maintains a database of Native American households on or near Indian reservations. It rates these homes for sanitation deficiency based on the adequacy of its sewer and water systems. Twelve administrative sub-units (called Areas) organize subsets of the deficient homes into projects. To initiate the project a tribe must formally make a request for assistance. Despite the formal involvement of the tribe, both the allocation of resources across reservations and the timing of projects are determined largely by factors outside of tribal control. Project funding is prioritized among projects based on a formula which emphasizes "unmet needs," in other words the fraction of homes served by the project with various levels of sanitation deficiencies.[19] The total SFC Program funding is determined by the Congressional budget process and varies from year to year. The allocated funds are distributed across Areas, which then fund projects according to the priority list (Department of Health and Human Services, 1999).

The mechanism underlying appropriations for hospital construction is less formal and may be more subject to manipulation by tribes. Nevertheless, as will be discussed in the next section, there does appear to be a discrete change in infant mortality around the time

[18] An excellent resource on the subject is "Water and Sanitation," published on behalf of the World Health Organization (2001).
[19] Prioritized projects must be declared to be "feasible," which means their costs do not substantially exceed those of comparable projects in the Area.

of construction of hospitals. These short-term changes will be used to identify the impact of health investments on infant outcomes.

2. Conceptual Framework

Consider a representative household j living in a fixed community containing J households. The household allocates resources between water, sewerage, hospital care, and other consumption. It uses the following decision rule:

$$max_{w,s,b,c} \quad U_j \ \ (h_j \ (w_j \ (p_w),s_j \ (p_s),b_j(p_b),n(h_1...h_J)), \ c_j \ )$$

$$s.t. \quad Y_j = c_j + p_w w_j + p_s s_j + p_b w_b,$$

where the household's utility function U is a function of its sanitation-related health h and all other consumption c. Health is determined by investment in water w, sewerage s, and hospital care b, as well as by the level of neighborhood health n. The household allocates resources across water w, sewerage s, hospital care b, and other consumption c subject to a budget constraint based on the level of income Y. The variables p_w, $p_{s,}$ and p_b represent the prices of water, sewerage, and hospital care, respectively, and the price of other consumption is normalized to 1. Neighborhood health n is a function of the levels of health of each household in the community.

Sanitation investments made by the household are likely to generate two distinct externalities that benefit other infants. First, a household's investment in sewerage reduces the level of infectious disease in the community sanitation network. This will tend to benefit other households with inadequate sanitation facilities. In other words, untreated water is safer to drink if those potentially contaminating it are healthier. This effect is predicted to be most important in communities with low levels of sanitation and to be reflected in rates of spread through fecal-oral transmission such as gastrointestinal disease.

Second, a household's increased consumption of water leads to hand-washing, bathing and household cleanliness, which reduces a wide range of infectious diseases in the home. This in turn reduces the likelihood that household members transmit airborne or person-to-person infection to other members of the community. The external benefits to this type of sanitation investment are likely reflected in lower rates of respiratory disease, and are likely to be most evident in densely populated areas.

Thus, an investment by the household in water or sewerage improves the health of its members, which in turn generates a health externality benefiting its neighbors. In the absence of a either a Coasian market in which these externalities are traded or a well-functioning government, the level of investment in water and sewerage will be inefficiently low. Each household j chooses a level of water w^*, sewerage s^* and hospital care b^* such that $\delta U_j/\delta w^* = p_w$, $\delta U_j/\delta s^* = p_s$, and $\delta U_j/\delta b^* = p_b$ (ignoring corner solutions), where w* and s* are particularly likely to be below the social optimum. This issue is compounded by the large fixed cost associated with some types of sanitation projects (such as upgrading a water filtration plant) and capital market imperfections. Both the health externality and the potential free-rider problem point to the social benefit of public provision of sanitation. In principle, there could also be externalities associated with hospital construction, but I do not focus on them here.

The question of which public entity should have provided health facilities on Indian reservations is a complicated one. Theoretically, tribes could have invested in sanitation projects and hospitals if they believed them to have large returns and were not credit-constrained. The lending market on Indian reservations has historically been very weak, however.[20] The degree to which tribal members believed in the benefits of modern medicine varied. Furthermore, after a long history of subjugation by the Bureau of Indian Affairs, many tribal governments were in disarray by the mid-1950s. This combination of factors makes it unsurprising that it is the Federal government that has been the major provider of health facilities on Indian reservations. Federal provision may be advantageous if externalities are important. The issue is revisited in Section 6.

[20] Kolluri and Rengert (2000) report that private mortgage lending on Indian reservations is extremely rare. As of 1994, homeowners in the Navajo Nation had no private mortgage loans. Impediments to lending include the fact that the private sector is reluctant to contract over areas where state and local courts lack jurisdiction. The Federal government holds land in trust which cannot be sold by tribes or individuals. The GAO (2001) notes that "access to capital is difficult for tribes, sometimes because they have insufficient collateral" (p.13).

3. Data and Empirical Strategy

3.1 Data

The SFC program data are graciously provided by the Department of Environmental Health and Engineering of the Indian Health Service (IHS). The database lists all projects funded by the program, and includes information on the number of homes served, the appropriation date, the completion date, and the IHS Area. In some cases, information on the reservation and or/tribe is also included. In cases missing information on the name of the reservation, the project name and the IHS Area are used to determine the location of the project. Reservations are successfully identified in about 85 percent of the cases. Projects with an ambiguous location are discarded from the sample. I exclude the small fraction of projects which last more than five years because their effects are likely to occur incrementally and are therefore difficult to identify. Other unusual projects and projects in Alaska are excluded as well.[21]

The mortality data for the project comes from the Mortality Detail Files published by the National Center for Health Statistics (NCHS). I use publicly available data for the years 1968-1998.[22] Data for years prior to 1968 is unpublished and obtained from NCHS. Natality data for the years 1968-1998 also comes from publicly available NCHS files. The natality and mortality detail files contain either a 50 or 100 percent sample of all United States deaths in each year. For years prior to 1968, data on the number of live births by county by race is collected from state vital statistic offices or imputed.

Several limitations of the data are discussed in the data appendix. One important issue is that the SFC Program data provides information at the reservation level, while Vital Statistics data provides data on the county of residence. Reservations frequently cross county boundaries, and some counties contain more than one reservation. To deal with

[21] The data appendix describes the selection criteria for projects.
[22] Permission was obtained to access confidential county identifiers for data years starting in 1989 for natality and mortality data.

this issue, I aggregate counties into "county groups" so that every relevant county and every reservation is in exactly one county group.[23]

Hospital data is from the American Hospital Association electronic files which include a list of all hospitals in operation biannually from 1970 to 1984 and annually from 1986 to 2000. The hospitals are matched to AHA published books for 1966 and 1968. For odd years 1967-1985 I assume a hospital is in operation if it is in operation the subsequent year. For years prior to 1966, I incorporate information from an Indian Health Service report on hospital construction (U.S. Public Health Service, 2000). There are 29 IHS hospitals in the analysis at the beginning of the period and 36 hospitals at the end of the period.

Other data sources include the Regional Economic Information System for the years 1969-1998 and the 1960-1990 decennial censuses.

The county group-year is the unit of analysis in the empirical work. I exclude county groups with fewer than 50 Indian live births in any sample year and those that received no sanitation projects during the sample years. The final analysis examines 3,699 sanitation projects, 37 hospitals, and 38 county groups observed in 39 years.[24] Summary statistics are shown in Table 1.

The sample of 38 county groups is comprised of 222 counties that are highly representative of reservation counties in general. In 1960, the 16,297 Indian births in the sample represent 67 percent of all U.S. Indian live births; in 1998, the 21,271 births in the sample represent 53 percent of all U.S. Indian live births. These numbers suggest that the 38 county groups represent the vast majority of Native American infants born on or near reservations.[25]

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[23] For a complete discussion, see the data appendix.

[24] For analyses of white outcomes, I remove four county groups with less than fifty white births in at least one year. Data on infant mortality for Menominee County, WI is unavailable for 1960-61 and one county group is omitted in those years as a result.

[25] The fraction Native Americans living on or near reservations is estimated to have fallen from three-quarters to less than one-half over the period. The fraction of urban Indian births increased from 28 to 46 percent. Although most reservations are rural, a few reservations are located within the boundaries of metropolitan areas. Births in reservation counties and urban births are not mutually exclusive.

3.2 Empirical Strategy

The analysis exploits differences in size, timing, and location of Federal sanitation projects to identify the impact of sanitation investment on infant mortality. A causal interpretation of the analysis requires that, net of the control variables, the timing of sanitation projects is uncorrelated with other factors that are likely to affect infant health. As described in Section 1, the allocation of projects is based primarily on need and annual Congressional appropriations. The level of sanitation deficiency in a county group is correlated with economic conditions on the reservation. It is therefore important to control for county-group fixed effects, year fixed effects, other time-varying characteristics of places that could affect health such as the number of hospitals, and a county-group-specific linear time trend. The county-group-specific time trends control for different rates of economic growth and any other unobserved slowly changing characteristics of reservations over time. Net of these controls, the exact timing of the projects is plausibly due to idiosyncratic events in the appropriation process. Every county group in the sample received at least one sanitation project over the time period; areas that received no Federal sanitation provision are not used as controls. The effect of sanitation improvements is identified from differential timing of discontinuous jumps in the cumulative number of homes treated by the program.

The proxy for sanitation investment is the cumulative number of homes treated by the SFC program divided by the estimated number of Indian households. Loosely speaking, this is the estimated fraction of Indian homes with sanitation provided by the program.[26] Depreciation of sanitation investments is assumed to be unimportant, a reasonable assumption given the low depreciation rate and the fact that the analysis will exploit sudden changes in the number of homes treated by the program.[27]

Similarly, discrete changes in the number of Indian Health Service hospitals are used to identify the effect of hospital care on infant mortality. Because most construction activity was in the 1960s, this is the time period for which the estimate will be identified. Fifteen

[26] In practice, homes may be the beneficiaries of multiple projects over time, and the fraction of homes treated by the program can exceed 100 percent.
[27] I will consider depreciation when I estimate project costs in Section 5.

county groups have at least one Indian Health Service hospital. The analysis includes some areas that are never treated. Sensitivity analysis (not shown) reveals that limiting the analysis to the subset of county groups with IHS hospitals does not substantively affect the results.

The dependent variable in the analysis is the Indian infant mortality rate (IMR). As is common in the literature, the Indian IMR is constructed by dividing the number of Indian infant deaths in the county group in the year (regardless of the birth year) by the number of thousands of Indian live births in the year. In other words, the infant mortality rate is the number of infant deaths per thousand live births. Linked birth-death data are unavailable for most years in the sample period and are not used in the analysis.

The basic econometric equation takes the following form:

$$Indian\ IMR_{jt} = \beta_1 * FractionHomes_{jt} + \beta_2 * NumberHospitals_{jt} + X_{jt} * \beta_3$$

$$+ \textstyle\sum_t \delta_t \lambda_t + \sum_j \gamma_j \alpha_j + \sum_j (\gamma_j * year)\pi_j + \varepsilon_{jt},$$

where the dependent variable is the Indian infant mortality rate in county group j in year t, $FractionHomes_{jt}$ is the cumulative number of homes treated through year t in county group j divided by the number of Indian households, $NumberHospitals_{jt}$ is the number of IHS hospitals in operation in the county group j in year t, X_{jt} is a vector of time-varying characteristics of county groups, δ_t is a vector of year dummies, γ_j is a vector of county group dummies, and γ_j*year* represents a linear county-group-specific time trend. This framework implies that sanitation projects and hospitals cause a one-time permanent shift in the infant mortality rate. Other than the number of hospitals, time-varying characteristics of county groups are included only for years after 1968 due to data limitations. I weight the regressions by the number of Indian households in 1980 to improve precision.

The unit of observation is the county-group-year. As noted by Bertrand, Duflo and Mullainathan (2002), failing to account for serial correlation when computing standard errors may lead to over-rejection of the null hypothesis. I allow for correlated errors within county groups over time by clustering at the county group level. The final analysis includes observations for 38 county groups over 39 years.

