Demand for Immunization, Parental Selection, and Child Survival

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ABSTRACT

This study focuses on the estimation of household demand for immunization as well as its technological effect on the survival probability of a child in rural India. Careful attention is paid to the consequences of parental selection and heterogeneity on survival technology. The results suggest that child mortality is negatively related to the likelihood of purchasing vaccination, but imperfect vaccination substantially reduce the beneficial effect. Results also suggest that mothers with a high risk of child mortality engage in compensatory behavior and ignoring this first type selection underestimates the impact of immunization on child survival. However, mothers also engage in complementary behavior by reinforcing endowments when they choose among different health inputs. The second type selection mitigates the effect of the first type of selection.

JEL Classification: I12, J13
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I. Introduction

Over the last two decades, immunization has been a major focus of child survival programs throughout the world. In fact, several studies have focused on the effect of immunization on health outcomes. Most of them, however, did not explicitly account for the problem caused by family's dynamic decision. Expectant families observe signals on the likelihood of child death. These signals then affect subsequent behavior of families which in turn affects the likelihood of child's death. When this kind of dynamic behavior is ignored, regression estimates no longer have a simple interpretation and may provide misleading estimates of the causal relationships among demand for health inputs and its health outcomes.

The goal of this study is to estimate an immunization demand function and the impact of immunization on the probability of child survival using a household production framework. In order to achieve the goal, the study addresses the following issues. First, careful attention is paid to issues of consequences of parental selection on survival technology. Several researchers have pointed out that a mother's prenatal health care is dependent upon the risk of child mortality (Panis and Lillard, 1994; Rosenzweig and Schultz, 1991; Rosenzweig and Wolpin, 1988; Rosenzweig, 1986; Harris, 1983). Likewise, postnatal health care for children might be conditioned on whether a mother with high risk of child mortality is more likely to vaccinate her children, engaging in *compensatory* behavior. A mother's selection of child immunization might be also conditioned on birth outcome and histories of disease occurrence to their child, since parents will adjust their behavior to the production of child survival when they observe these.[1] Furthermore, it is probable that a mother who is favorable to prenatal care might also be

[1] It is also noteworthy that the World Health Organization recommends high immunization priority to less healthy children (WHO, 1986).

more likely to obtain postnatal care, engaging in *complementary* behavior. Given a child's mortality in various biological determinants, these selections influence observed mortality, since a child's immunization coverage will depend on the family's selection of health inputs. The model and estimation techniques adopted in this paper accounts for the underlying selections which bias the estimation results.

The study also addresses the issue of partial (imperfect) immunization due to either dropout or skipped vaccinations, i.e., imperfect vaccination. The failure to obtain additional immunization might result from several factors: a lack of awareness, an experience of complications after immunization, and/or shortage of vaccine supplies. These factors may be related with the state-dependency problem in immunization. For example, a mother has a strong incentive to have her child vaccinated at the early stage of a child life since the hazard of mortality is highest and a mother is better informed. However, this incentive might get weaker at later stages of the child's life. The impact of the imperfect immunization on the probability of child survival is examined.

There is also an issue of the role of health care disseminating information on other health care. For example, prenatal care might play two distinct roles in affecting child's health and parental behavior that may be expressed through equations. Such care may directly lead to greater survival rates of children. On the other hand, such care may increase access to the following care since it disseminates information on how to produce new health input more efficiently. This second role of prenatal care is thus similar to what Rosenzweig and Schultz (1982) hypothesized for public health programs, because they reduce the cost of acquiring information relevant to the production of health. Although this is not the main topic of the study, this paper examines the two distinct roles of health care.

This study uses the 1992-93 National Family Health Survey (NFHS) in India. In India, the immunization of children against six fatal but preventable diseases (tuberculosis, diphtheria, whooping cough (pertussis), tetanus, polio, and measles) has been an important cornerstone of the child health-care system since its first introduction to the country in 1978 (WHO, 1986).[2] The 1992-93 survey data contains detailed histories of a child's immunization as well as considerable information on socioeconomic, demographic and community measures. This study uses this information to estimate a child's health production function focusing on children born in the period 12-48 months before the survey. In order to construct a variable measuring household expenditure, the 1993 (50th round) National Sample Survey (NSS) in India is also used. The log of per capita household expenditure is projected based on household head's occupation, education, age, and residence using the NSS and merged into the NFHS.

The results from the child mortality model indicate that parents' higher likelihood of purchasing postnatal inputs substantially reduce the risk of child mortality. Furthermore, there is a significant and adverse impact on the probability of child's survival due to imperfect vaccination. Results also suggest that mothers with a high risk of child mortality compensate for inherently weak endowment. Ignoring this first type selection underestimates the impact of immunization on child survival. However, mothers also engage in complementary behavior by reinforcing endowments when they choose among different health inputs. This second type

[2] As part of the National Health Policy, the Expanded Programme on Immunization (EPI) was introduced in 1978 with the objective of providing free vaccination services to all eligible children and expectant mothers. In order to step up the pace of immunization, the Universal Immunization Programme (UIP) was introduced in 1985-86 and is being implemented through the existing network of the primary health-care system, including Primary Health Centres (PHCs), sub-centres and referral centres called Community Health Centres. See WHO (1986) for details.

selection mitigates the effect of the first type selection. The results are robust regardless of the various choice of model (reduced form, conditional form, or hybrid form model).

In the next section, a household decision model is constructed in which immunization explicitly enters as a postnatal input in a child survival production function. Data and sample selection are discussed in section III. Section IV reports estimates of the effect of immunization on child survival as well as the effects of demographic and socioeconomic variables on demand for child immunization. Section V summarizes the study.

II. The Model

Several researchers have modeled production functions which control for the unobserved heterogeneity (Wolpin, 1997; Rosenzweig and Wolpin 1995, 1988; Rosenzweig and Schulz, 1983a, 1983b; Olsen and Wolpin, 1983). The model constructed here follows a development in Rosenzweig and Wolpin (1988), and Wolpin (1997). Consider a household which exercises choice over consumption, the number and quality of surviving children given budget constraint. The number of surviving children is produced by inputs into a survival production function. Each child of the household has inherent family endowment which contains family specific genetic and environmental attributes affecting a child's mortality.

It is assumed that the selection of health products is cumulative and there are three instances in which parents can select health inputs for their child: prenatal, at delivery, or postnatal. These variables can also be referred to as health production inputs followed by the tradition of the Becker (1965) model. Overall susceptibility to a certain disease would depend on mother and child's biological characteristics, nutrition and feeding, and parents prenatal, delivery, and postnatal behavior which are preventive, curative or both. The survival probability of a child of a household/mother at a certain time of life is then given by the following survival production function. For notational convenience, subscripts for child and mother are suppressed. Children's disturbance terms in each function are also suppressed.

$$(1) \qquad S_t = \Gamma(t, T^1, T^2, T^3, x, \mu)$$

where the t is the child age, T^1 , T^2, T^3 are respectively the mother's prenatal behavior (T^1), delivery behavior (T^2), and postnatal behavior (T^3) until child age t-1, x is a vector of biological and nutritional characteristics which affect a child's postnatal probability to survive, and μ family endowment.

The household reduced form demand functions for inputs T^1, T^2, and T^3 can be derived from the maximization of the household utility function. The reduced form demand functions can be written as

$$(2) \qquad T^i = \Psi^i(p, M, z, \eta^i, \varepsilon^i) \qquad i = 1, 2, 3.$$

where p represents prices of all goods, M household income, z other household and community characteristics that affect the demand for inputs, η^i represent mother's selections in each demand functions, and ε^i represent new event(s) until i which affect mother's behavior. For example, parents come to know the gender of child at delivery, which affect their postnatal care behavior. Mother's selection is based on information sets and available technology parameters associated with the beginning of the each successive period: prenatal care, Ω_1 (μ, ε^1; Λ); delivery care Ω_2 (μ, η^1, ε^2; Λ); postnatal care, Ω_3 (μ, η^1, η^2, ε^3; Λ) where Λ represents available input technology parameters. The confounding relationships between equations thus can be best summarized as

$$Cov(\eta^i, \varepsilon^{i+t}) = 0, \; Cov(\eta^{i+t}, \varepsilon^i) \neq 0, \; Cov(\eta^i, \mu) \neq 0, \text{ and } Cov(\eta^i, \eta^j) \neq 0.$$

It is natural to have $Cov(\eta^i, \varepsilon^{i+t}) = 0$ with time t>0, because ε^{i+t} is by definition unforeseen by parents before behavior i occurs. On the contrary, mother's selection of child immunization might be conditioned on birth outcome including child's gender, i.e. $Cov(\eta^3, \varepsilon^2) \neq 0$, because parents will adjust their postnatal behavior to the production of child survival when they observe these.[3] Some researchers have addressed $Cov(\eta^1, \mu) \neq 0$. Harris (1982) pointed out that the effect of prenatal care on infant mortality is biased when selective timing of care is ignored: knowing that a pregnant woman being in frail health, she is more likely to seek early prenatal medical care than her counterpart whose health is robust. Rosenzweig and Schultz (1991), in a study of demand for medical care services, found that high-risk women are more likely to obtain Caesarean section and amniocentesis, whereas ultra-sound and X-ray treatments are less obtained by high-risk women. Panis and Lillard (1994) found that women with a high risk of miscarrying have a higher than average probability of seeking prenatal care, i.e., there is adverse self-selection in the use of prenatal care.

