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An exploration of China's mortality decline under Mao: A provincial analysis, 1950–80

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Abstract

China's growth in life expectancy between 1950 and 1980 ranks as among the most rapid sustained increases in documented global history. However, no study of which we are aware has quantitatively assessed the relative importance of various explanations proposed for these gains. We create and analyse a new province-level panel data set spanning 1950-80 using historical information from Chinese public health archives, official provincial yearbooks, and infant and child mortality records contained in the 1988 National Survey of Fertility and Contraception. Although exploratory, our results suggest that increases in educational attainment and public health campaigns jointly explain 50-70 per cent of the dramatic reductions in infant and under-five mortality during our study period. These results are consistent with the importance of non-medical determinants of population health improvement – and under some circumstances, how general education may amplify the effectiveness of public health interventions.

Keywords

mortality; China; health improvement; less developed countries; population health; education

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Contributors
GM and KE participated in the conception of the study, data analysis, and writing of the paper. KB and QZ participated in the data analysis and the writing of the paper. All authors have seen and approved the final version.

Competing Interests
We declare we have no competing interests.

Ethics committee approval
This study was approved by the Stanford University Institutional Review Board.

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1. Introduction

China's growth in life expectancy at birth from 35–40 years in 1949 to 65.5 years in 1980 is among the most rapid sustained increases in documented global history (Banister and Preston 1981; Ashton et al. 1984; Coale1984; Jamison 1984; Banister 1987; Ravallion 1997; Banister and Hill 2004). These survival gains appear to have been largest during the 1950s, with a sharp reversal during the 1959-61 Great Leap Famine that was then followed by substantial progress again during the early 1960s (see Figure 1). A more moderately-paced mortality decline continued through the later 1960s and 1970s throughout the large-scale social and economic disruptions of the Cultural Revolution (Banister and Hill 2004). Altogether, between 1963 (the first on-trend year after the Great Leap Famine) and 1980, the average annual gain in life expectancy was nearly one year of life, rising from 50 to 65.5 (World Bank 2009).

Many explanations for China's Mao-era mortality decline have been proposed. Perhaps the most prominent is the expansion of primary health care services, including growth in the supply of China's famed "barefoot doctors" during the late 1960s (Sidel 1972; Dong and Phillips 2008). Other common explanations include widespread public health campaigns (childhood immunisations in particular); improvements in water, sanitation, and nutrition; and gains in educational attainment (Banister and Preston 1981; Ashton et al. 1984; Coale 1984; Jamison 1984; Banister 1987; Campbell 1997 and 2001; Banister and Hill 2004; Zhao and Kinfu 2005; Hipgrave 2011).

To the best of our knowledge, this paper is the first to test these explanations using disaggregated sub-national data. Substantial variation across provinces in China's mortality decline (Figure 1) suggests promise in this approach. Specifically, we analysed a new province-year panel data set spanning 1950-80 which we assembled using historical information from Chinese public health archives, official provincial yearbooks, and China's 1988 National Survey of Fertility and Contraception. Using panel data techniques, we related changes in provincial infant and under-five mortality rates to changes in province-level measures of each candidate factor. Importantly, we also paid careful attention to changes in explanatory variables that may have occurred *in response* to changes in mortality – or that may have been targeted to areas with pre-existing trend differences in mortality rates.

A note about data quality is warranted (Section 3 discusses data quality issues in greater detail). Given well-known concerns about the quality of vital registries in many developing countries (including China during the Mao era) (Mathers et al 2005; Zhang and Zhao, 2006), our analyses instead utilized annual provincial mortality rates for infants and children under-five for years 1950-80 constructed using fertility histories from the 1988 National Survey of Fertility and Contraception. These fertility histories closely resemble those collected by the well-known Demographic and Health Surveys (DHS). This 1988 "two per 1,000" fertility survey is among the largest ever conducted and includes nationally- and provincially-representative data from 459,000 ever-married women ages 15 to 57 across all of China's provinces. Previous assessments have found the survey to be of good quality (Johansson and Nygren 1991; Coale and Banister 1994; Mason et al. 1996), with strong consistency between

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the fertility survey and the 1982 census (Coale and Banister 1994). Although the survey's fertility history records are not nationally-representative back in time (Gakidou and King 2006), this does not preclude internally valid assessments of infant and child mortality declines across China. More generally, our exploratory work created an important new dataset that facilitates further research on China's population health history.

Overall, we find that the expansion of education during the 1950s together with large-scale public health campaigns jointly explain roughly 50-70 per cent of the reduction in China's infant and under-five mortality rates between 1960 and 1980. Much of this association is linked to lagged, life-long effects of educational gains: the expansion in post-primary school enrolment during the 1950s has a large, statistically significant association with mortality decline after 1960. This finding is consistent with a large literature establishing better infant and child survival among more educated mothers, even after controlling for a variety of maternal characteristics (Caldwell 1979; Preston 1980; Barrera 1990; Thomas et al. 1991; Elo and Preston 1996). We also find that public health interventions had heterogeneous effects in a manner suggesting complementarity with gains in general education.

The rest of this paper is organised as follows. The next section provides a brief overview of China's population health history under Mao and explanations proposed for its 1950-80 mortality decline. We then present our new data set in the third section, explaining how we collected and coded its variables. The fourth section describes our statistical methodology, and the fifth reports our main results. Finally, the concluding section discusses potential behavioral mechanisms that could explain our main findings.

2. China's population health history and explanations for mortality decline under Mao

2.1 Historical Chinese context

Large social and economic transformations marked the first decades of the People's Republic of China. Following decades of war, the new government under Mao Zedong established a centrally planned economy in 1949, and agricultural collectives were nearly universal in rural areas by the mid-1950s. The late 1950s saw larger strides towards collectivisation and industrialisation under the Great Leap Forward, resulting in a profound agricultural crisis and devastating famine between 1959 and 1961 (Lin 1998; Wu 2005; Naughton 2007; Li and Yang 2005; Meng and Qian 2006; Chen and Zhou 2007; Almond et al. 2010). After a period of subsequent consolidation and adjustment, Mao embarked on more pronounced and violent class struggle through the 1966-76 Cultural Revolution. Mao Zedong died in 1976, and a few years later the Household Responsibility System in rural areas ushered in transition to a market-based economy.

2.2 Explanations for mortality decline under Mao

We studied a number of candidate explanations proposed for the Mao-era mortality decline (Jamison 1984), focusing on four broad categories of factors: public health interventions, increases in general education, public health and educational synergies, and the expansion of primary health care.

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Public health interventions—The development and diffusion of public health technologies played a central role in reducing global mortality throughout the twentieth century (Rosen 1958; Preston 1975, 1980; Tomes 1998; Cutler and Miller 2005; Cutler et al. 2006; Miller 2008; Jayachandran et al. 2010). In China, major public health campaigns were prominent under Mao – and were imbued with Maoist China's nationalistic activist spirit. These “Patriotic Health Campaigns” encompassed a wide range of public health activities and focused heavily on rural areas. Observers propose that the patriotic overtones and mass citizen involvement of these campaigns contributed to their success (Campbell 2001; Zhang and Unschuld 2008). For example, Salaff (1973, p.551) suggests that China's mortality decline between 1953 and 1957, which resembles that of the US between 1900 and 1930, was “primarily due to the unique social organisation of Chinese public health practices.” If implemented effectively, many of these campaigns (e.g. midwife training, campaigns against malnutrition, or immunization promotion) held the potential for immediate impact on the survival of infants and young children. Table 1 summarises the timing and provincial coverage of these campaigns using information from our new dataset (described in Section 3).