3.3 The Timing of Projects

The data contain information on the year of appropriation and the year of completion of each sanitation project. The average length of time between appropriation and completion is about two years. Neither date accurately reflects the time the project begins to affect infant health. For long projects, it is likely that the initial effects begin before the completion date.[28] There also may be benefits that accrue after the completion date, as households learn to make use of the new investments and health externalities are transmitted through the population. Thus, one can expect the full effect of the sanitation project to be in evidence a few years after completion.

Column I of Appendix Table 1 reports coefficients from separate regressions using various leads and lags of the sanitation treatment variable relative to the appropriation date. The coefficients are plotted in Figure 6. The results show that there is no significant trend in infant mortality prior to the appropriation date, after controlling for year effects, county-group fixed effects, and a county-group-specific linear time trend. This is suggestive evidence that the precise timing of sanitation projects is not correlated with other determinants of infant mortality, net of the control variables.

The same exercise is performed relative to the completion date in column II of Appendix Table 1. Figure 7 plots the coefficients from column II showing the "effect" of the treatment variable with various leads and lags from the completion date. There is some reduction in infant mortality prior to the completion date. This drop is probably due to longer projects that generated health benefits prior to the completion date.

In Table 2, I consider three different measures of the effect of sanitation on infant mortality, with and without controls for the number of hospitals. Columns I and II shows results from regressions that include the cumulative fraction of homes for which sanitation was appropriated two years ago. The estimated coefficients suggest that, after

[28] Recall that I have excluded projects lasting more than five years.

controlling for the number of hospitals, a 10 percentage point increase in the fraction of homes treated reduces infant mortality by 0.50 per 1000 births. This is a conservative estimate of the effect of sanitation because it ignores benefits of some longer projects and any delayed benefits that may accrue after project completion.

In columns III and IV, I consider the fraction of homes completed three years ago to be the treatment variable. The estimated effect in column IV, that a 10 percentage point increase in the fraction of homes treated reduces infant mortality by 0.84 per 1000 births, is somewhat larger. This is an estimate of the medium run effect of the projects on the population, and may include some mobility response.

Measurement error in an independent variable typically biases the estimated coefficient towards zero. An analysis using a variable based on the number of homes completed may understate the true effect of the intervention if measurement error is substantial. One solution to this problem is to use an instrumental variable that is correlated with the independent variable of interest but not significantly correlated with the measurement error in that variable.

In the current context, a good instrument exists. The number of homes for which sanitation funding has been appropriated lagged five years is highly correlated with the number of completed homes lagged three years. There is no reason to believe that measurement error in the completion date of a project is correlated with its appropriation date. The first stage of the instrumental variables analysis is shown in Appendix Table 2. The instrumental variables estimates of the effect of sanitation are shown in columns V and VI of Table 2. They are very similar the weighted least squares estimates. I therefore use the weighted least squares estimation strategy for the remainder of the analysis, and consider column IV to represent my base specification.

I include a control for the number of hospitals constructed or listed in the American Hospital Association survey in the previous year. Controlling for the number of hospitals reduces the estimated effect of sanitation. In the robustness checks at the end of the section, I show that other time-varying characteristics do not change the coefficients on sanitation or hospitals very much for the years in which they are included.

Table 2 suggests that an additional hospital is associated with a reduction in infant mortality of roughly 1.5 per 1000 births relative to trend. The variation identifying this effect is the construction of eight new hospitals, mostly in the 1960s, and one closure. Column III of Appendix Table 1 shows the coefficients from separate regressions with various leads and lags of the hospitals variable.[29] Infant mortality is high relative to trend in areas before hospitals are constructed. There is a significant decline in infant mortality around the time a hospital is introduced. The interpretation of this result will be discussed in the following section.

4. Results

4.1 Main Results

The basic results are shown in Table 3. The weighted least squares regressions include year fixed effects, county-group fixed effects and a county-group-specific time trend. The estimated coefficient in the first column implies that a 10 percentage point increase in the fraction of homes treated with sanitation reduces Indian infant mortality by 0.84 per 1000 births. Columns II and III demonstrate that the bulk of the effect stems from a reduction in post-neonatal deaths rather than neonatal deaths. This is to be expected because environmental conditions are thought to be important determinants of mortality in the post-neonatal period. Evaluated at weighted sample means, the implied elasticity of post-neonatal mortality with respect to sanitation investments is -0.27.

Table 3 shows that an additional Indian Health Service hospital is associated with a reduction in infant mortality on the order of 1.5 per 1000 births. As in the case of sanitation, most of the reduction is in post-neonatal deaths. This is unsurprising given the fact that the variation identifying the effect is largely from changes in the 1960s. It was not until the mid-1970s that hospitals made significant gains in care for premature infants

[29] I do not include estimates for 9 and 10 year lags because those regressions exclude the bulk of the 1960s and have very little identifying variation.

(Cutler and Meara, 1997). The estimates imply that the reduction in infant mortality from the construction of a new hospital was similar to that of a sanitation project affecting 18 percent of the homes in an area.

There are several reasons to be cautious in the interpretation of the coefficient on the hospitals variable. There are only a small number of changes during the sample period. In addition, hospital construction appears to be concentrated in areas with high pre-existing infant mortality rates relative to trend. Finally, the presence of an Indian Health Service hospital may affect the likelihood of birth and death reporting as well as the coding of race.[30] For these reasons, the hospital results should be considered suggestive. I focus on the sanitation interventions for the remainder of the analysis.

4.2 Sanitation and Infant Mortality by Disease

Table 4 investigates the impact of sanitation investment on the infant mortality rate by disease. The table presents coefficients from separate regressions, each of which includes county fixed effects, year fixed effects, a county-group specific linear time trend, and a control for the number of hospitals in the previous year. Because the sample period covers three disease coding regimes, I use a disease coding crosswalk for infant diseases described by MacDorman and Rosenberg (1993). For completeness, I report results for all of the categories they list, although they do not consider all to be comparable over time.[31]

I also report coefficients on two disease categories I create. The "gastrointestinal" disease category includes most of the illnesses specified in the "certain gastrointestinal" category suggested by MacDorman and Rosenberg, as well as a number of infectious diseases likely to be affected by sanitation such as typhoid, paratyphoid, and cholera. The "infectious respiratory" category includes pneumonia, influenza, whooping cough,

[30] IHS hospitals are likely to increase the likelihood that an infant is coded as "Indian" at birth or death. It is also possible that births and deaths in isolated areas would be more likely to be recorded. The estimated effect of a hospital may be an understatement of the true effect if the biases are more important in the coding of deaths than births.

[31] In the case of SIDS, they suggest no early coding category and I include this as zero. See the data appendix for more information on disease coding.

and bronchitis. The "diseases related to sanitation" category is the combination of the "gastrointestinal" and "infectious respiratory" categories I created. The "diseases not related to sanitation" category is a combination of all the disease categories listed by MacDorman and Rosenberg (1993) except for the "certain gastrointestinal" and "pneumonia and influenza" categories.

About three quarters of the observed effect of sanitation on infant mortality can be attributed to diseases that one would expect to be related to sanitation *a priori*. Sanitation has a sizeable effect on both gastrointestinal disease and infectious respiratory disease. The implied elasticities are roughly -0.5 for both categories evaluated at weighted sample means. Similar effects are found for the MacDorman and Rosenberg categories "certain gastrointestinal" and "pneumonia and influenza". As expected, most other disease categories show no significant correlation with the timing of sanitation projects.[32]

Recall that two distinct mechanisms mediate the impact of sanitation on the two disease categories. Gastrointestinal illness tends to be ameliorated by improvements in water quality, largely determined by the sanitation system. Respiratory disease is likely to be impacted by the level of water use and cleanliness in the community. The results suggest that both the biological impact of clean water and the behavioral response induced by the reduced price of water are important factors in the infant mortality decline.[33]

4.3 Externalities of Sanitation Projects

The effect of the SFC sanitation interventions on neighboring white infants is interesting to study.[34] White infants are potentially affected by the SFC program in several ways. First, white infants might receive direct services from the program. For example, if a sanitation project improves the water filtration system for a town, all households in the town would benefit regardless of race. White infants might also live in a household with

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[32] Exceptions are the rate of death from accidents and complications of the placenta.   It is likely that these results are spurious.
[33] An alternative interpretation is that the improved water quality reduced gastrointestinal disease
[34] I do not investigate the externalities of hospitals on whites because of the presence of Indian Health Service hospitals may affect coding by race.

a Native American person eligible for services from the SFC program.[35] Finally, Indian infants receiving the intervention might be coded as white infants in the mortality data.

Second, white infants could benefit from the externality generated by healthier Native Americans in their communities. As noted in Section 2, these health benefits can be separated into two types of effects. If white households lack a clean water source, improvements to their neighbor's sewerage would reduce their exposure to gastrointestinal disease. In addition, if water use of Native American households increases, the entire community would be less exposed to diseases transmitted by air or personal contact such as respiratory disease.

Table 5 shows that there is a statistically significant effect of the SFC interventions on mortality of white infants from respiratory diseases.[36] The magnitude of the effect on respiratory disease is too large to be plausibly due to inconsistent coding of race.[37] There is a small and marginally statistically significant effect on mortality from certain gastrointestinal diseases. The small effect is consistent with the notion that whites did not directly benefit from improved water quality. Rather, the evidence points to a general improvement in the disease environment or water quantity affecting respiratory disease levels. As described in Section 2, increased household water consumption and cleanliness on the part of direct beneficiaries of the program could spill over into a healthier environment for the entire community. Unfortunately, data on water consumption to test this hypothesis is unavailable.

One implication of the health externality hypothesis is that white infants should experience greater sensitivity to sanitation improvements if their household is in closer contact with Indian households. Because detailed data on residential location by race is

[35] Intermarriage rates between individuals describing themselves as "white" and "Native American" are quite high, although they may be lower in the reservation areas under study here.

[36] Four county groups with fewer than fifty white live births per year are excluded from this analysis. The coefficient on the overall infant mortality rate for whites is negative but statistically insignificant.

[37] As discussed in the data appendix, about thirty percent of infants coded as Indian at birth are coded as white at death. Because whites are a much larger group in the population, the reverse is not true. If the ratio of Indian to White births in area is 10:1 and the observed reduction in respiratory deaths among Indians is 3.96 per 1000 Indian births, a reduction in the white respiratory infant mortality rate of 0.13 per thousand could plausibly be explained by inconsistent coding. The observed rate reduction is 0.64 per 1000. The reduction in gastrointestinal disease, in contrast, could plausibly be explained by miscoding.

unavailable at the beginning of this time period, I use the number of Native Americans per square mile as a proxy for the degree to which white infants are exposed to Indians. The Native American density variable is interacted with the treatment variable used in the base specification. The analysis (not shown) indicates that, as predicted by the model, the coefficient on the interaction of Native American density and the sanitation variable on infant mortality from respiratory disease is negative and statistically significant. This pattern is not evident for gastrointestinal disease.[38] The interaction term does not appear to be correlated with Indian infant mortality from either disease. The evidence is consistent with the notion that the spatial distribution of Native Americans is important to white outcomes, but better data is required to explore this hypothesis rigorously.

The effect of sanitation interventions on the sanitation-related infant mortality rate for whites is less than 15 percent of the effect for Native Americans. Nevertheless, it is worth noting that the number of white infants affected may be quite large. On average, the number of white infants in a county group is about ten times greater than the number of Indian infants. Thus, even a small reduction in the white infant mortality rate may result in the survival of a greater number of white infants than Native American infants. This issue is revisited in Section 5.

4.4 Heterogeneous Effects

It is likely that the effect of sanitation investment depends on the initial level of health and sanitation of the population. For example, as noted above, the source of drinking water may be most important when initial sanitation levels are low. The interaction of the effect of sanitation on respiratory disease is somewhat less clear. It is possible that if respiratory disease is sufficiently pervasive or sufficiently rare, sanitation may not provide much benefit.