Likewise, child postnatal care and delivery care may be conditioned on family endowment, i.e. $Cov(\eta^2, \mu) \neq 0$ and $Cov(\eta^3, \mu) \neq 0$, if a mother with high risk of child mortality is

[3] There is also an issue of heterogeneity in the endowment of children born *within* the family. Although this is potentially an important issue, little evidence exists how health inputs are allocated across family members as a function of their inherent endowments. There is a special case in which prenatal inputs for the prior-born children are used as instruments for the difference in prenatal inputs between the later- and prior-born (Rosenzweig and Wolpin, 1988). But one could argue that the lagged instrumental method may perform poorly in part due to the validity of instruments. This is especially true for postnatal care, where, unlike prenatal health input, qualities of child are already known by parents when family decisions about postnatal inputs are made. In this paper we only consider the effects of gender and sibling composition of a child.

more likely to vaccinate her children and seek delivery in a modern facility. Finally, a child's immunization status may be conditioned on the selection of prenatal care and delivery in a modern health facility (i.e. $Cov(\eta^i, \eta^j) \neq 0$) if a mother favorable to prenatal care, conditional on her observable characteristics, is also more likely to obtain delivery care as well as postnatal care.

Given a child's mortality in various biological determinants, the mother's selections influence observed mortality, since a child's immunization coverage will depend on a rational family's selection. If a mother with high risk of child mortality is more likely to invest in their children, engaging in *compensatory* behavior, the effect of health care on child survival will be understated. The theory also suggests that the demand for postnatal input is likely to be correlated with the histories of postnatal stochastic terms. Omitting these variables may understate the impact of immunization, if a mother is more likely to vaccinate a weaker child, again engaging in compensatory behavior. If women who are more likely to obtain prenatal care are also more likely to obtain postnatal care, engaging in *complementary* behavior by reinforcing child investment, then ignoring this additional selection might bias the results as well.

Several medical studies try to examine the relation of mothers' psychological factors regarding demand for immunization. But as they point out, a few attitude or belief variables may not capture all the heterogeneity of parents and it is likely that immunization-seeking behavior is influenced by other unobserved factors.[4] This study employs two types of equations as follows, given the correlation among equations. The child survival production function is the first equation and it estimates the effect of immunization on child mortality. In this equation, child mortality is defined as the conditional probability of dying between the first and fourth birthdays among those who survive the first year. This age group was selected because full immunization is recommended for all children by age one and data is collected for the children born in the period 12-48 months before the survey.[5] It is modeled as failure time processes represented by a log hazard of duration equations. The log hazard of child survival production equation at time t is given by

$$\text{(3)} \qquad \ln h(t) = \alpha t + \beta_1 T^1 + \beta_2 T^2 + \beta_3 T^3 + x\gamma + \mu + \xi$$

where h is the log-hazards of child postnatal mortality and t is age of the child. The effect of age is assumed to be piecewise linear with some nodes.

The conditional likelihood of child survival (L^S) is then given by

$$L^S(\mu) = \begin{cases} S^C = \Gamma(t^c, T, x, \mu) & \text{if the child is still alive at the survey date (c: censored)} \\ S^u = \Gamma(t^s, T, x, \mu) & \text{if the child died between 12 and 48 months (u: uncensored)} \end{cases}$$

For the computation of S^u, a monthly window during which the child died is created.

The second type equation is the reduced form demand functions and it is used to estimate the effects of selected variables on factor demand. We measure a child's immunization status which indicates whether the child are fully immunized, partially immunized, or not immunized at all. Children who have received BCG vaccine, measles vaccine, three doses of DPT

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[4] See Strobino et. al. (1996) for a review.

[5] The usual truncation problem arises whenever the input is defined to depend on the duration of life or it is dependent on the achievement of a given age. For example, immunizations given after some age is reached would be truncated by death prior to the immunization age thus be spuriously related to life expectancy. However, this is unlikely a problem here since the data is restricted to the children born in the period 12-48 months before the survey, and the majority of children (among those who have vaccination card) vaccinated in the NFHS met the criteria by WHO.

vaccine, and three doses of polio vaccine (not counting polio 0) are considered fully immunized. Children who have had one or more vaccinations but are not fully immunized are defined as partially immunized. T^3 equals zero if the child is not immunized at all, one if the child is partially immunized, and two if the child is fully immunized. It belongs to the *j*th category if:

$$c_{m-1} < T^3 < c_m \quad (m = 1, 2)$$

Because T^3 is observed only ordinal, we can normalize the transitory residual (i.e. $\nu \sim N(0,1)$), and assumes that $\eta^3 \sim N(0, \sigma^2_{\eta^3})$. That is, the covariance matrix of $\eta^3 + \nu_j$ (Σ) is $\sigma^2_{\eta^3} 1_j 1_j^{'} + I_j$ where 1_j is a *j* dimensional vector of ones and I_j is a *j* dimensional identity matrix. Demand for prenatal care and delivery care is modeled as a binary choice model, respectively.

As mentioned earlier, prenatal care and delivery care may not only directly lead to greater survival rates of children, but they increase access to the following care since it disseminates information on how to produce new health input more efficiently. Our model cannot predict how prenatal care will lead to greater postnatal care, *per se*. However, such effect may not be zero.[6] In this study, the model is estimated, first ignoring the indirect effects in a reduced form demand function and then considers them in a conditional form model.

When inputs are treated as endogenous, the joint marginal likelihood is given by

$$(4) \qquad \int_{\mu}\int_{\eta^1}\int_{\eta^2}\int_{\eta^3} f(\mu,\eta^1,\eta^2,\eta^3)\prod L^S(\mu)\prod L^1(\eta^1)\prod L^2(\eta^2)\prod L^3(\eta^3)\, d\mu\, d\eta^1 d\eta^2 d\eta^3$$

[6] One implication of the household framework is that anything that affects the cost of input consumed, whether directly useful to the production of health or not, may influence the demand for health inputs and thus indirectly affect health.

where $f(\mu, \eta^1, \eta^2, \eta^3)$ denotes the four dimensional normal density function. In order to exploit efficiencies, this full specification model is estimated jointly based on a Full Information Maximum Likelihood (FIML) method.

III. Data and Variables

The 1992-1993 National Family Health Survey (NFHS) in India gathered information on a representative sample of 89,777 ever-married women age 13-49 residing in 88,562 households. The survey also collected information on children born to interviewed women in the four years preceding the survey. An advantage of the NFHS is that the data set collected health information for children who died. Several researches examined the determinants of immunization coverage by using only living children because no immunization information was obtained for children who died (e.g. Pebley et. al., 1996). The restriction of immunization estimates to living children probably has resulted in overestimate of immunization coverage, which is not a problem of using the NFHS data set. The analysis focuses on children in rural India born 12-48 months preceding the survey. The total number of children belonging to this group is 26,575, among which 542 died. The total number of household is 19,776 and the maximum number of children from the same mother is three.

Three types of questionnaires were used in the NFHS–one for ever-married women within households, one for households, and one for villages. For our analysis, selected variables from the household questionnaire, and the village questionnaire were merged into the individual data file for women of childbearing age. The child data file used in this paper was then created from the augmented individual women data file. Thus, the record for each child includes selected characteristics of the child, the child's mother, the child's father, the mother's household, and the mother's village. The sample design for some states is self-weighting, but in other states certain sectors of the population are over-sampled. It is therefore necessary to use weights to restore the correct proportions. All estimates in this paper make use of weighted numbers at the national level. Details of the sample design are described in the report for the NFHS in India (IIPS, 1995).