The first “Patriotic Health Campaigns” were launched in the early 1950s and focused on environmental sanitation, trash removal, latrine construction, composting human excrement (“night soil”) before use as fertiliser to reduce the concentration of intestinal parasites, and combating the ‘four pests’ (rats, flies, mosquitoes, and bedbugs [*cimex lectularius*]) (Jamison 1984; Banister 1987; Hipgrave 2011). Mao Zedong aggressively promoted health improvement in rural areas, establishing the first of many ‘multisectoral’ initiatives for health—a nine-person Subcommittee on Schistosomiosis, which led China's parasitic disease control efforts since the mid-1950s. Other disease-specific campaigns did not simply target transmission vectors. The campaign against tuberculosis began with widespread BCG vaccination in major cities prior to expanding to rural areas and incorporating drug treatment regimens and case management (Jamison 1984). China's anti-malaria campaign combined intensive environmental management (indoor residual insecticide spraying and larval breeding site control), mass chemoprophylaxis, and individual treatment (Jamison 1984). Systematic efforts to vaccinate the population against polio, measles, diphtheria, whooping cough, scarlet fever, and cholera were rapid and reputedly successful (China nearly eradicated smallpox within the span of only three years (Jamison 1984; Banister 1987), with the last documented cases occurring in Tibet and Yunnan in 1960 (Jamison 1984)). Finally, the “modern midwifery” campaigns—short, intense training of midwives emphasizing sanitary childbirth—retrained most of China's midwives during the 1950s (Banister 1987).

Educational gains—A large literature suggests that general education is an important contributor to good health (Marmot et al. 1991; Hurt et al. 2004; Khang et al. 2004; Lleras-Muney 2005; Cutler et al. 2006; Cutler and Lleras-Muney 2008; Marmot et al. 2008; Stringhini et al. 2010; Heckman et al. 2014). A robust association between education and health has been established in contemporary China (Banister and Zhang 2005; Liang et al. 2000; Feng et al. 2012; Chen and Eggleston 2013).

The underlying behavioral mechanisms linking general education to health are not well-understood. Education may improve the ability of parents and other caregivers to absorb and

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act upon new health information important for infant and child health (Caldwell 1979; Preston 1980; Barrera 1990; Thomas et al.1991; Strauss and Thomas 1995; Elo and Preston 1996; Case et al. 2005; Song and Burgard 2011). Increased educational enrolment may also have contributed to the rising age at marriage observed during the Mao era (from 17.5 for those first married in 1950-54 to 22.3 for those first married in 1980; Wang and Yang 1996, p.303), and scholars have shown that mothers' age at marriage matters for infant and child health in China (Mason et al. 1996).

There are also a variety of mechanisms through which education may have had more immediate contemporaneous effects on health. Increased enrolment among school- aged children may have benefitted the health of younger siblings by transmitting new information into the home, and children's literacy and numeracy skills may have helped parents who themselves lacked formal schooling. Increased educational enrolment may also have raised expected future income and quality of life, strengthening individual incentives to invest in their own and their children's health (Friedman 1957; Hall 1978).

China made large strides in primary and secondary education under Mao. In 1949, more than 80 per cent of China's population was illiterate (Zhou 2009). Enrolment rates in primary and middle schools were abysmal: 20 and 6 per cent, respectively (Zhou 2009). During the 1950s, capital investments in primary and secondary school infrastructure increased tenfold, and dramatic increases in attendance followed. Primary school enrolment rates rose to 80 per cent by 1958 and to 97 per cent by 1975, and secondary school rates increased to 46 per cent by 1977 (Hannum 1999; Narayan and Smyth 2006). Although there were widespread school closures during the Cultural Revolution (1966-76), the stock of human capital nevertheless rose dramatically under Mao. According to educational attainment estimates derived from China's 1982 and later censuses (Barro and Lee 2010), average years of schooling among Chinese ages 25 and over increased four-fold in the Mao era, from 0.7 years of schooling in 1950 to 3.7 years of schooling in 1980. Among young adults age 25 to 29, average years of schooling rose from 1.6 in 1950 to 5.7 in 1980. The increase in educational attainment among young women during the Mao era was especially large: a ten-fold increase from less than half a year of schooling in 1950 to slightly more than five years of schooling by 1980 (Barro and Lee 2010).

Education and public health synergies—Conceptually, there are reasons to predict that public health interventions have heterogeneous effects by level of educational attainment. In traditional theoretical models of health production, education and health technologies including public health interventions are complementary (Grossman 1972, 2006). This is partly because the full effect of many public health interventions relies on the behavioral response of individuals and households– and those with more education may be more likely to adopt or apply them. For example, since many campaigns provided health information, more educated parents (especially mothers) would have been better able to absorb and act upon that information (Strauss and Thomas 1995; Case et al. 2005). Alternatively, those with low levels of education may benefit more from population-wide public health interventions if they are initially in worse health.

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Basic medical care—Numerous studies argue that basic medical care—including the supply of doctors and essential drugs—is positively associated with improved infant and child survival (Jamison 1984; Banister 1987; Campbell 1997 and 2001; Banister and Hill 2004; Zhao and Kinfu 2005; Cutler et al. 2006; Hipgrave 2011). Physician and hospital supply grew dramatically under Mao due to a variety of factors (including increases in government financing, the introduction of social insurance for urban public employees, and the launch of China's Rural Cooperative Medical System in the mid-1950s). Rural Cooperative Medical Schemes (CMS) were vigorously promoted and became widespread in the late 1960s as part of the Cultural Revolution. The CMS functioned as a financing mechanism supporting much of the rural health system, including China's famous “barefoot doctors.” As secondary school graduates with only three to six months of medical training, China's barefoot doctors were heterogeneous in skill, ranging from ill-trained health workers to skilled and committed clinicians (Sidel 1972; Zhang and Unschuld 2008; Hipgrave 2011). In exchange for CMS support, they provided essentially free basic primary and emergency medical care and also helped to facilitate China's “Patriotic Health Campaigns.”

3. Construction of a new province-year population health database, 1950-80

An important contribution of our project is the construction of a new province-year data set spanning the years 1950-80. Because China's government collected extensive statistical information to operate its centrally planned economy, archival data sources hold considerable potential for studying the determinants of population health improvement under Mao.

We combined information from three major sources to build our new dataset. (1) The first was archival public health records (*Weishengzhi*) from each province. Official provincial committees assembled this information during the 1980s and early 1990s using data from epidemiological surveillance stations, provincial health department archives, local government registers, and other administrative sources. From these *Weishengzhi*, we extracted and digitised complete information about each province's public health campaigns during the Mao era. (2) The second data source was the 1988 National Survey of Fertility and Contraception, from which we constructed our infant and under-five mortality rate measures for each province in each year (using cohort life tables). (3) The third data source was China's official provincial yearbooks (supplemented by the *China Statistical Data Compilation, 1949–2003*, available from the China Data Center at the University of Michigan.) Drawing on data assembled by the National Bureau of Statistics of China, these yearbooks provided detailed information on a variety of demographic, economic, and social indicators.