I look at the relationship between the effect of sanitation and initial conditions in two ways. First, I look for evidence that earlier projects have a greater effect on health outcomes. I consider years 1983 and above to be in the later part of the sample because

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[38] Indeed, the coefficient on the interaction of sanitation and density on gastrointestinal disease is positive and marginally significant.

1983 is the first year in which the average county group had at least 50 percent of the final fraction of homes completed. Second, I divide the county groups into two categories based on their 1960-62 infant mortality rates from sanitation-related disease. I refer to those groups with greater than the median value of initial sanitation-related infant mortality as "initially sicker". The subsequent analysis uses the years 1963-1998.

The results, shown in Table 6, paint a fairly consistent picture. Sanitation projects had a larger effect on sanitation-related infant mortality in the early (pre-1983) period and had a larger impact in places with inferior initial sanitation-related health.[39] This pattern is quite strong for gastrointestinal disease. Sanitation induces its entire effect on gastrointestinal mortality in earlier years and in less healthy places. In contrast, the impact of sanitation on infectious respiratory disease is not very sensitive to the initial level of illness in the community. This is consistent with the notion that sanitation projects may not be particularly beneficial in areas with very high levels of infectious respiratory disease.

4.5 Robustness Checks

One would like control for a number of additional factors that could independently affect health outcomes and might be correlated with the timing of sanitation projects and hospital construction. Annual data at the county level is not readily available for the early years in the period. A number of annual control variables are available for the years 1969-1998, however. I include several variables from the Natality Detail files, such as weight at birth, age of mother, and the log of the number of births.[40] I also consider variables from the Regional Economic Information System (REIS): log per capita income, the employment to population ratio, transfer payments per capita, and medical assistance payments per capita. The REIS variables are not race-specific.

Table 7 shows that, without additional controls, the coefficient on sanitation is smaller in the 1969-1998 period than in the full sample. This is not surprising given the finding in

[39] The latter effect is not statistically significant.
[40] Recall that birth and death data are not linked. Rather, I aggregate information from the natality files to the county-group level.

the previous section that the benefit of sanitation appears to diminish over time. The coefficient on the number of hospitals is larger in the 1969-1998 sample. However, the estimated coefficient is based on only three changes in the number of hospitals, so it should not be interpreted as an accurate measure of the effect of an additional hospital. The inclusion of controls in column III only slightly reduces the estimated effect of sanitation investment for the 1969-1998 period.

Several of the control variables are independently interesting. There is a very strong positive correlation between the fraction of low birth-weight births and infant mortality. The fraction of teen-aged mothers does not have a statistically significant correlation with infant mortality, but the fraction of mothers aged 35 and older is associated with higher rates of infant death. An increase in the log of the number of live births, perhaps reflecting underlying economic growth, is correlated with lower infant mortality. The REIS variables are not statistically significant. This may be because the variables are not race-specific and do not provide an adequate picture of economic conditions affecting Native Americans.

4.6 Impacts on Other Health Outcomes

If sanitation affects infant mortality, it probably affects other health outcomes as well. There is no robust relationship between the timing of sanitation projects and mortality of other age groups (analysis not shown). This does not rule out the possibility, however, that sanitation investments improve health beyond the effect on infant mortality.

By improving the disease environment, sanitation probably reduces the incidence of non-fatal infectious disease. This hypothesis cannot be tested with the available data. However, it is worth noting that the costs of morbidity associated with infectious disease are high, even in the absence of fatalities. A study of two villages on the Hopi Reservation in the 1960s found that the average infant visited a doctor 2-3 times for diarrhea-related illness (Rubenstein *et al.*, 1969).[41] More recent studies find much lower

[41] Interestingly, the study also documents an effect of a Public Health Service indoor plumbing intervention in one of the villages in reducing infant doctor visits.

rates of illness, and continued declines since 1980 (Holman *et al.*, 1999).[42] Even in the recent period, however, the average diarrhea-related hospitalization for children under 5 lasted 2-4 days. The disruption associated with infectious disease suggests that even a modest improvement would make a substantial difference in the lives of children and their caretakers.

There is an additional potential health benefit of sanitation. Prior to the SFC program, many households obtained water from cisterns provided by the Bureau of Indian Affairs and other sources. These sources sometimes contained chemicals that could cause health problems after many years of use.[43] If the SFC program reduced long-term exposure to toxic chemicals, the effect would not be captured in this analysis.

I do not analyze the effect of hospitals on mortality among other age groups. However, there are good reasons to believe that hospitals improve health for older children and adults. The reduction in infant mortality is likely to be a mere fraction of the health benefits hospitals generate.

5. Implications

5.1 Contribution of the Interventions to Indian Infant Mortality Declines and Indian-White Convergence

What would have happened if the sanitation projects had never occurred? One can use the estimated coefficients in the model to simulate what would have happened in the absence of the intervention if other factors were unchanged.[44] In sample areas, sanitation interventions are responsible for about 17 percent of the overall decline in the Indian infant mortality rates. Holding other factors constant, the Indian infant mortality rate would be 67 percent higher today, or 15.3 per 1000, in sample areas had the SFC

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[42] These results are corroborated by the 1987 National Health Interview Survey Supplement on American Indians and Alaskan Natives. About nine percent of one-year-olds surveyed had been to the doctor in the previous month because of diarrhea-related illness. The event was rarer for older children.

[43] This was noted in informal conversations with IHS officials.

[44] I use the estimated regression coefficients from the model to predict the infant mortality rate if the fraction of homes treated equals zero. This exercise is a conservative estimate of the total effect of the program because some of the benefits may be hidden in the year effects and the county-group-specific time trend.

program never existed. The estimates suggest that hospitals and sanitation combined explain 43 percent of the narrowing of the Indian-white infant mortality gap in sample areas, with 34 percent of the narrowing attributable to sanitation alone.[45]

5.2 The Cost of Saving A Baby

By comparing the costs of a sanitation project to its effect on infant mortality, one can develop a crude estimate of the cost per infant "saved," *i.e.* the expenditure per infant that would have died in the absence of the program. This exercise requires several assumptions. First, I make the conservative assumption that the observed impact on two categories of infectious disease, gastrointestinal and infectious respiratory diseases, accurately reflects the total change in infant mortality due to a sanitation intervention. In other words, a 10 percentage point increase in the fraction of homes with sanitation causes an extra 0.63 per 1000 Indian infants and an extra 0.08 per 1000 white infants to survive annually (or 2.9 Indian and 3.2 white infants). Assume that if the sanitation facility is maintained, the benefits accrue in perpetuity. The annual cost to maintain the structure is based on an estimated depreciation rate of 1.5 percent.[46] I assume that the survival of infants born in the future is worth somewhat less than the survival of those today, using a discount rate of 5 percent.

The average cost of treating one home is $3,766 (in 2000 dollars). Roughly speaking, the analysis implies a $5 million public sanitation investment (including the present discounted cost of maintenance) saves one additional infant per year in perpetuity. The cost of the intervention per "present discounted infant" saved is about $214,000.[47] This figure is somewhat higher if one considers the social cost of collecting public funds.

[45] These estimates include the estimated effect of the interventions on white infants.

[46] According to the Bureau of Economic Analysis Fixed Assets Tables, the average annual depreciation rate for government sewer system structures and water supply facilities over the 1960-1998 period is just under 1.5 percent.

[47] Because the coefficients are based on weighted regressions, the means used in these calculations are also weighted. The number of Indian homes in a county group is 55,056. A 10 percentage point increase in the number of homes treated is 5,506. At an average cost per home of $3,766 (2000 dollars), the intervention costs $20.7 million plus $6.5 million in present discounted costs of maintenance. The (weighted) average numbers of births in an area is 4,450 Indian infants and 36,371 white infants. The intervention saves 2.9 Indian and 3.2 white infants annually, or a total of 128 present discounted infants. The cost per present discounted infant is about $214,000. This number could be multiplied by 1.3 or 1.5 to account for the cost

If one assumes that an infant surviving as the result of sanitation would live a healthy life to age 60, the cost per discounted life-year is just under $11,000. Although this estimate is rough, it gives a sense of the cost-effectiveness of the program. Typically, economic studies estimate the value of a healthy life year at about $75,000 to $150,000 (Cutler and Meara, 1999). By this metric, the return to sanitation investment is very high even if reductions in infant mortality are the only benefit. However, it is not clear that these numbers are appropriate for infants. The value of a life-year for infants may be somewhat lower because relatively few investments have been made in them.

Alternatively, one might compare these numbers to the cost of other infant health interventions. Cutler and Meara (1999) estimate that spending an additional $40,000 per low birth weight infant increased survival by 11.8 years on average, or 10.5 quality-adjusted life years (QALYs). If these life years are discounted using a comparable methodology to the one above, the cost per life year is just over $11,000.[48] Sanitation interventions appear to be comparable to the cost of neonatal intensive care in saving infant lives. Both of these interventions are much cheaper than targeted expansion of Medicaid insurance coverage. Currie and Gruber (1996) estimate that offering public health insurance to the poor improves infant survival at a price of $840,000 per infant, a cost more than three times higher than sanitation investment.

For comparison, one can generate a rough estimate of the cost of hospital investment. I use information from a 1970 American Hospital Association survey as well as 1970 cost estimates from Cutler and Meara (1997).[49] According to the AHA Survey, the average 1970 value of short-term Federal hospital plant assets is $3.17 million (in 2000 dollars). This is used as a proxy for construction cost. The average annual operating expenses are $5.46 million per hospital (in 2000 dollars).

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of public funds, but I do not make the calculation here in an effort to be comparable with other estimates in the literature.

[48] In other words, I assume that these additional life years accrue over a 60-year period and discount them at a rate of 5 percent. Also note that, in contrast to the study of premature infants, it is reasonable to assume that infants affected by the sanitation intervention would lead healthy lives if they survived.

[49] I choose 1970 because most of the changes identifying the coefficient are early in the sample.

There are several ways to evaluate the cost of a hospital per infant saved. At one extreme, one might consider the total present discounted operating costs of the hospital as well as the construction costs. This methodology yields an estimate of $814,000 per infant saved.[50] Alternatively, one might ignore construction costs and only include the fraction of the hospital costs spent on infants. I use Cutler and Meara's (1997) estimate that infants accounted for 4.1 percent of medical expenditure in 1970. This methodology yields a very low marginal cost of hospital care per infant saved of $32,000. In other words, the construction and operation of a hospital is a much more expensive means to reducing infant mortality than sanitation investment. However, once in operation, the marginal cost of infant care per life saved is quite low - well below the cost of other common health interventions.

A full cost-benefit analysis of investment in sanitation and hospitals would require an accurate valuation of an infant life as well as other benefits of the interventions. For every additional infant that survives, it is likely that many more experience reductions in days of illness. General health benefits probably accrue to older children and adults as well. These, in turn, may improve long run economic outcomes. The reduced burden of carrying water is also a direct benefit of the sanitation improvements.

6. Conclusions

In 1960, more than five percent of Indian infants living in reservation counties died in the first year of life. Today the Indian infant mortality rate stands at less than one percent in those same areas, and the Indian-white infant mortality gap has dramatically narrowed. In the interim, the Indian Health Service invested over $100 million annually in sanitation and operated dozens of hospitals on and near Indian reservations. This study exploits variation in the timing of sanitation projects and hospital construction to provide a quasi-experimental estimate of the causal impact of these health inputs on infant mortality.

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[50] Using a 5 percent discount rate, the present discounted value of hospital expenses is estimated around $109 million dollars. Construction costs are just under 6 million dollars. The reduction in the number of Indian infant deaths is 1.48 per 1000, or 141 present discounted infants saved by a typical hospital. If one sums the present discounted value of operating expenses and construction costs, and divides by the present discounted number of infants the resulting figure is $814,000. I ignore any potential benefits to white infants in this calculation.

I find that a ten percentage point increase in the fraction of homes with sanitation improvements reduced infant mortality by 0.84 per 1000 births. The Sanitation Facilities Construction program can explain about a third of the convergence in the Indian-white infant mortality gap. Indian infant mortality in sample areas would be about 67 percent higher in the absence of the program, holding other factors constant. Sanitation investment reduced gastrointestinal and respiratory diseases, and had its largest impact in locations with high initial infant mortality rates from these diseases. The evidence also suggests that hospitals reduced infant mortality by 1.5 per 1000 births.

