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Shige Song
Sarah A. Burgard

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Shige Song
Chinese Academy of Social Sciences

Sarah A. Burgard
University of Michigan

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Author Contact Information:
Shige Song
Institute of Sociology, Chinese Academy of Social Sciences
5 Jiannei Dajie
Beijing 100732
P.R.China
Phone: 86-10-64460722,
Fax: 86-10-85195566
E-mail: sgsong@ccpr.ucla.edu

Sarah A. Burgard
Department of Sociology
University of Michigan
500 South State Street
Ann Arbor, MI 48109-1382
Phone: (734) 615-9538
Fax: (734) 763-6887
Email: burgards@umich.edu

* The first author can be reached at the Institute of Sociology, Chinese Academy of Social Sciences, 5 Jiannei Dajie, Beijing 100732, P.R.China, E-mail: sgsong@ccpr.ucla.edu. We thank Bruce Link, Donald Treiman, Richard Carpiano, and Susan Short for helpful comments, but all remaining errors are our own. Burgard was supported by center grants from NICHD (R24 HD041028) and NIA (P30 AG012846-14) to the Population Studies Center, University of Michigan.

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ABSTRACT

The fundamental cause argument represents a distinctively sociological approach to explaining persistent social disparities in health across a range of sociohistorical contexts. We elaborate and test this U.S.-based argument using nationally representative survey data from China covering births from 1970 to 2001, and focusing on social disparities in infant mortality over a period of dramatic social, political, and macroeconomic change. Our results show that despite the massive changes during the last several decades, the increasing use of medical pregnancy care, and the steady decline in the overall risk of infant mortality, disparities in infant mortality by mother's education and urban/rural place of residence remained largely unchanged. During this period, more educated women were increasingly likely to take advantage of the newly-available prenatal care and delivery assistance facilities, while urban women maintained a stable advantage over rural women in use of these facilities. This differential utilization of highly-effective maternal care technology has maintained social disparities in infant mortality over a period of major social and technological change in China, providing support for the fundamental cause argument.

INTRODUCTION

The relationship between social stratification systems and individual life chances has always been at the center of sociological inquiry. An important stream of this research tradition concerns health consequences of social stratification and inequality, and has documented a robust and consistent association between social conditions and health and longevity (Black, Morris, Smith, and Townsend 1982; Robert and House 2000; Williams 1990). Among the many efforts to explain this persistent disparity in health among different social groups, the fundamental cause of disease argument proposed by Link and Phelan (1995) represents the latest development toward an integrated and distinctively sociological approach to the study of health and health disparities. According to this argument, health inequality is an inevitable result of social stratification because higher position in society brings with it a more resources that can be used to prevent and cure disease, and thus to achieve better health. The fundamental cause argument thus accommodates the "causal" effect of specific biomedical and psychological intervening mechanisms in shaping the pattern of health and disease at a given place and time (Link and Phelan 2000), but it also goes a step further and emphasizes the role of social conditions as "meta-causal" determinants or "fundamental causes" of health from a dynamic macro historical perspective. Social disparities in health persist over time and across contexts despite drastically different intervening mechanisms, including disease profiles, medical innovations, public health interventions, and health behaviors. When old mechanisms (such as malnutrition and poor sanitation) cease to generate social disparities in health, new mechanisms (such as overeating and tobacco use) will take their place as stratifying factors (Link and Phelan 2000; Phelan, Link, Diez-Roux, Kawachi, and Levin 2004).

China presents a good test case for the fundamental cause argument for several reasons. First, China represents a low-to-middle income, non-Western social context quite distinct from the Western industrialized societal model on which the argument was built and has thus far been tested. Second, China experienced several massive social engineering efforts during the past century that have resulted in drastic social changes that could threaten the stability of the relationship between social conditions and health. The Cultural Revolution that took place from 1966 to 1976 represented a serious effort by Chinese political leaders to reduce the level of social inequality and change the prevailing social stratification order. This is one of the rare cases in modern history that the fundamental cause itself – the social stratification system – was markedly altered in way that weakened the intergenerational transmission of social advantages (Deng and Treiman 1998; Zhou and Hou 1999). The economic reforms that followed in the late 1970s, however, represented a drastic reversal. Economic development and rapid growth, instead of social equity, have been the top priority in the post-reform era and have increased social inequality dramatically. Finally, China experienced a major epidemiological transition during the past half century. A high level of mortality due to infectious diseases and malnutrition shifted to a drastically reduced level of mortality with chronic and degenerative diseases as the major causes of death (Cook and Dummer 2004). This rapid epidemiologic transition was caused by a combination of factors including political regime change, economic development and improved living standards, and improvement in public health facilities. Such a rapid epidemiological transition makes it possible for investigators to observe the replacement of infectious diseases by chronic diseases as the major threats to health over a very condensed period of time. Massive social and economic changes combined with shifts in the prevailing causes of health disparities and the mechanisms that underlie their connection with social conditions make China a uniquely challenging yet convincing test case for the fundamental cause argument.[1]

In this paper we aim to elaborate the fundamental cause argument and empirically test it in the Chinese context using infant mortality as the measure of health. We examine women's education and urban/rural place of residence, two central indicators of social conditions in the Chinese context, mothers' use of prenatal care and professional delivery assistance as indicators of the key technological interventions that can reduce infant mortality, and the associations of these factors with the risk of mortality for their infants born between 1970 and 2001. We conduct our analysis in two steps: first, we use standard multilevel models to establish the relationships between the risk of mortality for each birth and mother's education and place of residence, controlling for other variables including the use of prenatal care and professional delivery assistance. Second, we jointly model the risk of infant mortality and likelihood of using prenatal care and professional

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[1] Extant research has focused on the impact of these drastic social transitions on the economic and social aspects of life chances, such as educational attainment (Deng and Treiman 1998; Hannum and Xie 1994; Zhou, Moen, and Tuma 1998), income (Walder 1990; Wu and Xie 2003), and occupational attainment (Walder 1995; Zhou, Tuma, and Moen 1997), while little attention has been paid to how social transitions influence the most fundamental aspects of life chances – life and death.

delivery assistance, going beyond much of the prior infant mortality literature by allowing for endogeneity in the association between the use of medical pregnancy care and infant mortality risk. In other words, we test whether women's decisions about using medical pregnancy care depend on her expected pregnancy outcomes, and how this association may bias results obtained from models that do not address endogeneity in the decision to use medical care. Using the jointly estimated models, we examine whether education and urban/rural residence show a consistent relationship with infant mortality over time, and whether they work through the focal intervening mechanisms of prenatal care and delivery assistance. By doing so, we contribute to the literature by presenting the first direct and integrated test of the fundamental cause argument that simultaneously addresses all three core components – social conditions (mother's education and urban/rural residence), intervening mechanisms (prenatal care and professional delivery assistance use), and distal health outcomes (infant mortality) – while controlling for the potential endogenous selection bias that often leads to inaccurate or erroneous substantive conclusions.

The Fundamental Causes of Infant Mortality: A Sociological Explanation

As researchers have discovered across a wide variety of social and temporal contexts, a steady decline in overall population levels of mortality and morbidity from various causes has coincided with the persistence of social disparities in the rates of mortality and disease from these same causes (Cleland, Bicego, and Fegan 1991; Link, Northridge, Phelan, and Ganz 1998; Pritchett and Summers 1996; Rosen 1979; Williams 1990; Wise, First, Lamb, Kotelchuck, Chen, Ewing, Hersee, and Rideout 1988). The past

20 years have seen a drastic increase in the number of studies focused on the persistence of social inequalities in health and on understanding the biomedical, social, and psychological pathways by which socioeconomic status (SES) may affect health (for discussion, see Adler and Ostrove 1999; Robert and House 2000; Williams 1990). A majority of recent studies, however, adopts a “downstream approach” – a biomedical conceptual model that focuses primarily on the relationship between proximate risk factors and health outcomes while treating SES as a confounding factor (Adler, Boyce, Chesney, Cohen, Folkman, Kahn, and Syme 1994; Black, Morris, Smith, and Townsend 1982; Rothman 1986).