Table 1 lists the variables in each model equation, their definitions and their mean. The information on immunization coverage is derived both from vaccination cards, when the mother has one, and from the mother's memory, when she cannot show a card. Each mother was asked whether she had a vaccination card for each child born since January 1988. If a card was available, the interviewer copied the date for each vaccination. If the mother could not produce a vaccination card, she was asked whether the child had received any vaccinations. If any vaccination had been received, the mother was then asked whether the child had received one or more vaccinations against each of the six fatal diseases. For DPT and polio, information was obtained on the number of injections or oral doses given.

Given the absence of data on the prices of immunization, prenatal care, and delivery in a modern health facility, the child survival model is identified by several variables representing household economic status and community characteristics: i.e., per capita household expenditure, house quality, a degree of crowding within the household, religion, access to health care facility in a village, and all-weather road in a village. On the contrary, access to safe drinking water and access to a sanitary toilet facility are only included in the survival production function because they are considered as health technology which directly affect health outcome and do not affect the demand for health inputs. Birth spacing, breastfeeding, and birth orders are also included in survival production function as a measure of maternal depletion and child nutrition.[7] These variables are, however, treated exogenous in the analysis in order to avoid additional complication of the model.[8]

The NFHS data set does not contain information on household income. The study utilizes the 1993 (50th round) National Sample Survey (NSS) in India to project per capita household expenditure. It is projected based on father's occupation (7 categories), education (8 categories), age, age squared, and their residence (24 State dummies). Only father's characteristics are included in the estimation, since the mother's labor is assumed to be endogenous in child health investment decisions. Per capita expenditure is used as a measure of long-run income since it is considered a good proxy for measure of permanent income.[9] See Department of Statistics (1993) for detailed information on the NSS.

Our theory suggests that mother's demand for immunization is likely to be correlated with birth outcome ($Cov(\eta^{i+k}, \varepsilon^{i}) \neq 0$). In this context, child's sex plays a role in India where

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[7] The NFHS does not contain detailed information on months of breastfeeding. Furthermore, although the NFHS contains information on breastfeeding with some supplementation, we could not use this information because there have not been any dead children who have had breastfeeding with some supplementation.

[8] These variables are often thought of as endogenous in the literature (e.g. Barrera, 1990; Rosenzweig and Wolpin, 1988). However, the use of survey data to estimate the impact of these variables on the risk of child mortality entails serious inferential problems as well (Wolpin, 1997). On the other hand, this raises a general issue with the child survival production function, that it is in general impossible to measure all relevant inputs, especially lagged inputs. Given the econometric model adopted here, addressing all these issues is beyond the focus of the paper.

[9] The NSS does not contain reliable information on income. See Strauss and Thomas (1995) for pros and cons of using different measures of income. Also see Deaton (1997) for the difficulties of measuring income as well as consumption in developing countries. Because we are predicting the per capita expenditure using a different data set, the estimated coefficient of per capital expenditure may not be efficient.

son preference is common. In India, a child's sex is usually not known until the time of delivery. When the gender outcome is revealed at delivery, this affects parents' behavior leading to different treatment of sons and daughters. Although a child's sex is not an input to survival process, we include them in the survival production function as well to consider different chances of survival by gender in India. The child's sibling composition is included in all models to capture the effect of resource competition. Because higher-order births are born into families that already have a number of children who compete for resources and parental care, these variables are expected to play an important role in parents' demand for health input. Furthermore, the resource competition may depend on the sex composition of the surviving old siblings. Thus, the number of older surviving male and female siblings is included separately in the models.

Health care costs are difficult to measure and often do not vary markedly across mothers in most of the environments from which survey data are derived. Reduced-form estimates of the effects of variation in prices on measures of human capital investments are thus absent from most previous literature. To proxy for the cost of access to general health-care facilities, availability of an all-weather road connecting the village to the outside and a health-care facility in the village are included in all reduced form demand equations. There are several types of health-care facilities in India. We include a measure of the availability of the following kinds of facilities in the mother's village: Primary Health Centre, sub-centre, government hospital, private hospital, dispensary/clinic, or NGO family planning/health clinic.

There is a considerable interstate variation in the coverage rate for different vaccinations and child mortality rate. Figure 1 shows the percentage of children who are fully vaccinated by State; it ranges from 2 percent in Nagaland to 74 percent in Goa. Generally, the western and southern states do relatively well with respect to full coverage immunization, whereas the northeastern and central states have a poor vaccination performance as well as lower child survival. There is also a negative relationship between the immunization rate and crude death rate of children (Figure 2). In order to consider the considerable interstate fixed effects which may not be captured by the other independent variables, the paper includes these 24 State dummy variables in all models as controls.

Table 2 presents the percentage of children age 12-48 months who received each vaccine at any time before the interview by source of information and selected demographic and socioeconomic characteristics. We use information from both vaccination cards and mother's memory. The information does not provide the date of vaccination and it might have higher percentage of children who did not meet the criteria recommended by WHO. However, Goldman and Pebley (1994) demonstrate that inclusion of maternal recall data improves the accuracy of estimates of immunization coverage even though it is subject to recall error. The coverage rate, defined in this way, varies by type of vaccine. Only 31 percent of children aged 12-48 months are fully vaccinated, and 37 percent have not received any vaccine.[10]

Thirty-two percent of children have had one or more vaccinations but are not completely vaccinated, i.e. partially immunized. The analysis of partial immunization provides some insight into the causes of the low coverage rate for full immunization. According to the NFHS, an exceptionally low rate of measles vaccination and high dropout rates during the three-part DPT and polio vaccination series are the main causes of the low rate of full immunization (Appendix 1). Thirteen percent of children ages 12-48 months failed to reach full immunization because they missed only one vaccination. Among the 13 percent who missed only

[10] See Munshi and Lee (2000) for issues of measuring immunization coverage.

one vaccination, 70 percent missed measles vaccination. The dropout rates between the first and third doses of DPT and polio vaccination are 24 and 21 percent, respectively. This may reflect the time-dependency problem in vaccination. The measles vaccination rate is particularly low in part because it is given to a baby much later stage of life (9 months) than the other vaccines are. Since the hazard of mortality is highest at the early stage of life, a mother has a strong incentive to have her child vaccinated. However, the incentive might be much weaker after 9 months because a child might already have had all vaccination except measles and survived 9 months. If measles vaccines are more expensive for mothers to get, it will exacerbate the problem.[11] The outcome of this incomplete immunization will be discussed later.

Immunization coverage increases with mother's education. Hindu children are more likely to be more vaccinated than Muslim children are. Children with elder siblings tend to have lower vaccination rates. Coverage is also higher for boys than for girls. Mortality rates are much higher for the group who is not immunized. The crude death rate of fully vaccinated children ages 12-48 months is 7.5 per 1,000 children while it is 43.7 for those who are not vaccinated. The crude death rate of partially vaccinated children is 14.2.

[11] Although the 1992-93 NFHS did not collect information on the reasons not receiving child prenatal and postnatal care, the 1998-99 NFHS-2 did collect some information on reasons for not receiving a prenatal check-up. The preliminary results (IIPS, 2000) suggest that about 60 percent of mothers did not receive a prenatal check-up because they think it is not necessary. The reason for expensive cost is only 15 percent. This may shed a light on the

IV. Estimation Results

A. Mother's Compensatory and Complementary Behavior

Table 3 presents estimation results of the unobserved heterogeneity structure. This corresponds to the full specification of the model (model 5 in Table 4), where prenatal care, place of delivery, and immunization status are all considered endogenous. The diagonal elements are standard deviations of the heterogeneity, whereas the off-diagonal elements are correlation coefficients among heterogeneity. The result suggests that there are two types of self-selections of a mother.