The cost of saving an infant by improving sanitation is estimated at $214,000. This method of promoting infant survival is comparable in cost to neonatal intensive care and less expensive than providing public health insurance for the poor. The cost of constructing and operating a hospital per infant life saved is also higher than sanitation investment. However, once in operation, the marginal cost of infant care per life saved is quite low. By this measure, both interventions appear to be cost-effective means to reducing infant mortality. Investments in sanitation and hospitals also buy other improvements in health and quality of life, although they are not analyzed here.

In sum, public health investment in poor rural areas appears to reduce infant mortality substantially. If one believes, as is suggested by the analysis, that this type investment faces diminishing marginal returns, then it is probably the case that such sanitation in a less developed country would have greater returns and more external benefits.[51] One caveat is that a small-scale sanitation project may not have the desired effect if contagious disease from surrounding areas mitigates the benefits to infant health.

The evidence presented here also suggests that sanitation investment yields important health externalities. The results provide an interesting contrast to those reported in Troesken (2001). He finds a reduction in black typhoid rates arising from municipal water provision in American cities around the early 20th century. The extension of public water services to blacks in a climate of extreme political racism is surprising. A natural

[51] Of course, both the costs and benefits of various interventions may vary in the developing country context.

explanation for the uncharacteristic public generosity towards blacks is the presence of health externalities. However, Troesken is unable to find evidence supporting the presence of externalities across racial groups in his data.

The intervention described in this paper is less puzzling. By the 1960s, altruism might have been adequate to motivate Federal sanitation provision to Indians. Nevertheless, I do find evidence suggesting that health benefits accrue to whites. These spillovers appear to stem from an improved disease environment generally, rather than from a direct change in water quality in white households. The declines in the white infant mortality rate are small. However, the number of white infants surviving as the result of the program is somewhat greater than the number of Indian infants because of the relative sizes of the two groups. Thus, the benefits would probably be large enough to justify Federal intervention even if the Federal government only valued white outcomes.[52]

The congressional testimony surrounding the adoption the SFC Act speaks to the issue. The language is generally altruistic and paternalistic in tone, emphasizing the severe deprivation of the Indian people. Nevertheless, one witness from an Indian advocacy group did make the following case for Federal investment in sanitation:

> One other factor that cannot be emphasized too strongly...is that poor sanitation facilities on Indian reservations have a direct effect upon the health of the surrounding non-Indian communities. You cannot quarantine these diseases; you cannot quarantine polluted streams; you cannot quarantine flies, they get from one place to the other. And when an effort is made to improve sanitation facilities on Indian reservations, we are, in fact, performing a service for non-Indian communities in the same area....So in those terms I think that this is merely legislation for the general welfare.[53]

Although perhaps not the primary motivation of the legislation, the potential for health benefits to whites was recognized at the program's inception.[54]

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[52] As early as 1802, the Federal government attempted to control infectious disease among Indians living near American military outposts. It is highly improbable that the motivation was altruistic.

[53] Published hearings for May 5-6, 1959, House of Representatives, Committee on Interstate and Foreign Commerce, Subcommittee on Health and Safety, testimony of Arthur Lazarus of the Association on American Indian Affairs, p. 68-69.

[54] Bergman, Grossman and Erdrich (1999) note that Senator Alan Bible (D-Nev.) had received complaints from some white constituents about contamination of their water supply from tribal lands.

The analysis also sheds light on why tribes might have chosen not to invest in sanitation facilities prior to the SFC Program. Indians receive only a fraction of the returns to sanitation projects. Although the cost of sanitation per infant saved is reasonable compared to other investments, the cost per Indian infant is around $449,000.[55] Even with perfect credit and information, it is possible that a poor tribe would choose to invest its scarce resources elsewhere.

The presence of significant health externalities suggests that the public sector has an important role to play in allocating resources to sanitation. In the context of the Sanitation Facilities Construction program, the intervention also narrowed interracial health differentials, but that need not be the case. A health intervention targeted at a small disadvantaged group could increase health differentials if the health externalities were very large. The interaction between externalities, community size and public decision-making is an interesting area for further research.

[55] I repeat the exercise performed in Section 5. The present discounted number of Indian infants saved from a 10 percentage point intervention is 60.6. The expenditure per Indian infant is $449,000. It is not clear how one would want to adjust this number for the cost of collecting public funds.

7. Data Appendix

7.1 Natality Data

Natality Data for 1968-1988 come from publicly available Natality files from the National Center for Health Statistics. These files contain either a 50% or 100% sample of detailed records of all births from all states. Similar data for 1989-1998 is available with permission from the NCHS and contains confidential county identifiers for every birth in the United States. I exploit available data on weight at birth and age of mother. Data on the number of live births by county by race prior to 1968 has been collected and hand-entered where necessary from a subset of individual states (CA, ID, KS, ME, MN (partial), MS, MT, OK, SD, WA, and WI). The number of live births by race for 1960-1967 for counties lacking published data is assumed to be the same as that for the earliest available data (typically data from 1968).

7.2 Mortality Data

Mortality Data for 1968-1988 come from publicly available Mortality Detail files from the National Center for Health Statistics. The files contain a 100% sample of all deaths starting in 1973 and a partial sample in earlier years. Similar data for 1989-1998 is available with permission from the NCHS and contains confidential county identifiers for every birth in the United States. Unpublished data was obtained from the NCHS for the years 1959-1967.

7.3 Cause of Death

The mortality data includes cause of death codes. Data for the years 1960-1967 uses the ICD-7 classification, for the years 1968-1978 uses the ICD-8 classification, and for the years 1979-1998 uses the ICD-9 classifications.

As used in this paper, gastrointestinal disease refers to the following diseases described in ICD-9 and their equivalents in earlier years: Cholera, Typhoid and Paratyphoid fevers, Other Salmonella infections, Shigellosis, Other food poisoning, Amebiasis, Other protozoal intestinal diseases, Intestinal infections due to other organisms, Regional enteritis, Idiopathic procolititis, Vascular insufficiency of intestine, Other noninfectious gastroenteritis and colitis, Perinatal disorders of the digestive system, and Symptoms involving digestive system.

The following are included in the Infectious Respiratory Category: Whooping Cough, Acute Bronchitis and Bronchiolitis, Viral Pneumonia, Pneumococcal Pneumonia, Other bacterial Pneumonia, Pneumonia due to other unspecified organism, Pneumonia in infectious diseases classified elsewhere, Pneumonia organism unspecified,
Influenza, Bronchitis not specified, Chronic Bronchitis, and Pneumonia of the fetus and newborn.

The other diseases categories are those described in the crosswalk of infant mortality categories in the appendix of MacDorman and Rosenberg (1993), p.50. For completeness, I include every disease category they list, although some are not considered sufficiently comparable for trend analysis.

7.4 Age

Infant deaths are those that occur at less than one year of age. Neonatal deaths are those occurring at less than 28 days of age. Post-neonatal deaths are those occurring between 28 days and 11 months of age. Deaths at an unspecified number of days or weeks are considered neonatal; those at an unspecified number of months are considered post-neonatal.

7.5 Race

Race codes in the vital statistics data are problematic. Newborn infants are assigned a race based on an algorithim of their parents' races prior to 1989. Starting in 1989 births are coded by race of mother. For data collected from individual states on the number of live births by county by race for 1960-1967 the method of assigning race varied.

Hahn, Mulinare, and Teutsch (1992) note a high level of discrepancy between race of infants at birth and at death in a study of matched vital statistics data for 1983-1985. More than a third of infants coded "Indian" at birth are coded "White" at death. The reverse is rarely true; infants coded "White" at birth are coded "Indian" at death one tenth of one percent of the time. This fact leads to a systematic understatement of the Indian infant mortality rate. Because Indians are such a small group, it does not have a sizable impact on the estimated white infant mortality rate.

7.6 Sanitation Data and Project Selection Criteria

Sanitation project data was provided courtesy of the Indian Health Service Sanitation Facilities Construction Program, Department of Environmental Health and Engineering. The database consists of more than 10,000 sanitation projects constructed in the years 1959 to the present. Variables include IHS area, project name, number of homes affected, cost of project, and sometimes identification of the reservation and tribe. In cases lacking information on reservation, the project name was used to identify the reservation wherever possible. In total, about 85 percent of projects were successfully matched to a reservation and/or county. Projects that could not be matched were discarded.

A number of sanitation projects were excluded from the sample. First, I excluded projects that were labeled emergency, special, urban, training, operations and management, or appeared to be for facilities rather than homes. I also eliminated projects for which the location was ambiguous or the completion date was missing. This results in 5,804 projects. Eliminating projects greater than five years in duration results in 5,406 projects.

A second round of selection is based on location. I eliminate projects in Alaska and in county groups with less than 50 Indian births in at least one sample year. I also eliminate one project prior to 1962 in Menominee County, WI due to missing data. The final data set contains 3,699 projects.

7.7 Hospital data

Information on hospitals is available from the American Hospital Association (AHA). I use biannual electronic files for the years 1970-1984 and annual files for the years 1986-2000. These files are matched to the "Guide Issue" published by the AHA for the years 1966 and 1968. For odd years 1969-1985, I assume a hospital was in existence if it was in existence the subsequent year. For years prior to 1966, I use information from the U.S. Public Health Service's *Health Care Facilities Engineering Millennium Report* (2000). This publication includes hospital construction dates for Indian Health Service hospitals built since the mid-1950s. However, it does not always distinguish between new hospitals and replacement hospitals. If a hospital operating in 1966 according to the AHA sources is not listed as having been constructed between 1957 and 1966, I assume it was in operation throughout the period.

7.8 Construction of County Groups

Vital statistics data provides information on county of residence, while information on sanitation projects includes the reservation. Reservations cross county lines, and some counties contain more than one reservation. To deal with this problem, I construct groups of contiguous counties such that every relevant county is in exactly one county group and every reservation is in exactly one county group. The 379 relevant counties are compressed into 138 county groups. County groups are then excluded if they have less than 50 Indian births in any year in the sample or if they never receive a sanitation project. The final analysis includes 222 counties in 38 county groups.

In 1960 and 1961, data is unavailable for Menominee County, WI because it became a county in 1962. I exclude the county group for those two years.

7.9 Inflation adjustment

Project costs are adjusted using the CPI-U using the 1982-1984 base year (available from the Bureau of Labor Statistics at ftp://ftp.bls.gov/pub/special.requests/cpi/cpiai.txt). All costs of projects are reported in 2000 dollars.

7.10 Number of Households

Annual estimates of the number of population by race by county are obtained from the U.S. Census Bureau for the years 1990 onwards, and are imputed using a constant geometric rate for each decade between decennial Census data years prior to 1990. The number of households is estimated using national race-specific averages of the households per population for each year using the PUMS data for 1970, 1980, and 1990. The number of households per person is imputed linearly between census years.