Building on the sociological work of Durkheim (1951), House (1990), Lieberson (1985), and Williams (1990), Link and Phelan propose a distinctive sociological “upstream” approach, arguing that the key to understanding persistent social inequalities in health is that: (1) higher status provides access to an array of resources, including money, knowledge, prestige, power, and social connections, that enable individuals in control of these resources to avoid hazardous exposures and to pursue better health, regardless of specific intervening risk factors or diseases that are prevalent at the time; and (2) regardless of status, individuals strive to achieve better health and longer life whenever possible by using whatever available resources they have to take advantage of new knowledge or technological interventions (Link, Northridge, Phelan, and Ganz 1998; Link and Phelan 1995; Link and Phelan 1996; Phelan and Link 2005; Phelan et al. 2004). The fundamental cause argument thus reorients health researchers to the longstanding sociological focus on the unequal distribution of resources and their impact on life chances and valued outcomes (Carpiano, Link, and Phelan Forthcoming). By widening the focus from more individualistic and proximate risk factors such as health behaviors, use of medical care, and psychosocial stress to encompass the unequal social distribution of resources that determine exposure to these risks and capacity to take protective actions, the fundamental cause approach distinguishes itself from competing arguments focused only on specific biomedical or psychological pathways and achieves a more broadly applicable sociological framework.

Though it is an attractive and broadly-applicable explanation for social disparities in health, our literature review reveals very few empirical studies that explicitly test the fundamental cause argument. Two extant studies focus exclusively on the link between social conditions and access to/use of health-promoting interventions. Using data collected by the Behavioral Risk Factor Surveillance System (BRFSS), Link and colleagues (1998) documented significant education and income differences in the use of the Pap smear test and mammography, both highly effective preventive measures that can reduce cancer mortality. Taking a very different approach and using ethnographic data from two diabetes clinics, Lutfey and Freese (2005) recently showed that patients' education and income influence both the administration of diabetes treatments and their effectiveness. A third study focused on the social conditions-health link, comparing the effects of the stratification systems of the US and Iceland on health in each country (Olafsdottir 2007). This study concluded that education, employment, and relative poverty had similar effects on health in both US and Iceland, supporting the notion of SES as a fundamental cause of health and health disparities across societal contexts. A fourth study moves toward a more integrated test of all three paths implicated in the fundamental cause argument: from social conditions to health outcomes, from social conditions to intervening mechanisms, and from intervening mechanisms to health outcomes. Phelan and colleagues (2004) use data from the National Longitudinal Mortality Study to show that SES inequality in mortality from highly preventable diseases is much greater than inequality in mortality from less preventable diseases. This implies that higher SES individuals are able to use their greater resources to reduce their risk of death from the preventable diseases to a greater extent than their lower SES counterparts, by taking advantage of technological innovations, improved knowledge of healthy behaviors, or other intervening mechanisms. But as Phelan and colleagues acknowledge, their conclusions remain inferential since they do not include measures of these mechanisms in their analysis. As they conclude, "…a more complete test of the dynamic aspects of the theory would systemically assess changes in gradients between socioeconomic status and mortality over time in relation to emerging health information and technology" (Phelan et al. 2004: 280).

In the present study we follow up on their suggestion, addressing all three paths implicated in the fundamental cause argument. We assess the relationship between two indicators of social conditions, mother's education and urban/rural residence, and infant mortality over a thirty year period (1970 – 2001) in China. We examine how these indicators influence the use of prenatal care and professional delivery assistance, two medical innovations that were becoming much more widely used over these three decades. Finally, we assess how these medical interventions influenced the risk for infant mortality, and consider the extent to which they explain the lower risk of infant mortality for highly educated and urban women.

Elaborating and Applying the Fundamental Cause Argument

While it is an elegant and powerful framework, the fundamental cause argument needs to be further elaborated, substantiated, and tailored to apply to specific sociohistorical contexts like the Chinese case examined here, and to produce testable empirical hypotheses. First, specific measures of social conditions should be carefully examined and selected, because different measures may not be relevant in all social contexts. Second, investigators must posit and explore how different markers of social conditions may work through distinct intervening mechanisms to influence health. Finally, to assess the applicability of the fundamental cause approach to health disparities in a particular sociohistorical case, investigators should study how intervening mechanisms arise and change over time, to identify any secular trend in the social selectivity with which individuals use these mechanisms to translate resource advantages into health advantages, and to assess the stability of the relationship between social conditions and health over the course of these changes.

In their own empirical tests of the fundamental cause argument, Link and Phelan use measures of education and income as indicators of social conditions, but they also acknowledge that future work should examine social class, power, prestige, and social capital (Link and Phelan 2000). They argue that these markers of social status determine access to these resources, and such key resources can be used to pursue good health. Following their logic, then, other characteristics that stratify access to such key resources could also act as fundamental causes. For example, Schulz et al. (2002) argue that race-based residential segregation is a fundamental cause of racial disparities in health in the United States. In the context of Chinese society, urban versus rural residence is such a characteristic. The household registration or *hukou* system, an internal passport system active since the early 1960s that was designed to prevent rural-to-urban migration (Wu and Treiman 2004), ensures that urban Chinese residents have exclusive access to higher-income jobs, better educational opportunities, and contemporary state-sponsored pension and health care systems (Braveman and Tarimo 2002; Liu, Hsiao, and Eggleston 1999). This policy of residential restriction maintains large urban/rural differences in average incomes, housing quality, access to social welfare services, and quality and coverage of medical services favoring urban residents and their children. Not surprisingly, infant mortality is much lower among urban residents than among rural residents in China (Mason, Lavely, Ono, and Chan 1996; Ren 1995). Education is another key indicator of social status in China, and there is extensive evidence from a variety of social contexts for an inverse relationship between mother's education and infant mortality (Bicego and Boerma 1993; Caldwell 1994; Cleland 1990; Desai and Alva 1998; Hobcraft 1993; Ware 1984). Though the intervening mechanisms and their causal nature are debated, many investigators have argued that better educated mothers have lower rates of infant mortality because they are more likely to use modern health services and to pursue other health enhancing behaviors (Caldwell 1994; Desai and Alva 1998).

While both higher education and urban residence reflect social advantage and are likely to influence infant mortality through some of the same intervening mechanisms, such as medical pregnancy care use, we expect that each may make distinct contributions. Further, the stability over time of the association of each with infant mortality could differ. First, these two measures may be associated with the use of medical care during pregnancy and birth for different reasons. Modern medical facilities are much more widely available in urban areas than in rural areas due to greater investment in urban public health facilities over the period considered here; for example, Knight and Song (1999: 160) report that that the number of hospital beds and qualified medical doctors per 1,000 people were three to seven times higher in urban than in rural areas between the mid 1960s and the mid 1990s. Better access is thus likely to be one of the main reasons for the urban advantages in medical pregnancy care use. While highly educated women are more likely to live in urban areas and thus have increased access to prenatal care or delivery assistance, education may also have an effect on infant mortality independent of urban residence and other factors. More educated women tend to have more knowledge and better understanding of the effectiveness of modern medical technology and they are more likely than their less educated counterparts to be associated with other educated people, including those who with some medical and health care knowledge (e.g. medical personnel). Educated women also tend to be more capable of persuading other people (especially family members) to accept their decisions regarding child-bearing and child-care issues (Bloom, Wypij, and Gupta 2001). These factors mean that better educated women are probably more likely to take advantage of new medical innovations whenever and wherever they become available (Anson 2004; Chen, Xie, and Liu 2007; Li 2004; Short and Zhang 2004).

It is also important to explore multiple indicators of social conditions to empirically establish that each maintains an association with health over time. A persistent or re-emerging relationship as intervening mechanisms change is central to the fundamental cause argument, and should be examined carefully across social status indicators. This is especially true when generalizing the argument to different sociohistorical contexts, and when using a measure of social conditions not tested in other examinations of the fundamental cause approach, as we do here. In the Chinese context, we would expect that the advantages associated with high levels of education may remain more stably associated with infant mortality risk over time than the advantages associated with urban residence. Since the contemporary urban advantage in China largely is due to explicit government policy, it is also responsive to policy changes, especially those influencing the distribution of public health expenditures. Future policy changes could thus lead to further changes in the relative advantage associated with place of residence. By contrast, education is a marker of social status that increases knowledge and other important resources valuable in any macroeconomic or residential context, so it may be less sensitive to policy change and thus may have a more stable relationship over time with infant mortality.

In the section that follows, we briefly describe the dramatic political, social and macroeconomic changes in China over the past several decades and discuss how these changes have shaped the relationship between social conditions, medical pregnancy care use, and infant mortality risk. Two countervailing forces are of particular relevance: the rapid economic growth brought about by the economic reforms that began in the late 1970s and improvement in medical technology on the one hand, and the rising social inequalities and decimation of the rural collective health care system on the other. We also briefly discuss the one-child family planning policy, instituted in the early 1980s, and the rising importance of the traditional Chinese preference for sons in the wake of economic reforms. In the context of these countervailing influences, the use of medical pregnancy care has increased and infant mortality risk has fallen for the population overall (Chen, Xie, and Liu 2007; Short and Zhang 2004). According to the fundamental cause argument, the associations between health and resources like mother's education and urban residence will re-express themselves even as societal, technological and disease profile circumstances change. Given the massive changes China has experienced over the last several decades, this analysis puts the fundamental cause argument to a very strong test.

