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Does Family Planning Reduce Infant Mortality? Evidence from Surveillance Data in Matlab, Bangladesh[1]

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Abstract

Analyzing the effect of family planning on child survival remains an important issue but is not straightforward because of several mechanisms linking family planning, birth intervals, total fertility, and child survival. This study uses a dynamic model jointly explaining infant mortality, whether contraceptives are used after each birth, and birth intervals. Infant mortality is determined by the preceding birth interval and other covariates (such as socio-economic status). The decisions about using contraceptives after each birth are driven by similar covariates, survival status of the previous child, and the family's gender composition. Birth spacing is driven by contraceptive use and other factors.

We find favourable effects of contraceptive use, reducing infant deaths in second and higher order births. Because the mortality risks for first-borns is higher than for later births and contraceptive use reduces the number of higher order births, the net effect on the total infant mortality rate is small.

Key words: child mortality, family planning, contraceptive use, demography, dynamic panel data models, Bangladesh.

JEL codes: I1, J13, C33

1. Introduction

Family planning programs were initiated for the wellbeing of mother and child. The mechanisms involved relate to family-building patterns like short birth intervals, young (or relatively old) age of the mother at birth, and many births in a short time period. Births that occur at the extremes of maternal age or are preceded by very short birth intervals are at higher mortality risk, as is widely discussed in the demographic literature (see for example, Haaga 1989; Alam and David 1998; Arulampalam and Bhalotra 2006; Omariba et al. 2008; DaVanzo et al. 2008). Through family planning practice a couple can decide the time of birth, the time span between two births, and the (maximum) number of children they want to have. Contraceptive use is a means of family planning and if it leads to a reduction in the proportion of births at these high risks then infant mortality in the population would decline if the level of contraceptive use rises.

Several studies conducted in Bangladesh (and the Matlab region in particular) reveal that the percentage of lower–order births has increased with rising contraceptive use (for example, Koenig et al. 1992; LeGrand and Philips 1996). By reducing the number of infants born, contraceptive use can enhance the chances for survival: It can, for example, avoid contamination of infectious diseases among closely spaced siblings or reduce siblings' competition for scarce resources such as parental time allocated to child care or the availability of food. Potter (1988) emphasized that proportionally greater reduction of fertility among women whose reproductive health status is poor and the change in family relationships and parenting practices may be crucial ways in which family planning can favourably affect infant mortality.

However, while the theoretical acceptance is wide, empirical evidence on the conjecture that family planning reduces infant mortality is rare. The magnitude of such an effect is also in question. Demographers have different views about the favourable effects of family planning on infant mortality and this thus remains an important issue for further investigation (for reviews see Bongaarts 1987; Trussell 1987; Potter 1988; LeGrand and Philips 1996). Different explanations are documented in the literature. Bongaarts argues that the direct effects of contraceptive use on mother's age at birth, birth interval and the number of higher order births are largely offset by the rise in the proportion of high-risk first births, so that the net effect of contraceptive use on infant mortality is small. Secondly, he argues that many of the apparent effects of child-bearing patterns on child mortality are correlated with other factors (see Hobcraft et al. 1985), which needs to be taken into account in the analysis. Several researchers disagree with Bongaarts's first argument. For example, Trussell (1987) argues that Bongaart's analysis is likely to mislead policy makers because the fraction of first births automatically rises due to the total fertility decline, so that the total infant mortality rate at aggregate level is a misleading measure of child health. He emphasizes the need of taking into account the artificial inflation of first-borns when measuring the impact of family planning on infant mortality at the aggregate level. He also argues that the mortality reducing effect of family planning is important among women who use contraception to space their births or to eliminate unwanted high order births.

A recent review conducted by Yeakey et al. (2009) emphasizes the policy relevance of studying the behavioural pathways linking contraceptive use to birth spacing and timing of births and to perinatal and infant mortality. They reviewed fourteen studies, which all find that the use of contraceptives is protective against short birth intervals. This review also points out methodological flaws of the existing studies, which could undermine the accepted rationale for expanding family planning programs to help deliver the maternal and child health benefits of birth spacing. Existing studies typically use retrospective birth-history data collected in cross-sectional surveys, potentially introducing recall bias and heaping of birth intervals at six-month intervals. A few studies investigated either ever-use or never-use of contraceptives by mothers, not considering the timing of contraceptive use in relation to births.