Table 2 presents summary statistics for all variables included in our analyses, both for the entire 1950–80 study period and by decade. Appendix Table 1 describes the years for which each variable is available. The rest of this section describes each type of variable used in our analyses (see the Data Appendix for more detail).

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3.1 Major public health intervention data

Scholars have long noted the need for assembling disaggregated data that exists about China's public health campaigns (Mason et al. 1996). We obtained, coded, and digitized annual provincial public health records using historical compilations (*Weishengzhi*) from all provinces (other than Tibet and Guizhou) between 1950 and 1980, covering about 95% of China's population during the Mao era. To collapse across closely related vector- and disease-specific campaigns, we used principal component analysis to create indices for each major category of public health intervention. The resulting indices measure sanitary campaigns (water, sanitation, and hygiene; food quality; and campaigns against typhoid, dysentery, and diarrhea); early vaccination campaigns (against pertussis, diphtheria, smallpox, typhoid, meningitis, cholera, measles, and tuberculosis); reproductive health programs (midwife training and family planning); efforts to control mosquito-borne diseases (malaria and dengue); and campaigns against other infectious diseases (pertussis, typhus, influenza, meningitis, polio, and tuberculosis). We measured large-scale nutrition programs using a single dichotomous variable.

Table 1 shows the number of provinces with each type of major public health campaign in each year between 1950 and 1980. (A “0” in Table 1 denotes that the campaign was not explicitly mentioned in the public health archives for that province-year. We interpret this to imply the absence of a campaign for that province-year, but we cannot rule out low intensity activity.) There is considerable year-to-year variation in the total number of campaigns, with the fewest during the Great Leap Famine (1961) and the early years of the Cultural Revolution (1966-71).

3.2 Data on infant and under-five mortality rates

Our primary dependent variables were province-year infant mortality rates and under-five mortality rates, calculated using age-specific death rates experienced by each birth cohort (i.e., obtained from cohort life tables that we build). These variables were constructed using the maternal fertility histories of the June 1988 National Survey of Fertility and Contraception conducted by China's State Family Planning Commission. This “two per 1,000” fertility survey includes data on every pregnancy and birth reported by a nationally-representative sample of more than 450,000 ever-married women aged 15 to 57 in 1988. The survey was designed to be provincially as well as nationally representative, systematically sampling 2 out of every 1,000 primary units (“residence small groups” under neighbourhood committees in urban areas, and “village small groups” under administrative villages in rural areas; Wang and Yang 1996; Mason et al. 1996).

Scholars who have used this data for demographic analyses have reported it to be good quality (Lavely 1991; Johansson and Nygren 1991; Coale and Banister 1994; Mason et al. 1996). An important virtue of using the 1988 National Survey of Fertility and Contraception rather than alternative sources of mortality data is that they are not generally subject to well-known limitations of vital registry data (both in developing countries generally and in China – see Banister 1987; Liang and White 1996; Zhang and Zhao, 2006).

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Despite these strengths, however, using the survey data also has limitations. An important one is that because the sample only included women alive in 1988, the experiences of the children of these women are not representative of all children alive between 1950 and 1980 (Banister 1987; Gakidou and King 2006). However, these data still permit internally valid analyses of differential changes in infant and child survival associated with major factors proposed to explain the Mao-era mortality decline. Another limitation is incomplete documentation of mothers' migration histories, although available data indicates that for 98% of the births in our sample, mothers were still living in the same province in which births occurred (only 11% of mothers reported ever migrating, almost always prior to marriage). The *hukou* household registration system has strictly limited internal migration since its implementation in the early 1950s, and the generations growing up in the Mao era were relatively immobile except for state-mandated moves (such as the "sent-down youth" of urban areas forced to the countryside in the 1960s and 1970s). According to the nationally representative China Health and Retirement Longitudinal Study baseline survey of 2011-2012, 90 per cent of Chinese age 45 and older still live in the same county in which they were born (indeed, 58 per cent of rural adults live in the same *village* in which they were born); and only six per cent live in a province different from that of their birth (Smith et al. 2013).

3.3 Education data

To study the relationship between educational gains and mortality decline, we ideally would have liked data on educational attainment by province and year (or cohort); however, the only data available was enrolment in primary, secondary, and higher education. Because higher educational enrolment was so low during this period, we combined the secondary and higher education categories; hereafter "secondary" refers to this combined category. To create enrolment rates, we estimated school-aged (age 6-11 and 12-18) population denominators for intercensal years by interpolation using age group population counts from the 1953, 1964 and 1982 population censuses. Because age group population counts were only available in five-year intervals (population aged five to nine, population aged 10-14, etc.), we assumed that populations were equally distributed within five year age brackets. The resulting enrolment rates are highly correlated with the much more limited school enrolment rate data available from China Data Online. As Table 2 shows, the resulting primary and secondary school enrolment rates grew dramatically during the Mao era.

3.4 Basic medical care data

We studied China's expansion of primary and hospital-based medical care using measures of doctors and hospital beds per 10,000 population. Table 2 shows large increases of both during the Mao era – physicians per head nearly doubled between the early 1950s and 1970, and hospital beds per head increased by nearly 250 per cent.

3.5 Data on other socioeconomic and demographic characteristics

China experienced sweeping socio-economic change under Mao, so it is important for us to account for these changes as much as possible in our analyses. We therefore included a variety of province-year socio-economic and demographic variables from China's official

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provincial yearbooks in our dataset. Specific variables included per capita GDP, provincial government revenue, fruit and grain production, total population, population composition by gender and urban/rural status, retail price indices, and birth rates (on China's fertility decline and population control policies, see discussion in Greenhalgh and Winckler 2005).

4. Empirical strategy

4.1 Contemporaneous determinants of 1950-80 infant and under-five mortality rate reductions

We utilized panel data methods to analyse the contemporaneous relationship between infant and child mortality rates and the key explanatory variables described in Section 3, accounting for other changes such as increases in living standards and food availability. For each province *p* and year *y*, we began by estimating ordinary least squares (OLS) regressions of the general form:

$$ln\left(mortality_{py}\right)=\alpha+\Sigma_h\beta intervention_{hpy}+\Sigma_c\gamma_c control_{cpy}+\delta_p+\delta_y+\varepsilon_{py}, \quad (1)$$

Where *mortality* is the infant mortality rate or under-five mortality rate in each province-year; *intervention* represents a vector of the key explanatory factors noted above (enrolment rates, basic health care infrastructure, and public health interventions); *control* is a vector of province-year control variables (shown in Table 2 and described in Section 3.5); and δ_p and δ_y represent province and year fixed effects (accounting for level differences in mortality rates across provinces as well as the common mortality rate time path in China). We allowed the relationship between mortality rates and major explanatory factors to vary across different historical periods. To do so, we interacted school enrolment and select health intervention variables with indicators for periods of distinctly different aggregate mortality rate trends. Specifically, we included indicators for the 1960-65 period (Great Leap Forward recovery period) and the 1966-80 period (meaning the main effects for each explanatory variable pertain to the remainder of our sample years, the 1950s).