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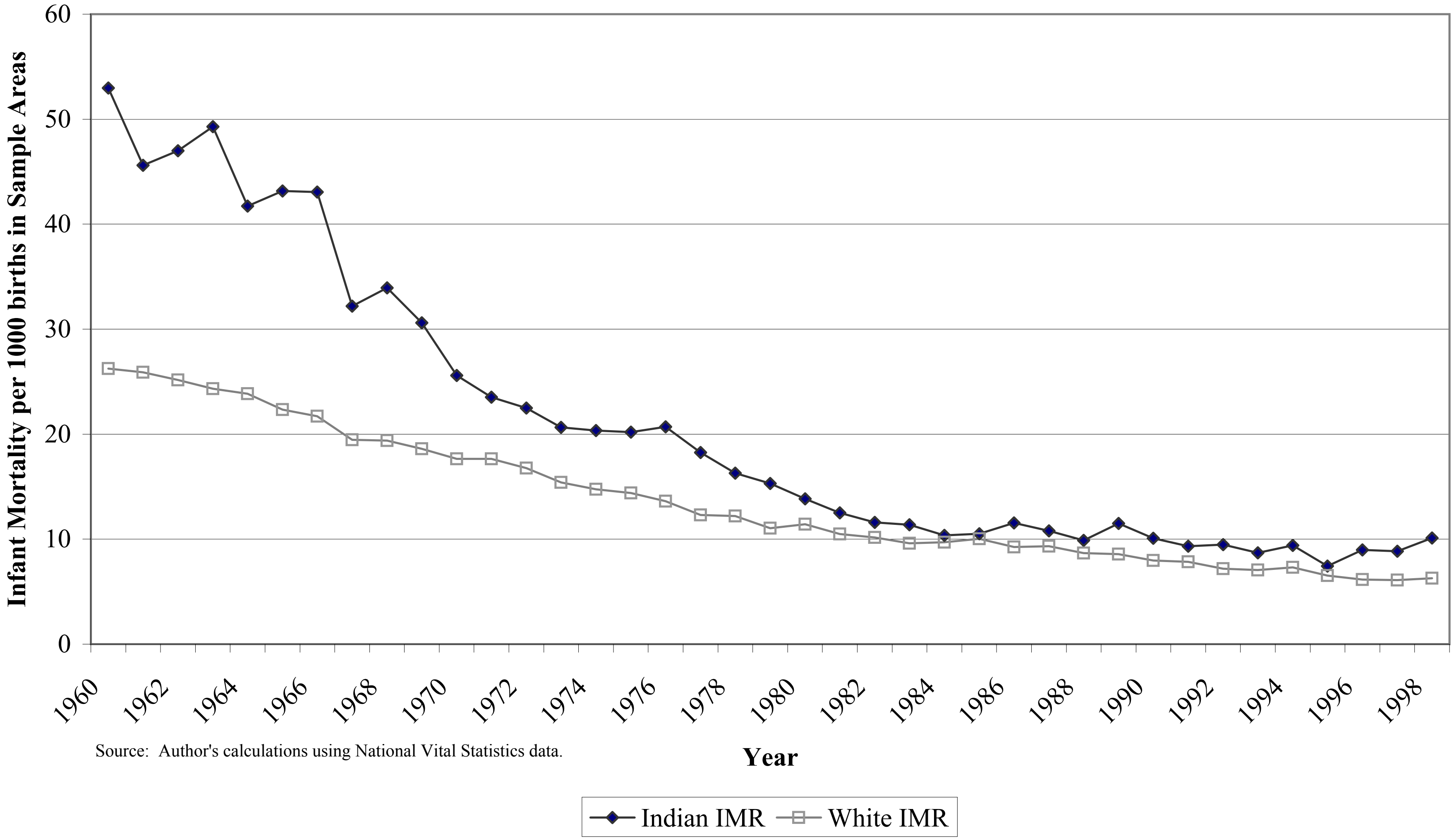
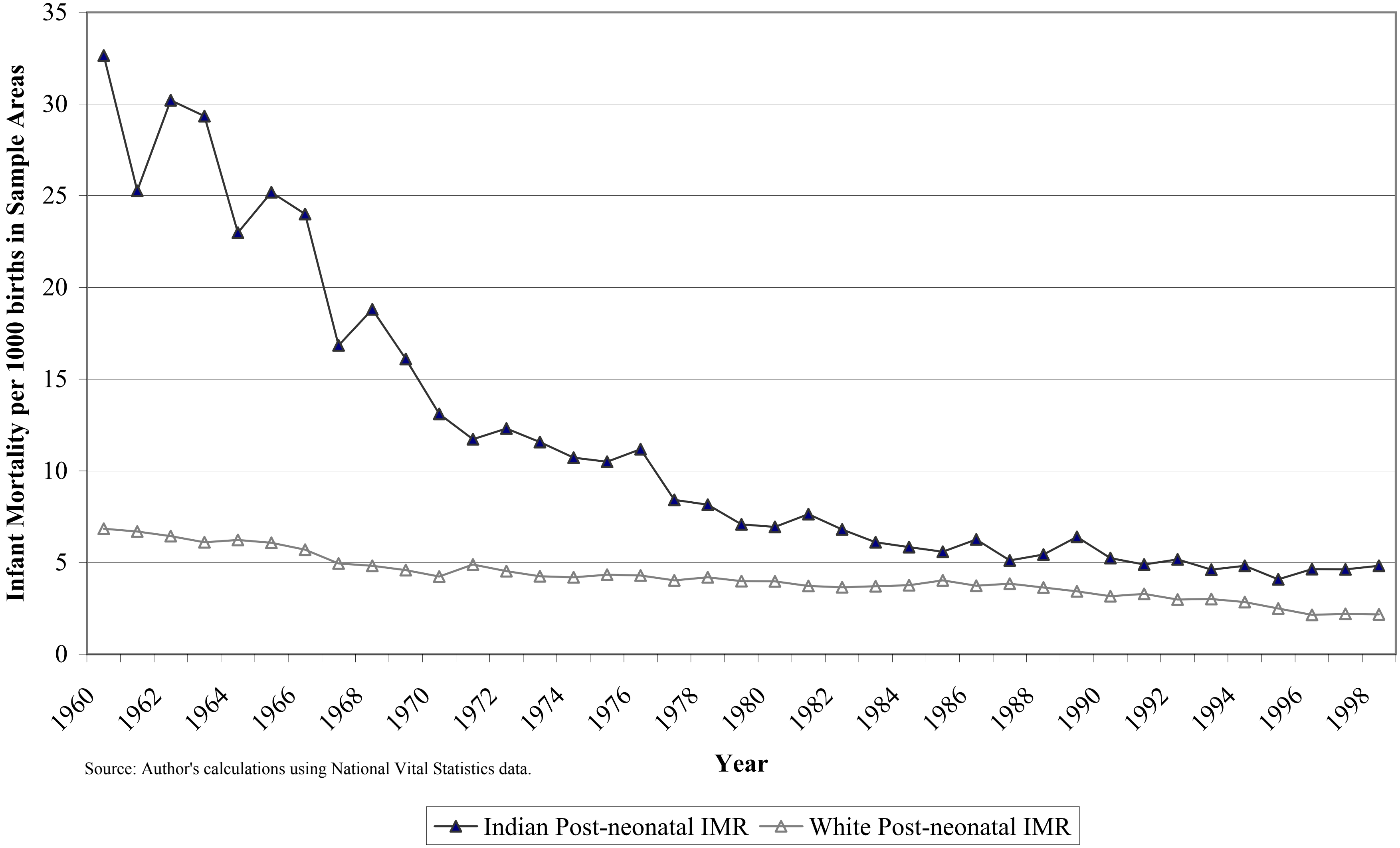
Figure 1.
Infant Mortality by Race in Sample Areas, 1960-1998



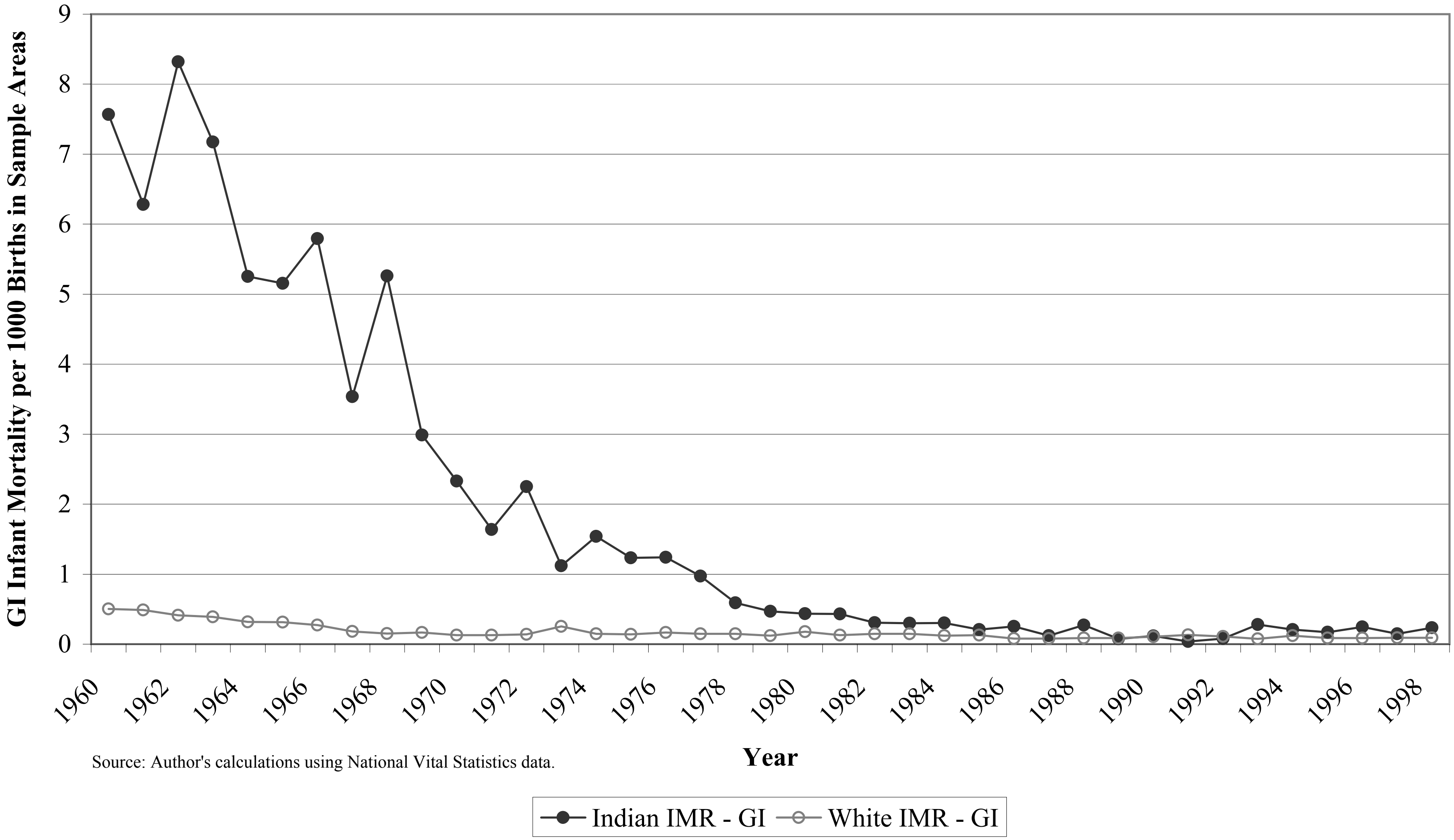
Source: Author's calculations using National Vital Statistics data.

