Mortality, Fertility and Human Capital Investment: Evidence from Immunization Program in India

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Abstract

I exploit the shock to mortality caused by the Universal Immunization Program in India to study the impact of declining child mortality on fertility and human capital investment decisions of households. Between 1980 and 1990, immunization rates for the main childhood diseases in India increased 50 to 60 percentage points. Using country-level changes in immunization rates interacted with state-level initial mortality in 1980 as an instrument for child mortality changes, I find that a 1 percentage point decline in child mortality reduces births last year by about 5 percent, and increases female schooling by 0.4 years, an increase of about 7 percent. While previous papers have focused on the "horizon effect" where declines in adult mortality increase human capital accumulation, my findings point to another mechanism of the quantity/quality tradeoff that works through child mortality and fertility declines.

JEL Codes: O12, J13, J22, I21
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1 Introduction

What is the effect of declining child mortality on fertility and human capital investment decisions? To answer this question, I exploit the large improvements in child mortality driven by Universal Immunization Program (UIP) in India. UIP started in 1985 aiming to immunize at least 85 percent of all infants (0-12 months) against six main childhood diseases.[1] Between 1980 and 1990, immunization rates for tuberculosis increased 63 percentage points, while immunization rates for the others increased about 50 percentage points on average. I estimate a large impact of the program on child mortality, with the program potentially accounting for a 4 percentage point reduction in under-5 child mortality.[2] The program can be viewed as an exogenous shock to child mortality and provides an opportunity to understand the complex relationship between mortality, fertility and educational decisions.

The theoretical literature models the effect of adult mortality and child mortality on fertility and education decisions separately.[3] A decline in the adult mortality affects fertility and education decisions through increased returns to education, the so-called "horizon effect." Decreases in adult mortality encourages educational investment as it increases the horizon over which returns to investments in human capital can be realized. Using household data from Sri Lanka and sub-Saharan Africa respectively, Jayachandran and Lleras-Muney (2009) and Fortson (2007) provide empirical evidence for this channel. Changes in child mortality, on the other hand, might work their way through fertility directly. There can be several mechanisms from child mortality to fertility. One is such where, at high levels of mortality parents engage in hoarding and bear more children relative to their desired number to ensure the survival. As the survival probability of each child increases, parents do not have to insure themselves by having more children.[4]

[1] The diseases are diphtheria, pertussis, tetanus, polio, typhoid and childhood tuberculosis.

[2] Kumar (2009a) and Kumar(2009b) also evaluate the impact of the program on child mortality and find substantially smaller effects. I discuss possible reasons for this difference in the text.

[3] A notable exception is Soares (2005) that models both.

[4] See Kalemli-Ozcan (2001, 2002) and Tamura (2005).

Another mechanism is about the returns to big family as highlighted by Soares (2005). If parents get utility from the number of offsprings surviving into adulthood and raising their own children, decreases in child mortality increases the probability to survival to adulthood, therefore, decreases the return to having a large family. Both adult and child mortality declines might induce a quality-quantity trade-off, but the underlying mechanism might differ. In the case of a decline in adult mortality, increases in educational investments driven by higher future return will cause a reduction in fertility. In the case of a decline in child mortality, decreases in fertility might cause parents to increase educational investments since now it is cheaper to invest in each surviving child. It is a daunting task to separate out these channels empirically. The literature focused on life expectancy at age 15 to pin down the adult mortality channel. The parallel literature that focuses on child mortality used mortality rates under 5. Both approaches remain vulnerable to the fact that simultaneous changes might drive mortality at any age together with fertility and education. I propose an alternative approach. By focusing on a program that solely targets child mortality, my goal is to provide evidence on the child mortality driven quality-quantity trade-off. To the best of my knowledge this has been a first in the literature.

I build child mortality rates by state and year and individual level fertility rates by year using birth histories from Demographic Health Surveys. I employ a difference in differences strategy where I compare mortality changes across states with high and low initial child mortality in 1980 (before the program). My identifying assumption is that the immunization program had disproportionately larger impact on states with high initial mortality. Without the program, the change in fertility for a one percentage change in mortality would be same in high and low mortality states. States with low initial child mortality may already have had access to vaccines or had health care services that could more adequately battle childhood diseases. My estimates indicate that the program reduced child mortality by approximately 4 percentage points (or approximately 36 percent) for states at mean initial mortality levels. To guard against the possibility that these differences were driven by prior trends, I show that prior to the program, there was no significant difference in changes in child mortality across states identified as high and low mortality states. After running reduced form specifications where I investigate the effect of the program on fertility and education decisions, I also undertake an IV analysis. I instrument state-level child mortality with the initial mortality interacted with country level immunization rate. This allows me to gauge the size of child mortality effect on fertility and education. I also control for regional GDP differences because economically active and more developed states may have both lower mortality and lower fertility and higher education.

My results are as follows. Reduced form estimations show that the program had substantial effects on fertility and education. I estimate that relative to states with zero initial mortality the program reduced births last year by .032 in states with mean initial mortality. This corresponds to a decline of 14.7 percent. Next, I find that program led to .84 years increase in female years of schooling relative to states with zero initial mortality. Given that the average female schooling was about 6 years, the program effect corresponds to a 14 percent increase for the affected cohorts. Interestingly, however, the program did not have any statistically significant effect on male education. This is consistent with the literature that shows gender specific program effects.[5] My findings suggest that girls may be the marginal children and they are provided with more family resources as they become available with the reductions in fertility. My IV estimates show that 1 percentage point decline in child mortality led to .010 reduction in births, which corresponds to a 5 percent decline. Finally, I show that 1 percentage point decrease in child mortality increased female schooling by 0.4 years, which translates to a 7 percent increase. Both of these effects are relative to the sample mean.

My results have important aggregate implications. The empirical literature on mortality and development mostly uses cross-country data and regresses countries' growth rates or per capita income levels on life expectancy. This literature faces several chal-

[5] See Chin (2005), Banerjee et al.(2004), Jensen (2010), Munshi and Rosenzweig (2004), Duflo (2003).

lenges. First, it is difficult to establish causality since growth, income, and life expectancy are all simultaneously determined variables. Another challenge is the difficulty in identifying the exact mechanism through which increased life expectancy has a positive effect on development. The main channel according to the theoretical literature is the quality-quantity trade-off, on which there has not been robust evidence. The aforementioned papers such as Jayachandran and Lleras-Muney (2009) and Fortson (2009) provide credible evidence on one channel which works through the "horizon effect" and adult mortality. In this paper I provide systematic evidence on the quality-quantity trade-off that is driven by lower child mortality and accompanying declines in fertility.

The literature also focuses on the morbidity channel, where lower morbidity encourages higher investments in children. This literature generally focuses on the morbidity declines associated with hookworm eradication or malaria reductions (See Miguel and Kremer (2004), Bleakley (2007)). My initial mortality rates by state are not by disease and hence I cannot estimate the extent of initial morbidity and the associated decline afterwards. Although I cannot fully rule out the possibility that my results are affected by this, I believe that this is not a major concern. My reasoning is based on the fact that the six childhood disease that I use are the main killers of children aged 0-4 and UIP directly targets these diseases.