According to this review none of the existing studies used randomized controlled trials to test the effect of contraceptive use on the outcome of interest-infant mortality. Implementing such a design would require not only a very large sample size, but also monitoring continuous episodes of contraceptive use, pregnancies, conceptions, completion of pregnancies, and the morbidity and mortality outcomes of morther and child at least one year postpartum. Indeed, in this regard it seems that an observational design is perhaps inevitable as a feasible alternative. Ideally such a design should be implemented prospectively. Thus, the use of the prospective data from Matlab Bangladesh might be a good alternative for randomized controlled trials (see for example Philips et al. 1982). Several studies using Matlab data investigated the determinants of infant mortality (DaVanzo and Starbird 1991; Hale et al. 2006; DaVanzo et al. 2007, 2008). However, these studies do not assess explicitly the magnitude of the effect of contraceptive use. Taking into account limitations of all fourteen studies, and in line with the emphasized importance of taking into account correlation and unobserved heterogeneity (Hobcraft et al. 1985; LeGrand and Phillips 1996), the review of Yeakey et al. (2009) concludes that more rigorous modelling is needed, preferably on the basis of longitudinal prospective data. This is exactly where the current study aims to contribute.

In the Matlab ICDDR,B area community health workers through their monthly routine visits record episodes of contraceptive use, pregnancies, conceptions, and the morbidity and mortality outcomes for all children until five years old. Therefore, using longitudinal prospective data from Matlab known to be of exceptional accuracy and completeness, this study first investigates the effects of infant death and other factors (such as socio-economic status or gender composition of the household) on subsequent contraceptive use, and second, the effects of contraceptive use after a birth on birth intervals and infant mortality. Our main analysis is based upon a model with three parts: an equation explaining infant mortality, a model part that explains whether contraceptives are used after a child is born, and an equation explaining birth intervals. (Sterilization is not considered since the mothers in our sample did not initiate sterilization.) Infant mortality is determined by covariates reflecting socio-economic status, age of the mother, gender of the child, etc., but also by the length of the preceding birth interval. The decision to use contraceptives is driven by similar covariates, but also by survival status of the previous child and the family's gender composition. Birth spacing is driven by contraceptive use and other factors.

Each part of the model also incorporates unobserved mother specific heterogeneity, and the various unobserved heterogeneity terms are allowed to be correlated, so that the estimates of the parameters reflecting the causal effects are consistent under general assumptions about the nature of heterogeneity. This makes the model similar in spirit to a recently developed model for birth spacing, fertility, and neonatal mortality in Bhalotra and van Soest (2008). Furthermore, we perform simulations aimed at uncovering the linkage between contraceptive use, birth spacing and infant mortality, taking into account the effect of an increasing fraction of first- born children on the aggregate infant mortality rate.

2. Data

2.1. ICDDR,B area and interventions

The International Centre for Diarrheal Disease Research, Bangladesh (ICDDR,B) started the Maternal Child Health and Family Planning (MCH-FP) programme in October 1977 in half of the health and demographic surveillance system (HDSS) area in Matlab to assess the extent to which maternal and child health and family planning services can reduce fertility and mortality in a rural population. In this area, formerly known as MCH-FP area and currently as ICDDR,B area, additional health services were provided and data were collected on events like births, deaths, causes of deaths, marriage, divorce, migration-in, migration-out, family planning practice, and a range of health indicators, for a population of 89,350 from 70 villages. The other half of the Matlab area remained under the standard government health systems and is known as comparison area, with a population of 85,596 from 79 villages. The large population of the ICDDR,B area with different levels of intensity and coverage and the relative isolation of villages permitted the designation of four treatment blocks where special services are offered, and of contiguous comparison areas in which demographic dynamics are monitored but the contraceptive-use history data are absent. The data from the comparison area therefore cannot be used for the purpose of analysis in this paper.

