APPROPRIATELY ASSESSING THE EFFECTIVENESS OF PREGNANCY CARE IN REDUCING INFANT MORTALITY: EVIDENCE FROM CHINA, INDIA, AND SOUTH AFRICA

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ABSTRACT
Statistical efforts to assess the effectiveness of medical pregnancy care for reducing infant mortality have resulted in mixed findings. We focus on the way that adverse or positive selection can obfuscate the true association between medical pregnancy care use and infant mortality risk. We focus on identifying these biases and exploring the relative effectiveness of different statistical methodologies in reducing the bias. Using data on recent births from China, India, and South Africa in the 1990s, we estimate and compare mother-level random effect models, mother-level fixed effect models, joint mother-level random effect models (the multilevel multiprocess model), and propensity score matching. Selection bias is a substantive issue without a single best statistical solution; using the specific example of medical pregnancy care and infant mortality, we compare the performance of these of statistical corrections across very different societal contexts and examine the extent to which pregnancy care effectively promotes infant survival.

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INTRODUCTION

Reducing infant mortality has been a major public policy goal worldwide, and various forms of pregnancy care have been introduced and funded aggressively to achieve that goal. Major elements of medical pregnancy care include prenatal care services and medical delivery assistance. Prenatal care can identify women at increased risk of adverse pregnancy outcomes, provide advice to improve women's well being and the fetal environment during the pregnancy, and help to establish good relations between women and health care providers (Magadi, Madise and Rodrigues 2000). Adequate delivery care can reduce the risk of child deaths due to anoxia, hypoxia, and other respiratory conditions, reduce neonatal infections, and improve the survival of preterm and low birth weight babies (Victora and Barros 2001). Delivery assistance from a trained and well-equipped medical provider may also reduce the risk of maternal mortality (Maine and Rosenfield 1999). Despite these potentially positive effects of pregnancy care, statistical efforts to assess its effectiveness for reducing infant mortality often yield counterintuitive results. For example, Chen et al. (2007) reported that while prenatal care significantly reduced infant mortality risk (odds ratio = 0.68), professional delivery assistance did not improve the survival of Chinese infants over the last several decades (odds ratio = 1.11, non-significant). By contrast, using the same sample but different statistical methodology, Song and Burgard (2008) reported that both prenatal care (odds ratio = 0.27) and professional delivery assistance (odds ratio = 0.52) significantly reduced the risk of infant mortality. In this paper we use a variety of modeling strategies to explore and appropriately address selection mechanisms that may obfuscate our ability to assess the effectiveness of medical care for improving infant survival.

The key to understand the disagreement between the results of Chen and colleagues (2007), who found no effect of professional delivery assistance on infant survival, versus those of Song and Burgard (2008), who found a protective effect, lies in the potential (positive or adverse) selection processes that may influence the observed relationship between medical pregnancy service use and infant mortality risk, net of any actual effects that the former may have on the latter. Positive selection occurs when women who are socioeconomically advantaged, and whose infants thus already have a survival advantage, are also more likely than less advantaged mothers to obtain high quality pregnancy care (Jeffrey et al. 2000). The problem of positive selection is relatively simple to address, by using adequate controls for mothers' socioeconomic status and health so that an artificial association between the use of medical pregnancy care and infant survival does not arise.

In the case considered here, however, the relationship between professional delivery assistance (and to a less extent, prenatal care) and infant mortality was obfuscated by adverse selection processes that illustrate the concept of endogeneity. Given the expense of medical care and limited economic resources of many households, many Chinese mothers' decisions to use medical pregnancy care were likely dependent on their knowledge about the likelihood of experiencing difficulties in delivery or the likelihood of having adverse birth outcomes (Briscoe, Akin and Guilkey 1990; Panis and Lillard 1995). Investigators often do not have access to women's private knowledge of their likely pregnancy and delivery risks, and using "naïve" statistical methods that do not take this endogeneity bias into consideration violates important assumptions underlying most statistical estimation procedures. A key assumption violated here is that covariates like the decision to use prenatal care must not be correlated with random components in the model. If we do not explicitly controlling for women's private knowledge of their own level of risk, this element enters the random component in the statistical model and thus produces a strong correlation with pregnancy care use. By contrast, the multilevel multiprocess model used by Song and Burgard effectively corrects for the endogeneity bias by jointly estimating the model predicting infant mortality and the models predicting pregnancy care use, while allowing the random components of the infant mortality equation and those of the pregnancy care equations freely to correlate.