Figure 2.
Post-neonatal Infant Mortality by Race in Sample Areas, 1960-1998



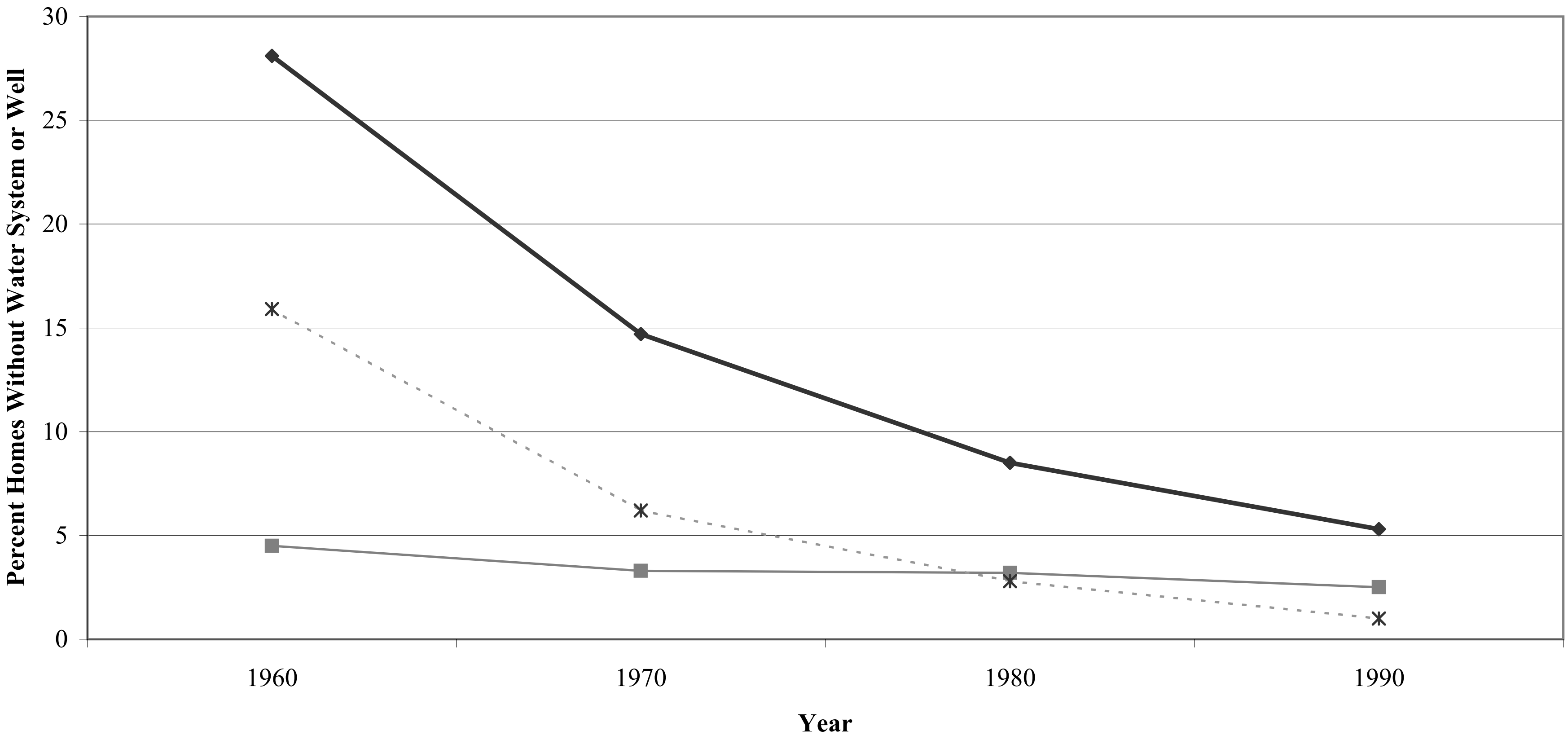
Source: Author's calculations using National Vital Statistics data.

Figure 3.
Gastrointestinal Infant Mortality by Race in Sample Areas, 1960-1998



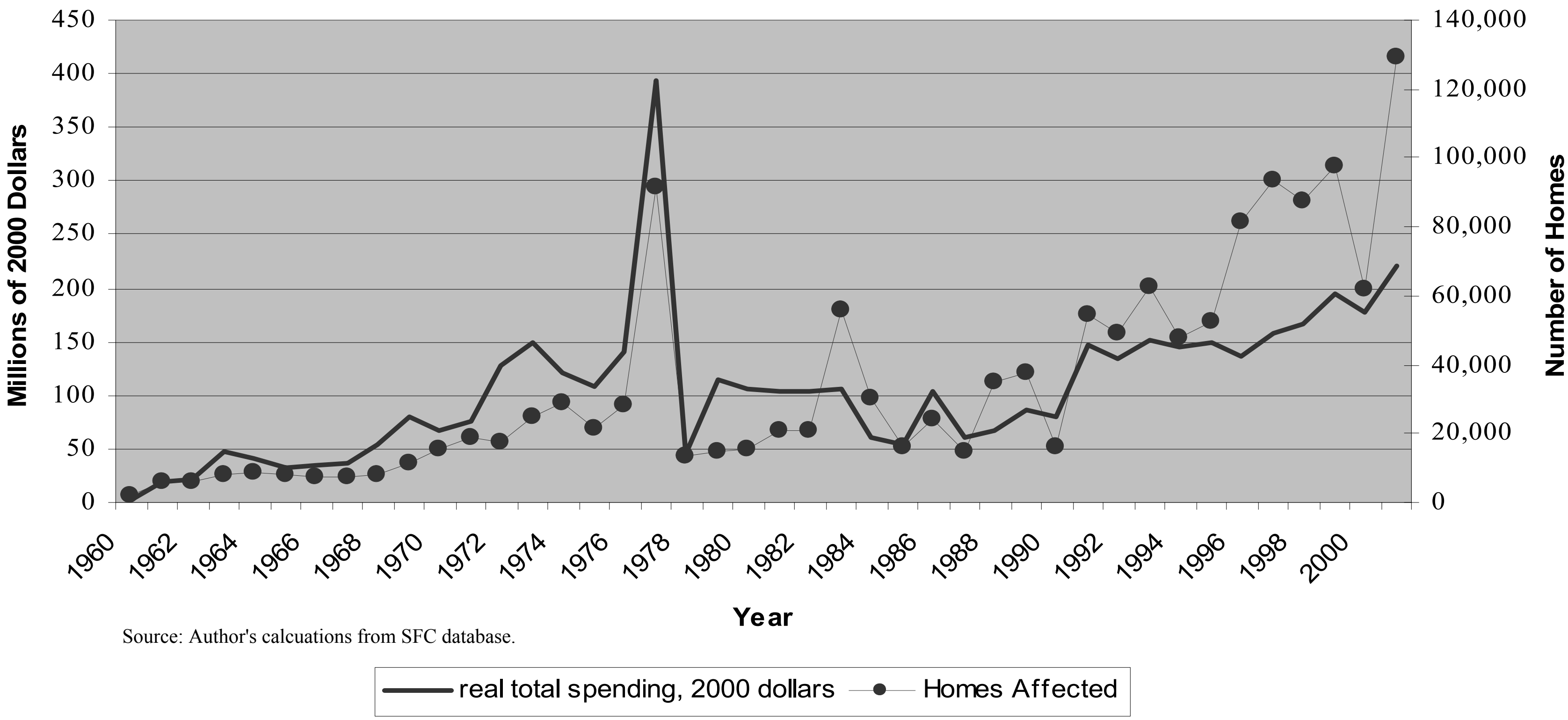
Source: Author's calculations using National Vital Statistics data.

Figure 4.
Fraction Rural U.S. Homes Lacking Water by Race, 1960-1990



Source: Author's calculations using IPUMS data.
Note: Fraction lacking water refers to households with neither a water system or well. Includes households in places with less than 50,000 population in non-metropolitan counties.

Figure 5.
SFC Program Annual Homes Treated and Real Total Spending, 1960-2001 by Appropriation Year



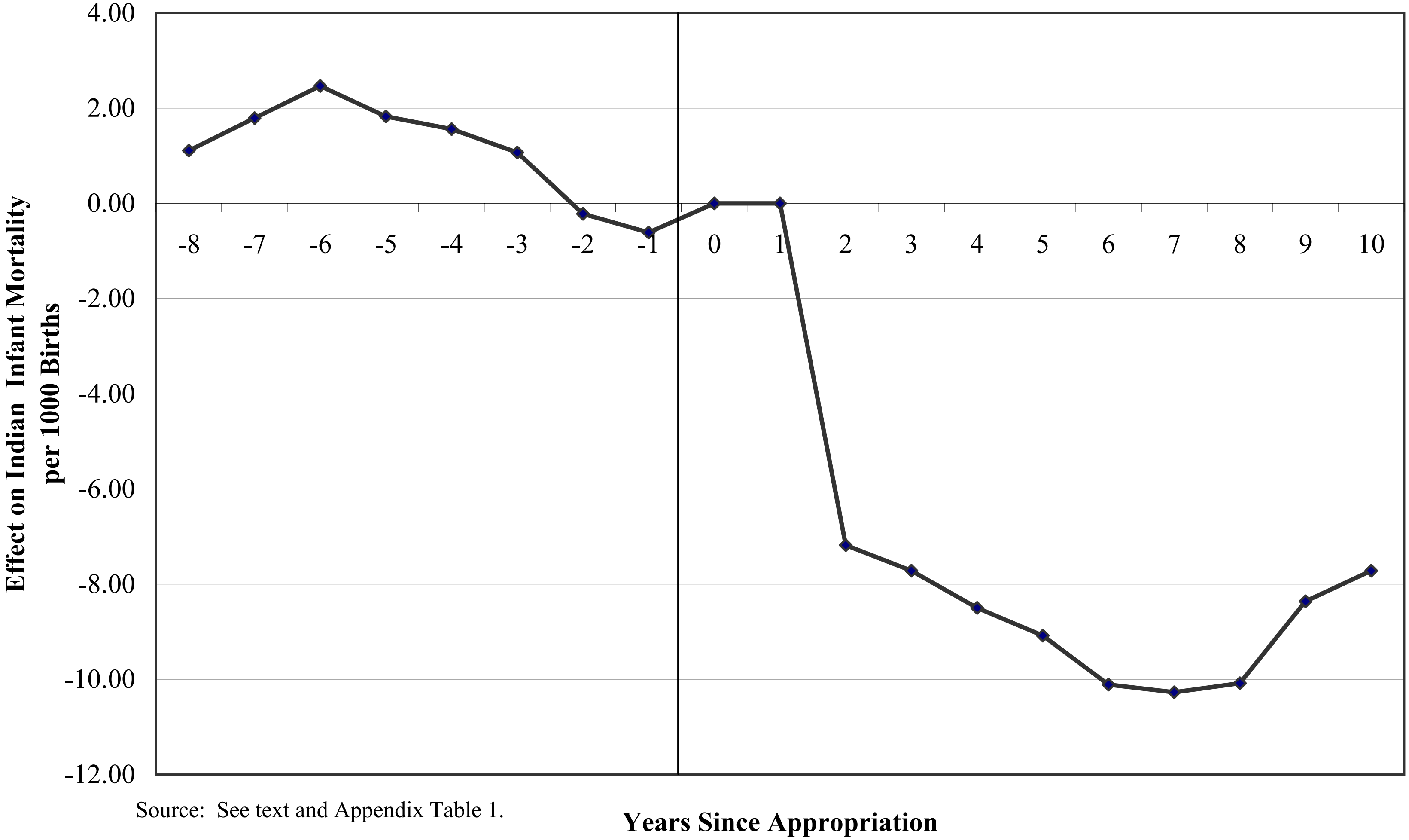
Source: Author's calcuations from SFC database.

Table 1. Summary Statistics

	Unweighted	*Weighted Means*
Number of County Groups	38	
Number of Years	39	
Number of Observations	1,480	
Sanitation Project Statistics		
Number of Projects	3,699	
Number of Homes Per Project	100.2	
Mean Cost Per Project (2000 dollars)	446,564	
Mean Cost Per Home (2000 dollars)	3,766	
Mean Length to Completion (years)	2.0	
County Group Statistics		
Number of Indian Households	6,170	55,056
Fraction Households Indian	0.16	0.09
Number of Indian Live Births	515	4,550
Indian Infant Mortality Rate (IMR) per 1000 births	22.3	20.2
Indian IMR 1960-1962	45.8	44.9
Indian IMR 1996-1998	10.7	9.2
White IMR	14.9	14.4
Fraction Households Treated Through 1998	1.45	1.00
Number of IHS Hospitals	0.95	8.01
Initially Healthier Treatment Area Statistics		
Fraction Households Treated Through 1998	1.36	0.92
Indian Infant Mortality Rate (IMR)	18.4	14.1
Indian IMR 1960-1962	33.5	28.0
Indian IMR 1996-1998	10.0	8.3
Initially Sicker Treatment Area Statistics		
Fraction Households Treated Through 1998	1.53	1.05
Indian Infant Mortality Rate (IMR)	26.2	24.2
Indian IMR 1960-1962	58.7	56.0
Indian IMR 1996-1998	9.7	9.8