Data have been collected systematically through regular household visits (once every two weeks until January 1998, and once every month since then). These data, in combination with ICDDR,B population censuses and surveys, permit the evaluation of health and family planning services with a degree of accuracy that is rare in low-income settings (LeGrand et al., 1996). Analysis of levels and trends and a comparison between the ICDDR,B area and the comparison area shows clear evidence that the MCH-FP intervention reduces fertility and under-five mortality (see for example, LeGrand et al. 1996; Hale et al. 2006; DaVanzo et al. 2007, 2008).

2.2. Study sample

We analyse a sample of 31,968 singleton live births and 13,232 mothers who continuously lived and gave all their births in the ICDDR,B area. The data cover the period July 1982 to December 2005; the data before 1982 are not (yet) available for this type of research. A similar set of data was used in several companion papers like Saha and van Soest (2011), but this is the first time we also consider the contraceptive use data available after each birth.

2.3. Variables and descriptive statistics

The dependent variables in our models are the length of each time interval between births, a dummy for using contraceptives after each birth, and a dummy for infant mortality of each child born alive. The covariates include birth order of the child, gender of the child, and age of the mother at the time of birth of the child; education of the mother is captured by dummy variables; this may proxy the mother's ability to take good care of her children but may also proxy the family's socio-economic status. Education and occupation of the father also reflect the family's socio-economic status. Another family level covariate is religion, which is included because contraceptive practice may vary between the two groups. In Matlab, different patterns of fertility behaviour are observed by religion (Huffman et al. 1987). To control for environmental factors, we include a dummy for access to running drinking water (a dummy for piped drinking water / tube well), and the distance to the nearest health facility (defined as a sub-centre or ICDDR,B hospital).

The average number of children born per mother is 2.42 and 82.7 percent of all mothers in the sample are Muslims. The mean age of mothers at birth is respectively 24.7 years, and the average birth interval is about 48 months with standard deviation 23 months, and about 11 percent birth intervals are shorter than 24 months. 48 percent of all mothers never attended school. On average, mothers residing within 2 kilometres of distance to a health facility and 88 percent of all mothers have access to running water (tube well/pipe water).

During the observation period (July 1982-December, 2005), mothers used contraceptives after about 84 percent of all 31,968 child births. In 11 percent of all cases they did not use contraceptives, and about in 4.8 percent of all cases the information on contraceptive use was missing (see Figure 1). The missing observations occur for the most recent births because it is too early to observe contraceptive use status. The average duration of contraceptive use is about 31.4 months with a standard deviation 27.9 months. In about 12 percent of all cases, mothers started using contraceptives more than one year after the previous birth (see Figure 1). In about 55 percent of all cases, they started using contraceptives earlier than 12 months after the previous birth and continued until more than 12 months after birth (see Figure 1). These are the cases where mothers were using contraceptives exactly one year after their previous birth.

Among users, 20.67 percent used *pills*, 46.63 percent used *injections*, 4.74 percent used *IUD*, 11.06 percent used *condoms*, 0.43 percent used *sterilization* and 0.81 percent used a *traditional* method.

Table 1 shows that there is a clear positive relationship between contraceptive use and birth interval length. The birth interval until a next birth is about 53 percentage points (from 24 percent to 77 percent) more likely to be longer than 36 months if a mother uses contraceptives at any time after birth (irrespective of starting time and continuation). There is some variation between the birth interval and the contraceptive method used: using injections or condoms is associated with longer birth intervals than using other methods (pill, traditional, IUD; not shown in the Table).

The bivariate relationships between the socioeconomic variables and contraceptive use and infant mortality are given in Table 2. The results are in line with expectations; for example, first births, shorter preceding time intervals between births, mothers younger than 20, and illiterate mothers are particularly disadvantaged in terms of child survival, and also in contraceptive use. For most covariates, the association with child mortality is opposite to that with using contraceptives, but there are some exceptions. For example, although contraception is higher among Hindu than among Muslim families, it is evident that infant mortality is also higher among Hindus. The latter is in line with findings for India; see Bhalotra et al. (2010).