We calculated Huber-White standard errors clustered at the province level to address heteroskedasticity and autocorrelation (relaxing the assumption of independent and identically distributed disturbance terms within provinces over time) (Bertrand et al. 2004). Due to the limited number of clusters (28), we explored alternative methods of hypothesis testing including pairs-cluster, cluster residual, and wild t-bootstrapping (see Cameron, Gehlbach and Miller 2008); results are shown in Appendix Table 2.

Finally, we explored the robustness of our results using a variety of alternative approaches, including specifications using alternative mortality estimates, individual birth-level data, and using coarser estimates of school-aged population. Our key results are not highly sensitive to these approaches (although vary in precision), and results from each are available in Appendix Tables 3-5.

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4.2 Gains in education during the 1950s and the 1960-80 reduction in infant and under-five mortality rates

Because the full health benefits of education are likely to include both contemporaneous effects and effects realized over time (as better-educated mothers bear and raise their children, for example), we estimated the relationship between increases in educational enrolment during the 1950s and subsequent mortality rates between 1960 and 1980, while still allowing for effects from contemporaneous enrolment. For each province *p* and year *y* between 1960 and 1980, we estimated ordinary least squares (OLS) regressions of the general form:

$$\begin{aligned} ln\left(mortality_{py}\right) &= \alpha + \Sigma_l \mu_l enrolment_{lpy} \\ &+ \Sigma_l \lambda_l (enrolment \quad change)_{lp} \\ &+ \Sigma_h \beta_h health_{hpy} \\ &+ \Sigma_{lh} \phi_{lh} (enrolment \quad change)_{lp} \\ &\times health_{hpy} \\ &+ \Sigma_c \gamma_c conteol_{cpy} \\ &+ \delta_y + \varepsilon_{py}, \end{aligned} \quad (2)$$

where *enrolment* is a vector of school enrolment rates at each level *l; enrolment change* is the change in school enrolment rates between 1950 and 1960 at each level; *health* is a vector of health interventions; *control* is a vector of additional province-year control variables (shown in Table 2 and described in Section 3.5), and δ_y represent year fixed effects (accounting for time-varying shocks to infant and child survival common across China). Equation (2) includes a vector of interactions between changes in school enrolment rates and major public health interventions, and does not include provincial dummy variables (δ_p) because they are colinear with our measure of provincial enrolment changes during the 1950s.

4.3 Exploring potential reverse causality: Targeting analysis

In interpreting the results of our main analyses, it is critical to consider whether or not changes in our key explanatory variables might have been a response to changes in mortality, or if they might have been be targeted to areas with differentially changing infant and child mortality rates. Any meaningful relationship between health intervention “scale-ups” and immediately preceding mortality rates might suggest that interventions were “targeted” to areas with differentially better or worse mortality environments, for example. For brevity, we refer to any such relationship between pre-existing mortality and interventions as “targeting,” even though the relationship need not arise because of deliberate behavior.

To conduct this targeting analysis, we used the following procedure. First, we defined large increases in each key explanatory variable. For continuous variables, these were year-to-year changes that exceed the 95th percentile in the distribution of annual changes; for dichotomous variables, these were years in which the variable changes from zero to one. Next, we created dummy variables that denote the two years prior to these “scale-ups” for

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each explanatory variable. Finally, we re-estimated equation (2) including these "pre-scale-up" dummy variables as additional independent variables. Statistically significant estimates for a pre-scale-up indicator would suggest the presence of targeting.

5. Results

5.1. Contemporaneous determinants of mortality decline

Table 3 reports estimates from equation (1) for our two key dependent variables: the provincial infant mortality rate and provincial under-five mortality rate. Because we use the natural logarithm of these death rates, point estimates can loosely be interpreted as per cent changes in mortality rates associated with marginal changes in each independent variable. Groups of independent variables are shown in separate panels. Panels A and B report three estimates for our key explanatory variables – main effects corresponding to the base period (the 1950s) and two additional estimates for the periods 1960-65 and 1966-80. Implied mortality changes for the latter two periods can be calculated by adding the base and subsequent period-specific estimates. For brevity, we do not report estimates for control variables.

Panel A shows that primary school enrolment rates are associated with small but significant increases in mortality during the base period (the 1950s), and the net association is close to zero in subsequent periods. Although secondary education is negatively correlated with reductions in infant and under-five mortality during the 1966-80 period, the net effect when combined with base period estimates is not significant. Table 3, panel B shows that healthcare infrastructure is associated with small increases in contemporaneous infant and under-five mortality rates, particularly in the 1960-66 and 1966-80 periods. However, as Section 5.4 explains, our targeting analysis suggests that little weight should be placed on the estimates for healthcare infrastructure because these measures are correlated with pre-existing trends in mortality. Panel C also shows that only sanitary campaigns and vaccination rates are statistically significant in explaining contemporaneous mortality decline. However, these cannot be interpreted as causal effects since these programs appear to be targeted to high mortality areas (discussed in section 5.4).

5.2 The Relationship between Gains in Education during the 1950s and the 1960-80 Reduction in Infant and Under-Five Mortality Rates

Table 4 reports estimates of the relationship between changes in school enrolment during the 1950s and reductions in infant and child mortality rates during the 1960s and 1970s obtained from equation (2). Panel A reports estimates of the association between the expansion of educational enrolment during the 1950s and subsequent mortality decline. Changes in primary school enrolment are positively correlated with subsequent infant mortality rates (1.5%, $p<0.01$) and under-five mortality rates (1.7%, $p<0.01$), a puzzling finding that may be explained by the fact that provinces with the worst conditions at the beginning of the Mao era—such as low economic development, significant war devastation, low human capital investment—would have had both the largest gains in primary school enrolment rates (having started from the lowest base) and high mortality rates. (Recall that we are unable to control independently for province fixed effects because of colinearity with the 1950s gains

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in education). Increases in secondary education enrolment during the 1950s are negatively and statistically significantly correlated with subsequent infant and under-five mortality rates (−11.9%, $p<0.01$ for lnIMR; −12.0%., $p<0.01$ for lnU5MR).

Panel B shows that given educational enrolment increases in the 1950s, primary school enrolment rates are significant correlates of contemporaneous infant (1.4%, $p<0.01$) and under-five mortality rates (1.5%, $p<0.01$), whereas contemporaneous secondary enrolment rates are not. We also find a positive correlation between healthcare infrastructure and mortality; because our targeting analyses (discussed below) suggest that reductions in mortality preceded shifts in healthcare supply, it is unreasonable to interpret this relationship as causal.

Several public health campaigns are also statistically significant and negatively correlated with infant and child mortality rates (panel C), including sanitary campaigns, infectious disease control, and campaigns against malnutrition (−0.2% - 14.4%, $p<0.01$ for lnIMR; −0.2% - −3.8%, $p<0.01$ for lnU5MR). However, our targeting analyses suggest that the sanitary campaigns may capture pre-existing trends in mortality and should be interpreted with caution.