The rest of the paper is organized as follows. Section 2 provides a brief review of the related papers. Section 3 explains the program. Section 4 describes the data. Section 5 presents the empirical strategy and results. Section 6 presents robustness checks. Section 7 concludes.

2 Related Literature

Theoretically the effect of health and lower mortality on growth is ambiguous. On the one hand, lower mortality increases population growth and reduces income per capita. On the other hand, in response to lower mortality changes in fertility and human capital investment behaviors may increase TFP and the rate of human capital accumulation. Behavioral changes in fertility and education lead to quantity-quality trade-off. While the first-order effect of decreases in adult mortality is to increase human capital investment, first-order effect of child mortality is to decrease fertility. Both mechanisms shift quantity-quality trade-off towards fewer children with more education. (See Kalemli-Ozcan (2001, 2002), Tamura (2005), Soares (2005).) Most of the available evidence on the subject is from cross-country studies and they report positive effects of life expectancy on income growth (see Lorentzen, McMillan and Wacziarg (2008), Bloom and Sachs (1998), Gallup, Sachs, and Mellinger (1999), and Bloom et al. (2003).) However, since countries suffering from high mortality and ill health are also disadvantaged in other ways, most of these cross-country studies cannot suggest more than correlative evidence. Alternatively, Shastry and Weil (2003), Weil (2007), Ashraf et al. (2008) take a different approach and use calibrations based on microeconomic estimates to show the effect of health on growth. They find positive but small effects. In a recent influential paper, Acemoglu and Johnson (2007) instrument changes in life expectancy with dates of global health interventions to combat 15 major diseases and find that although these interventions increased life expectancy, they had a negative causal effect on income per capita.[6]

Several recent papers have turned to country-specific evidence, relying on natural experiment that provide plausible exogenous variation in life expectancy. Jayachandran and Lleras-Muney (2009) use exogenous declines in maternal mortality between 1946 and 1953 in Sri Lanka to show the effect of life expectancy on educational investment. They find that one year increase in life expectancy increased female literacy by 0.7 percentage point (2%) and years of schooling by 0.11 years (3%). Using household data from Brazil, Soares (2006) finds that a one-standard-deviation decrease in adult mortality decreases total number of births by 2.5-3.7% and increases years of schooling by 2.2-3.1%. Fortson (2007) uses individual data from sub-Saharan African countries and finds that children living in areas with 10 percent regional HIV prevalence complete 0.3 fewer years

[6]See Cervellati and Sunde (2009) and Bloom, Canning and Fink (2009) for discussion of their findings.

of schooling (7%) compared to children living in areas with zero HIV prevalence.

In addition to mortality, a number of papers have also investigated the impact of morbidity on educational outcomes. Miguel and Kremer (2004) and Bleakley (2007) show that deworming interventions improved educational outcomes in Kenya and American South, respectively. The fact that worm infections are rarely fatal but individuals who have these infections suffer substantial morbidity allow them to study the effect of morbidity on human capital accumulation. Bleakley (2007), employing a strategy similar to this paper, shows that areas with higher initial levels of hookworm infection benefited more from the eradication of this disease and experienced greater increases in school attendance and literacy.

Although UIP was an extensive program in terms of coverage and potential effects on the development, the repercussions of it has not been studied in detail. On exception of this is Kumar (2009a), which finds that immunization program decreased probability of primary school completion by 7.2% and increased secondary school completion by 11%. However, he does not find any program effect on literacy or average years of schooling. He explains the negative impact on primary education with lower average health among marginal surviving children. Additionally, Kumar (2009b) shows that exposure of first-born child to the program is associated with lower cumulative fertility (1%) and larger birth intervals (2.5%).

3 Universal Immunization Program

Following smallpox eradication in the 1970s, India launched the Expanded Program on Immunization (EPI). Initially six childhood diseases were targeted: Diphtheria, pertussis, tetanus, polio, typhoid and childhood tuberculosis. However, the EPI was mostly limited to urban areas. To achieve national coverage, the program was universalized and renamed Universal Immunization Program (UIP) in 1985. Measles vaccine was included in the program and typhoid vaccine was discontinued. The program was introduced in a phased manner from 1985 to cover all districts in the country by 1990. The objective of UIP was to cover at least 85 percent of all infants (0-12 months) and immunize more than 90 million pregnant women and 83 million infants over a five year period. The program was given the status of 'National Technology Mission' in 1986 by the Indian government, accelerating the program and increasing coverage rapidly. UIP became a part of the Child Survival and State Motherhood (CSSM) Program in 1992 and Reproductive and Child Health (RCH) Program in 1997.

Figure 1 shows the national immunization coverage rates for 5 vaccines and diseases. The figure illustrates that the UIP was not only large in scale, leading to 50-60 percentage point increases in coverage, but the program was also implemented within a relatively short time period. For example, in the case of tuberculosis, the BCG vaccine coverage increased from 8 in 1985, at the inception of the UIP to 66 by 1990. According to UNICEF vaccine preventable diseases (VPDs) kill approximately 2 million children every year. Increase in immunization coverage and declines in incidence of vaccine preventable diseases are expected to decrease the infant and under-five mortality in India, providing a unique opportunity to study the effect of child mortality on fertility and education. The large and discrete nature of the increase in coverage is likely to provide variation in child mortality that is less likely to be confounded with long run trends. I compare child mortality in 1980, before the program, to child mortality in 1990, the target date for near universal coverage. Additionally, I exploit the variation across states by comparing states with high and low initial child mortality. The assumption is that the near universal coverage mandate within a short time span resulted in differential treatments across states. Across 26 states in India, the realized declines in child mortality were larger in states with higher levels of initial child mortality, suggesting a convergence led by the immunization program. This pattern is shown in Figure 2. The relationship between initial child mortality and declines in child mortality between 1980 and 1990 is statistically significant at 1 percent level in a univariate regression.

4 Data

I use 1992-1993, 1998-1999 and 2005-2006 Demographic Health Surveys for India. The DHS surveys are nationally representative samples designed to gather detailed demographic and fertility information of women. In the survey, adult women (aged 15 to 49) answer retrospective questions about each birth, including year of birth, gender, and year of death, in case the child died. I use women's birth histories to construct the number of births in each year of their lives.

In addition to using retrospective birth histories, I construct child mortality rates by state and year. Under-five mortality rate is the probability of a child dying before reaching the age of five, if subject to age-specific mortality rates of that state and year. Under-five mortality is calculated as follows:

$$MR_{0-5} = (1 - \prod_{a=0}^{5} \frac{deaths_{a,t,s}}{children_{a,t,s}}) * 100 \tag{1}$$

where a refers to age, t refers to year and s refers to state. In my sample, average under-five mortality is 13.3 percent in 1980 and 10.1 percent in 1990.[7] Child mortality in 1980 by state is taken as state initial mortality, which is the mortality rate before the immunization program.