Finally, Table A1 in the annex gives a more detailed picture of the associations between contraceptive use and infant mortality of successive children. First, it shows that contraceptive use after a given birth is much less common when the child that is born dies during its infancy than when it survives its infancy (the contraceptive use rates are 46.4% (=617/1331*100%) and 83.4%, respectively. Second, the infant mortality rate among children born after an interval during which contraceptives have been used is much smaller than the infant mortality rate among births not preceded by contraceptive use (34.0 versus 62.2 per 1000 births). A possible explanation may be that contraceptive use helps to avoid short birth intervals and short intervals lead to larger mortality risk, but alternative explanations are possible, such as common observed or unobserved factors driving mortality and family planning decisions. The econometric model will disentangle these various explanations.

3. Model

The model explains infant mortality (that is, whether the child survives its first twelve months or not) of each child born, contraception decisions after each live birth, intervals between live births, and fertility decisions. It builds on the model of Bhalotra and van Soest (2008) but adds the decisions to use contraceptives or not. To be precise, the endogenous variables in the model are the following, with *i* denoting a mother and $t=1,..,T_i$ denoting consecutive live births:

M_{it} : Infant mortality dummy: 1 if child *t* dies; 0 if it survives the first twelve months after birth.

C_{it} : Contraceptive use dummy: 1 if mother *i* uses contraception after giving birth to child *t*; 0 otherwise.

F_{it} : Decision to have another child (1) or not (0).

B_{it} : Log birth interval preceding birth of child *t* (*t>1* only*)*

The sequence of events, which is the basis for the dynamic structure of the model, is illustrated in the following time line:

C_{i1}, F_{i1} C_{i2}, F_{i2} C_{i3}, F_{i3} C_{i4}, F_{i4}

---+-------------+-------------+---------------+-----

M_{i1} B_{i2} M_{i2} B_{i3} M_{i3} B_{i4} M_{i4}

We do not explain the timing of the first birth (or the decision to use contraceptives before the first birth. The first event we explain is infant survival of the first born child M_{i1}. The second is the decision to use contraceptives or not at any time after birth 1 and (if there is a second birth) before birth 2 (C_{i1}). The information on the exact timing of contraceptive use (starting and ending date) is not very reliable, which is why we only explain the binary decision. Since contraception usually starts at least one year after a live birth, it is a good approximation to treat this variable as an event that takes place when infant mortality of the latest born child is already known. At the same time, the mother also may decide not to have any more children (F_{i1}); this decision is never observed directly, but if a next birth is observed we know that $F_{i1} = 1$.

If $F_{i1} = 1$, a next birth will take place, and if it takes place before the end of the survey window, we observe the birth interval B_{i2}. The second born child can die during infancy or survive, etc.: the sequence of events continues until the mother decides not to have more children ($F_{iT} = 0$) or at the end of the observation period (December 2005).

The model we use is recursive in the sense that each dependent variable may depend on outcomes realized earlier in the sequence of events, but not on future outcomes. Moreover, each outcome may depend on unobserved factors common to all children of a given mother, treated as unobserved individual effects. We use probit equations for the binary outcomes and a regression equation for the continuous outcomes. Below we discuss the equations for the various outcomes in detail.

Infant mortality

The equation for infant mortality is similar to that in Bhalotra and van Soest (2008). For higher birth orders, a dynamic probit equation with random mother specific effects is used, where the regressors include the preceding birth intervals and variables like the mother's age at birth, which is a function of previous birth intervals: For child t ($t=2,\ldots,T_i$) of mother i, the equation is

$$M_{it}^{*} = X_{it}\beta_m + Z_{it}\gamma_m + \alpha_{mi} + u_{mit} \qquad (1)$$

$$M_{it}=1 \text{ if } M_{it}^{*}>0 \text{ and } M_{it}=0 \text{ if } M_{it}^{*}\leq 0$$