The Chinese Context: Rapid and Dramatic Social Change

The pre-reform Mao era in China (1949-the end of the 1970s) was characterized by a Soviet-style centrally planned economy with a special focus on heavy industry, collective agricultural production organized by People's Communes, low levels of residential mobility, and universal welfare coverage (including medical care) in urban areas and nearly universal coverage in rural areas. While average household income was low during this period, so was the level of social inequality. Moreover, this period saw the establishment of a comprehensive low-cost rural preventive health system based on the commune system and funded by government subsidies, small mandatory contributions from residents into commune welfare funds, and small co-payments at the point of service. The rural health system achieved wide population coverage and focused on preventive services that were beneficial for maternal and child health, even though the level of medical technology was relatively low (Chen 2001; Hsiao 1995; Liu and Cao 1992; Short and Zhang 2004). This pre-reform rural health system reduced levels of mortality among infants and others and thereby significantly increased life expectancy (Banister and Hill 2004; Hsiao 1995; Jamison and World Bank. 1984; Mason, Lavely, Ono, and Chan 1996; Short and Zhang 2004). In 1949 the infant mortality rate in China was about 250 per thousand births (Jamison and World Bank. 1984), but it decreased drastically to about 50 per thousand births by 1981 and further to 32 per thousand by 2000 (Banister and Zhang 2005).[2]

The death of Mao in 1976, however, brought major changes that impacted progress in the reduction of infant mortality and may have increased social disparities therein. The Cultural Revolution was ended, rural economic reform dismantled the commune system and commune-based rural cooperative medical system, and a central productive role was restored to rural households. In most areas, communal funds collapsed and responsibility for funding health services was decentralized to the village level, requiring the introduction of much higher fees for services and a new emphasis on more expensive, curative care (Kaufman and Jing 2002). The coverage of the rural cooperative medical system thus declined drastically from over 90% of the population in 1980 to 5% in 1985 (Liu and Cao 1992), leaving the majority of rural residents largely uninsured and dependent on the free market for basic medical services.

While there has been concern about the potential population health impacts of the sudden increase in costs of medical care and decline of subsidized preventive services, researchers have found that mortality rates at all ages continued to fall after the economic reforms (Banister and Hill 2004), and that the use of pregnancy-related services

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[2] By comparison, the average infant mortality rate for developed regions in the world was 59 deaths per thousand births in the early 1950s, and declined to less than 10 per thousand in the early 2000s (Frisbie 2005).

continued to rise, though they were still under-utilized (Short and Zhang 2004). To explain the seeming paradox, researchers have argued that while the post-reform period brought rising socioeconomic inequality and deteriorating basic preventive health services, it also brought unprecedented prosperity and economic freedom in both rural and urban areas. These gains in economic standing, combined with the continued rise in average levels of women's education, appear to have compensated for the negative effects of the social and economic upheaval, and led to continued health gains in the population. For example, while subsidized preventive pregnancy care was no longer available to many rural families, they could increasingly afford to pay for it under the new, market-based system.

Dramatically increased social disparities arising after the economic reforms may have differential impact on the risk of infant mortality for different social groups: it may have increased the risk for less educated mothers and those living in rural areas, relative to the risk for well-educated women and urban residents, who probably benefited most from the economic reforms. One of the key intervening mechanisms that could link these increasing household socioeconomic and urban/rural inequalities to persisting social disparities in infant mortality is a widening gap in the use of medical pregnancy care. Prenatal care and professional delivery assistance have been shown to be the most effective interventions for reducing infant mortality in China (Chen, Xie, and Liu 2007; Wang, Ren, Shaokang, and Anan 2004) and elsewhere (Frisbie, Song, Powers, and Street 2004; Gortmaker 1979; Hong and Ruiz-Beltran 2007; Panis and Lillard 1995). A systematic maternal health care program was introduced in the 1980s and utilization and maternal health indicators improved thereafter (Wu, Viisainen, Li, and Hemminki 2008), but access to modern medical care in the post-reform period was diverging due to the increasing costs of these services and greater emphasis on medical infrastructure investment in urban areas.

Moreover, the introduction of major family planning policy changes, the “one-child-per-couple” policy, and the intersection of the new policies with a longstanding tradition of son preference (Li and Cooney 1993; Short, Zhai, Xu, and Yang 2001) may have affected access to and use of medical pregnancy care in China. The one-child policy, which became effective in the early 1980s at a national scale, initially aimed to limit each woman to a single birth, though additional children were allowed for some families and the details of the policy have varied across regions and over time. Pregnancies that were not “approved” under the system resulted in serious consequences for families, and women were less likely to use prenatal care or professional delivery assistance for unapproved pregnancies because of high financial and social costs (Chen, Xie, and Liu 2007). This combination of factors increased the risk of mortality for second or higher-order births. By the mid-to-late 1990s, the family planning program began to include more maternal and infant health service components as the Chinese government became aware of its unintended negative health consequences (Chen, Xie, and Liu 2007; Short and Zhang 2004). Family planning agencies thus became an important provider of prenatal care, in addition to local clinics and hospitals, and in many cases had more dedicated resources than clinics and hospitals (Kaufman, Zhirong, Xinjian, and Yang 1992; Short and Zhang 2004).

While family planning facilities began to increase their provision of medical pregnancy care in the last years of the period covered here, and thus increased access for some women, the introduction of family size restriction policies in the 1980s triggered a series of changes that may have also changed women's decision-making about using these services. The economic reforms of the late 1970s decentralized responsibility for economic self-sufficiency back to households, increasing the importance of sons for rural household production and old age support for parents. These changing incentives, combined with the longstanding traditional preference for sons in China, began to negatively impact females. A number of studies have documented excessive female infant mortality (Banister 2004; Ren 1995) and differential treatment of male and female infants in the post-Mao period (Chen, Xie, and Liu 2007; Short and Zhang 2004; Short, Zhai, Xu, and Yang 2001; Song and Burgard 2008). Families that already had a male child were less likely to seek prenatal care or delivery assistance for subsequent pregnancies (Li 2004), and formal delivery assistance use also was more likely if previous births had resulted in daughters and parents were hoping for a son (Short and Zhang 2004). These China-specific conditions must be factored into our examination of trends and social disparities in infant mortality over the post-Mao period.

Hypotheses

After a long period of increasing social equality, the economic reforms of the late 1970s and early 1980s increased household economic resources for most Chinese in the 1980s and 1990s, pointing toward declining infant mortality risk. These gains could have particularly improved outcomes among the poorest families, for whom infant mortality risk was highest. At the same time, however, medical pregnancy care and other health-promoting goods became more expensive after the collapse of the subsidized rural health system, pointing toward higher risk for mortality for families with fewer resources. These countervailing trends and the central premise of the fundamental cause argument lead us to our first two hypotheses about the link between social conditions and infant mortality risk:

Hypothesis 1(a): *Children of better educated women had a lower risk of infant mortality between 1970 and 2001 in China, and (b) the association remained relatively stable over this period*.

Hypothesis 2(a): *Children of urban women had a lower risk of infant mortality between 1970 and 2001 in China, and (b) the association remained relatively stable over this period*.

The fundamental cause argument also posits that as new health promoting knowledge and technology emerge, individuals with the most resources will be able to make use of it most quickly and effectively. The availability of medical pregnancy care in China was spreading at the same time as economic inequalities were growing in the wake of economic reforms, so we expect that:

Hypothesis 3(a): Better educated women were more likely to use medical prenatal care and professional delivery assistance between 1970 and 2001, and (b) their advantage increased after the economic reforms of the late 1970s.

Hypothesis 4(a): Urban women were more likely to use medical prenatal care and professional delivery assistance between 1970 and 2001, and (b) their advantage increased after the early 1980s, when the formerly subsidized rural medical system was privatized.

It is also important to note that in the context of family size limitation policy and the growing influence of son preference in the 1980s and 1990s in China, the presence of an older male sibling also became a particularly salient influence on infant mortality risk and the likelihood that women would use medical pregnancy services. Thus, we must consider how sibship composition and birth order may shape the associations between social conditions and infant mortality and between social conditions and medical pregnancy care use when testing the first four hypotheses.