The first type of self-selection is related to the compensating behavior of mother. The correlation coefficient of the mother heterogeneity of the survival production function and that of the demand for immunization ($\rho_{\mu\eta^3}$) is 0.498 and statistically significant at one percent significance level. The correlation coefficients of the mother heterogeneity between the survival production function and the demand for delivery care ($\rho_{\mu\eta^2}$) and demand prenatal care ($\rho_{\mu\eta^1}$) is 0.427 and 0.537 respectively, and they are statistically significant as well. The significant and positive correlation coefficients between the survival production function and the three reduced-form demand functions implies that women with a relatively higher risk of losing their child are more likely to seek prenatal care, delivery care at a modern facility, and postnatal care. The finding about prenatal care is consistent with Panis and Lillard (1994). That is, there is adverse self-selection in the use of prenatal care. So mothers could be said to compensate for inherently weak endowment, engaging in remedial behavior.

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reasons for partial immunization; cost may not be as important as mother's awareness of effectiveness in explaining child health investment in India.

The second type of selection is related with family's complementary behavior which most previous literature ignored. The correlation coefficients between three reduced-form demand functions are all positive ($\rho_{\eta^3\eta^2}$ = 0.258, $\rho_{\eta^3\eta^1}$ = 0.247, $\rho_{\eta^2\eta^1}$ = 0.368), and statistically significant at one percent significance level, suggesting that women who are more likely to obtain one health care are also more likely to obtain another health care. This means that women engage in complementary behavior by reinforcing investment when they choose among health inputs.

Ignoring the selections identified above will bias the estimation results. The sign of the bias will, in general, be indeterminate without knowledge of how all input allocations respond to these unobservable variables. However, if we take only these three inputs into consideration, the probability limit of estimated coefficient of immunization in the child mortality specification will be

$$\text{(5)} \qquad p\lim(b_3) = \beta_1 \frac{Cov(T^1, T^3)}{Var(T^3)} + \beta_2 \frac{Cov(T^2, T^3)}{Var(T^3)} + \beta_3 + \frac{Cov(\mu, T^3)}{Var(T^3)}$$

Thus ignoring the adverse selection between a mother's frailty and demand for child immunization (positive $\rho_{\mu\eta^3}$) will understate the true impact of immunization on child survival. Likewise, ignoring the selection between mother's frailty and demand for prenatal care ($\rho_{\mu\eta^1}$) and between mother's frailty and demand for delivery care ($\rho_{\mu\eta^2}$) will understate the true impact of each care on child survival. However, ignoring the additional selection, mother's reinforcing investment behavior (positive $\rho_{\eta^2\eta^3}$ and $\rho_{\eta^1\eta^3}$) may overstate the impact of immunization on child survival if both β_2 (the coefficient of delivery care in the hazard model) and β_1 (the coefficient of prenatal care in the hazard model) are negative.

B. Effect of the Mother's Selection on Child Mortality

Table 4 indicates how important it is to account for these two types of selection. All columns in the table present the results of unconditional reduced form input demand models. That is, none of the demand for health care models includes other health care, ignoring the indirect effect of health care on increasing the access of the following care. In column 1, each model is estimated separately and the mother's demand for health care inputs is still treated exogenous to consider only the effect of mother's child invariant fixed-effects. The results indicate that immunization has a very large and significant beneficial effect on child mortality. The impact of full immunization is -1.635, suggesting that full vaccination decreases the risk by 80% ($1-e^{\beta}$). This means that the risk of vaccinated children is about one-fifth of that of non-vaccinated children. The impact of partial immunization is much smaller than that of full immunization, (-1.008, 64%), suggesting that skipping one or two vaccinations substantially reduces the beneficial effect of immunization. The results are not surprising at all, because the crude death rate of non-vaccinated children is about six times as high as that of fully vaccinated children and three times as high as that of partially immunized children. Delivery in a modern health clinic also has a significant beneficial effect on child survival (-0.367, 31%), but the impact of prenatal care on child mortality is insignificant.

In column 2, the immunization coverage model and the child survival production function are estimated jointly, considering the potential correlation between two equations. The mother's behavior during pregnancy and at birth are still treated exogenous to consider only the effect of adverse selection on demand for immunization. When the selection in demand for immunization is considered, the effect of immunization becomes much larger (-1.621 (80%) for partial immunization and -2.919 (95%) for full immunization), suggesting that ignoring the adverse selection between the mother's frailty and demand for child immunization (positive $\rho_{\mu\eta^3}$) substantially underestimates the beneficial effect of immunization. Furthermore, the beneficial effect of delivery care on child mortality becomes no longer statistically significant. Likewise, column 3 present results where the child survival production function and delivery care equation are estimated jointly and column 4 reports estimated results considering the correlation between the survival production function and prenatal health care equation. The results are qualitatively same. When the delivery in a modern health clinic and prenatal care are separately treated as the only endogenous variable in each model, their effects become very large (-1.210 and -0.833, respectively) and significant at one percent significance level. Thus, ignoring the adverse selection between a mother's frailty and *any* health inputs substantially understate the true impact of child health care on child survival.

However, once the mother's complementary behavior between health inputs is considered, the estimated coefficients become smaller. The result is reported in column 5 where all four models, child mortality, demand for immunization, demand for delivery care, and demand for prenatal care are jointly estimated. The estimated coefficients of immunization status are -1.445 for partial immunization and -2.498 for full immunization and both of them are lower than the results of column 2. The estimated coefficients of delivery care and prenatal care are -0.818 and -0.635, and both of them are substantially lower than the results of column 3 and 4, respectively. These results suggest that mother's reinforcing behavior (positive $\rho_{\eta^2\eta^3}$ and $\rho_{\eta^1\eta^3}$) mitigates the effect of mother's compensatory behavior, which is what is exactly predicted by equation (5).

Table 4 also summarizes the effect of other control variables. In all models, birth spacing, sex of child, and the indicator of first child, and the use of clean water had a statistically significant influence on child survival. Child mortality is substantially higher for girls than for boys. The coefficient on whether a child is breastfed is also significant. However, the result should be interpreted with caution since the practice of breastfeeding is almost universal in India and it is treated as exogenous (see footnotes 7 and 8). The other variables have no significant impact on child mortality, suggesting that they operate mostly through demand for health inputs. In fact, the literature is extremely heterogeneous with respect to the specification of mortality function even within the household production framework. Estimates of technological effects of inputs on health have been sometimes obtained from a hybrid function (e.g. Panis and Lillard, 1994) in which variables that do not fit into the category of inputs, such as income and price variables, often appear as determinants. These variables sometimes play a role in purging omitted variable bias. If certain health inputs are omitted, the child mortality specification is essentially a hybrid of a production function and the reduced form demand function. However, if child survival production function is correctly specified, these measures may not have substantial effect on child mortality.

To explore this issue, the child survival production function is re-estimated including per capita household expenditure. The result is reported in column 2 of Table 5. For comparison, the results of the full specification model (column 5 of Table 4) is reported again in column 1 of Table 5. The coefficient of the log of per capita household expenditure variable is not significant at all although the beneficial effect of all inputs diminishes slightly. The insignificant income effect provides support for the hypothesis that the child mortality specification captures most important input factors and other control variables and the coefficients of these variables may be interpreted as survival production technology coefficients.

Column 3 of the table presents results, considering the indirect role of health care in affecting following health care. That is, the prenatal care variable is included in the delivery care model and immunization coverage model, and both prenatal care and delivery care variables are included in the demand for immunization model. Again, all four models are estimated jointly. The result is quite similar to the full specification model, suggesting that the dramatic change in the coefficients of health inputs in column 5 of Table 4 should be explained by mother's self-selection and it might not be a side effect of our choice of reduced form model. Once mother's both selections are considered, the indirect role of health care in triggering additional child health input matters little for child survival. This issue will be discussed more in detail in the following section.

C. Results of the Immunization Coverage Model

Table 6 reports the ordered-probit estimation results of the immunization coverage model. The two threshold effects in the model are significant at one-percent level. Column 1 corresponds to column 1 of Table 4 in which all equations are estimated separately. Column 2 corresponds to column 5 of Table 4 where all equations are estimated jointly. Column 3 corresponds to column 2 of Table 5 where the hybrid function is used for the child survival function. Column 4 is a conditional form of immunization coverage model in which both prenatal care and delivery care variables are included but treated exogenous. Column 5 corresponds to column 3 of Table 5 where prenatal care and delivery care variables are treated endogenous in the conditional form demand model. The corresponding estimation results for the delivery care and prenatal care models are also presented in appendices 2 and 3, respectively.