Here X_{it} contains (functions of) the strictly exogenous variables, such as gender of the child, socio-economic status indicators of the household (mother's and father's education, etc.) and characteristics of the village where the household resides. Z_{it} denotes the vector of explanatory variables that are functions of previous outcomes (and are therefore not strictly exogenous). It includes the preceding log birth interval B_{it}, but also (functions of) age of the mother at birth t

and, following the literature on scarring (see, for example, Arulampalam and Bhalotra 2006), survival status of the previous child M_{it-1}. The mother specific unobserved heterogeneity term α_{mi} captures unobservable time invariant characteristics influencing the propensity do die of all children in the family. The error term u_{mit} captures idiosyncratic health shocks specific to child t. We assume that the u_{mit} follow a standard normal distribution, independent of each other and of all covariates, and that α_{mi} is normally distributed with mean 0 and variance $\sigma^2_{\alpha m}$ independent of all u_{mit} and X_{it} (but not of Z_{it}).

For mortality of the first child, a separate equation is needed, since in this case there is no preceding birth interval and no preceding mortality outcome. Age at first birth is assumed to be strictly exogenous and can therefore be included in X_{i1}. The equation for infant mortality of child 1 is then given by:

$$M_{i1}^{*} = X_{i1}\beta^{1} + \theta\alpha_{mi} + u_{mi1} \qquad (2)$$

$$M_{i1}=1 \text{ if } M_{i1}^{*}>0 \text{ and } M_{i1}=0 \text{ if } M_{i1}^{*}\leq 0$$

Here β^1 and θ are additional parameters to be estimated and the error term u_{mi1} is assumed to satisfy the same assumptions as the other u_{mit} .

Contraceptive use

We model the observed decisions C_{it} to perform family planning through the use of contraceptives at any time after birth t and (if there is a next birth) before birth $t+1$ (t=1,...,T_i) using the following probit equation:

$$C_{it}^{*} = X_{it}\beta_c + Z_{it}^{c}\gamma_c + \alpha_{ci} + u_{cit} \qquad (3)$$

$$C_{it} = 1 \text{ if } C_{it}^{*}>0 \text{ and } C_{it} = 0 \text{ if } C_{it}^{*} \leq 0$$

Here X_{it} contains the same strictly exogenous explanatory variables as before. Z_{it}^{c} is the vector of predetermined explanatory variables in this equation, including survival status of preceding sibling and family composition variables (number of surviving girls and boys to mother i). The mother specific unobserved heterogeneity terms α_{ci} capture unobservable time invariant characteristics influencing family planning practice. The error terms u_{cit} capture idiosyncratic errors to the decision of family planning practice after each child birth. We assume that the u_{cit} follow a standard normal distribution, independent of each other and of all covariates, and that α_{ci} is normally distributed with mean 0 and variance $\sigma^2_{\alpha c}$ independent of all u_{cit} and X_{it} (but not of Z^c_{it}).

Birth-spacing

For a mother who has given births to T_i children, we observe the exact log durations in between two consecutive births $b_{2i},\ldots,b_{T_i i}$ preceding births $2,.....,T_i$. We model these intervals using the following equation:

$$b_{it} = X_{it}\beta_b + Z^b_{it}\gamma_b + \alpha_{bi} + u_{bit} \qquad (4)$$

Here X_{it} denotes the vector of strictly explanatory variables, as before. Z^b_{it} includes survival status of the preceding sibling, the family composition variables (numbers of surviving girls and boys) and the decision to use contraception C_{it}. The latter captures the mechanism of family through contraceptive use: the use of contraceptives delays the next birth and possibly therefore also reduces the total number of births. The mother specific unobserved heterogeneity term α_{bi} captures unobservable time invariant characteristics influencing the birth interval. The error term u_{bit} captures idiosyncratic errors. We assume that the u_{bit} follow a normal distribution, independent of each other and of all covariates, and that α_{bi} is normally distributed independent of all u_{bit} and X_{it} (but not of Z_{it}).