I use immunization coverage estimations by WHO/UNICEF. Based on the official data reported by countries WHO/UNICEF provides its own estimations after correcting for potential biases. Estimations are available for BCG (tuberculosis vaccine), the third dose of diphtheria and tetanus toxoid and pertussis vaccine (DTP3), the third dose of polio vaccine (Pol3) - the first dose of measles vaccine (MCV). In my estimations, I use the average immunization rate for tuberculosis. However, in robustness section I show similar results for other vaccines. I also use state level GDP as additional controls. Data on state level GDP between 1960 and 2000 were obtained from CDs distributed by the

[7] The regression coefficient on the relationship between my country level estimations and official data between 1960-2005 is 1.03 (0.100).

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Table 1 reports the descriptive statistics. Panel A shows the means of the variables such as age, births last year, under-5 mortality, and immunization coverage rates that prevailed in 1980 and 1990. Panel B shows the means organized by birth cohort and in particular report separately the education levels of birth cohorts born prior to the program (1970-74, 1975-79, 1980-84) and after the program (1985-89, 1990-92). The bottom panel, Panel C, illustrates the variation in average number of births, under-5 mortality, and state GDP across states. I first calculate weighted averages by state and report the unweighted means and standard deviations of state averages. The table shows the dramatic increase in immunization rates as well as the decline in under-5 mortality which fell from 11.3 percent to 8.7 percent. The table also illustrates the large variation in mortality rates across states with the highest mortality state starting with under-5 mortality of 20.4 percent and lowest mortality state exhibiting a rate of 4.3 percent in 1980. By 1990, the gap between the highest and lowest had shrunk to 11.5 percentage points.

5 Empirical Framework and Results

5.1 Effect of Immunization on Child Mortality

I first examine the impact of the immunization program on child mortality rates. I begin with a simple difference in differences framework comparing states with high and low initial mortality rates. To examine the impact on child mortality, I created cell level data by state and year. The years I examine are 1980, the pre-treatment year, and 1990, the post-treatment year. I run the following regression to show the effect of immunization program on child mortality.

$$Child \ \ Mortality_{st} = \alpha + \beta Immunization \ \ Rate_t \ \ x \ \ Initial \ \ Mortality_s + \theta Immunization \ \ Rate_t$$
$$+ \zeta Initial \ \ Mortality_s + \mathbf{X}'_{st}\gamma + \epsilon_{st} \tag{2}$$

where s denotes state and t denotes year. Immunization rate is the country level immunization rate for tuberculosis in year t.[8] State initial mortality is the under-5 mortality rate in the state in 1980. The interaction of the country-level immunization rate with state initial mortality identifies the effect of the immunization program. The idea behind this specification is that the immunization program resulted in differential treatment across states, with those with the highest initial mortality getting the largest treatment. In addition to this simple basic specification, I also add state fixed effects and year fixed effects in columns (2) and (3) which more flexibly control for unobserved heterogeneity across states and time-varying factors. These fixed effects absorb the effect of state initial mortality and immunization rate, respectively. Additionally, in column (3) I control for GDP per capita which varies by state and year. It is important to control for economic activity when studying the effect of mortality on development. Richer and more developed states can have both lower mortality levels and also have lower fertility and higher human capital investment. Therefore, not controlling for economic activity may lead to omitted variable bias.

In all specifications in Table 2, there is a significant negative relationship between child mortality and the interaction between country level immunization rate and state initial mortality. It suggests that states with higher initial mortality benefited more from immunization program and experienced larger decreases in child mortality. According to column 3, a 10 percentage point increase in immunization rate reduces child mortality

[8] In the empirical analysis reported in the main body of the paper, I use country-level tuberculosis immunization rates. The results on mortality are the same regardless of the choice of vaccine. In Table 9 I report the results on fertility and education using other diseases.

by .625 percentage points for states at the mean initial mortality (11.3 percent) relative to states with zero initial mortality. As mentioned in the previous section, Figure 2 presents the visual representation of these results. The figure shows that states with higher initial mortality experienced larger declines in child mortality.

One issue is whether this relationship reflects longer run convergence across states. I examine this issue by investigating the same relationship for 1970-1980. Figure 3 depicts the relationship between state initial mortality in 1980 and changes in child mortality between 1970 and 1980, before the immunization program was in action. The figure reveals that prior to the immunization program, there was no significant difference in changes in child mortality across states identified as high and low mortality states in 1980. Another concern is that there may have been other health interventions that also impacted child mortality. To the best of my knowledge, there were no other major health interventions under way during the same time period. However, to check for this possibility, I examine whether adult mortality also exhibit similar patterns of improvement as child mortality. Since immunization should not have impacted adult mortality during this period, this provides a good falsification test. Figure 4 shows changes in adult mortality by initial state child mortality in 1980. Reassuringly, we see no systematic pattern for adult mortality changes.

5.2 Effects of Immunization on Fertility and Education

The previous section showed that states with higher initial mortality had larger declines in child mortality over the period 1980-1990. In this section, I examine whether the immunization program and the reduction in child mortality impacted fertility of mothers as well as the education level of the treated cohorts. To examine the impact on fertility of mothers, I specify the following reduced form regression that builds on the previous specification on child mortality.

$$Fertility_{ist} = \alpha + \beta Immunization\ \ Rate_t\ \ x\ \ Initial\ \ Mortality_s + \theta Immunization\ \ Rate_t \tag{3}$$
$$+ \zeta Initial\ \ Mortality_s + \mathbf{X}'_{ist}\gamma + \epsilon_{ist}$$

where i denotes the individual woman, s denotes state and t denotes year. The fertility variable is number of births last year for the individual woman. I examine fertility of women who are 15 to 49 years old, controlling for a quadratic function in age.

Table 3 shows the results. I report the results of the basic specification above in column (1). The effect of the interaction between immunization rate and initial mortality, which I interpret as the program effect, is negative and significant in all specifications. In other words, states with higher initial child mortality realized larger declines in fertility relative to the states with lower initial mortality. Column 2 shows the results with state and year fixed effects. Column 3 is my preferred specification as it controls for both state and year fixed effects in addition to state GDP. According to the preferred specification in column (3), a 10 percentage point increase in immunization rate reduces births by .005 for states at mean initial mortality relative to states with zero initial mortality.[9] Tuberculosis immunization rate increased approximately 63 percentage points so the decline in fertility due to the program was .032. Average births last year was .217 in 1980 so this translates into an approximate decline of 14.7 percent. Since the decline in fertility between 1980 and 1990 reported in Table 1 is approximately 33 percent ((.16-.24)/.24)) the program can explain approximately 45 percent of the total decline in fertility over my sample period.

I next turn to the effect of the immunization program on education levels of the treated cohort.