Most variables have the expected sign and they are significant. When the two types of selection are considered, all estimated coefficients move away from zero, suggesting that ignoring the two types of selection substantially underestimates the effect of control variables (column 1 vs. 2). The use of hybrid production function including per capita household expenditure barely changes the results (column 3). The most interesting feature of Table 6 is the dramatic change in the coefficients of prenatal care and delivery care when they are estimated jointly. The coefficient of prenatal care variable changes from 0.377 in column 4 to -0.178 in column 5 and it is no longer significant. Likewise, the coefficient of prenatal care changes from 0.474 in column 4 to 0.123 in column 5 and it is not significant any more. The result for delivery in a modern facility model in Appendix 2 is qualitatively same. The indirect role of prenatal care in increasing access to the delivery care disappears when all models are estimated jointly. To summarize, when the mother's selections between equations are considered, the indirect role of health care in triggering additional child health input disappears. So it can be said a mother who is favorable to prenatal care, conditional on her observable characteristics, is also more likely to obtain delivery care as well as postnatal care and this substitutes the indirect role of health care.

The mother's level of education also had a substantial impact on child immunization status. Since the effect of per capita household expenditure and other family economic status are controlled for, it also reflects the influence of accessibility to information, mothers' preference, and other quality of the home environment on immunization. This is consistent with the notion that education provides a mother with skills in acquiring and decoding new information, and thus effectively lowers the cost of using more information about new health techniques. Another possible explanation is that more highly educated mother desire healthier child and will be able to provide a home environment that is more conducive to better health. The results also show that a mother who watches television or listens to radio at least once a week is more likely to have her child vaccinated, suggesting that mothers who are exposed to mass media are more likely to have access to information on child health care. We also found that mother's age at child's birth has a positive but nonlinear effect on immunization coverage and it is significant.

The results also reveal the effect of child characteristics on immunization. Boys have substantially higher vaccination rates than girls, reflecting the strong preference for sons that exists in India. The findings also illustrate the favored treatment of first-born children. Given controls for mother's and child's characteristics, results show that all economic status related variables have significant effects on immunization coverage. Per capita household expenditure has the expected sign and it is highly significant. The coverage is higher for children living in a good quality house and less crowded house.

As expected, the results show that the connection with an all-weather road in local areas has a significantly positive effect on child's immunization, suggesting that accessibility of health-care facilities may be effective in spreading vaccinations. However, availability of clinics has unexpected sign and it is insignificant. The estimate of this variable assumes that no correlation exists between the variables and unobserved component in the outcome. Because immunization programs may be placed using criteria that are related to the outcomes being studied (i.e., non-random program placement) this condition is often violated. Clinics in rural

India might be first placed where immunization rate is low and mortality rate is high. Treatment of this potential problem is not addressed here.

V. Summary

Many researchers have tried to explain what causes infant and child mortality to decline in a demographic transition. The prevailing view is that the most important causes are improvements in public health-care technology and the introduction of new health-care systems. For example, the universal immunization programs, which are often referred to as "the most cost-effective route to child's better health" (WHO, 1998), surely had a large impact. Despite considerable gains in immunization coverage over the last few decades, however, at least two million children still die from vaccine-preventable diseases, including more than a million from measles, and close to 0.4 million from pertussis (whooping cough) (WHO, 1998). By using a family health survey data set, this paper estimates the demand for immunization and the effect of immunization coverage on the probability of child survival. For this purpose, a household dynamic production model is constructed in which immunization enters as a postnatal input. Careful attention is paid to addressing issues of potential correlation among immunization status, place of delivery, prenatal care and the consequences of parental selections on survival technology.

The results from the child mortality model indicate that vaccinating children has a very large effect on child mortality. Low child mortality is positively related to the increased likelihood that a parent purchases immunization for his or her child. However, the impact of partial immunization is much smaller than that of full immunization, which suggests that partial immunization, due to either dropout or missing vaccinations, substantially reduces the beneficial effect of immunization. Results also suggest that a mother who perceives her unborn child faces a risk of death compensates for their beliefs in a beneficial way. Consequently, estimations that ignore this first type of selection underestimate the impact of immunization on child survival. However, women also engage in complementary behavior by reinforcing endowments when they choose among health inputs. Estimations that ignore this second type of selection overstate the impact of the first type of selection. The estimation results from demand for child immunization indicate that when mother's selection is considered, the indirect role of health care in triggering additional child health input disappears.

References

Becker, G. S. 1965. "A theory of the allocation of time," *Economic Journal* 75: 493-517.

Barrera, A. 1990. "The interactive effects of mother's schooling and unsupplemented breast-feeding on child health," *Journal of Development Economics* 34: 81-98.

Deaton, A. 1997. *The Analysis of Household Surveys* (Baltimore: The Johns Hopkins University Press), Chapter 1.

Department of Statistics. 1993. *Sarvekshana*, Ministry of Planning, Government of India, Vol. 17, No. 3 & 4.

Harris, J.E. 1982. "Prenatal medical care and infant mortality", in V. R. Fuchs ed. *Economic Aspects of Health* (Chicago: The University of Chicago Press)

Goldman, N and A. R. Pebley. 1994. "Health cards, maternal reports, and the measurement of immunization coverage in Guatemala", *Social Science and Medicine*, 38: 1075-1089.

IIPS (Interantional Institute for Population Sciences). 1995. *National Family Health Survey,* (India, Bombay: MCH and Family Planning)

——————. 2000. *National Family Health Survey (NFHS-2)* (India, Bombay: MCH and Family Planning)

Meghir, C. 1992. "Female labour supply and on-the-job search: an empirical model estimated using complementary data sets" *The Review of Economic Studies,* 59 (3):537-559.

Munshi, R. and S-H Lee, 2000. *Child Immunization in Madhya Pradesh*, National Family Health Survey Subject Reports, no. 15, Mumbai: Institutional Institute for Population Sciences; and Honolulu: East-West Center Program on Population and Health.

Olsen, R. J. and K. I. Wolpin. 1983. "The impact of exogenous child mortality on fertility: a waiting regression with dynamic regressors," *Econometrica*, 51: 731-49.

Panis, C. W.A., and L. A. Lillard. 1994. "Health inputs and child mortality: Malaysia," *Journal of Health Economics*, 13: 455-89.

Pebley, A. R., N. Goldman, and G. Rodriguez. 1996. "Prenatal and delivery care and childhood immunization in Guatemala: Do family and community matter?" *Demography*, 33: 231-247.

Rosenzweig, M. R. and T. P. Schultz. 1982. "Child mortality and fertility in Colombia: individual and community effects", *Health Policy and Education*, 2: 305-48.

——————. 1983a. “Estimating a household production function: heterogeneity, the demand for health inputs, and their effects on birth weight,” *Journal of Political Economy*, 91: 23-46.

——————. 1983b. “Consumer demand and household production: the relationship between fertility and child mortality”, *American Economic Review*, AEA Papers and Proceedings, 73: 38-42.

——————. 1991. “Who receives medical care? Income, implicit prices, and the distribution of medical services among pregnant women in the United States, *Journal of Human Resources*, 26: 473-508.

Rosenzeweig, M. R. and K. I. Wolpin. 1988. “Heterogeneity, intrafamily distribution, and child health”, *Journal of Human Resources*, 23: 437-461.

——————. 1995. “Sisters, siblings and mothers: the effects of teen-age child bearing on birth outcomes,” *Econometrica,* 63:303-326.

Strauss, J. and D. Thomas. 1995. “Human resources: empirical modeling of household and family decisions,” in J.R. Behrman and T.N. Srinivasan (eds.), *Handbook of Development Economics*, Vol. 3 (North-Holland: Amsterdam).

Strobino, D. V. Keane, E. Holt, N. Hughart, and B. Guyer. 1996. “Parental attitudes do not ex plain under-immunization”, *Pediatrics*, 98:1076-1083.

WHO (World Health Organization). 1986, *The Expanded Programme on Immunization in South-East Asia*, SEARO Regional Health Papers 12: *India*. New Delhi.

—————. 1998. Report of the Technical Review Group Meeting, 7-8 June 1998, Vaccine Research and Development. WHO/VRD/GEN/98.02.