Finally, the fundamental cause argument implies that enhanced access to health promoting information and technology “explains” why high status individuals maintain their health advantages in the face of social and technological change and changing disease risk profiles. Given the high effectiveness of medical pregnancy care in reducing infant mortality risk, we posit that:

Hypothesis 5: Mother’s education is associated with the risk of infant mortality in China between 1970 and 2001 because of differential utilization of prenatal care and professional delivery assistance by women with varying levels of education.

Hypothesis 6: Urban residence is associated with the risk of infant mortality in China between 1970 and 2001 because of differential utilization of prenatal care and professional delivery assistance by women living in urban versus rural areas.

DATA AND METHODS

Data

To test these hypotheses we use data from the National Family Planning and Reproductive Health Survey (NFPRHS), a nationally representative sample survey conducted by the State Family Planning Commission of China (SFPC) in 2001. The survey utilized a stratified multistage clustered sample to collect information from 39,586 women aged 15 to 49 and living in family households in 31 provincial administrative units in China. All selected women were asked to provide a complete pregnancy history, including the outcome of each pregnancy. For each live birth, the survey also collects information on the mother’s use of prenatal care and professional delivery assistance, the newborn’s sex, month and year of birth, and survival over the first year of life. In the full model, we use a total of 56,831 live births from 31,515 women; in a sensitivity analysis that focuses on first and second births only, we use a total of 48,856 live births from 31,515 women.

Underreporting of births and infant deaths has been a problem for most fertility surveys in China, presumably because of the strict one-child policy (Merli and Raftery 2000; Zeng, Tu, Gu, Xu, Li, and Li 1993). This may be particularly problematic for the NFPRHS study used here because the agency that collected the data is also responsible for collecting information on women's fertility, with the end goal of meeting fertility limitation goals. As such, various methods were implemented to minimize the conflict of interest and reduce underreporting of births. Importantly, the sampling plan was designed to be representative only at the national level, and not at the provincial level or any lower levels. This ensured that local family planning officials could not be held responsible for true fertility levels in their areas (Chen, Xie, and Liu 2007). In a recent study, Zhang and Zhao (2006) compared fertility rates derived from Chinese household registration data, Censuses, intercensal surveys, retrospective fertility surveys, and annual surveys of population change, and showed that retrospective fertility surveys (which we use in this research) and annual surveys of population change yielded the best possible enumeration and highly consistent estimates.

Measures

Infant mortality is coded as a dichotomous variable where 1 = infant died and 0 = infant survived the first year. The use of prenatal care use and professional delivery assistance are coded so that 1 = service was used and 0 = not used. Women are classified as having received prenatal care if they received a prenatal check-up, including medical confirmation of the pregnancy, assessment of the pregnancy and menstrual history, and a number of other biometric measurements including height, weight, blood pressure, and heartbeat of the fetus (Chen, Xie, and Liu 2007; Short and Zhang 2004). Professional delivery assistance refers to assistance at the birth provided by health professionals, including medical doctors and nurses; trained or untrained midwives are not considered health professionals in this study.

We measure social conditions with indicators of mother's education, coded as continuous years of schooling, and urban or rural residence, coded so that 1 = living in an urban neighborhood committee (*juweihui*) and 0 = living in a rural village committee (*cunweihui*). We create five birth cohort categories to represent historical periods, distinguishing those born in 1970-1980, 1981-1985, 1986-1990, 1991-1995, and 1996-2001. Using five-year birth cohorts is common in population research and, in this particular case, the five year periods represent the pattern of macro historical changes relatively well. The first birth cohort covers ten years instead of five (1970-1980) because there are relatively few births in these early years; these births were drawn from the oldest women in our sample, while many of the respondents were too young to have given birth in the 1970s. Moreover, we wanted to compare the pre-reform and economic reform period of the 1970s with the post-reform periods. The infant's sex is coded so that 1 = male and 0 = female, with better outcomes expected for male children due to the longstanding tradition of son preference in China. We also include typical sociodemographic and maternal health controls commonly used in analyses of infant mortality. Mother's ethnicity is coded so that 0 = Han ethnic majority and 1 = ethnic minority, with better outcomes expected for socially-advantaged Han respondents. Mother's age at childbirth is a continuous variable generated by subtracting month and year of the infant's birth from month and year of the mother's birth. Birth order is coded so that 0 = first birth, 1 = second birth, 2 = third birth, and 3 = fourth or higher birth (topcoded due to small numbers of higher-order births). Previous adverse pregnancy indicates whether the focal birth was preceded by any poor outcomes such as stillbirth or miscarriage, where 1 = mother had a previous adverse pregnancy outcome and 0 = no previous adverse outcome. In a sensitivity analysis we focus on first and second order births only, and examine the sex of an older sibling, coded so that the focal child is: 1 = first birth, 0 = second birth and has an older sister, or 2 = second birth and has an older brother.

Analytic Strategy

We conduct two sets of statistical analyses to test our research hypotheses. In the first step, we estimate a set of multilevel logistic regressions separately for each of three outcomes: infant mortality, prenatal care use, and professional delivery assistance, where mothers constitute the level-1 units and infants constitute the level-2 units. These models are used to establish the associations of infant death and medical pregnancy care use with social status, and trends in the associations over time. In the second step, we estimate multilevel, multiprocess logistic regression models that jointly evaluate the likelihood of infant mortality and the use of prenatal care and professional delivery assistance, while allowing the random components of the three equations to be correlated. By explicitly estimating these correlations between the random components of each equation, we can assess the presence and magnitude of endogeneity, or mother-level correlations between the risk that a woman's child will die in infancy and her decisions about using medical pregnancy care. All models are estimated using the open source statistical software aML using the full information likelihood method (Lillard and Panis 2003). Model fit is assessed based on AIC and BIC (Akaike 1973; Raftery 1995).

Step 1: *Multilevel Logistic Regressions of Infant Mortality, Prenatal Care Use, and Professional Delivery Assistance Use*

Let Y_{ij}^{*} be the latent propensity for death before age one of the i^{th} child from the j^{th} woman and Y_{ij} be the observed infant mortality indicator. The latent propensity can be modeled as function of a set of woman and child level covariates X_{ij} and woman (μ_j) and child level (ε_{ij}) unobserved characteristics in the following formulation:

$$Y_{ij}^{*} = \beta_{ij} X_{ij} + \mu_j + \varepsilon_{ij} \tag{1}$$

Infant mortality occurred ($Y = 1$) if $Y^{*} > 0$; otherwise $Y^{*} \leq 0$. Since Y_{ij} is dichotomous, it is common to assume that the child-level residual term ε_{ij} follows a logistic distribution that is independent across women and children, with a mean of zero and variance of one; and the woman-level unobserved heterogeneity term $\mu_j \sim N(0,\psi)$ and is independent across women. The following random intercept logistic regression is estimated:

$$\text{logit}\left\{\Pr(Y_{ij} = 1)\right\} = \beta_{1ij} X_{ij} + \beta_{2ij} P_{ij} + \beta_{3ij} D_{ij} + \mu_j \tag{2}$$

Here X_{ij} represents a vector of covariates, both child-level (*i)* and mother-level (*j*), P_{ij} represents the use of prenatal care, and D_{ij} represents professional delivery assistance for each child.

Equation (1) can also be used to model the use of prenatal care and professional delivery assistance, which yields the following random intercept logistic regression equations:

$$\text{logit}\left\{\Pr(P_{ij}=1)\right\} = \beta_{ijp} Z_{ijp} + \zeta_{jp} \tag{3}$$

$$\text{logit}\left\{\Pr(D_{ij}=1)\right\} = \beta_{ijd} Z_{ijd} + \zeta_{jd} \tag{4}$$

In Equations (3) and (4), the probability that the i^{th} birth of the j^{th} woman has received prenatal care or professional delivery assistance is modeled as function of a vector of observed covariates Z and a mother-level unobserved heterogeneity term ζ .

***Step 2**: Multilevel Multiprocess Models to Account for Endogenous Selection Effects*

The random intercept logistic regression models depicted in Equations (2) to (4) can be used to establish the pattern and trend in the relationship between infant mortality, social conditions, and medical care use, while controlling for other variables. However, this modeling strategy suffers from several weaknesses. First of all, estimating the infant mortality model separately from the prenatal care and delivery assistance model precludes the possibility to separate and estimate the direct effect of mother's education on infant mortality from the indirect effect mediated through prenatal care and delivery assistance use. Second, the coefficient estimates for prenatal care and professional delivery assistance use in Equation (2) are likely to be biased by the presence of endogeneity; specifically, women should be more inclined to use prenatal care or medical delivery assistance if they foresee difficulties or problems during pregnancy or at delivery (Briscoe, Akin, and Guilkey 1990; Panis and Lillard 1995). In more technical terms, endogeneity refers to the situation where the decisions to use prenatal care and/or professional delivery assistance are correlated with the woman-level unobserved heterogeneity in the infant mortality equation (μ_j in Equations (1) and (2)). This situation violates a vital assumption of regression modeling that covariates must be uncorrelated with the error term, and can lead to biased estimates.