[9] I multiplied the coefficient -.004 by mean initial mortality of 11.3. The immunization rate variable ranges between 0 and 1 so a 10 percentage point increase translates into .1 x .05 = .005.

$$Education_{isc} = \alpha + \beta Immunization \;\; Rate_c \;\; x \;\; Initial \;\; Mortality_s + \theta Immunization \;\; Rate_c$$
$$+ \zeta Initial \;\; Mortality_s + \mathbf{X}'_{isc}\gamma + \epsilon_{isc} \tag{4}$$

where i denotes the individual, s denotes state and c denotes birth cohorts. Education is measured as years of schooling. Included birth cohorts are 1980-1984, 1985-1989 and 1990-1992. Cohorts 1985-1989 and 1990-1992 are the treated cohorts since the immunization program began in 1985. For these regressions, I align the state GDP per capita to be that which prevailed while the cohort was of school-going age, 5 to 15. Since states with higher economic activity may have higher education and lower child mortality due to other underlying reasons, it is important to control for state GDP during the periods that the cohort is of school-going age.

Table 4 shows the results for females and males. Turning to the education results for females, the coefficient on "Immunization Rate" is positive indicating that years of schooling increased as immunization rate increased. The large negative coefficient on "State Initial Mortality" indicates that states with the highest initial mortality in 1980 have the lowest female schooling levels. The interaction terms which I interpret as the effect of immunization program on female years of schooling is positive and significant in all specifications. Again, in my preferred specification which includes state GDP reported in column (3), I find that a 10 percentage point increase in the immunization rate increases schooling for females by .134 years for states at mean initial mortality relative to states with zero initial mortality. The program resulted in a 63 percentage point increase in immunization rate from 1980 to 1990 so the total increase in female schooling due to the immunization program could be as large as 0.84 years. This translates into an approximate increase of 14 percent given that average schooling among females for the 1980-84 cohort was around 6 years.

5.3 Effect of Child Mortality on Fertility and Education - 2SLS Estimates

In the previous section, I examined the reduced form effects of the immunization program on child mortality, women's fertility, and education levels of the treated cohorts. In this section, I exploit the large exogenous change in immunization rates brought about by the program as an instrument for reductions in child mortality. This 2SLS specification allows me to gauge the size of the mortality effect on fertility and education. Before reporting the 2SLS estimates, I first report the estimates from simple OLS specifications relating state-specific child mortality rates to fertility as in the following:

$$Fertility_{ist} = \alpha + \beta Child \;\; Mortality_{st} + \mathbf{X}'_{ist}\gamma + D_s + D_t + GDP_{st} + \epsilon_{ist} \tag{5}$$

where child mortality is the mortality rate for children younger than 5 years old by state and year. D_s and D_t control for state and year fixed effects, respectively. $\mathbf{X}'_{ist}$ includes age and age-squared; and ϵ_{ist} is the error term.

Results are reported in columns (1)-(3) in Table 5. The OLS coefficients are all positive but in specifications which include year and state fixed effects, the coefficients are no longer significant. The OLS coefficients, however, may suffer from omitted variables bias or reverse causality. Columns (4)-(6) report the instrumental variables estimates. I instrument child mortality with the interaction of county level immunization rate and state initial mortality. First stage estimates are negative and statistically significant at 1 percent level, suggesting that immunization program led to larger declines in child mortality in states with higher initial mortality. Second stage results show that there is a positive and significant relationship between child mortality and number of births per year. According to my preferred specification in column (6), 1 percentage point decrease in child mortality reduces births by .010, which is approximately a 5 percent decline in births.[10]

[10]Basically, the IV estimate of child mortality on fertility is the ratio of reduced form effect to the first-

Similarly, I run the following OLS estimation for education:

$$Education_{isc} = \alpha + \beta Child \;\; Mortality_{sc} + \mathbf{X}'_{isc}\gamma + D_s + D_c + GDP_{sc} + \epsilon_{isc} \qquad (6)$$

Table 6 displays the results for females. OLS estimations, in columns (1)-(3), show that declines in child mortality increases years of schooling for females. 2SLS estimates are reported in columns (4)-(6) and are considerably larger than the OLS estimates.[11] According to the coefficient reported in column (6), the size of the child mortality effect on schooling is substantial. A 1 percentage point decrease in child mortality increases female schooling by 0.4 years. Since average female schooling for the 1980-84 cohort was around 6 years, this translates into a 7 percent rise in female schooling. Table 7 shows the results for males. For males, the OLS coefficients are positive and significant, columns (2) and (3), once we control for year and state fixed effects. The 2SLS coefficients, however, reported in columns (4)-(6) are not significant.

It is important at this point to compare my educational outcomes to others in the literature as well as discuss possible channels. In their paper on the effect of maternal mortality reductions on female education, Jayachandran and Lleras-Muney (2009) report that an increase of a year in life expectancy at 15 results in .11 years of additional schooling, an increase of 3 percent.[12] Converting my reductions in child mortality to changes in life expectancy, I estimate that an increase of a year in life expectancy at birth translates into about a 1.5 percentage point reduction in under-5 mortality. According to the estimates in column (3) this would result in about 0.6 years of additional schooling for females, an increase of about 10 percent.[13] While my estimates appear to be large, it is difficult to make a direct comparison since I focus on life expectancy at birth while Jay-

stage effect of immunization program on child mortality.

[11]First stage results are slightly different in fertility regressions (Table 5) and education regressions. The difference is stemming from the fact that two datasets are structured differently and cover different years.

[12]Kumar (2009a) also provides estimates of UIP on education outcomes. He finds no impact on years of schooling but finds that the fraction who complete primary school decreases while the fraction who complete secondary school increases.

[13]A 1 percentage point decrease in child mortality increases female schooling by 0.4 years, therefore, 1.5 percentage point decrease in child mortality leads to 1.5*0.4=0.6 years, which is 0.6/6=10%

achandran and Llleras-Muney (2009) focus on life expectancy at age 15. They also point out that infant and child mortality should not affect human capital investments through the horizon effect since such investments do not begin until after age 5. While the horizon effect is not in operation, Table 3 and Table 5 demonstrated that the immunization program reduced fertility. Education of the treated cohort can increase if parents trade off the number of children for higher quality, i.e. better educated children. One thing we need to establish, however, is that the number of children per household did indeed decline over this period. In other words, taking into account reductions in both child mortality and fertility, is it the case that *net* fertility declined? I examine this question in Figure 5. The left axis (square symbol) refers to the average number of children born per woman each year who are expected to survive to age 5. The right axis (diamond symbol) refers to the net reproduction rate, which is defined as the number of daughters born per woman who are expected to survive. Unlike the previous measure, the net reproduction rate incorporates information on adult survival probability.[14] Figure 5 shows that by both measures, net fertility declined in India over this period. The simultaneous reduction in net fertility and increase in education is consistent with a quantity-quality tradeoff which is triggered by shocks to child mortality which works its way through the fertility channel.

There are several caveats to the above interpretation. First, to the extent that the reductions in fertility increase household resources that are used to educate older or younger children in the household, my estimates would tend to understate the impact on education. Second, another important channel is the impact of immunization on child morbidity. As cited in the introduction, a number of papers have found arguably causal impact of improvements in child health on educational outcomes (Miguel and Kremer

[14]Net reproduction rate is calculated as:

$$NRR_{a,t} = \sum_{a=0}^{49} \frac{Female\ \ Offsprings_{a,t} * (1 - q_{a,t)}}{Women_{a,t}}$$

where a, t denote to age and year, respectively. q is the probability of survival to age a. Adult mortality estimates by state and year is from Saikia et al. (2010).