Wolpin, K. I. 1997. “Determinants and consequences of the mortality and health inputs of infants and children,” in M.R. Rosenzweig and O. Stark (eds.), *Handbook of Population and Family Economics*, Vol. 1 (Amsterdam: North-Holland)

Table 1. Definitions and mean values of variables

Variable	Definition (In case of dummy variable value 1 if the specified condition is met, 0 otherwise)	Equation[a] I	II	III	Mean
Full immunization	Child has received BCG, measles, and three doses of DPT and polio vaccines	X			0.308
Partial immunization	Child has had one or more of vaccines, but not fully immunized	X			0.294
Prenatal care	Mother received prenatal checkup for this child	X	X		0.417
Mother's education		X	X	X	
Literate, < middle	Mother is literate with less than middle school				0.156
≥ Middle complete	Mother is literate with middle school complete or higher education				0.109
Mother's age	Mother's age at childbirth, and square term	X	X	X	23.6 (5.73)
Media exposure	Mother watches television or listens to radio at least once a week or visits a cinema at least once a month	X	X	X	0.386
Birth spacing	Child's birth spacing (months)	X			26.1 (22.3)
Log of per capita household expenditure	Predicted based on husband's age, age squared, education (8), occupation (7), and residence (24) by using 1993 National Sample Survey of India		X	X	5.61 (0.26)
Child's sex	Child is a boy	X	X		0.509
Child's birth order		X	X	X	
Order 2-3	Child's birth order is 2 or 3				0.413
Order 4-5	Child's birth order is 4 or 5				0.203
Order ≥6	Child's birth order is 6 or above				0.126
Breast feeding	Child has ever been breastfed	X			0.985
Muslim	Child lives in a household whose head is Muslim	X	X	X	0.131
Type of house	Type of house is *pucca*, or *semi-pucca* (quality house)		X	X	0.382
Crowding	Child lives in a household with three or more persons per sleeping room		X	X	0.584
Sanitary toilet	Child lives in a household that has own or shared flush toilet facility	X			0.062
Safe drinking water	Child lives in a household that uses piped/tap water, hand pump, tanker truck, or bottled water as the main source of drinking water	X			0.355
Health-care facility	Child lives in a village that has a Primary Health Centre, sub-centre, government hospital, private hospital, dispensary/clinic, or Non-Government Organization family planning/health clinic	X	X	X	0.676
All-weather road	Child lives in a village that is connected by an all-weather road	X	X	X	0.488
Complication at childbirth	Mother experienced difficulty at childbirth	X	X		0.102
Number of children	Number of children age 12-48 months			26,228	

a. Equation I is child mortality model, II demand for immunization model, and III demand for prenatal care. Other variables include 24 State dummy variables in all equations, two thresholds in Equation II. Based on the weighted sample. Standard errors are in parentheses.

Table 2. Percentage of children vaccinated and crude death rate by vaccination type

	Percentage vaccinated					
Selected Variables	**BCG**	**Polio 3**	**DPT 3**	**Measles**	**All**[a]	**None**[c]
Total (percentage)	55.0	47.2	45.3	38.3	30.8	39.9
Source of information						
Vaccination card	87.5	82.9	82.5	65.5	58.4	4.3
Mother's report	47.1	38.5	36.2	31.6	24.1	48.5
Mother's education						
Illiterate	47.1	38.6	36.6	30.4	23.2	47.7
Literate < Middle school complete	70.4	64.0	62.5	52.5	44.6	23.6
Middle school/above	86.2	81.1	79.5	71.4	62.6	9.4
Prenatal care						
Yes	74.9	67.9	66.2	56.7	47.7	19.3
No	40.8	32.4	30.4	25.1	18.7	54.5
Child's sex						
Boy	57.3	49.1	47.3	40.1	32.1	37.3
Girl	52.6	45.2	43.3	36.4	29.5	42.4
Child's birth order						
1	63.3	56.5	54.6	47.2	38.9	31.1
2-3	58.7	50.6	48.7	41.3	33.5	36.3
4-5	48.2	40.2	38.1	31.0	24.2	46.3
≥6	37.2	28.5	27.0	21.8	15.9	58.6
Difficulties at child birth						
Yes	63.2	55.4	54.3	45.3	38.5	31.6
No	54.1	46.3	44.3	37.5	29.9	40.7
Religion						
Hindu	57.0	49.2	47.5	40.1	32.4	37.6
Muslim	40.5	33.7	31.1	26.1	19.8	54.7
Heath-care facilities						
Yes	59.5	51.7	50.0	42.3	34.5	35.1
No	45.6	37.8	35.6	29.9	23.0	49.7
Crude death rate (per 1,000)						
Vaccinated	10.8	9.0	9.3	8.0	7.4[a]	--
Not vaccinated	34.8	32.9	31.8	30.1	14.4[b]	38.0[c]

Based on the weighted sample.
The number of observations is 26,228.

a. Fully vaccinated.
b. Partially vaccinated.
c. No vaccination.

Table 3. Heterogeneity structure estimates

	μ	η^2	η^1
Child mortality (μ)	.575 *** (.160)	--	--
Immunization (η^2)	.833 *** (.044)	1.464 *** (.044)	--
Prenatal care (η^1)	.563 *** (.054)	.356 *** (.033)	2.195 *** (.100)

Standard errors are in parentheses. Diagonal elements are standard deviation, and off-diagonal elements are correlation coefficients.
Estimates of the heterogeneity structure corresponding to the full specification under the assumption of endogenous immunization and prenatal care.
*** indicates significance from zero at 1 percent.

Table 4. Estimates of child mortality model (Proportional Hazard)

	(1)	(2)	(3)	(4)	(5)
Family FE	No	Yes	Yes	Yes	Yes
Endogenous immune.	No	No	Yes	Yes	Yes
Endogenous prenatal.	No	No	No	Yes	Yes
Prenatal in immune.	Yes	Yes	Yes	Yes	No
Immunization					
Full	-1.2398 ***	-1.3316 ***	-2.5393 ***	-2.0531 ***	-2.0474 ***
	(0.1764)	(0.1880)	(0.2981)	(0.2884)	(0.2881)
Partial	-0.7215 ***	-0.7840 ***	-1.3735 ***	-1.1368 ***	-1.1341 ***
	(0.1235)	(0.1351)	(0.1824)	(0.1666)	(0.1665)
Prenatal care	-0.2872 **	-0.2962 **	-0.1270	-0.6652 ***	-0.6641 ***
	(0.1314)	(0.1408)	(0.1421)	(0.1825)	(0.1820)
Boy	-0.4257 ***	-0.4682 ***	-0.4121 ***	-0.3888 ***	-0.3890 ***
	(0.0931)	(0.1009)	(0.1013)	(0.0943)	(0.0943)
Breastfed	-0.3041	-0.3055	-0.2735	-0.2876	-0.2877
	(0.3181)	(0.3606)	(0.3601)	(0.3219)	(0.3218)
Birth spacing	-0.0204 ***	-0.0205 ***	-0.0209 ***	-0.0203 ***	-0.0203***
	(0.0033)	(0.0035)	(0.0035)	(0.0033)	(0.0033)
Birth order					
2-3	0.7985 ***	0.7952 ***	0.7818 ***	0.7432 ***	0.7434 ***
	(0.1645)	(0.1763)	(0.1766)	(0.1660)	(0.1659)
4-5	0.8107 ***	0.8116 ***	0.7568 ***	0.6909 ***	0.6914 ***
	(0.1873)	(0.2039)	(0.2038)	(0.1900)	(0.1900)
≥6	0.7882 ***	0.8248 ***	0.7152 ***	0.6175 ***	0.6183 ***
	(0.2284)	(0.2519)	(0.2530)	(0.2351)	(0.2351)
Mother's education					
Literate	-0.3353 **	-0.3420 *	-0.1986	-0.1458	-0.1469
	(0.1709)	(0.1846)	(0.1852)	(0.1826)	(0.1825)
Mid/above	-1.0263 ***	-1.0450 ***	-0.7854 **	-0.6772 *	-0.6789 *
	(0.3427)	(0.3550)	(0.3588)	(0.3528)	(0.3528)
Mother's age					
At birth	0.0224	0.0208	0.0299	0.0356	0.0355
	(0.0575)	(0.0645)	(0.0639)	(0.0582)	(0.0582)
Age squared	-0.0004	-0.0003	-0.0005	-0.0006	-0.0006
	(0.0010)	(0.0012)	(0.0011)	(0.0011)	(0.0011)
Muslim	0.0478	0.0638	-0.0538	-0.0451	-0.0444
	(0.1418)	(0.1614)	(0.1609)	(0.1466)	(0.1465)
Castes/tribe	0.0336	0.0465	-0.0002	-0.0220	-0.0218
	(0.1056)	(0.1194)	(0.1192)	(0.1081)	(0.1080)
Clinics	0.0282	0.0467	0.0776	0.0511	0.0509
	(0.0988)	(0.1120)	(0.1116)	(0.1002)	(0.1002)
All-weather road	-0.1042	-0.1385	-0.1064	-0.0631	-0.0633
	(0.0989)	(0.1155)	(0.1140)	(0.1004)	(0.1004)
Sanitary toilet	-0.1679	-0.1586	-0.1061	-0.0991	-0.0999
	(0.3749)	(0.4013)	(0.4025)	(0.3813)	(0.3812)
Water	-0.1629	-0.1551	-0.1332	-0.1443	-0.1444
	(0.1061)	(0.1186)	(0.1177)	(0.1071)	(0.1071)
Baby size					
Big	0.0622	0.0771	0.0630	0.0507	0.0508
	(0.1369)	(0.1497)	(0.1494)	(0.1379)	(0.1379)
Small	0.0923	0.1046	0.0965	0.0845	0.0845
	(0.1210)	(0.1323)	(0.1327)	(0.1226)	(0.1226)
Difficult delivery	0.0139	-0.0034	0.0269	0.0330	0.0328
	(0.1690)	(0.1821)	(0.1818)	(0.1707)	(0.1706)
ln-L	-25798.2	-25353.0	-25347.2	-37240.5	-37240.6