One way to address this endogeneity is to jointly estimate the infant mortality model (Equation 2) and the prenatal care and the professional delivery assistance models (Equations 3 and 4), while allowing the three unobserved heterogeneity terms, μ_j , ζ_{jp} , and ζ_{jd} to freely correlate (Panis and Lillard 1995; Skrondal and Rabe-Hesketh 2004). While the correlation between the unobserved heterogeneity components from the prenatal care equation (ζ_{jp}) and the professional delivery assistance equation (ζ_{jd}) is likely to be positive, the correlations between the unobserved heterogeneity component from the infant mortality equation (μ_j) and those from the prenatal care equation (ζ_{jp}) and the professional delivery assistance equation (ζ_{jd}) could be positive, negative, or zero. The sign and the magnitude of these correlations reveal important information about the relationship between infant mortality, prenatal care and professional delivery assistance use beyond what the included covariates can capture. Estimates of the effects of prenatal care and delivery assistance from the conventional single-equation models are unbiased only when these correlations are zero.

RESULTS

Descriptive Results

Table 1 presents descriptive statistics of variables used in the analyses. Means and standard deviations (in parentheses) or percentages are presented by the cohort of the infant's birth. Average educational attainment of the mothers of these infants almost doubled between 1970 and 2001, from about 3.8 years to about 7.3 years. The fraction of infants born to urban mothers increased slightly, from about 15 percent to about 19 percent. The majority of births in each cohort were first births, with a substantial minority of second births and small numbers of higher-order births. Prenatal care use was 3.5 times higher in the most recent birth cohort, at 77 percent, compared to the earliest cohort, at 22 percent of births. Professional medical assistance also rose dramatically from about one in four births in the 1970s to about two in three births in the late 1990s. This drastic increase in both prenatal care and professional delivery assistance use places the relationship between social conditions and infant mortality in a context of rapid technological change, crucial for our test of the fundamental cause argument.

Multivariate Results

Results from Single Equation Models

To provide a first look at the relationship between infant mortality and mother's education and urban residence, Table 2 reports results from three nested multilevel logistic regression models of infant mortality that include random intercept terms. We present unstandardized coefficients with standard errors in parentheses, and random effect components and model fit statistics are presented at the bottom of the table for each model. Model 1 includes all predictors except for prenatal care and professional delivery assistance use. We omit 1981-1985 as the reference cohort in all models because it marks the transitional cohort born at the beginning of the economic reform period and during the introduction of the one-child policy. Model 2 adds indicators of prenatal care use and professional delivery assistance to see how they influence the estimated association between infant mortality and our indicators of social conditions. Model 3 adds interaction terms between the child's birth cohort and mother's education, and between birth cohort and urban residence, to test for stability over time in the association between infant mortality and our markers of social status. Models 1 and 2 test Hypotheses 1(a) and 2(a) and will show support if mother's education and urban residence are significantly and negatively associated with infant mortality risk. Model 3 is a test of Hypotheses 1(b) and 2(b), and we will find support for these if the interactions between birth cohort and mother's education and urban residence are not statistically significant, indicating a stable relationship between social conditions and infant mortality risk during a period of immense social change.

Comparing Models 1 and 2 in Table 2 shows that mother's education and urban residence are significantly negatively associated with infant mortality, net of controls for prenatal care and professional delivery assistance, cohort of birth, and other key predictors. The lack of statistical significance of the interaction coefficients added in Model 3 shows that the associations between infant mortality and our measures of social conditions do not differ significantly over birth cohorts. The model fit statistics also suggest that Model 3 is the least preferred among all three models. The findings presented in Table 2 thus provide support for our first two sets of hypotheses. Models 1 and 2 also show that net of all other predictors, infant mortality risk was lower in 1986-1990 than in 1981-1985, the omitted category, but there are no other significant birth cohort differences (this finding is discussed further below). The use of prenatal care significantly decreases the log odds of infant mortality by 39%, but the use of professional delivery assistance is not associated with infant mortality in Models 2 and 3. The observed relationships between medical prenatal and delivery care and infant mortality accord with an earlier study using the same data (Chen, Xie, and Liu 2007).

Turning to the association between social conditions and the use of medical pregnancy care, Table 3 reports coefficients obtained from two sets of random intercept logistic regression models predicting prenatal care use (Models 4 and 5) and professional delivery assistance (Models 6 and 7). Models 4 and 6 provide the tests for hypotheses 3(a) and 4(a), and we will find support if mother's education and urban residence are significantly positively associated with prenatal care and professional assistance use. Models 5 and 7 test hypotheses 3(b) and 4(b), and will show support if the interactions between birth cohort and mother's education and urban residence show a significant increase in the association between social conditions and these forms of medical care use over the 1970-2001 period.

The results presented in Table 3 show that mother's education and urban residence are positively associated with prenatal care use and professional delivery assistance, and the association between mother's education and the use of both services increased for births occurring after 1985, relative to those in the early period of economic reforms and the introduction of the one-child policy. For example, manipulation of coefficients from Model 5 shows that net of overall changes over time in the use of prenatal care, a one year increase in mother's education increases the odds of prenatal care use by 50% in 1971-1980 (odds ratio = exp(0.43-0.02)), by 54% in 1981-1985, by 63% in 1986-1990, by 77% in 1991-1995, and by 90% in 1996-2001. Models 5 and 7 are preferred to Models 4 and 6 based on both AIC and BIC, but we fail to find support for

Hypothesis 4(b), as there is no significant change in the association between urban residence and the use of prenatal care or professional delivery over the 1970-2001 period. Moreover, while the advantage of urban women in obtaining professional delivery assistance was stable over most of this period, it actually began to decline in the late 1990s.

The remaining coefficients in Models 5 and 7 are in keeping with expectation. Importantly for our analysis, we find that net of all else a previous adverse pregnancy outcome significantly and substantially increases a mother's propensity to use prenatal care and delivery assistance. This suggests that women are more inclined to seek medical help if they expect difficulties with a specific pregnancy, indicating that indicators of prenatal care and delivery assistance use may be endogenous in models of infant mortality. Significant mother-level random components in the infant mortality, prenatal care, and professional delivery assistance models indicate non-ignorable mother-level clustering induced by unmeasured heterogeneity across women.[3]

Results from Jointly Estimated Models

In order to test hypotheses 5 and 6 and establish whether social conditions are a fundamental cause of infant survival because higher status people are more likely to take

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[3] We do not control for the child's sex in models of medical pregnancy care use because most mothers during this period did not know the sex of their child before birth, and hence, it should not have affected their use of these services. Sensitivity analyses show that including child's sex as predictor for prenatal care and professional delivery assistance use has little impact on coefficients for other covariates.

advantage of health promoting technology, we need to separate the direct effects of social conditions on infant mortality from the indirect effects mediated through prenatal care and delivery assistance use. Table 4 presents results from the jointly estimated multilevel multiprocess regression models, which are composed of the equations for infant mortality, prenatal care use, and professional delivery assistance. As discussed above, these equations are the same as those estimated separately in Models 3, 5 and 7, but here we allow the mother-specific unobserved heterogeneity components to correlate across equations. Hypothesis 5 will be supported if mother's education has a significant positive association with prenatal care and professional delivery assistance use, but is not directly associated with infant mortality. Similarly, Hypothesis 6 will be supported if urban residence has a significant positive association with prenatal care and delivery assistance use, but not with infant mortality, when we estimate the three equations jointly.

The results presented in Table 4 show that mother's education and urban residence no longer have any direct effects on infant mortality, after we control for their associations with prenatal care and delivery assistance use by using the jointly estimated model. Moreover, adjusting for endogeneity in the decision to use medical care also changes estimates of the associations of prenatal care and professional delivery assistance with infant mortality. Specifically, while professional delivery assistance was not associated with infant mortality in the single-equation Model 3, it is significantly protective in the joint model, and the estimated effect of prenatal care is more than three times as large in Model 8 as in Model 3. With regard to the fundamental cause argument, it is clear that in this Chinese context highly educated and urban women enhanced the survival chances of their infants mainly through greater use of effective medical pregnancy and delivery care.