(2004),Bleakley (2007)). To the extent that a direct morbidity channel exists, my estimates here would overstate the impact of child mortality changes on education.

The last issue to be addressed is my finding that the immunization program increased years of schooling for girls, but not boys. Gender-specific effects which resulted from programs have been documented in other studies (see Chin (2005), Banerjee et al.(2004), Jensen (2010), Munshi and Rosenzweig (2004), Duflo (2003)). It may be the case that reduction in fertility frees up time for girls since they are more likely to have child care duties. Table 1 shows that there is substantial gender gap in schooling between males and females. My results suggest that female children are the marginal children who benefit from family resources which become available with the reductions in fertility.

6 Robustness

My identification strategy rested on the assumption that the immunization program had larger treatment effects on states with higher initial child mortality. I did indeed find that states with higher initial mortality in 1980 had larger declines in mortality from 1980 to 1990, as well as larger declines in fertility and increases in female schooling. One concern is that states with different initial child mortality also might have different underlying trends in these outcome variables irrespective of the immunization program. I test for pre-trends before the immunization program by running the following regressions using the data between 1970 and 1980:

$$\begin{aligned} Fertility_{ist} &= \alpha + \beta Initial \;\; Mortality_s x Post_t + \theta Post_t + \zeta Initial \;\; Mortality_s \\ &+ \mathbf{X}'_{ist}\gamma + D_s + D_t + GDP_{st} + \epsilon_{ist} \end{aligned} \tag{7}$$

and

$$Education_{isc} = \alpha + \beta Initial\ \ Mortality_s\ \ x\ \ Post_c + \theta Post_c + \zeta Initial\ \ Mortality_s \tag{8}$$
$$+ \mathbf{X}'_{isc}\gamma + D_s + D_c + GDP_{sc} + \epsilon_{isc}$$

where Post is a fake treatment dummy that takes 1 in 1980, and zero otherwise.

Results are shown in Table 8. Column (1) shows that there is indeed a pre-existing trend in fertility before the immunization program. However, the relationship has the opposite sign of the relationship found in Table 3. According to this table, states with higher initial mortality were experiencing smaller declines in fertility relative to the states with lower mortality. This behavior is consistent with a high child mortality environment in which the pre-cautionary motive is strong and parents continue to have children to guarantee a specific number of survivors (Kalemli-Ozcan 2002, 2003). However, this gap reverses sign with the program as shown in Table 3 and states with higher initial mortality start to experience larger decreases in fertility. This suggest that I may be understating the program effect and my estimates provide a lower bound for the program effect on fertility. In columns (2) and (3), I test for pre-trends in female and male education. Cohorts born between 1970-1980 were not exposed to the program, and therefore, the increase in education across cohorts should not differ systematically across high and low mortality states. Indeed, the coefficients are not statistically significant indicating that there are no pre-existing trends in female/male years of schooling correlated with initial state mortality.

Next, I show the robustness of my results to the choice of vaccine included in the immunization and report these results in Table 9. In my analysis, I used BCG (vaccine for tuberculosis) coverage as country level immunization rate. In this section, I repeat the main specifications for fertility and education using DTP1, DTP3, Pol3 and MCV vaccines.[15] As can be seen from the table, the results are quantitatively similar and

[15]DTP1 and DTP3 are first and third doses for diphtheria, tetanus and pertussis; Pol3 is the third dose

robust to the choice of vaccine.

7 Conclusion

In 1985, India launched a large-scale immunization program which increased the country level immunization rates against basic childhood diseases by 50-60 percentage points. This major health intervention resulted in large declines in under-5 child mortality. Using fertility histories from Demographic Health Surveys for 1992-93, 1998-1999 and 2005-2006, I study the impact of this large shock in child mortality on fertility and human capital investment decisions of the household. Under the assumption that the program had a disproportionately large impact on states with high initial child mortality, I use the country level immunization rate interacted with state initial mortality as an instrument for child mortality. My estimates suggest that a 1 percentage point decline in child mortality reduces births last year by about 5 percent. I check for pre-program trends and find no systematic relationship between initial child mortality in the state and child mortality changes prior to 1980. I also find no systematic pattern relating adult mortality changes during this period to state's initial child mortality in 1980, arguing against the relevance of other unobserved health improvements. While fertility was declining during the prior period, it was declining more slowly in high mortality states, suggesting that I may be understating the impact of child mortality on fertility. My estimates also suggest that a 1 percentage decline in child mortality increases female schooling by 0.4 years, an increase of about 7 percent. Interestingly, I find no significant effect on male schooling. While previous papers have focused on the "horizon effect" where declines in adult mortality increase human capital accumulation, my findings point to another mechanism of the quantity/quality tradeoff that works through child mortality and fertility declines.

for polio and MCV is the vaccine for measles.

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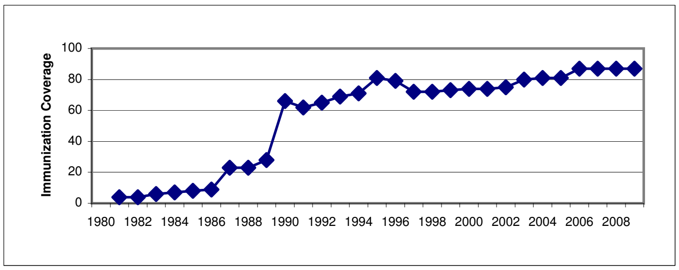
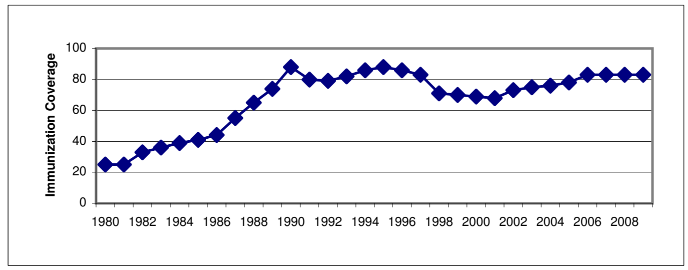
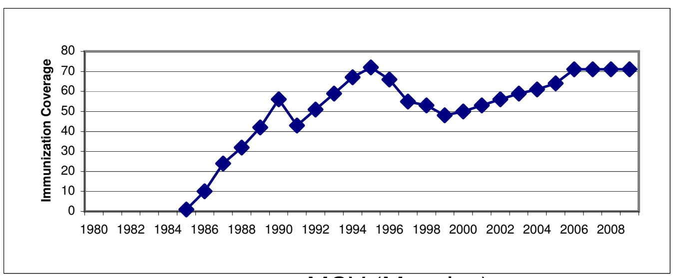
Figure 1: National Immunization Coverage in India