The interactions between lagged school enrolment and public health interventions in Table 4 provide more nuanced insight into the complex relationship between education and child survival. We find heterogeneous relationships between public health interventions and infant and child mortality rates across provinces experiencing differential gains in education. For example, the interaction between gains in secondary education and subsequent reproductive health campaigns (−2.6%, $p<0.1$ for lnIMR and lnU5MR) are negative, consistent with education amplifying the benefits of such campaigns (perhaps by enabling mothers to understand and act upon information about reproductive health, contraception, and the benefits of childbirth in hygienic environments). On the other hand, estimates for the interaction between malnutrition campaigns and gains in secondary education during the 1950s are positive (72%, $p<0.05$ for lnIMR; 63%, $p<0.05$ for lnU5MR), which is consistent with better-educated patients having more information about infant and child nutrition absent these campaigns. Ultimately, we are only able to speculate about the sources of this heterogeneity.

5.3 Graphical Analysis of the Infant and Under-Five Survival Benefits Associated with Gains in Education during the 1950s

To more clearly illustrate the role of education in China's Mao-era mortality decline, Figure 2 shows observed infant and under-five mortality rates over time together with mortality rates predicted for two counterfactual scenarios using equation (2). Panel A plots three infant mortality rate series: (1) raw observed rates, (2) infant mortality rates predicted by equation (2) assuming no enrolment gains during the 1950s (i.e., setting the change in education enrolment 1950-1960 variables to zero and adjusting subsequent rates downward accordingly), and (3) infant mortality rates predicted by holding school enrolment rates constant at their mean 1950s level (assuming no enrolment gains during the entire study period by setting the change in education enrolment 1950-1960 variables to zero and holding

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subsequent education constant at the observed 1950s-era mean). Panel B shows equivalent plots for under-five mortality rates.

In general, Figure 2 shows that predicted survival benefits associated with gains in school enrolment during the 1950s peak in the middle and late 1960s (presumably when affected cohorts began having children) and then taper off throughout the 1970s (as fertility declined). At the end of the 1960s, the 1950s education gains explain about 80 per cent of the decline in infant mortality and 75 per cent of the decline in under-five mortality. Enrolment gains during the 1950s also explain about 70 per cent of the decline in infant mortality and 55 per cent of under-five mortality decline between 1960 and 1980. Because we include living standard and nutritional status measures, school enrolment is unlikely to merely proxy for these factors.

5.4 Targeting results

Table 5 reports results from our targeting analysis. To take account of what data was potentially available to policymakers at the time, we use mortality data from provincial vital registries in addition to infant and child survival data from the 1988 National Survey of Fertility and Contraception. Overall, there is little evidence of targeting: rapid scale-ups of our key explanatory variables were not generally preceded by differential changes in the infant or under-five mortality rates. The exceptions are healthcare supply (doctors per 10,000 population, and using vital registry data, hospital beds) and public health campaigns to improve sanitation and vaccinations. The negative estimate for crude death rate and hospital beds suggests that rapid expansions of hospital infrastructure occurred in provinces already experiencing differentially declining mortality. Alternatively, the positive estimate for doctors implies that large expansions of physician coverage may have occurred in response to differentially increasing mortality rates. (Interestingly, these healthcare supply results are consistent with Mao Zedong's charge that the Ministry of Health was biased in favor of advantaged areas in the case of hospital infrastructure—as well as with Mao's subsequent emphasis on expanding the supply of barefoot doctors to redress the imbalance; see Lampton 1974.) We therefore place little emphasis on the estimates for hospital beds, doctors, and sanitary and vaccination campaigns shown in Tables 3 and 4.

6. Conclusion

This paper describes the construction of a new provincial database on Chinese mortality and its determinants under Mao Zedong – and uses it to study China's unprecedented mortality decline between 1950 and 1980. We find that gains in education (and to a lesser extent, its interactions with major public health interventions) may explain an important share of the striking reductions in infant and under-five mortality during the Mao era. In particular, we find suggestive evidence of lagged lifetime benefits of better education. Taken together, educational gains during the 1950s and their interactions with public health interventions appear to explain about 80 per cent of infant mortality decline and 75 per cent of under-five mortality decline through the 1960s, and 55-70 per cent of the declines over the entire 1960-80 period.

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Because we find that shifts in the supply of medical care (measured as hospital beds and physicians per capita) appear targeted to areas with differentially-changing mortality trends, we are ultimately unable to assess their importance directly. However, our results nonetheless imply that a substantial share of declining mortality appears linked to non-medical factors (and we also note that China's emphasis on barefoot doctors began in the late 1960s, years after the largest mortality reductions).

The relationship between education and survival in our sample is robust and generally consistent with other empirical studies suggesting a causal relationship (Glewwe 2002; Lleras-Muney 2005; Cutler et al. 2010; Chou et al. 2010). Empirical studies of Indonesia, Taiwan, Brazil and China (Thomas et al. 1991; Currie and Moretti 2003; Breierova and Duflo, 2004; Chen and Li 2009; Chou et al.2010) find a strong role of parental education in improved infant and child health. Some studies in high-income countries have reported mixed results about the relationship between education and adult health (Lindeboom et al. 2009; Clark and Royer 2013; McCrary and Royer 2011; Lochner 2011), but our focus on infant and child health implicates different pathways. Some studies in developing countries also cast doubt on the role of maternal education for child health (Desai and Alva 1998; Zhang 2012), but these studies generally focus on environments having undergone epidemiological transitions (for evidence on high school completion in China after Mao, see Zhang 2012). Nonetheless, given limitations discussed throughout the paper, we emphasize that our findings should be interpreted cautiously. Our hope is that the analyses presented in this paper and the accompanying dataset that we have compiled will provide the basis for further work on population health improvement in China.

Understanding the behavioral mechanisms through which general education may improve health is an important area for future research. Given the breadth of socioeconomic controls that we include in our analyses, we discount simple explanations about improvements in material well-being. One broad category of explanations is related to cognitive capacity: better-educated people are more efficient in processing information, so they benefit more from the diffusion of knowledge about health. Another is that education raises permanent income, which is not captured well by contemporaneous province-year socio-economic controls (Friedman 1957; Hall 1978). Beyond material resources *per se*, higher permanent income can strengthen incentives for people to invest more time and effort in their own health – an important mechanism highlighted by economic research on longevity (Murphy and Topel 2006).