Standard errors in parentheses. Other variables include 24 State dummy variables.
The number of observations is 26,228.
*, **, *** indicate significance from zero at 10 percent, 5 percent and 1 percent, respectively.

Table 5. Estimates of immunization coverage model (Ordered Probit)

	(1)	(2)	(3)	(4)	(5)
Prenatal care	0.4712 ***	0.7440 ***	0.7470 ***	0.0196	..
	(0.0172)	(0.0319)	(0.0323)	(0.0773)	
Big baby	-0.0637 ***	-0.0993 **	-0.1043 ***	-0.1157 ***	-0.1156 ***
	(0.0230)	(0.0397)	(0.0401)	(0.0409)	(0.0409)
Small baby	-0.0404 **	-0.0679 **	-0.0658 *	-0.0699 **	-0.0699 **
	(0.0201)	(0.0340)	(0.0342)	(0.0350)	(0.0350)
Difficult delivery	0.0505 *	0.0949 **	0.1002 **	0.0978 **	0.0978 **
	(0.0263)	(0.0439)	(0.0441)	(0.0448)	(0.0447)
Per capita HH expend.	0.5402 ***	0.9077 ***	0.9143 ***	1.1084 ***	1.1136***
	(0.0412)	(0.0798)	(0.0804)	(0.0860)	(0.0835)
Mother's education					
Literate	0.2202 ***	0.3780 ***	0.3830 ***	0.4939 ***	0.4965 ***
	(0.0223)	(0.0432)	(0.0436)	(0.0464)	(0.0453)
Mid/above	0.4529 ***	0.7894 ***	0.7886 ***	0.9719 ***	0.9768 ***
	(0.0309)	(0.0602)	(0.0608)	(0.0657)	(0.0634)
Boy	0.1355 ***	0.2391 ***	0.2382 ***	0.2449 ***	0.2451 ***
	(0.0155)	(0.0255)	(0.0256)	(0.0263)	(0.0262)
Good house	0.1002 ***	0.1772 ***	0.1762 ***	0.2260 ***	0.2272 ***
	(0.0172)	(0.0328)	(0.0330)	(0.0345)	(0.0343)
Crowding	-0.0443 ***	-0.0841 ***	-0.0864 ***	-0.0939 ***	-0.0941 ***
	(0.0157)	(0.0297)	(0.0298)	(0.0309)	(0.0309)
Muslim	-0.2978 ***	-0.5344 ***	-0.5354 ***	-0.5657 ***	-0.5662 ***
	(0.0230)	(0.0449)	(0.0452)	(0.0468)	(0.0468)
Caste/tribe	-0.0745 ***	-0.1312 ***	-0.1346 ***	-0.1707 ***	-0.1715 ***
	(0.0176)	(0.0336)	(0.0339)	(0.0351)	(0.0350)
Clinics	0.0941 ***	0.1622 ***	0.1608 ***	0.1618 ***	0.1619 ***
	(0.0167)	(0.0318)	(0.0321)	(0.0331)	(0.0331)
All-weather road	0.0791 ***	0.1413 ***	0.1398 ***	0.1767 ***	0.1777 ***
	(0.0163)	(0.0309)	(0.0311)	(0.0324)	(0.0322)
Birth order					
2-3	-0.1001 ***	-0.1505 ***	-0.1557 ***	-0.2043 ***	-0.2055 ***
	(0.0225)	(0.0360)	(0.0363)	(0.0377)	(0.0372)
4-5	-0.2116 ***	-0.3179 ***	-0.3289 ***	-0.4252 ***	-0.4277 ***
	(0.0298)	(0.0511)	(0.0514)	(0.0537)	(0.0527)
≥6	-0.3855 ***	-0.5807 ***	-0.5895 ***	-0.7285 ***	-0.7322 ***
	(0.0384)	(0.0677)	(0.0681)	(0.0712)	(0.0699)
Media	0.1891 ***	0.3282 ***	0.3255 ***	0.3784 ***	0.3798 ***
	(0.0170)	(0.0328)	(0.0330)	(0.0346)	(0.0342)
Mother's age					
At birth	0.0351 ***	0.0600 ***	0.0615 ***	0.0725 ***	0.0727 ***
	(0.0096)	(0.0175)	(0.0176)	(0.0183)	(0.0183)
Age squared	-0.0005 ***	-0.0009 ***	-0.0009 ***	-0.0011 ***	-0.0011 ***
	(0.0002)	(0.0003)	(0.0003)	(0.0003)	(0.0003)
Thresholds					
Cut-off1	3.3876 ***	5.6579 ***	5.7046 ***	6.5165 ***	6.5377 ***
	(0.2519)	(0.4849)	(0.4879)	(0.5149)	(0.5077)
Cut-off2	4.3625 ***	7.3162 ***	7.3678 ***	8.2111 ***	8.2323 ***
	(0.2520)	(0.4917)	(0.4953)	(0.5234)	(0.5164)