The joint Model 8 also includes three new random effect parameters representing the correlations between the mother-specific unobserved heterogeneity terms in the equations predicting infant mortality, prenatal care use and professional delivery assistance. The positive and statistically significant correlation coefficients show that women who gave birth to infants at high risk of mortality were more likely to use both prenatal care (correlation = 0.43) and professional delivery assistance (correlation = 0.37). Taken together with the statistically significant coefficient associated with a previous adverse pregnancy outcome in models predicting prenatal care and professional delivery assistance (shown in Models 5 through 8), these positive correlation coefficients support the claim of the fundamental cause argument that individuals do not passively accept threats to health. Within the limits of their resources, they use knowledge and technological innovations to try to improve their health and the health of their families, particularly when the risk of poor outcomes is high (Briscoe, Akin, and Guilkey 1990).

As a sensitivity analysis, we focus on aspects unique to the Chinese context to assess whether they exert undue influence on our conclusions about the fundamental cause argument. Table 5 presents results from Model 9, a re-estimation of Model 8 with the analytic sample restricted to first and second births only and the addition of information about the older sibling’s sex, if the focal child has one. With these changes, we are able to focus on pregnancies that were likely to have occurred in compliance with the strict family planning policy; rural families, which make up the large majority of our sample, were frequently allowed to have a second child. As suggested by Short and

Zhang (2004), mothers were unlikely to have avoided prenatal care or delivery assistance for first or second births in order to escape fines or other sanctions. We can also examine whether and how son preference may have influenced the risk of infant mortality or the decision to use medical pregnancy care, net of the effects of the family planning policy, by comparing births that occurred first with those that occurred after there was already a daughter or son in the household.

Results for Model 9 are substantively unchanged from those reported in Model 8, suggesting that our main conclusions about the fundamental cause argument are not driven by the family planning policy imposed in China or the strong tradition of son preference that has become more salient with policy and macroeconomic changes in recent decades. Importantly though, we find that having an older brother rather than an older sister does not significantly increase the risk for mortality but it does change mother's choices about using medical pregnancy services. Women are much more likely to use prenatal care (odds ratio = 5.16) and delivery service (odds ratio = 8.00) for their first birth, compared with their likelihood of use for a second birth when a daughter is already present. Moreover, compared to pregnancies occurring after a daughter is present in the home, those occurring after a son is already present in the home are even less likely to receive prenatal care (odds ratio = 0.74) or delivery service (odds ratio = 0.83).These results suggest the influence of son preference on women's decisions to use medical pregnancy care, net of the obvious and more universal effects of higher birth order. Other important observations to be drawn from Table 5 relate to the pattern of cohort differences in infant mortality and in the association between urban residence and the use of prenatal care and professional delivery assistance. When considering only first and second births, the overall trend in infant mortality risk is clearer than in Model 8, with the highest rates of death in the 1970s, before and during the economic reforms, and lower rates in the early 1980s and thereafter. Considering the equations for the use of prenatal care and delivery assistance, the gap between rural and urban respondents began to decline in the most recent birth cohort, coinciding with the expansion of prenatal and delivery services through family planning agencies in the mid-to-late 1990s.

DISCUSSION

This study is the first direct empirical test of the fundamental cause argument that simultaneously investigates the associations between an indicator of health (infant mortality), indicators of social conditions (mother's education and urban residence), and measures of medical/technical intervening mechanisms that could underlie the relationship (medical prenatal care and delivery assistance). By jointly modeling the risk of infant mortality, use of prenatal care and use of professional delivery assistance, while correcting for endogenous selection bias, we are also able to build on prior tests by assessing the different components of the fundamental cause argument simultaneously. Moreover, we test the argument using data from China, an entirely different social context compared to the extant studies using Western industrialized countries as cases, and one that saw massive social, economic, and political change over the period considered here. We are thus able to provide a particularly strong test of the core element of the fundamental cause argument: that the association between social conditions and health will re-emerge even when the mechanisms underlying it change.

We use mother's education and urban residence as central indicators of social conditions because they represent distinctive type of resources and may influence infant mortality differently in China than elsewhere. While U.S. researchers generally have not considered urban residence a crucial component of social status, the explicit residential restriction policy and differential investment favoring urban areas mean that the urban-rural divide is one of the crucial stratifying characteristics in contemporary China. Our results show that urban children and those born to highly educated mothers have a significant and stable survival advantage despite massive social and macroeconomic changes from 1970 to 2000 in China. A dramatic population-wide increase in the use of prenatal care and professional delivery assistance between 1970 and 2001 did not weaken the association between social conditions and infant mortality, despite the high effectiveness of both interventions in reducing mortality. Instead, better educated Chinese women were more able to take advantage of these medical interventions, and their advantage actually increased over the 1970-2001 period.

Rural children's disadvantage in infant mortality risk also appears to be generated by greater use of prenatal care and professional delivery assistance in urban versus rural areas, but the advantage of urban children did not increase over time in the same way that the advantage of those born to educated women did. The urban-rural difference in medical care usage is probably largely determined by differences in availability of services. Availability and accessibility of prenatal care and professional delivery assistance are driven by policy decisions regarding public health infrastructure investments, such as the economic reforms of the late 1970s that eliminated subsidized preventive care for most rural residents. The decline in the rural/urban difference in medical pregnancy services use that we observe for the most recent birth cohort of the late 1990s could also reflect policy change leading to changes in access, as it coincides with the introduction of more prenatal and birth assistance services to the services provided by family planning agencies after the mid 1990s. These findings suggest that the advantage associated with urban residence is much more sensitive to macro social changes than the advantage associated with mother's education, especially those policy changes with implications for public health expenditure allocation between urban and rural populations. These findings support our argument that distinctive measures of social conditions should be examined and the different mechanisms through which they may work, or may show changes in influence over time or across contexts, deserve further empirical attention.

Our modeling strategy also provides novel results and implications for future research on the predictors of infant mortality. By comparing results from the jointly estimated equations in the multilevel multiprocess model against results from single equation models, we are able to show that the statistically significant effect of mother's education on infant mortality arises because traditional models cannot separate the indirect effect (channeled through prenatal care and delivery assistance use) from the direct effect of mother's education, and do not adequately control for the endogeneity of decisions to use medical pregnancy services. Taken together, our results suggest that the widely used single-equation approach to modeling the risk of infant mortality may have led to underestimates in previous studies of the contribution of prenatal care and professional delivery assistance to reducing infant mortality. For example, using rural residents from the same sample used in our study and standard regression models that do not address the issue of endogeneity, Chen, Xie, and Liu (2007) report that the use of prenatal care significantly reduces infant mortality risk (odds ratio = 0.68), but the use of professional delivery assistance does not (odds ratio = 1.11, not statistically significant). For the purpose of comparison, we re-estimated our multilevel multiprocess model (Model 8) using only rural residents, and counter to the results of Chen and colleagues, we found significant effects of prenatal and professional delivery assistance use on infant mortality, with coefficients quite consistent with those shown in Tables 4 and 5.

This study is also the first to put the fundamental cause argument to a test outside a Western industrialized societal context, in the drastically different social and cultural context of China. Given the massive social engineering to reduce social inequality during the Cultural Revolution of the 1966-1976 followed by equally momentous reforms leading to strong economic growth but rising inequality in the 1980s and 1990s, the supportive evidence presented in this study indicates the wide applicability and explanatory potential of the fundamental cause argument as a general sociological framework to understand persistent social disparities in health. At the same time, our sensitivity analysis also shows the importance of considering context-specific details when applying the fundamental cause argument in a particular social-historical context. Most centrally, effects of the son preference tradition in China are evident in models predicting prenatal care use and professional delivery assistance, with second pregnancies occurring after a son has already been born receiving less medical pregnancy care than those occurring after a daughter has already been born and parents are still hoping for a son.

Despite its strengths, the data we use here has several limitations that should be considered when interpreting our results. Like many studies, we rely on cross-sectional data and retrospective reports about births and the use of medical pregnancy care. This means that only those women who survived to the date of survey interview will have their fertility history recorded and only those births are included in our analyses. In theory, recall bias may be an issue for women reporting on births that occurred years ago, and policies surrounding family planning restrictions could cause women to omit information about out-of-plan births, although misreporting due to policy restrictions has been shown to be much less severe than one would expect (Zhang and Zhao 2006). Given our argument for enumerating multiple dimensions of social conditions to adequately explore the fundamental cause argument, it is unfortunate that these data do not provide good information on mothers' income, wealth or occupations, which are important markers of social status and could make unique contributions to infant mortality risk. We also lack detailed information on the specific family planning restrictions particular women faced and the access they had to high quality medical services, as these varied across time and space over the period covered here. Our focus on urban residence and mother's education certainly captures some of these unmeasured characteristics, but future work using other data sources could continue to refine the work we have begun here.