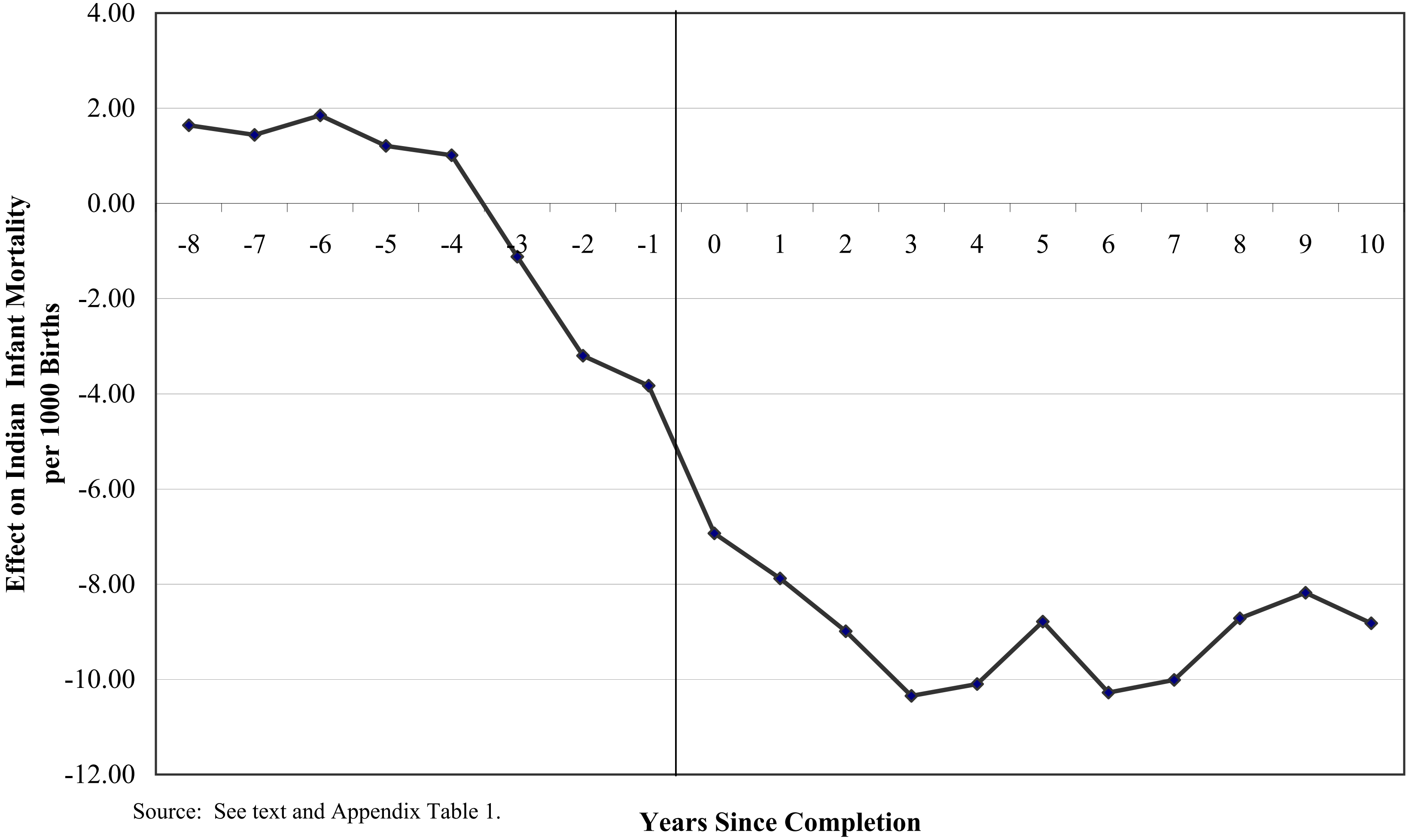
Notes: Means are weighted by estimated number of Indian households in 1980. Initial values based on 1960-62 average. Based on IHS residential sanitation projects less than 5 years in duration started and completed 1959-2001, excluding urban projects, special projects, and emergency projects. Analysis is for years 1960-1998. All county groups with at least 50 Indian live births in every year included except Alaska. One county group is omitted for 1960 and 1961 because data is unavailable for Menominee County, WI. "Initially sicker" are county groups with levels of sanitation-related infant mortality exceeding the median in 1960-1962. See data appendix for description of construction of county groups.

Figure 6.
Effect of Cumulative Fraction Homes Treated Relative to Appropriation Date
(coefficients from separate regressions)



Source: See text and Appendix Table 1.

Figure 7.
Effect of Cumulative Fraction Homes Treated Relative to Completion Date
(coefficients from separate regressions)



Source: See text and Appendix Table 1.

Table 2. Effect of Sanitation Projects on Indian Infant Mortality By Three Different Measures

Dependent Variable: Indian Infant Mortality Rate (Mean=20.2, Initial Value=44.9)	I Weighted Least Squares	I Weighted Least Squares	III Weighted Least Squares	IV Weighted Least Squares	V Instrumental Variables	VI Instrumental Variables
Fraction Homes Appropriated 2 Years Ago	**-7.18****	**-4.95***				
	(2.96)	(2.66)				
Fraction Homes Completed 3 Years Ago			**-10.35****	**-8.38****		
			(3.21)	(2.80)		
Fraction Homes Completed 3 Years Ago					**-10.41****	**-8.47****
Instrumented by Fraction Homes Appropriated 5 Years Ago					(3.52)	(3.15)
Number of Hospitals Previous Year		**-1.54****		**-1.48****		**-1.48****
		(0.46)		(0.39)		(0.40)
County Group Dummies	yes	yes	yes	yes	yes	yes
Year Dummies	yes	yes	yes	yes	yes	yes
County Group-Specific Linear Time Trend	yes	yes	yes	yes	yes	yes
Number of Observations	1480	1480	1480	1480	1480	1480
Number of County Groups	38	38	38	38	38	38
Number of Years	39	39	39	39	39	39
Root Mean Squared Error	8.04	8.00	8.01	7.98	8.01	7.98
R-squared	0.78	0.79	0.79	0.79		

Notes: Regressions, means, and initial values are weighted by estimated number of Indian households in 1980. Initial values based on 1960-62 average. Standard errors are in parentheses and clustered by county group. ** and * indicate statistical significance at the 5 and 10 percent levels, respectively. Based on IHS residential sanitation projects less than 5 years in duration started and completed 1959-2001, excluding urban projects, special projects, and emergency projects. Analysis is for years 1960-1998. All county groups with at least 50 Indian live births in every year included except Alaska. One county group is omitted for 1960 and 1961 because data is unavailable for Menominee County, WI. See data appendix for description of construction of county groups. Appendix Table 2 shows the first stage of the regression in column V.

Table 3. Effect of Sanitation Projects on Indian Infant Mortality By Age of Infant

Dependent Variable:	*Indian IMR* *(Mean=20.2, Initial Value=44.9)*	*Neonatal Indian IMR (less than 28 days)* *(Mean=9.1, Initial Value=18.0)*	*Post-neonatal Indian IMR (28 days to 11 months)* *(Mean=11.0, Initial Value=26.9)*
Fraction Homes Completed 3 Years Ago	**-8.38****	**-0.24**	**-8.14****
	(2.80)	(1.22)	(2.93)
Number of Hospitals Previous Year	**-1.48****	**-0.19**	**-1.29****
	(0.39)	(0.26)	(0.25)
County Group Dummies	yes	yes	yes
Year Dummies	yes	yes	yes
County Group-Specific Linear Time Trend	yes	yes	yes
Number of Observations	1480	1480	1480
Number of County Groups	38	38	38
Number of Years	39	39	39
Root Mean Squared Error	7.98	5.53	5.72
R-squared	0.79	0.56	0.74

Notes: Regressions, means, and initial values are weighted by estimated number of Indian households in 1980. Initial values based on 1960-1962 average. Standard errors are in parentheses and clustered by county group. ** and * indicate statistical significance at the 5 and 10 percent levels, respectively. Based on IHS residential sanitation projects less than 5 years in duration started and completed 1959-2001, excluding urban projects, special projects, and emergency projects. Analysis is for years 1960-1998. All county groups with at least 50 Indian live births in every year included except Alaska. One county group is omitted for 1960 and 1961 because data is unavailable for Menominee County, WI. See data appendix for description of construction of county groups.

Table 4. Effect of Sanitation Projects on Indian Infant Mortality By Disease

Dependent Variable: Indian Infant Mortality Rate from Disease Category		Coefficient on Fraction Homes Completed 3 Years Ago
Disease Categories Related to Sanitation	*(mean=4.58, initial value=16.06)*	**-6.34****
		(1.58)
Gastrointestinal Disease	*(mean=1.77, initial value=6.71)*	**-2.38****
		(1.03)
Certain GI Diseases (MR)	*(mean=1.30, initial value=2.45)*	**-2.53****
		(1.19)
Infectious Respiratory	*(mean=2.81, initial value=9.35)*	**-3.96****
		(1.02)
Pneumonia and Influenza (MR)	*(mean=1.95, initial value=2.76)*	**-3.07****
		(0.81)
Disease Categories Unrelated to Sanitation	*(mean=7.82, initial value=8.90)*	**-1.26**
		(1.56)
Congenital Anomalies (MR)	*(mean=2.50, initial value=3.74)*	**0.62**
		(0.51)
SIDS (MR)	*(mean=0.30, initial value=0.00)*	**0.07**
		(0.26)
Respiratory Distress Syndrome (MR)	*(mean=1.02, initial value=0.44)*	**-0.67**
		(0.50)
Short Gestation/Low Birthweight (MR)	*(mean=0.84, initial value=1.31)*	**0.16**
		(0.24)
Maternal Complications of Pregnancy (MR)	*(mean=0.63, initial value=0.44)*	**-0.77**
		(0.51)
Intrauterine Hypoxia/Birth Asphyxia (MR)	*(mean=0.83, initial value=1.33)*	**0.32**
		(0.59)
Perinatal Infections (MR)	*(mean=0.24, initial value=0.15)*	**0.05**
		(0.22)
Accidents (MR)	*(mean=0.63, initial value=0.67)*	**-0.84****
		(0.22)
Complications of Placenta etc. (MR)	*(mean=0.26, initial value=0.21)*	**-0.40***
		(0.22)
Birth Trauma (MR)	*(mean=0.41, initial value=0.42)*	**0.10**
		(0.27)
Hemolytic Disease of Newborn (MR)	*(mean=0.03, initial value=0.10)*	**-0.10**
		(0.07)
Diseases of Heart (MR)	*(mean=0.15, initial value=0.08)*	**0.20**
		(0.13)
Number of Observations per Regression		1480
Number of County Groups per Regression		38
Number of Years per Regression		39

Notes: Each cell represents a coefficient from a separate regression. Independent variable of interest is fraction of homes completed three years ago. Regressions include county-group fixed effects, year fixed effects, county-group-specific time trends, and number of hospitals in the previous year. Regressions, means, and initial values are weighted by estimated number of Indian households in 1980. Initial values based on 1960-1962 average. Standard errors are in parentheses and clustered by county group. (MR) indicates infant mortality disease categories evaluated by MacDorman and Rosenberg (1993) for code comparability. ** and * indicate statistical significance at the 5 and 10 percent levels, respectively. Based on IHS residential sanitation projects less than 5 years in duration started and completed 1959-2001, excluding urban projects, special projects, and emergency projects. Analysis is for years 1960-1998. All county groups with at least 50 Indian live births in every year included except Alaska. One county group is omitted for 1960 and 1961 because data is unavailable for Menominee County, WI. See data appendix for description of construction of county groups and disease coding.