Overall, our results provide empirical support for the importance of non-medical determinants of population health improvement – and under some circumstances, how education could improve the effectiveness of important public health interventions. Given China's rapidly aging population, we speculate that the education gradient in self-management of chronic diseases may play a central role in its demographic future as well.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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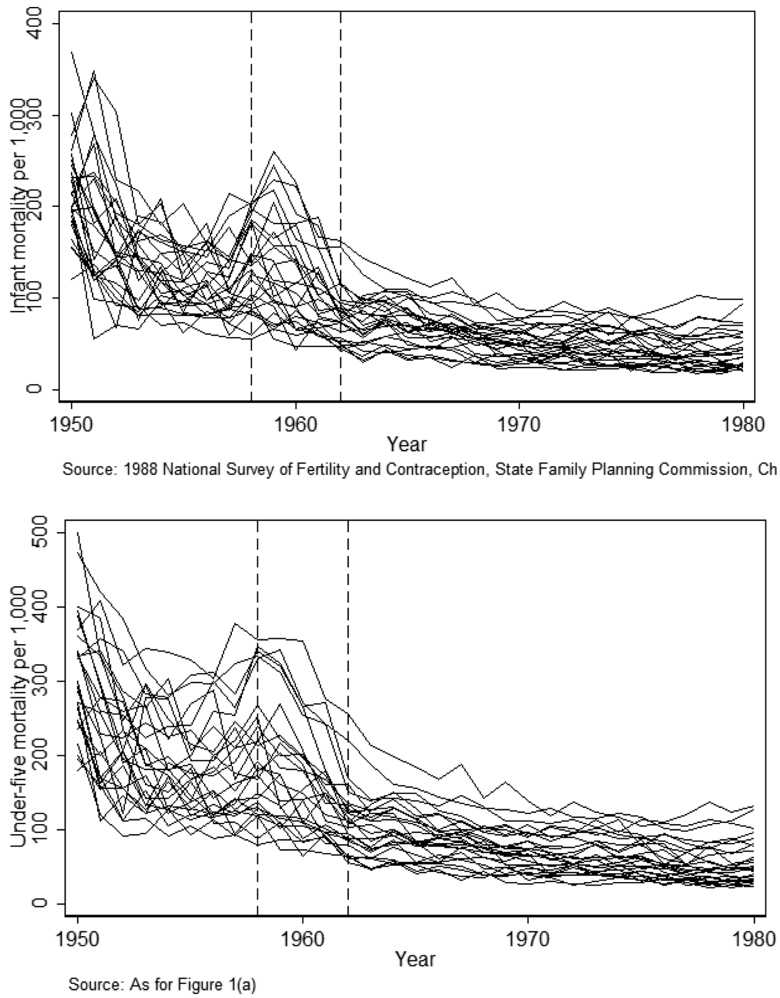

Figure 1.

(a) Infant mortality rate by province China, 1950-80

Figure 1(b) Under-five mortality rate by province China, 1950-80

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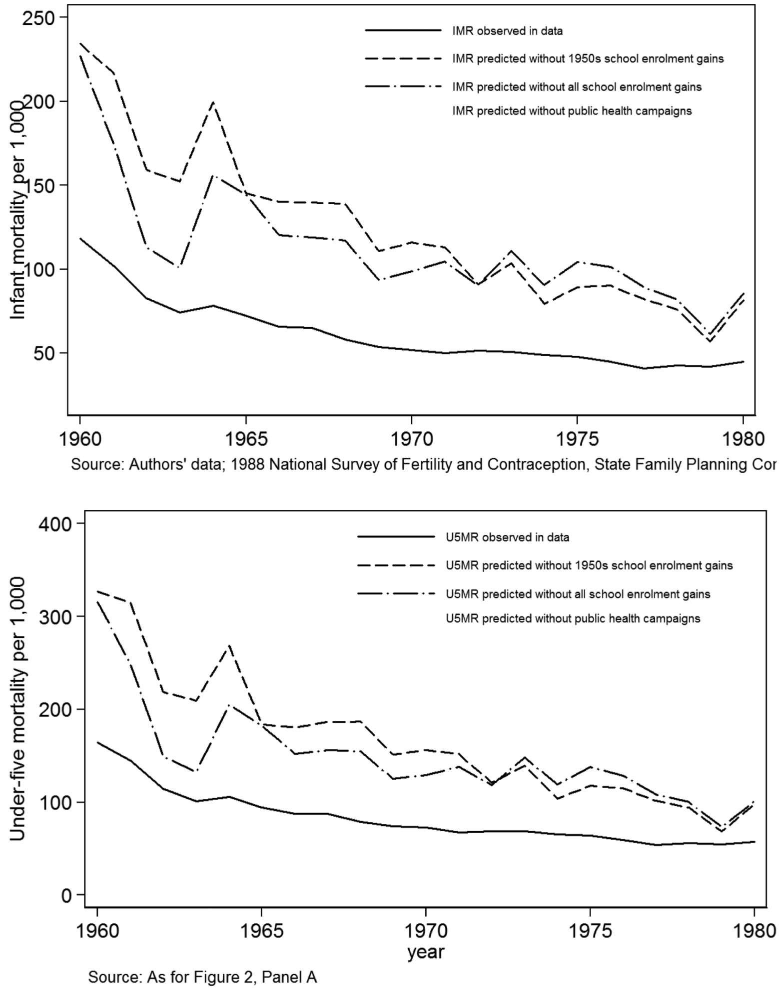

Figure 2.

(a) Effects of 1950s school enrolment gains on infant mortality rate: China, 1960-80

Counterfactual mortality rates are obtained by estimating equation (2) and using the resulting parameter estimates in combination with observed independent variable values over time (with the exception of school enrolment, which is adjusted to erase gains made in the 1950s or fixed at its earliest value) to predict mortality rates.

Figure 2(b) Effects of 1950s school enrolment gains on under five mortality rate: China, 1960-80

Counterfactual mortality rates are obtained by estimating equation (2) and using the resulting parameter estimates in combination with observed independent variable values over time (with the exception of school enrolment, which is adjusted to erase gains made in the 1950s or fixed at its earliest value) to predict mortality rates.