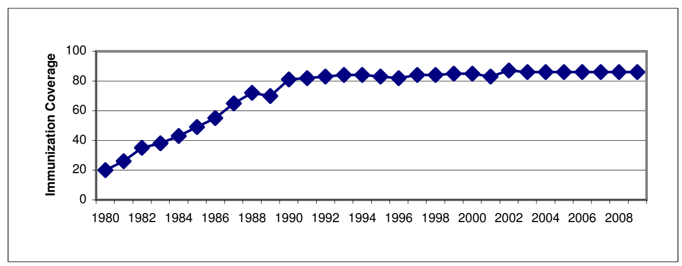
a- BCG (Tuberculosis)



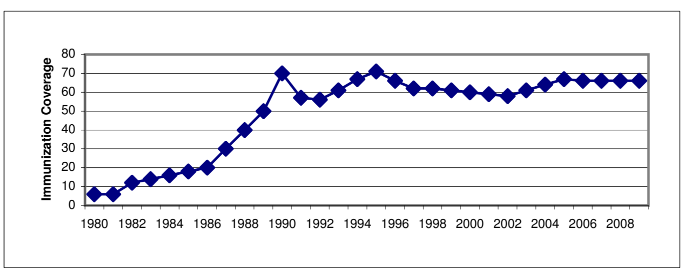
b- DTP1 (Diphtheria, pertussis, tetanus)



c- MCV (Measles)



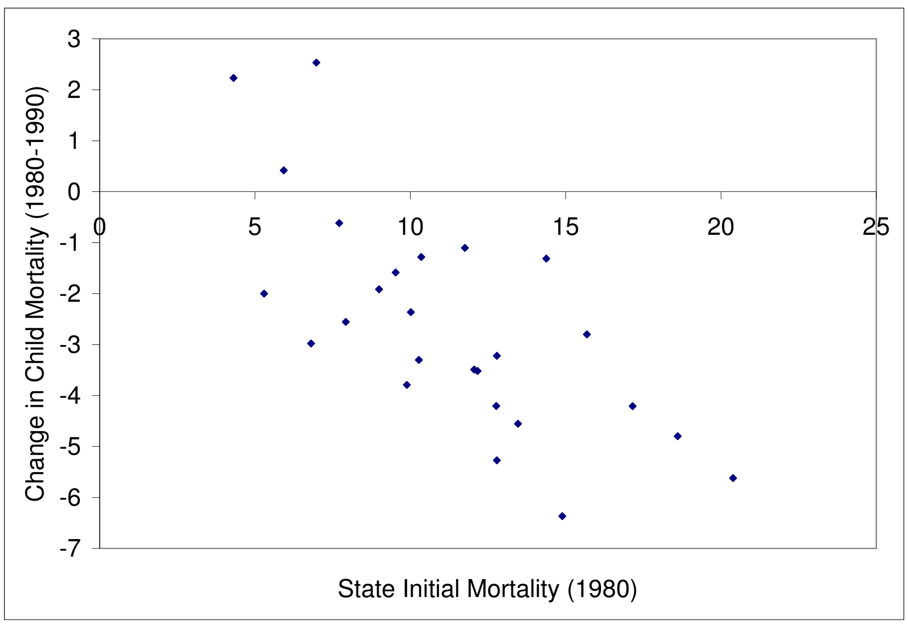
d- Pol3 (Polio)



e- DTP3 (Diphtheria, pertussis, tetanus)

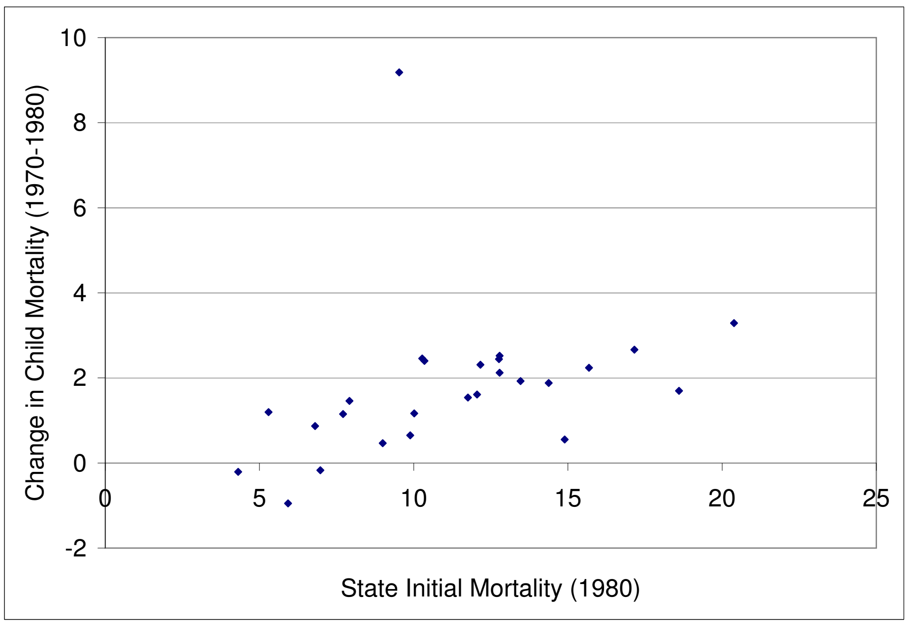
Source: WHO/UNICEF estimates of national immunization coverage.

Figure 2: Declines in Child Mortality across States: 1980-1990



Notes: Each dot represents a state. Mortality rates are the probability of a child dying before reaching the age of five, if subject to age-specific mortality rates of that state and year. The coefficient on initial mortality is -0.38 and statistically significant at the 1% level.

Figure 3: Robustness: Pre-trend Tests using 1970-1980 Data



Notes: Each dot represents a state. Mortality rates are the probability of a child dying before reaching the age of five, if subject to age-specific mortality rates of that state and year. The coefficient on initial mortality is not statistically significant at the 5% level.

Figure 4: Robustness: Declines in Adult Mortality across States: 1980-1990

Notes: Each dot represents a state. Mortality is the number of deaths per 100 adults. The coefficient on initial mortality is not statistically significant at the 5% level.