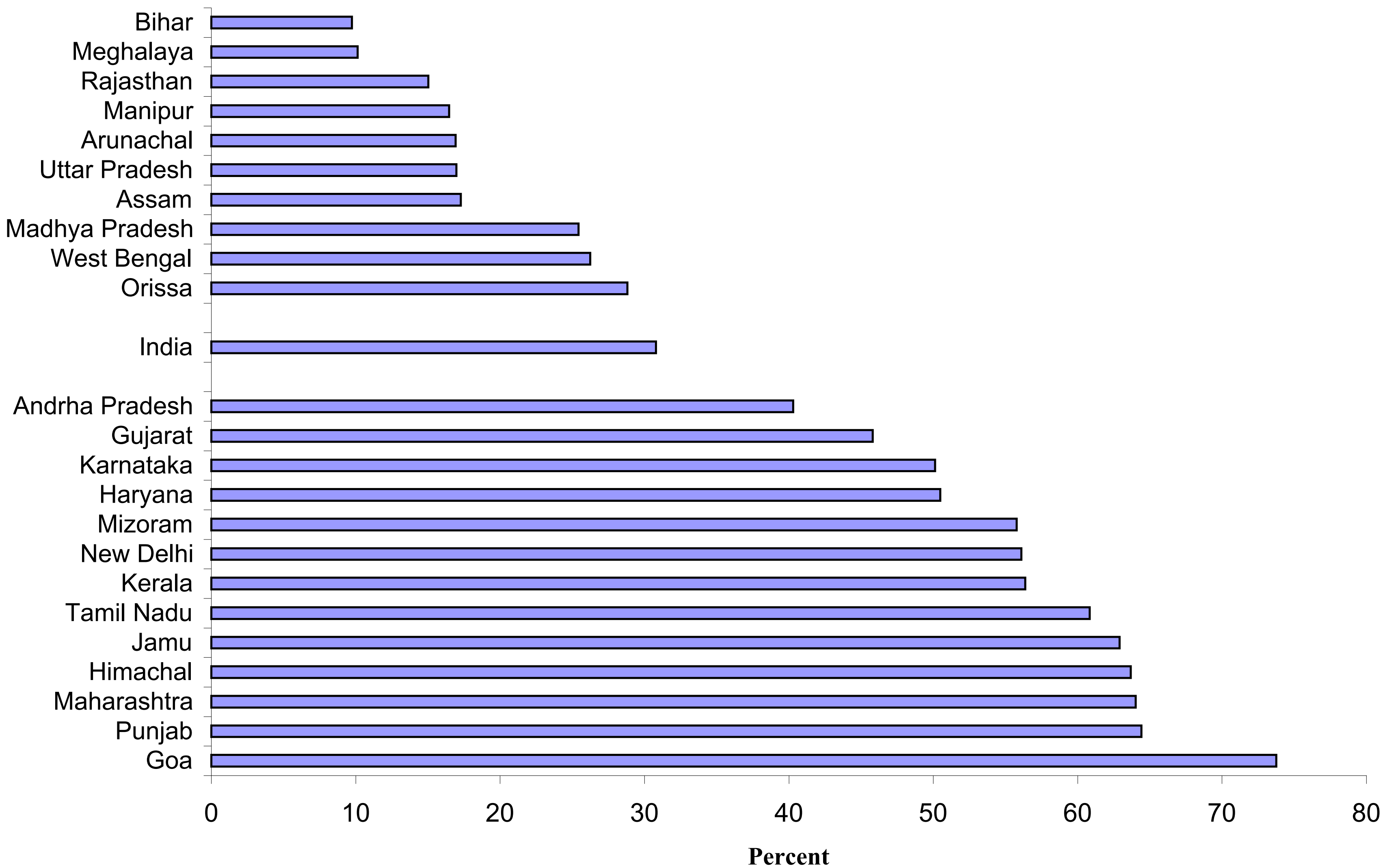
Each column corresponds to that in Table 4.
Standard errors in parentheses; other variables include 24 State dummy variables.
The number of observations is 26,228.
*, **, *** indicate significance from zero at 10 percent, 5 percent and 1 percent, respectively.

Appendix. Estimates of demand for prenatal care model (Probit)

	(1)	(2) & (3)	(4)	(5)
Mother's education				
Literate	0.3799 ***	0.7962 ***	0.9260 ***	0.9259 ***
	(0.0255)	(0.0644)	(0.0779)	(0.0778)
Mid/above	0.7119 ***	1.5588 ***	1.7623 ***	1.7612 ***
	(0.0349)	(0.0986)	(0.1170)	(0.1166)
Per capita	0.7569 ***	1.5878 ***	1.8587 ***	1.8588 ***
HH expend.	(0.0472)	(0.1169)	(0.1472)	(0.1470)
Muslim	-0.0744 ***	-0.2086 ***	-0.2259 ***	-0.2257 ***
	(0.0270)	(0.0652)	(0.0745)	(0.0744)
Caste/tribe	-0.1199 ***	-0.2424 ***	-0.2940 ***	-0.2940 ***
	(0.0208)	(0.0492)	(0.0578)	(0.0577)
Quality house	0.1913 ***	0.3963 ***	0.4376 ***	0.4371 ***
	(0.0200)	(0.0482)	(0.0566)	(0.0565)
Crowding	-0.0149	-0.0132	-0.0363	-0.0363
	(0.0184)	(0.0427)	(0.0498)	(0.0497)
Clinics	0.0237	0.0452	0.0498	0.0497
	(0.0200)	(0.0463)	(0.0536)	(0.0535)
All-weather	0.1581 ***	0.3120 ***	0.3570 ***	0.3562 ***
road	(0.0187)	(0.0447)	(0.0523)	(0.0522)
Birth order				
2-3	-0.2966 ***	-0.5614 ***	-0.6175 ***	-0.6169 ***
	(0.0264)	(0.0530)	(0.0602)	(0.0601)
4-5	-0.4870 ***	-0.9417 ***	-1.0575 ***	-1.0570 ***
	(0.0345)	(0.0765)	(0.0883)	(0.0881)
≥6	-0.7026 ***	-1.3556 ***	-1.5079 ***	-1.5072 ***
	(0.0449)	(0.1020)	(0.1195)	(0.1191)
Media	0.2004 ***	0.4306 ***	0.4746 ***	0.4740 ***
	(0.1950)	(0.0477)	(0.0560)	(0.0559)
Mother's age				
At birth	0.0514 ***	0.1048 ***	0.1104 ***	0.1104 ***
	(0.0116)	(0.0265)	(0.0299)	(0.0299)
Age squared	-0.0008 ***	-0.0018 ***	-0.0018 ***	-0.0018 ***
	(0.0002)	(0.0005)	(0.0005)	(0.0005)

Standard errors in parentheses; other variables include 24 State dummy variables.
The number of observations is 26,228.
*, **, *** indicate significance from zero at 10 percent, 5 percent and 1 percent, respectively.

Figure 1. Percentage of children who received all vaccinations by State



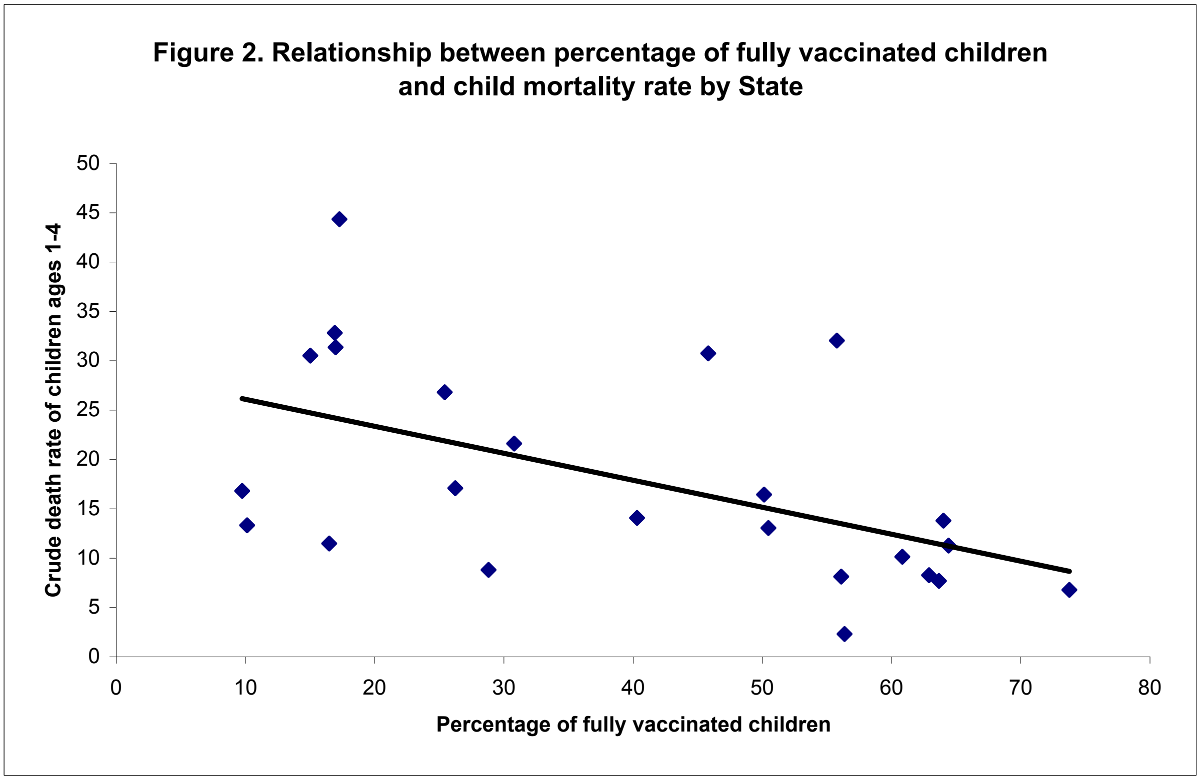


Figure 2. Relationship between percentage of fully vaccinated children
and child mortality rate by State
Crude death rate of children ages 1-4
Percentage of fully vaccinated children
0
5
10
15
20
25
30
35
40
45
50
0
10
20
30
40
50
60
70
80