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Table 1

Number of provinces with public health campaigns: 1950-1980

Number of provinces with a given public health intervention		1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
sanitary campaigns	for clean drinking water	3	3	3	4	3	4	6	5	3	4	4	1	1	3	3	3	2	1	1	1	1	1	1	2	2	3	2	2	2	1	3
	monitoring water	1	0	0	0	1	3	5	1	5	2	3	1	4	4	4	7	3	2	1	3	3	6	11	11	9	5	6	7	7	9	9
	monitoring disease prevention	7	5	5	6	3	4	5	6	6	5	4	4	4	4	4	5	3	2	2	2	2	2	2	3	3	3	3	4	7	6	6
	monitoring food	4	4	5	8	4	8	6	6	6	6	9	3	7	7	6	9	1	0	0	0	0	1	3	5	12	7	8	7	9	10	6
	patriotic public hygiene	4	4	12	8	8	6	8	5	11	6	5	3	4	6	8	8	2	0	0	2	4	3	4	3	5	3	5	9	14	14	14
	against typhoid	2	2	2	1	0	1	2	2	2	1	2	1	2	0	0	0	1	0	0	0	0	0	1	0	1	1	1	4	1	1	4
	against dysentery	1	2	0	0	1	2	2	2	1	2	2	3	2	4	3	2	2	1	1	1	1	1	1	1	1	1	2	1	2	3	3
	against diarrhea	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	2	2	2	0	0	1	1
vaccinations	pertussis	0	1	1	4	4	5	3	4	4	4	5	2	4	2	4	4	3	3	3	3	4	4	3	3	6	3	5	5	7	6	8
	diptheria	5	7	5	5	5	6	5	5	6	4	6	6	6	8	10	9	7	8	6	6	6	10	8	7	8	7	6	8	13	14	14
	smallpox	18	21	18	14	12	9	9	9	8	7	6	5	10	8	6	6	3	3	3	2	1	1	1	2	3	2	1	3	4	4	3
	typhoid	5	4	3	2	2	3	2	2	3	2	2	2	3	4	3	2	2	2	1	1	0	0	1	1	1	1	1	2	2	2	3
	meningitis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	4	4	3	5	5	4	6	5	6	4	3	6	5	5	7
	cholera	6	4	5	4	1	2	2	1	2	2	2	5	4	6	5	7	4	2	2	2	1	1	1	2	2	3	2	3	5	4	4
	measles	0	0	0	0	0	1	0	0	0	0	1	0	0	0	2	6	15	14	10	8	7	8	9	8	8	8	6	8	15	16	16
	tuberculosis	7	7	9	6	6	8	7	8	8	7	8	9	7	4	4	3	3	1	1	1	2	1	3	2	4	4	4	4	2	5	5
reproductive health	contraception	0	0	0	1	1	4	11	6	7	5	3	3	10	10	10	8	4	3	2	5	5	6	6	8	6	7	5	8	10	10	9
	midwifery	23	25	26	23	23	19	20	17	19	15	8	6	10	13	11	10	1	1	1	1	1	1	1	5	8	11	16	18	22	21	17
mosquito vector controls	malaria prevention	5	5	9	8	5	6	12	11	13	10	7	6	6	8	9	10	4	1	0	0	3	4	5	8	9	11	11	9	8	7	9
	dengue	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
	campaign against malaria	1	0	0	1	0	0	1	1	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
other infectious disease controls	pertussis	0	0	0	1	2	2	1	1	1	0	1	0	0	1	0	0	0	0	0	0	0	1	0	1	1	0	1	0	1	0	1
	typhus	1	2	2	1	1	2	2	1	2	4	3	2	3	1	2	2	1	1	1	1	1	1	1	1	1	1	2	1	1	1	1
	flu	0	0	0	1	0	1	1	2	2	0	0	0	0	0	0	0	1	0	0	0	0	2	3	2	0	1	1	1	1	1	0
	meningitisii	2	1	1	1	1	3	2	3	1	1	2	1	1	2	3	2	6	5	2	5	4	4	3	4	5	3	4	5	6	4	7
	polio	7	5	8	11	7	5	10	7	10	11	9	7	6	7	8	6	3	3	1	3	2	5	5	6	6	5	6	7	9	14	7
	tuberculosis	0	0	0	0	0	4	2	3	1	1	6	4	6	8	6	5	4	3	3	3	3	3	4	2	6	3	4	4	2	5	3
campaign against malnutrition		0	1	0	0	0	1	1	1	1	0	2	0	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	4	3

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Table 2

Descriptive statistics: full study period and by decade

	FULL SAMPLE	SUBSAMPLES BY DECADE		
	(N=390)	1950-1959 (N=90)	1960-1969 (N=106)	1970-1980 (N=194)
Infant mortality rate	74.43 (42.74)	128.06 (38.17)	79.14 (30.48)	46.97 (19.80)
Under-five mortality rate	104.65 (68.98)	193.64 (69.92)	107.33 (43.13)	61.90 (28.10)
Crude death rate	9.52 (4.08)	13.08 (2.67)	11.29 (5.21)	6.92 (1.07)
Education				
Primary education enrolment (% of children age 6-11)	0.81 (0.16)	0.68 (0.13)	0.73 (0.15)	0.91 (0.10)
Secondary and higher education enrolment (% of children age 12-18 and 18-21)	0 .15 (0.11)	0.05 (0.03)	0.08 (0.03)	0.24 (0.09)
Health				
# of hospital beds per 10,000 persons	15.88 (8.45)	8.88 (8.20)	14.63 (6.81)	19.81 (6.96)
# of doctors per 10,000 persons	11.58 (5.91)	8.26 (4.76)	12.44 (5.90)	12.65 (5.85)
percentage of province-years with public health interventions (%)				
sanitary campaigns	72% (0)	80% (0)	64% (0)	73% (0)
vaccinations	70% (0)	63% (0)	70% (0)	74% (0)
reproductive health	62% (0)	82% (0)	42% (0)	63% (0)
mosquito vector controls	28% (0)	37% (0)	19% (0)	29% (0)
other infectious disease controls	45% (0)	44% (0)	44% (0)	46% (0)
percentage of province-years with campaign against malnutrition (%)	3% (0.17)	4% (0.21)	3% (0.17)	2% (0.14)
Control variables: other socioeconomic characteristics of provinces				
Total population (10,000 persons)	2998.0 (1803.9)	2457.1 (1501.2)	2602.7 (1565.0)	3465.0 (1935.4)
Birthrate	27.59 (8.88)	32.7 (4.80)	31.7 (9.30)	22.82 (7.48)
Per cent of population over age 60	6.8% (0.01)	7.1% (0.01)	6.4% (0.01)	6.8% (0.01)
Per cent of population under age 5	13.4% (0.03)	14.5% (0.02)	14.4% (0.02)	12.5% (0.03)
Per cent of population Male	51.6% (0.01)	51.9% (0.02)	51.8% (0.01)	51.4% (0.01)
Per cent rural population (agricultural residents)	78.4% (0.20)	77.7% (0.23)	76.7% (0.21)	79.7% (0.18)
Per capita agricultural production (10,000 tons)	1.24 (1.15)	0.28 (0.32)	0.82 (0.50)	1.91 (1.22)
Per capita production of grain (10,000 tons)	0.295 (0.06)	0.287 (0.06)	0.259 (0.06)	0.318 (0.05)
Per capita production of fruit (10,000 tons)	0.007 (0.01)	0.007 (0.01)	0.007 (0.01)	0.007 (0.01)
GDP (current price, 100 Million RMB)	72.83 (60.13)	34.88 (20.14)	46.10 (26.25)	105.05 (67.96)
Per capita investment in fixed assets (current price)	0.004 (0.00)	0.003 (0.00)	0.003 (0.00)	0.006 (0.00)
Per capita local revenue (current price)	0.005 (0.00)	0.003 (0.00)	0.004 (0.00)	0.006 (0.00)
General retail price index (preceding year=100)	103.12 (45.83)	100.78 (2.01)	100.52 (7.50)	105.62 (64.72)

Standard deviations in parentheses

N= number of province-years

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Table 3

Contemporaneous determinants of infant and under-five mortality rate: 1950-80

Dependent Variable		**lnIMR**	**lnU5MR**
		Cohort Life Table	
Panel A			
Primary education enrolment (% of children age 6-11)	base	0.830*** (0.290)	0.967*** (0.227)
	1960-1965	−1.193** (0.510)	−1.150*** (0.331)
	1966-1980	−0.900** (0.370)	−1.056*** (0.305)
Secondary and higher education enrolment (% of children age 12-18 and 18-21)	base	2.722 (1.852)	2.606* (1.481)
	1960-1965	−1.295 (1.613)	−1.43 (1.264)
	1966-1980	−3.574* (2.061)	−3.134* (1.745)
Panel B			
Hospital beds per 10,000 persons	base	0 (0.005)	−0.004 (0.004)
	1960-1965	0.002 (0.003)	0.004 (0.003)
	1966-1980	0.008 (0.005)	0.010** (0.004)
Doctors per 10,000 persons	base	−0.011 (0.007)	−0.012* (0.006)
	1960-1965	0.004 (0.006)	0.014** (0.005)
	1966-1980	0.021*** (0.006)	0.023*** (0.005)
Panel C			
Sanitary campaigns		−0.024** (0.010)	−0.020* (0.011)
Vaccinations		0.019** (0.007)	0.011* (0.006)
Reproductive health		−0.004 (0.014)	−0.006 (0.011)
Mosquito vector controls		0.003 (0.006)	0.002 (0.006)
Other infectious disease controls		0.018* (0.009)	0.008 (0.011)
Campaigns against malnutrition		−0.051 (0.079)	−0.03 (0.056)
Province effects		yes	yes
Year effects		yes	yes
Province-year control variables		yes	yes
N		390	390
R-squared		0.940	0.962