The multilevel multiprocess approach has been used to study infant mortality in other social contexts (Panis and Lillard 1995) as well as to examine other demographic phenomena, including contraceptive choice and discontinuation (Steele and Curtis 2003; Steele et al. 2005). However, it is not the only statistical choice appropriate to address endogeneity. A variety of methods have been employed in the past including the instrumental variable method (Ware 1984), fixed effect models, and propensity score matching. In this paper, we focus on the endogeneity inherent in the association between medical pregnancy care use and infant mortality risk to identify its nature, magnitude, and to elucidate the relative effectiveness of different statistical methodologies in handling the problem. Building on the results presented by Song and Burgard (2008) for China in the 1990s, we add two additional samples of pregnancies and births in 1990s India and South Africa to explore the robustness of these processes. For each of these countries we estimate and compare a series of models: a mother-level random effect model, a mother-level fixed effect model, joint mother-level random effect models (the multilevel multiprocess model), and propensity score matching. We aim to demonstrate that endogeneity bias is a substantive issue that does not have one single best statistical solution. In the absence of adequate data, as is the case for most population data sources used to study infant mortality, a range of statistical corrections may need to be applied and the results compared to best understand the effectiveness of medical interventions used to improve survival.

DATA AND METHODS

Data

We use several sources of data to explore the effectiveness of pregnancy care in improving infant survival. Comparing results across the very different social contexts of China, India, and South Africa improves our confidence in the robustness of the substantive relationship as well as the appropriateness of various modeling strategies for addressing issues of endogeneity. These nations all provide heterogeneous populations with considerable socioeconomic stratification and inequality in access to, and use of, medical pregnancy care. All three samples include retrospective pregnancy/fertility histories for reproductive-aged women, with detailed information recorded for multiple pregnancies/births.

For China 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 NFPRHS utilized a stratified multistage clustered sample to collect information from 39,586 women aged 15-49 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 and information about the use of medical pregnancy care for each. We use a total of 19,060 live births from 15,035 Chinese women.[1] Data from India are obtained from the 1998-1999 National Family Health Survey (NFHS-2) of India, conducted under the auspices of the Demographic and Health Survey series. This was the second of three large,

[1] 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 et al. 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 ensures 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 household registration data, Census, 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 survey of population change yielded the best possible enumeration and highly consistent results.

nationally-representative surveys designed to understand the health status of the entire population.[2] Within each state of India, a two-stage stratified random sampling design was used in all rural areas (villages, households) and a three-stage design was used in urban areas (cities/towns, urban blocks, households). The NFHS-2 collected information from more than 90,000 ever married women aged 15 to 49 and covered 99 percent of India's population living in all states of the nation. Detailed questions about prenatal care and delivery assistance were asked for the two most recent pregnancies since January 1995. We use a total of about 33,026 births from 28,978 women. South African data were obtained from the 1998 SADHS, conducted with technical assistance from Measure DHS and available as part of the Demographic and Health Survey project (Department of Health of South Africa and Macro International 2003). The SADHS used a multistage, clustered sampling frame stratified by province and by urban or nonurban area, based on the one used for the 1996 South African census.[3] Of the 12,327 eligible women aged 15 to 49, 11,735 were interviewed and were asked detailed questions about all pregnancies since January 1993. We use a total of about 5,066 births from 4,148 women in our analysis.

Measures

Infant mortality

Our outcome measure is infant mortality, coded so that 0 = survived first 12 months of life, and 1 = died before reaching age 12 months. Since the direct impact of medical pregnancy care on infant mortality likely wanes as the infant is exposed to more influences after birth and as she or he ages, for the Indian and South African samples we also conduct sensitivity analyses using more specific outcomes: neonatal mortality (death in the first seven days of life) and postneonatal mortality (death in the first month of life). Information on date of death is not available in the Chinese sample.