Figure 5: Decline in Net Reproduction Rate: 1980-1990

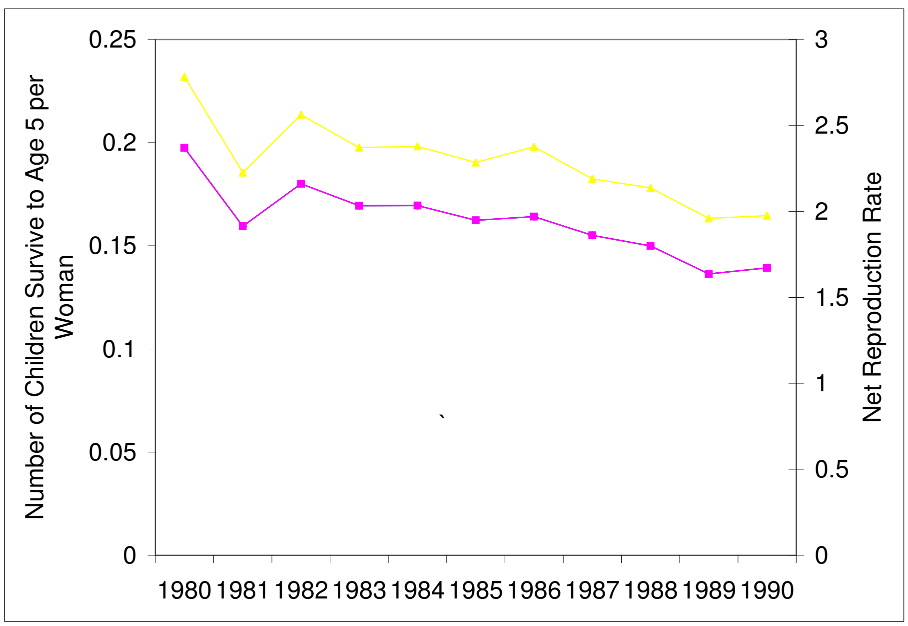


Table 1: Descriptive Statistics

Panel A: Country Level Data:								
	1980	1990						
Age	22.5	24.8						
Number of Births Last Year	0.240	0.163						
Number of Births Last Year (15-35 years old)	0.243	0.186						
Under-five Mortality (%)	13.3	10.1						
Immunization Coverage (%)								
BCG	5.8	69						
DTP1	31.6	83						
DTP3	10.8	62.2						
Pol3	6.8	61.6						
MCV	10	55.2						
Panel B: Cohort Level Data:								
	Female schooling		Male schooling					
	At Age 15	At Age 20	At Age 15	At Age 20				
Birth Cohort 1970-74	4.3	4.2	7.2	7.2				
Birth Cohort 1975-79	5.0	5.1	7.4	7.8				
Birth Cohort 1980-84	5.7	5.9	7.5	8.0				
Birth Cohort 1985-89 (treated cohort)	6.6	6.3	8.1	8.2				
Birth Cohort 1990-92 (treated cohort)	6.4		7.2					
C. State Level Data:	1980				1990			
	Mean	Std. Dev.	Min	Max	Mean	Std. Dev.	Min	Max
Number of Births Last Year	0.217	0.039	0.153	0.304	0.157	0.029	0.098	0.208
Number of Births Last Year (15-35 years old)	0.220	0.039	0.156	0.308	0.178	0.030	0.118	0.234
Under-five Mortality (%)	11.3	4.1	4.3	20.4	8.7	2.9	3.3	14.8
State GDP	6402.7	2819.6	2959.9	15087.3	8831.2	4070.7	3829.4	20352.6

Notes: Females and males between ages 15 and 49 are included. State level means are taken and unweighted means and standard deviations across 26 states are reported in the table. State GDP per capita is in 1993 prices. Under-five mortality rate is the probability of a child dying before reaching the age of five, if subject to age-specific mortality rates of that state and year. Immunization rate for each disease between ages 0 and 1 is at country level. DTP1 and DTP3 are first and third doses for diphtheria, tetanus and pertussis; Pol3 is the third dose for polio and MCV is the vaccine for measles.

Table 2: Effect of Immunization Program on Child Mortality

	Under-five Mortality		
	(1)	(2)	(3)
Immunization Rate x State Initial Mortality	-0.607***	-0.607***	-0.553**
	(0.123)	(0.174)	(0.249)
State Initial Mortality	1.035***		
	(0.007)		
Immunization Rate	2.722		
	(1.601)		
Year FE	No	Yes	Yes
State FE	No	Yes	Yes
State GDP	No	No	Yes
R^2	0.920	0.960	0.962
N	52	52	44

Notes: 26 states are included in the regressions. Under-five mortality rate is the probability of a child dying before reaching the age of five, if subject to age-specific mortality rates of that state and year. Under-five mortality, immunization rate and initial mortality is aggregated to state by year level. Included years are 1980 and 1990. State initial mortality is the under-five mortality in 1980 by state. Immunization rate is the country level immunization rate for tuberculosis by year. State GDP per capita by year is in 1993 prices. Robust standard errors clustered at state level are in parentheses. Asterisks denote significance levels (* 0.1 ** 0.05 *** 0.01).

Table 3: Effect of Immunization Program on Fertility

	Dependent Variable: Number of Births		
	(1)	(2)	(3)
Immunization Rate x State Initial Mortality	-0.003***	-0.003***	-0.004***
	(0.001)	(0.001)	(0.001)
State Initial Mortality	0.009***		
	(0.001)		
Immunization Rate	-0.042***		
	(0.013)		
Year FE	No	Yes	Yes
State FE	No	Yes	Yes
State GDP	No	No	Yes
R^2	0.040	0.043	0.043
N	325868	325868	304076

Notes: Women between ages 15 and 49 are used in the regressions. Included years are 1980 and 1990. State initial mortality is the under-five mortality in 1980 by state. Immunization rate is the country level immunization rate for tuberculosis by year. State GDP per capita by year is in 1993 prices. Regressions are weighted survey sampling weights. Robust standard errors clustered at state level are in parentheses. Asterisks denote significance levels (* 0.1 ** 0.05 *** 0.01).

Table 4: Effect of Immunization on Education

	(1)	(2)	(3)
	Dependent Variable: Years of Schooling		
	Panel A: FEMALES		
Immunization Rate x State Initial Mortality	0.094	0.121***	0.119***
	(0.058)	(0.037)	(0.040)
State Initial Mortality	-1.052***		
	(0.260)		
Immunization Rate	0.437		
	(0.858)		
R^2	0.061	0.123	0.124
N	84728	84728	76672
	MALES		
Immunization Rate x State Initial Mortality	0.028	0.040	-0.022
	(0.037)	(0.034)	(0.030)
State Initial Mortality	-0.444**		
	(0.183)		
Immunization Rate	0.185		
	(0.646)		
R^2	0.026	0.064	0.065
N	82719	82719	74797
Cohort FE	No	Yes	Yes
State FE	No	Yes	Yes
State GDP	No	No	Yes

Notes: Dependent variable is years of schooling. State initial mortality is the under-five mortality in 1980 by state. Immunization rate is the average country level immunization rate for tuberculosis when the cohort is younger than 12 months. Included birth cohorts are 1980-1984, 1985-1989 and 1990-1992. State GDP per capita when cohort is between ages 5 and 15 is in 1993 prices. Regressions are weighted by survey sampling weights. Robust standard errors clustered at state level are in parentheses. Asterisks denote significance levels (* 0.1 ** 0.05 *** 0.01).