Provinces used in analysis include: Anhui, Beijing, Fujian, Gansu, Guangdong, Guangxi, Hainan, Hebei, Heilongjiang, Henan, Hubei, Hunan, Inner Mongolia, Jiangsu, Jiangxi, Jilin, Liaoning, Ningxia, Qinghai, Shaanxi, Shandong, Shanghai, Shanxi, Sichuan, Tianjin, Xinjiang, Yunnan, and Zhejiang. Province-level controls include population, birth rate, per cent of population over 60, per cent of population under 5, per cent of population male, per cent of population in agriculture, per capita agricultural production, per capita grain and fruit production, gdp, per capita investment, per capita local revenue, and retail price index. Estimates for fixed effects and control variables available upon request. Standard errors reported in parentheses.

*$p<0.1$

**$p<0.05$

***$p<0.01$

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Table 4

Lagged education and interactions with public health interventions, 1960-80

Dependent Variable	**lnIMR**	**lnU5MR**
	Cohort Life Table	
Panel A		
Change in primary education enrolment 1950-1960	1.493*** (0.299)	1.730*** (0.319)
Change in secondary and higher education enrolment 1950-1960	−11.723*** (3.799)	−11.897*** (3.663)
Panel B		
Primary education enrolment (% of children age 6-11)	−1.343*** (0.256)	−1.464*** (0.251)
Secondary and higher education enrolment (% of children age 12-18 and 18-21)	−0.008 (0.754)	0.107 (0.686)
Hospital beds per 10,000 persons	0.031*** (0.006)	0.027*** (0.007)
Doctors per 10,000 persons	0.041*** (0.012)	0.039*** (0.013)
Panel C		
Public health campaigns (principal component indices)		
Sanitary campaigns	−0.16 (0.103)	−0.174 (0.108)
Vaccinations	0.155 (0.111)	0.163 (0.114)
Reproductive health	0.071 (0.089)	0.06 (0.085)
Mosquito vector controls	−0.042 (0.060)	−0.026 (0.056)
Other infectious disease controls	−0.158** (0.072)	−0.203** (0.072)
Campaign against malnutrition	−4.432*** (1.377)	−3.815** (1.348)
Interactions between 1950s increases in educational enrolment and 1960-80 public health campaigns		
Primary education and sanitary campaigns	0.021 (0.121)	0.036 (0.123)
Primary education and vaccinations	−0.205 (0.207)	−0.278 (0.194)
Primary education and reproductive health	0.295** (0.134)	0.365** (0.142)
Primary education and mosquito vector control	0.286 (0.225)	0.247 (0.183)
Primary education and other infectious disease control	0.387*** (0.125)	0.400*** (0.120)
Primary education and campaigns against malnutrition	−0.801 (0.644)	−1.087* (0.615)
Secondary education and sanitary campaigns	1.846 (1.481)	1.938 (1.542)
Secondary education and vaccinations	−1.166 (1.263)	−1.045 (1.302)
Secondary education and reproductive health	−2.609* (1.390)	−2.653* (1.346)
Secondary education and mosquito vector control	−0.486 (0.999)	−0.37 (0.994)
Secondary education and other infectious disease control	1.627 (0.989)	2.104** (0.993)
Secondary education and campaigns against malnutrition	72.366*** (23.286)	63.201** (22.489)
Province effects	no	no
Year effects	yes	yes
Province-year control variables	yes	yes

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Dependent Variable	**InIMR**	**lnU5MR**
	Cohort Life Table	
N	255	255
R-squared	0.835	0.870

Provinces used in analysis include: Anhui, Fujian, Gansu, Guangxi, Hebei, Heilongjiang, Henan, Hunan, Inner Mongolia, Jiangsu, Jiangxi, Jilin, Liaoning, Ningxia, Shaanxi, Shandong, Shanxi, Xinjiang, Yunnan, and Zhejiang. Province-level controls include population, birth rate, per cent of population over 60, per cent of population under 5, per cent of population male, per cent of population in agriculture, per capita agricultural production, per capita grain and fruit production, gdp, per capita investment, per capita local revenue, and retail price index. Estimates for fixed effects and control variables available upon request. Standard errors reported in parentheses.

[*] $p<0.1$

[**] $p<0.05$

[***] $p<0.01$

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Table 5

Targeting analysis

Dependent variables: Natural logarithm of infant mortality rate or crude under-five mortality rate in each province each year	lnCDR	lnIMR	lnU5MR
		Cohort Life Table	
Two years prior to scale up of primary education enrolment (% of children age 6-11)	0.029 (0.05)	0.018 (0.05)	−0.051 (0.05)
Two years prior to scale up of secondary and higher education enrolment (% of children age 12-18 and 18-21)	−0.044 (0.04)	0.011 (0.05)	0.008 (0.05)
Two years prior to scale up of hospital beds per 10,000 persons	−0.072* (0.04)	−0.056 (0.04)	−0.034 (0.04)
Two years prior to scale up of doctors per 10,000 persons	0.050** (0.03)	0.048* (0.03)	0.045 (0.03)
Two years prior to public health campaigns (principal component indices)			
Sanitary campaigns	0.028 (0.03)	−0.053* (0.03)	−0.076** (0.03)
Vaccinations	−0.014 (0.03)	−0.068** (0.03)	−0.029 (0.03)
Reproductive health	−0.032 (0.02)	−0.002 (0.03)	−0.018 (0.03)
Mosquito vector controls	−0.018 (0.03)	−0.024 (0.03)	0.028 (0.03)
Other infectious disease controls	0.031 (0.03)	0.016 (0.03)	0.025 (0.03)
Campaigns against malnutrition	−0.06 (0.06)	−0.056 (0.07)	−0.016 (0.06)
Province effects	yes	yes	yes
Year effects	yes	yes	yes
Province-year control variables	yes	yes	yes
N	358	390	390
R-squared	0.88	0.934	0.964

Provinces used in analysis include: Anhui, Beijing, Fujian, Gansu, Guangdong, Guangxi, Hainan, Hebei, Heilongjiang, Henan, Hubei, Hunan, Inner Mongolia, Jiangsu, Jiangxi, Jilin, Liaoning, Ningxia, Qinghai, Shaanxi, Shandong, Shanghai, Shanxi, Sichuan, Tianjin, Xinjiang, Yunnan, and Zhejiang. Province-level controls include population, birth rate, per cent of population over 60, per cent of population under 5, per cent of population male, per cent of population in agriculture, per capita agricultural production, per capita grain and fruit production, gdp, per capita investment, per capita local revenue, and retail price index. Estimates for fixed effects and control variables available upon request. Standard errors reported in parentheses.

*** $p<0.01$

* $p<0.1$

** $p<0.05$