Table 5. Effect of Sanitation Projects on White Infant Mortality By Disease

Dependent Variable: White Infant Mortality Rate from Disease Category		Coefficient on Fraction Homes Completed 3 Years Ago
Disease Categories Related to Sanitation	*(mean=1.06, initial value=3.46)*	**-0.87****
		(0.25)
Gastrointestinal Disease	*(mean=0.18, initial value=0.51)*	**-0.23***
		(0.12)
Certain GI Diseases (MR)	*(mean=0.09, initial value=0.14)*	**-0.28***
		(0.16)
Infectious Respiratory	*(mean=0.88, initial value=2.95)*	**-0.64****
		(0.22)
Pneumonia and Influenza (MR)	*(mean=0.58, initial value=0.92)*	**-0.54****
		(0.17)
Disease Categories Unrelated to Sanitation	*(mean=7.92, initial value=10.32)*	**-0.75**
		(1.14)
Congenital Anomalies (MR)	*(mean=2.62, initial value=3.98)*	**0.00**
		(0.32)
SIDS (MR)	*(mean=0.24, initial value=0.00)*	**0.16**
		(0.11)
Respiratory Distress Syndrome (MR)	*(mean=1.08, initial value=0.77)*	**-0.27**
		(0.22)
Short Gestation/Low Birthweight (MR)	*(mean=0.93, initial value=1.48)*	**-0.73**
		(0.49)
Maternal Complications of Pregnancy (MR)	*(mean=0.70, initial value=0.77)*	**-0.02**
		(0.18)
Intrauterine Hypoxia/Birth Asphyxia (MR)	*(mean=0.93, initial value=1.37)*	**-0.26**
		(0.33)
Perinatal Infections (MR)	*(mean=0.07, initial value=0.02)*	**-0.02**
		(0.03)
Accidents (MR)	*(mean=0.28, initial value=0.34)*	**-0.10**
		(0.08)
Complications of Placenta etc. (MR)	*(mean=0.40, initial value=0.59)*	**0.14**
		(0.19)
Birth Trauma (MR)	*(mean=0.51, initial value=0.81)*	**0.36**
		(0.29)
Hemolytic Disease of Newborn (MR)	*(mean=0.10, initial value=0.17)*	**-0.02**
		(0.06)
Diseases of Heart (MR)	*(mean=0.05, initial value=0.28)*	**0.01**
		(0.02)
Number of Observations per Regression		1326
Number of County Groups per Regression		34
Number of Years per Regression		39

Notes: Each cell represents a coefficient from a separate regression. Independent variable of interest is fraction of homes completed three years ago. Regressions include county-group fixed effects, year fixed effects, county-group-specific time trends, and number of hospitals in the previous year. Regressions, means, and initial values are weighted by estimated number of white households in 1980. Initial values based on 1960-1962 average. Standard errors are in parentheses and clustered by county group. (MR) indicates infant mortality disease categories evaluated by MacDorman and Rosenberg (1993) for code comparability. ** and * indicate statistical significance at the 5 and 10 percent levels, respectively. Based on IHS residential sanitation projects less than 5 years in duration started and completed 1959-2001, excluding urban projects, special projects, and emergency projects. Analysis is for years 1960-1998. All county groups with at least 50 Indian live births and 50 white live births in every year included except Alaska. See data appendix for description of construction of county groups and disease coding.

Table 6. Heterogeneous Treatment Effects

Dependent Variable:	I *Sanitation-Related Indian IMR 1960-1998* *(Mean=4.58, Initial Value=16.06)*	II *Gastrontestinal Indian IMR 1960-1998* *(Mean=1.77, Initial Value=6.71)*	III *Infectious Resp. Indian IMR 1960-1998* *(Mean=2.81, Initial Value=9.35)*	IV *Sanitation-Related Indian IMR 1963-1998* *(Mean=3.63, Initial Value=14.41)*	V *Gastrontestinal Indian IMR 1963-1998* *(Mean=1.36, Initial Value=5.45)*	VI *Infectious Resp. Indian IMR 1963-1998* *(Mean=2.27, Initial Value=8.97)*
Fraction Homes Completed 3 Years Ago	**-3.55****	**-1.12**	**-2.42**	**-2.64**	**0.83**	**-3.47****
	(1.27)	(1.05)	(1.56)	(1.76)	(0.62)	(1.67)
Fraction Homes * Post-1982	**3.62****	**1.74**	**1.88**			
	(1.48)	(1.09)	(1.69)			
Fraction Homes * Initially Sicker				**-2.00**	**-2.52****	**0.52**
				(2.41)	(0.88)	(2.51)
Number of Hospitals Previous Year and Interactions	yes	yes	yes	yes	yes	yes
County Group Dummies and Interactions	yes	yes	yes	yes	yes	yes
Year Dummies and Interactions	yes	yes	yes	yes	yes	yes
County Group-Specific Linear Time Trend and Interactions	yes	yes	yes	yes	yes	yes
Number of Observations	1480	1480	1480	1368	1368	1368
Number of County Groups	38	38	38	38	38	38
Number of Years	39	39	39	36	36	36
Root Mean Squared Error	3.71	1.83	3.10	3.29	1.55	2.83
R-squared	0.77	0.75	0.63	0.73	0.72	0.58

Notes: Regressions, means, and initial values are weighted by estimated number of Indian households in 1980. Initial values based on 1960-1962 average for columns I to III and 1963-1965 average for columns IV to VI. Standard errors are in parentheses and clustered by county group. ** and * indicate statistical significance at the 5 and 10 percent levels, respectively. Post-1982 is a dummy equal to one if the year is greater or equal to 1983, zero otherwise. "Initially sicker" is a dummy equal to one for county groups with levels of sanitation-related infant mortality exceeding the median in 1960-1962, zero otherwise. All relevant interactions are included in regressions. Based on IHS residential sanitation projects less than 5 years in duration started and completed 1959-2001, excluding urban projects, special projects, and emergency projects. All county groups with at least 50 Indian live births in every year included except Alaska. One county group is omitted for 1960 and 1961 because data is unavailable for Menominee County, WI. See data appendix for description of construction of county groups and disease categories.

Table 7. Robustness Check With Control Variables 1969-1998

Dependent Variable: Indian Infant Mortality Rate	I *1960-1998* *(Mean=20.2, Initial Value=44.9)*	II *1969-1998* *(Mean=14.1, Initial Value=25.3)*	III *1969-1998* *(Mean=14.1, Initial Value=25.3)*
Fraction Homes Completed 3 Years Ago	**-8.38****	**-6.70****	**-6.13****
	(2.80)	(2.56)	(2.79)
Number of Hospitals Previous Year	**-1.48****	**-2.46****	**-2.46****
	(0.39)	(0.92)	(0.86)
Fraction Indian Low Birth Weight (<2500 g)			**34.17****
			(16.65)
Fraction Indian Very Low Birth Weight (<1500g)			**189.15****
			(38.87)
Fraction Indian Mothers Under 20			**7.57**
			(9.64)
Fraction Indian Mothers 35 or Older			**40.56****
			(19.95)
Log Number of Indian Live Births			**-4.41****
			(1.86)
Log Per Capita Income			**-3.87**
			(4.69)
Employment to Population Ratio			**6.04**
			(16.59)
Per Capita Income Maintenance Transfers ('000s)			**-2.11**
			(7.88)
Per Capita Public Assistance Medical Payments ('000s)			**-3.54**
			(4.49)
County Group Dummies	yes	yes	yes
Year Dummies	yes	yes	yes
County Group-Specific Linear Time Trend	yes	yes	yes
Number of Observations	1480	1110	1110
Number of County Groups	38	37	37
Number of Years	39	30	30
Root Mean Squared Error	7.98	6.07	5.91
R-squared	0.79	0.63	0.66

Notes: Regressions, means, and initial values are weighted by estimated number of Indian households in 1980. Standard errors are in parentheses and clustered by county group. ** and * indicate statistical significance at the 5 and 10 percent levels, respectively. Based on IHS residential sanitation projects less than 5 years in duration started and completed 1959-2001, excluding urban projects, special projects, and emergency projects. Analysis in column I is for years 1960-1998. Initial values are based on 1960-62 average. Analysis in columns II and III is for years 1969-1998. Initial values are based on 1969-1971. Columns II and III exclude years before 1969 and Menominee County, WI because of missing data. Otherwise, all county groups with at least 50 Indian live births in every year included except Alaska. One county group is omitted for 1960 and 1961 because data is unavailable for Menominee County, WI. See data appendix for description of construction of county groups and other variables.

Appendix Table 1. Effect of Projects on Indian Infant Mortality

Dependent Variable: Indian Infant Mortality Rate (Mean=20.2, Initial Value=45.0)	I Effect of Fraction Homes Relative to Appropriation Date	II Effect of Fraction Homes Relative to Completion Date	III Effect of Number of Hospitals
8 year lead	**1.11**	**1.64**	**2.05****
	(2.24)	(1.93)	(0.46)
7 year lead	**1.79**	**1.44**	**2.13****
	(1.94)	(1.81)	(0.36)
6 year lead	**2.47**	**1.85**	**1.72****
	(1.63)	(1.54)	(0.43)
5 year lead	**1.83**	**1.21**	**1.84****
	(1.33)	(1.32)	(0.36)
4 year lead	**1.56**	**1.01**	**1.81****
	(1.20)	(1.35)	(0.41)
3 year lead	**1.07**	**-1.12**	**1.37****
	(1.09)	(1.64)	(0.60)
2 year lead	**-0.22**	**-3.20**	**-0.33**
	(1.13)	(2.17)	(1.12)
1 year lead	**-0.61**	**-3.83**	**-1.04**
	(1.89)	(2.90)	(0.99)
Current Year	**-2.69**	**-6.93****	**-2.20****
	(2.51)	(2.88)	(0.76)
1 year lag	**-4.36**	**-7.88****	**-1.93****
	(2.74)	(3.55)	(0.37)
2 year lag	**-7.18****	**-8.99****	**-1.35****
	(2.96)	(3.37)	(0.31)
3 year lag	**-7.72****	**-10.35****	**-1.62****
	(3.46)	(3.21)	(0.30)
4 year lag	**-8.50****	**-10.10****	**-1.12****
	(3.24)	(3.73)	(0.42)
5 year lag	**-9.08****	**-8.79****	**-1.07****
	(3.41)	(4.22)	(0.34)
6 year lag	**-10.11****	**-10.28****	**-1.25****
	(3.42)	(4.19)	(0.30)
7 year lag	**-10.27****	**-10.01****	**-0.89****
	(3.56)	(4.46)	(0.33)
8 year lag	**-10.08****	**-8.72***	**-1.36****
	(4.09)	(5.06)	(0.30)
9 year lag	**-8.36***	**-8.18**	
	(4.57)	(5.06)	
10 year lag	**-7.72**	**-8.82****	
	(4.58)	(4.27)	
County Group Dummies	yes	yes	yes
Year Dummies	yes	yes	yes
County Group-Specific Linear Time Trend	yes	yes	yes
Number of Observations	various	various	various
Number of County Groups	38	38	38
Number of Years	various	various	various

Notes: Each cell represents a coefficient from a separate regression. Regressions, means, and initial values are weighted by estimated number of Indian households. Initial values based on 1960-1992 average. Standard errors are in parentheses and clustered by county group. ** and * indicate statistical significance at the 5 and 10 percent levels, respectively. Based on IHS hospitals and residential sanitation projects less than 5 years in duration started and completed 1959-2001, excluding urban projects, special projects, and emergency projects. I omit regressions including 9 and 10 year lags for hospitals because information is not available prior to 1957. Analysis is for years 1960-1998. All county groups with at least 50 Indian live births in every year included except Alaska. One county group omitted for 1960 and 1961 because data is unavailable for Menominee County, WI. See data appendix for description of construction of county groups.

Appendix Table 2. First Stage of Instrumental Variables Analysis

Dependent Variable: Fraction Homes Completed 3 Years Ago (Mean=0.36)	
Fraction Homes Appropriated 5 Years Ago	**0.87****
	(0.04)
County Group Dummies	yes
Year Dummies	yes
County Group-Specific Linear Time Trend	yes
Number of Observations	1480
Number of County Groups	38
Number of Years	39
Root Mean Squared Error	0.05
R-squared	0.98
Partial F-test of Instrumental Variable	538.99

Notes: Regression is weighted by estimated number of Indian households in 1980. Standard errors are in parentheses and clustered by county group. ** and * indicate statistical significance at the 5 and 10 percent levels, respectively. Based on IHS residential sanitation projects less than 5 years in duration started and completed 1959-2001, excluding urban projects, special projects, and emergency projects. Analysis is for years 1960-1998. All county groups with at least 50 Indian live births in every year included except Alaska. One county group is omitted for 1960 and 1961 because data is unavailable for Menominee County, WI. See data appendix for description of construction of county groups.