Medical Pregnancy Care

Our key independent variables are measures of prenatal care and professional delivery assistance. For the Chinese NFPRHS sample, 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). For the Chinese sample, 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. For the Indian and South African samples, the same DHS women's survey instrument was used. Women are classified as having received prenatal care if they reported receiving antenatal care from a doctor or nurse/midwife. We will also explore using other items that were asked for each birth, including where women received antenatal care, how many visits they made and when in the pregnancy care was initiated, and whether they received a tetanus shot as part of their antenatal care, to make the indicator of prenatal care as similar as possible to the indicator for the Chinese sample. To inquire about professional delivery assistance, Indian and South African women were asked who assisted with the delivery of the child; a doctor is considered a professional, while nurses and midwives are classified together in the DHS survey. We will experiment with different ways of coding this variable to achieve the most similar measurement with the Chinese sample, including the addition of information about where the birth took place.

[2] In the most recent NFHS (2005-2006), information about medical pregnancy care was collected only for the most recent birth, precluding the use of many of the methods we employ here, so we used the 1998-1999 sample. This choice has the added benefit of representing a historical period that overlaps with those of the other two samples used here, improving the comparability of results.

[3] In addition, the Eastern Cape Province was stratified into five health regions, with each health region stratified into urban and nonurban areas.

Controls
We include controls for mother's education, a key measure of her socioeconomic status, mother's age, and her place of residence, as well as an indicator of any previous experiences with pregnancy or birth difficulties. We also add controls for the child's birth order and sex. Other measures of mother's SES will also be explored, including asset indexes that reflect ownership of consumer durables.

Analytic Methods
We will pursue a variety of methods designed to address issues of adverse selection, or endogeneity in the relationship between medical pregnancy care use and infant mortality risk. First, for each sample we will estimate "naïve" logistic regression models predicting infant mortality, including indicators of prenatal care and professional delivery assistance as additive covariates. These models will provide a baseline against which to compare our range of corrections for adverse selection. We will then use the following series of models, estimated using Stata 10SE or aML:

a) Single equation random effect models: includes a random term to adjust for the clustering of births within mothers, but do not control for the potential endogeneity of the decision to use medical pregnancy care and thus are vulnerable to biased estimates.
b) Fixed effect models: more robust because they do not rely on the normality assumption, but have several downsides. The effects of mother-level covariates cannot be identified, and the effective sample size shrinks significantly because all singleton births are excluded from the estimation procedure, as well as all multiple births if they do not differ on the use of pregnancy care.
c) Joint random effect models: rely on large sample of women with multiple births and the normality assumption; the model identification, however, does not hinge on the existence of sensible instrumental variables and thus provides an extremely flexible and generally applicable framework to deal with the endogeneity bias issue.
d) Propensity score matching: balances the group receiving pregnancy care and the group not receiving pregnancy care on observable characteristics but not on unobservables. This is in theory is a problem for the purpose of correcting for endogeneity bias; but will be addressed by including many covariates in the matching process, especially information related to a woman's risk of difficulties during pregnancy or at delivery. For example, a possible matching variable is an indicator of whether a woman experienced a stillbirth or miscarriage prior to the focal birth. Such experiences serve as indicators of unobserved mother-level characteristics, health conditions and genetic predisposition to adverse pregnancies.

EXPECTED RESULTS
Based on our findings using the Chinese NFPRHS sample (Song and Burgard 2008), we expect that comparing results from the multilevel, multiprocess model against results from more naive models will show that the impact of medical pregnancy care on infant mortality risk is underestimated when the impact of women's private knowledge about their own health and pregnancy histories on their choice to use these medical services is ignored. We suspect that results obtained when using propensity score matching may also provide similar results to those obtained from the multilevel multiprocess models, but at this time do not have a prediction about how results from these two strategies will compare with those obtained from fixed effects specifications. It may be difficult to estimate fixed effects models due to sample size limitations, though the large Indian sample offers the best possibility for this strategy.

We further expect to find that medical prenatal and delivery care decreases the risk of infant mortality in all three societies under investigation. These findings are crucially important in an environment of limited resources – if we are correct, it will suggest that investments in these interventions should be bolstered or at least maintained. If we find that these interventions are ineffective, or not as effective as believed, as suggested in some earlier studies, then other investments in basic infrastructure, nutrition, and social and economic inequality may be more effective in improving infant survival and population well-being. Our results will have broader implications for many central demographic questions about the effectiveness of interventions, as the use of these interventions, like medical care, is never random in socially stratified societies.

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