The fundamental cause argument provides a distinctively sociological framework to explain social disparities in health. In this paper we have contributed to the further development of the fundamental cause argument by elaborating and justifying the use of multiple indicators of social conditions, and by directing more attention to the intervening mechanisms that link different types of social advantage to infant mortality. We also provide the first fully integrated empirical test of the fundamental cause argument in the context of a rapidly changing society, examining the associations between social conditions and infant mortality and exploring the way that intentional and differential use of emerging medical technology reproduces the persistent social gradient in infant survival. Our findings suggest that due to the fundamental advantages associated with better education and urban residence, continued rapid economic growth and public health improvements in China are unlikely to solve the problem of social disparities in infant mortality rates, and any effective public health policies must be part of larger and comprehensive social policies promoting equity in household socioeconomic standing across the nation.

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Table 1. Descriptive Information for Study Variables by Birth Cohort.

	1970-1980	1981-1985	1986-1990	1991-1995	1996-2001
Mother's Education (years)	3.76 (3.93)	5.52 (4.33)	6.28 (4.03)	6.75 (3.83)	7.32 (3.77)
Urban Residence (%)	15	18	16	18	19
Ethnic Minority (%)	8	10	10	12	13
Male (%)	51	53	53	55	56
Mother's Age at Childbirth (years)	23.21 (2.57)	25.01 (3.23)	25.15 (3.93)	25.10 (3.78)	26.03 (3.91)
First Birth (%)	59	55	48	58	63
Second Birth (%)	30	29	33	29	30
Third Birth (%)	9	11	13	9	5
Fourth or Higher Birth (%)	2	4	5	4	2
Prenatal Care Use (%)	22	37	48	62	77
Professional Delivery (%)	24	35	41	52	67
Previous Adverse Pregnancy Outcome (%)	4	5	5	5	7
Number of Infant Deaths	228	205	194	154	131
N.	9,245	11,744	15,934	10,997	8,911

Note: Standard deviations in parentheses.
Source: 2001 National Family Planning and Reproductive Health Survey, China.

Table 2. Unstandardized Coefficients from Random Effect Logistic Regression Models of Infant Mortality.

	Model 1	Model 2	Model 3
Fixed Effects			
Birth Cohort[1]			
1971-1980	0.18	0.16	0.74
	(0.11)	(0.11)	(0.40)
1986-1990	-0.37***	-0.34**	-0.08
	(0.11)	(0.11)	(0.44)
1991-1995	-0.22	-0.16	0.20
	(0.12)	(0.12)	(0.47)
1996-2001	-0.05	0.06	0.45
	(0.13)	(0.13)	(0.51)
Mother's Education	-0.06***	-0.05***	-0.03
	(0.01)	(0.01)	(0.02)
Urban Residence	-0.34*	-0.30*	-0.51
	(0.14)	(0.14)	(0.28)
Ethnic Minority	0.74***	0.70***	0.70***
	(0.10)	(0.11)	(0.11)
Male	-0.04	-0.03	-0.03
	(0.07)	(0.07)	(0.07)
Mother's Age at Childbirth	-0.09***	-0.08***	-0.08***
	(0.01)	(0.01)	(0.01)
Birth Order[2]			
Second Birth	0.21*	0.17	0.17
	(0.09)	(0.09)	(0.09)
Third Birth	0.29*	0.23	0.23
	(0.13)	(0.13)	(0.13)
Fourth and Above	0.68***	0.60**	0.60***
	(0.18)	(0.18)	(0.18)

(Table 2 continued below)

Table 2, Continued. Unstandardized Coefficients from Random Effect Logistic Regression Models of Infant Mortality.

	Model 1	Model 2	Model 3
Prenatal Care		-0.39***	-0.39***
		(0.10)	(0.10)
Professional Delivery Assistance		0.04	0.05
		(0.09)	(0.09)
1971-1980 × Mother's Education			-0.06
			(0.03)
1986-1990 × Mother's Education			-0.03
			(0.03)
1991-1995 × Mother's Education			-0.02
			(0.03)
1996-2001 × Mother's Education			-0.04
			(0.03)
1971-1980 × Urban Residence			0.42
			(0.38)
1986-1990 × Urban Residence			0.12
			(0.41)
1991-1995 × Urban Residence			0.31
			(0.41)
1996-2001 × Urban Residence			0.20
			(0.45)
Constant	-2.46***	-2.50***	-2.85***
	(0.37)	(0.37)	(0.46)
Random Effect			
σ	1.51***	1.54***	1.53***
	(0.10)	(0.10)	(0.10)
N	56831	56831	56831
AIC	8840.03	8826.67	8837.92
BIC	8965.30	8969.83	9052.67

Note: Standard errors in parentheses.
[1]The reference category is 1981-1985.
[2]The reference category is the first birth.
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$
Source: 2001 National Family Planning and Reproductive Health Survey, China.

Table 3. Unstandardized Coefficients from Random Effects Logistic Regression Models for Prenatal Care and Professional Delivery Assistance Use.

	Prenatal Care Use		Professional Delivery Assistance	
	Model 4	Model 5	Model 6	Model 7
Fixed Effects				
Birth Cohort[1]				
1971-1980	-1.27*** (0.08)	-1.52*** (0.26)	-0.91*** (0.08)	-1.25*** (0.25)
1986-1990	1.28*** (0.06)	1.19*** (0.23)	0.79*** (0.06)	0.59** (0.23)
1991-1995	2.71*** (0.08)	2.04*** (0.29)	1.73*** (0.08)	1.23*** (0.29)
1996-2001	4.48*** (0.11)	2.65*** (0.37)	3.25*** (0.10)	1.28*** (0.35)
Mother's Education	0.50*** (0.01)	0.43*** (0.02)	0.30*** (0.01)	0.24*** (0.01)
Urban Residence	2.52*** (0.11)	2.58*** (0.16)	5.06*** (0.13)	5.26*** (0.18)
Ethnic Minority	-1.99*** (0.12)	-1.93*** (0.12)	-2.47*** (0.12)	-2.41*** (0.12)
Mother's Age at Childbirth	0.12*** (0.01)	0.12*** (0.01)	0.20*** (0.01)	0.20*** (0.01)
Birth Order[2]				
Second Birth	-1.61*** (0.05)	-1.62*** (0.05)	-2.04*** (0.06)	-2.04*** (0.06)
Third Birth	-2.25*** (0.09)	-2.24*** (0.09)	-3.01*** (0.09)	-3.00*** (0.09)
Fourth and Above	-2.97*** (0.14)	-2.90*** (0.14)	-3.88*** (0.15)	-3.83*** (0.15)

(Table 3 continued below)

Table 3, continued. Unstandardized Coefficients from Random Effects Logistic Regression Models for Prenatal Care and Professional Delivery Assistance Use.

	Prenatal Care Use		Professional Delivery Assistance	
	Model 4	Model 5	Model 6	Model 7
Previous Adverse Pregnancy Outcomes	0.58*** (0.13)	0.59*** (0.13)	0.58*** (0.12)	0.59*** (0.12)
1971-1980 × Mother's Education		-0.02 (0.02)		0.01 (0.02)
1986-1990 × Mother's Education		0.06*** (0.02)		0.03* (0.02)
1991-1995 × Mother's Education		0.14*** (0.02)		0.08*** (0.02)
1996-2001 × Mother's Education		0.21*** (0.03)		0.17*** (0.02)
1971-1980 × Urban Residence		-0.34 (0.23)		-0.33 (0.23)
1986-1990 × Urban Residence		0.28 (0.20)		-0.03 (0.20)
1991-1995 × Urban Residence		0.23 (0.25)		0.01 (0.25)
1996-2001 × Rural Residence		-0.59 (0.31)		-0.96** (0.30)
Constant	-6.04*** (0.29)	-5.58*** (0.32)	-5.23*** (0.28)	-4.90*** (0.29)
Random Effect				
σ	4.41*** (0.04)	4.41*** (0.03)	4.01*** (0.04)	4.01*** (0.04)
N	56831	56831	56831	56831
AIC	48556.30	48471.16	49829.41	49786.35
BIC	48681.57	48668.01	49954.68	49947.41

Note: Standard errors in parentheses.