Table 5: Effect of Child Mortality on Fertility

	Dependent Variable: Number of Births					
	(1)	(2)	(3)	(4)	(5)	(6)
	OLS			2SLS		
Under-five Mortality	0.010***	0.001	0.001	0.008***	0.008***	0.010**
	(0.001)	(0.003)	(0.003)	(0.002)	(0.002)	(0.004)
R^2	0.040	0.043	0.043	0.040	0.042	0.042
N	325868	325868	304076	325868	325868	304076
					First Stage	
Immunization Rate x State Initial Mortality				-0.377***	-0.376***	-0.380***
				(0.061)	(0.060)	(0.087)
R^2				0.950	0.983	0.983
N				325868	325868	304076
Year FE	No	Yes	Yes	No	Yes	Yes
State FE	No	Yes	Yes	No	Yes	Yes
State GDP	No	No	Yes	No	No	Yes

Notes: Women between ages 15 and 49 are used in the regressions. Included years are 1980 and 1990. Under-five mortality rate is the probability of a child dying before reaching the age of five, if subject to age-specific mortality rates of that state and year. Under-five mortality is instrumented by the interaction of initial mortality in 1980 and average country level immunization rate. Initial mortality is the under-five mortality in 1980 by state. Immunization rate is the country level immunization rate for tuberculosis. State GDP per capita by year is in 1993 prices. Regressions are weighted by survey sampling weights. Robust standard errors clustered at state level are in parentheses. Asterisks denote significance levels (* 0.1 ** 0.05 *** 0.01).

Table 6: Effect of Child Mortality on Female Education

	Dependent Variable: Years of Schooling					
	(1)	(2)	(3)	(4)	(5)	(6)
	OLS			2SLS		
Under-five Mortality	-0.454***	-0.185***	-0.185***	0.130	-0.392***	-0.396***
	(0.078)	(0.047)	(0.049)	(2.388)	(0.038)	(0.037)
R^2	0.084	0.122	0.122	.	0.121	0.121
N	84728	84728	83447	84728	84728	83447
				First Stage		
Immunization Rate x State Initial Mortality				-0.415***	-0.387***	-0.388***
				(0.041)	(0.021)	(0.020)
R^2				0.877	0.991	0.991
N				84728	84728	83447
Year FE	No	Yes	Yes	No	Yes	Yes
State FE	No	Yes	Yes	No	Yes	Yes
State GDP	No	No	Yes	No	No	Yes

Notes: Dependent variable is female years of schooling. Under-five mortality rate is the average probability of a child dying before reaching the age of five, if subject to age-specific mortality rates of that state when the cohort is between ages 0 and 5. Included birth cohorts are 1980-1984, 1985-1989 and 1990-1992. State GDP per capita is the average GDP per capita when cohort is between ages 5 and 15. State GDP per capita is in 1993 prices. Under-five mortality is instrumented by the interaction of initial mortality in 1980 and average country level immunization rate. Initial mortality is the under-five mortality in 1980 by state. Immunization rate is the average country level immunization rate for tuberculosis when the cohort is younger than 12 months. Regressions are weighted by survey sampling weights. Robust standard errors clustered at state level are in parentheses. Asterisks denote significance levels (* 0.1 ** 0.05 *** 0.01).

Table 7: Effect of Child Mortality on Male Education

	Dependent Variable: Years of Schooling					
	(1)	(2)	(3)	(4)	(5)	(6)
		OLS			2SLS	
Under-five Mortality	-0.196***	0.182***	0.188***	0.602	-0.063	-0.042
	(0.059)	(0.055)	(0.050)	(2.905)	(0.037)	(0.039)
R^2	0.032	0.064	0.065	.	0.063	0.064
N	82719	82719	81545	82719	82719	81545
					First Stage	
Immunization Rate x State Initial Mortality				-0.424***	-0.388***	-0.389***
				(0.042)	(0.023)	(0.021)
R^2				0.878	0.991	0.991
N				82719	82719	81545
Year FE	No	Yes	Yes	No	Yes	Yes
State FE	No	Yes	Yes	No	Yes	Yes
State GDP	No	No	Yes	No	No	Yes

Notes: Dependent variable is male years of schooling. Under-five mortality rate is the average probability of a child dying before reaching the age of five, if subject to age-specific mortality rates of that state when the cohort is between ages 0 and 5. Included birth cohorts are 1980-1984, 1985-1989 and 1990-1992. State GDP per capita is the average GDP per capita when cohort is between ages 5 and 15. State GDP per capita is in 1993 prices. Under-five mortality is instrumented by the interaction of initial mortality in 1980 and average country level immunization rate. Initial mortality is the under-five mortality in 1980 by state. Immunization rate is the average country level immunization rate for tuberculosis when the cohort is younger than 12 months. Regressions are weighted by survey sampling weights. Robust standard errors clustered at state level are in parentheses. Asterisks denote significance levels (* 0.1 ** 0.05 *** 0.01).

Table 8: Robustness: Pre-trend Tests using 1970-1980 Data

	(1)	(2)	(3)
	Fertility	Education	
	Number of Births	Years of Schooling	
		Females	Males
State Initial Mortality x Post	0.004***	0.005	-0.014*
	(0.001)	(0.017)	(0.008)
Post	-0.058***	0.959***	0.544***
	(0.020)	(0.304)	(0.123)
State Initial Mortality	0.004***	-0.306***	-0.116**
	(0.001)	(0.070)	(0.046)
R^2	0.040	0.073	0.022
N	151558	184185	175473

Notes: State initial mortality is the under-five mortality in 1980 by state. Included years are 1970 and 1980. Post refers to the period after the program. Regressions are weighted by survey sampling weights. Robust standard errors clustered at state level are in parentheses. Asterisks denote significance levels (* 0.1 ** 0.05 *** 0.01).

Table 9: Robustness: Other Diseases

Vaccines:	DTP1			DTP3			Pol3			MCV		
	Fertility	Education		Fertility	Education		Fertility	Education		Fertility	Education	
		Female	Male		Female	Male		Female	Male		Female	Male
Initial Mortality x Immunization Rate	-0.005***	0.128***	-0.037**	-0.005***	0.140***	-0.015	-0.016***	0.136***	-0.008	-0.002*	0.131***	0.003
	(0.001)	(0.020)	(0.017)	(0.001)	(0.019)	(0.017)	(0.001)	(0.017)	(0.015)	(0.001)	(0.016)	(0.018)
Year/Cohort FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State GDP	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.043	0.123	0.064	0.043	0.123	0.064	0.043	0.123	0.064	0.038	0.127	0.071
N	304076	76672	74797	304076	76672	74797	304076	76672	74797	359184	68716	67146

Notes: In fertility regressions women between ages 15 and 49 are used. Initial mortality is the under-five mortality at 1980 by state. Immunization rate is the country level immunization rate for each disease between ages 0 and 1. Included years are 1980 and 1990. Since measles information available since 1986, 1986 and 1990 are used in fertility regressions for measles vaccine. State GDP per capita by year is at constant 1993 prices. In education regressions included birth cohorts are 1980-1984, 1985-1989 and 1990-1992 in education regressions. Initial mortality is the under-five mortality per 100 children at 1980 by state. State GDP per capita when cohort is between ages 5 and 15 is at constant 1993 prices. DTP1 and DTP3 are first and third doses for diphtheria, tetanus and pertussis; Pol3 is the third dose for polio and MCV is the vaccine for measles. Regressions are weighted by survey sampling weights. Robust standard errors clustered at state level are in parentheses. Asterisks denote significance levels (* 0.1 ** 0.05 *** 0.01).