[1]The reference category is 1981-1985.
[2]The reference category is the first birth.
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$
Source: 2001 National Family Planning and Reproductive Health Survey, China.

Table 4. Unadjusted Coefficients from Multilevel Multiprocess Random Effects Logistic Regression Models for Infant Mortality, Prenatal Care Use, and Professional Delivery Assistance Use

	Model 8		
	Infant Mortality	Prenatal Care Use	Professional Delivery Assistance
Fixed Effect			
Birth Cohort[1]			
1971-1980	0.64	-1.62 ***	-1.24 ***
	(0.40)	(0.29)	(0.26)
1986-1990	-0.03	1.32 ***	0.62 ***
	(0.42)	(0.25)	(0.22)
1991-1995	0.25	2.22 ***	1.25 ***
	(0.44)	(0.30)	(0.28)
1996-2001	0.49	2.86 ***	1.37 ***
	(0.51)	(0.37)	(0.35)
Mother's Education	0.02	0.48 ***	0.27 ***
	(0.02)	(0.02)	(0.01)
Urban Residence	-0.07	2.75 ***	5.34 ***
	(0.27)	(0.18)	(0.19)
Ethnic Minority	0.47 ***	-2.08 ***	-2.50 ***
	(0.11)	(0.13)	(0.12)
Male	-0.01		
	(0.07)		
Mother's Age at Childbirth	-0.07 ***	0.12 ***	0.20 ***
	(0.01)	(0.01)	(0.01)
Birth Order[2]			
Second Birth	0.04	-1.64 ***	-2.00 ***
	(0.09)	(0.06)	(0.06)
Third Birth	0.06	-2.28 ***	-2.94 ***
	(0.13)	(0.09)	(0.09)
Fourth and Above	0.38 *	-3.00 ***	-3.79 ***
	(0.18)	(0.14)	(0.13)

(Table 4 continued below)

Table 4, continued. Unadjusted Coefficients from Multilevel Multiprocess Random Effects Logistic Regression Models for Infant Mortality, Prenatal Care Use, and Professional Delivery Assistance Use

	Model 8		
	Infant Mortality	Prenatal Care Use	Professional Delivery Assistance
Prenatal Care	-1.30 ***		
	(0.14)		
Professional Delivery Assistance	-0.65 ***		
	(0.13)		
Previous Adverse Pregnancy Outcomes		0.56 ***	0.56 ***
		(0.13)	(0.12)
1971-1980 * Mother's Education	-0.06	-0.02	0.01
	(0.03)	(0.02)	(0.02)
1986-1990 * Mother's Education	-0.03	0.06 ***	0.03 *
	(0.03)	(0.02)	(0.02)
1991-1995 * Mother's Education	-0.01	0.14 ***	0.08 ***
	(0.03)	(0.02)	(0.02)
1996-2001 * Mother's Education	-0.03	0.21 ***	0.16 ***
	(0.03)	(0.03)	(0.02)
1971-1980 × Urban Residence	0.41	-0.43	-0.35
	(0.37)	(0.26)	(0.24)
1986-1990 × Urban Residence	0.11	0.38	0.03
	(0.38)	(0.22)	(0.21)
1991-1995 × Urban Residence	0.17	0.31	0.08
	(0.39)	(0.26)	(0.25)
1996-2001 × Urban Residence	-0.13	-0.60	-0.85 **
	(0.45)	(0.32)	(0.31)
Constant	-2.50 ***	-5.94 ***	-4.83 ***
	(0.42)	(0.34)	(0.31)

(Table 4 continued below)

Table 4, continued. Unadjusted Coefficients from Multilevel Multiprocess Random Effects Logistic Regression Models for Infant Mortality, Prenatal Care Use, and Professional Delivery Assistance Use

	Model 8		
	Infant Mortality	Prenatal Care Use	Professional Delivery Assistance
Random Effect			
σ_1	1.61 ***		
	(0.08)		
σ_2		4.72 ***	
		(0.09)	
σ_3			4.10 ***
			(0.07)
ρ_{12}	0.43 ***	0.43 ***	
	(0.03)	(0.03)	
ρ_{13}	0.37 ***		0.37 ***
	(0.03)		(0.03)
ρ_{23}		0.39 ***	0.39 ***
		(0.01)	(0.01)

Note: Standard errors in parentheses.
[1]The reference category is 1981-1985.
[2]The reference category is the first birth.
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$
Source: 2001 National Family Planning and Reproductive Health Survey, China.

Table 5. Unstandardized Coefficients from Multilevel Multiprocess Random Effects Logistic Regression Models for Infant Mortality, Prenatal Care Use, and Professional Delivery Assistance Use, Using only First and Second Births.

	Model 9		
	Infant Mortality	Prenatal Care Use	Professional Delivery Assistance
Fixed Effect			
Birth Cohort[1]			
1971-1980	1.12 *	-1.64 ***	-1.54 ***
	(0.51)	(0.32)	(0.34)
1986-1990	0.39	1.19 ***	0.35
	(0.24)	(0.28)	(0.26)
1991-1995	0.68	2.19 ***	1.05 ***
	(0.57)	(0.34)	(0.31)
1996-2001	0.90	2.70 ***	0.98 *
	(0.62)	(0.41)	(0.38)
Mother's Education	0.04	0.47 ***	0.25 ***
	(0.03)	(0.02)	(0.02)
Urban Residence	-0.26	2.89 ***	5.62 ***
	(0.36)	(0.19)	(0.21)
Ethnic Minority	0.42 **	-2.04 ***	-2.47 ***
	(0.14)	(0.14)	(0.13)
Male	0.04		
	(0.09)		
Mother's Age at Childbirth	-0.07 ***	0.15 ***	0.24 ***
	(0.01)	(0.01)	(0.01)
Sibling[2]			
First birth	-0.03	1.64 ***	2.08 ***
	(0.12)	(0.07)	(0.07)
Second birth with elder brother	-0.16	-0.31 ***	-0.18 *
	(0.12)	(0.07)	(0.08)

(Table 5 continued below)

Table 5, continued. Unstandardized Coefficients from Multilevel Multiprocess Random Effects Logistic Regression Models for Infant Mortality, Prenatal Care Use, and Professional Delivery Assistance Use, Using only First and Second Births.

	Model 9		
	Infant Mortality	Prenatal Care Use	Professional Delivery Assistance
Prenatal Care	-1.72 ***		
	(0.20)		
Professional Delivery Assistance	-0.85 ***		
	(0.19)		
Previous Adverse Pregnancy Outcomes		0.58 ***	0.49 ***
		(0.15)	(0.14)
1971-1980 * Mother's Education	-0.07	-0.02	0.02
	(0.04)	(0.02)	(0.02)
1986-1990 * Mother's Education	-0.03	0.07 ***	0.05 **
	(0.04)	(0.02)	(0.02)
1991-1995 * Mother's Education	-0.03	0.16 ***	0.10 ***
	(0.04)	(0.03)	(0.02)
1996-2001 * Mother's Education	-0.06	0.23 ***	0.20 ***
	(0.04)	(0.03)	(0.03)
1971-1980 × Urban Residence	0.86	-0.40	-0.46
	(0.47)	(0.29)	(0.27)
1986-1990 × Urban Residence	0.41	0.21	-0.22
	(0.47)	(0.24)	(0.23)
1991-1995 × Urban Residence	0.39	0.13	-0.15
	(0.49)	(0.29)	(0.27)
1996-2001 × Urban Residence	-0.10	-0.93 **	-1.22 **
	(0.54)	(0.34)	(0.33)
Constant	-3.18 ***	-6.59 ***	-5.34 ***
	(0.57)	(0.38)	(0.34)

(Table 5 continued below)

Table 5, continued. Unstandardized Coefficients from Multilevel Multiprocess Random Effects Logistic Regression Models for Infant Mortality, Prenatal Care Use, and Professional Delivery Assistance Use, Using only First and Second Births.

Random Effect			
σ_1	2.05 ***		
	(0.11)		
σ_2		4.76 ***	
		(0.10)	
σ_3			4.20 ***
			(0.09)
ρ_{12}	0.47 ***	0.47 ***	
	(0.05)	(0.05)	
ρ_{13}	0.39 ***		0.39 ***
	(0.05)		(0.05)
ρ_{23}		0.39 ***	0.39 ***
		(0.01)	(0.01)

Note: Standard errors in parentheses.
[1]The reference category is 1981-1985.
[2]The reference category is the second birth with an older sister.
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$
Source: 2001 National Family Planning and Reproductive Health Survey, China.