Fertility decisions and right censoring

There is right-censoring in the data since some mothers will not have completed their fertility at the time of the survey. After the end of the observation window (ultimo 2005), some mothers will still have another birth, and others will not. In principle, this could be captured by the model as it is described until now, with a birth interval after the last observed birth that lasts longer than till the end of 2005.

Following Bhalotra and van Soest (2008), however, the model fit can be improved substantially by adding a separate equation reflecting the possible decisions to stop having children after each birth. The reason why this improves the fit is essentially that it can explain why some mothers who are still of reproductive age have no more births long before the end of the observation window. (We will assume that women are no longer of reproductive age when they reach age 45, an age beyond which very few births are observed in our data). Without the additional equation, this would have to be explained by a very long birth interval.

The equation determining whether the woman continues to have children after birth t ($F_{it}=1$) or not ($F_{it}=0$) is specified as follows:

$$F_{it}^{*} = X_{it}\beta_f + Z_{it}^{f}\gamma_f + \alpha_{fi} + u_{fit} \qquad (5)$$

$$F_{it} = 1 \text{ if } F_{it}^{*} > 0 \text{ and } F_{it} = 0 \text{ if } F_{it}^{*} \leq 0$$

As before, X_{it} denotes the vector of strictly exogenous explanatory variables. The vector Z_{it}^{f} includes survival status of the preceding sibling and family composition variables (based upon the number of surviving girls and boys). The mother specific unobserved heterogeneity term α_{fi} captures unobservable time invariant characteristics influencing the fertility decision after each child birth. The term u_{fit} captures idiosyncratic errors. We assume that the errors u_{fit} are standard normally distributed, independent of each other and of all covariates. The mother specific unobserved heterogeneity terms α_{fi} are normally distributed with mean 0 and variance $\sigma_{\alpha f}^{2}$, independent of all u_{fit} and X_{it}.

The outcome F_{it} is observed only partially. If birth t is not the last birth ($t<T_i$) then we know that the mother has decided not to stop having children, so $F_{it} = 1$. But if $t=T_i$, it is possible that she has decided to stop having children ($F_{it} = 0$), but it may also be the case that the next birth interval extends beyond the end of the observation window ($F_{it} = 1$ and right censoring).

Note that we have neither included contraceptive use as an explanatory variable for the decision to continue fertility, nor the fertility choice as a factor driving contraceptive use. This is because we see these two decisions as taken jointly (and at the same point in time), as illustrated on the time line at the beginning of this section. It is clear that the two decisions are related but modelling the mechanics of the decision process is beyond the scope of this study. Instead, we model two decisions in a reduced form type of way, not including the other decision on the right hand side.[2]

Confounding unobserved factors are controlled for by allowing arbitrary correlations amongst α_{fi}, α_{mi}, α_{bi}, and α_{ci}. We will assume they are drawn from a four-dimensional normal distribution with zero mean and an arbitrary covariance matrix, independent of the X_{it} and all the idiosyncratic error terms.

The five equations of this model (including the initial mortality equation) are estimated jointly using simulated maximum likelihood. Conditional on the random mother specific effects, the likelihood contribution of a given mother can be written as a product of univariate normal probabilities and densities over all births following the order of observed events as indicated on the time line sketched above and accounting for the possibility of right censoring. Since mother specific effects are unobserved, the actual likelihood contribution is the expected value of the conditional likelihood contribution, with the expected value taken over the four random effects. This is a four-dimensional integral, which is approximated using (smooth) simulated ML: Multivariate errors drawn from $N(0,I_4)$ are transformed into draws of the random effects using the parameters of the random effects distribution; the conditional likelihood contribution is then computed for each draw and the mean across R independent draws is taken. If $R\to\infty$ with the number of mothers N, this gives a consistent estimator; if draws are independent across households and $R\to\infty$ faster than $\sqrt{N}$, then the estimator is asymptotically equivalent to exact ML (see, for example, Hajivassiliou and Ruud 1994). To reduce the sampling variance in the simulations, we used Halton draws (see Train 2003). The results we present are based on $R=50$. We checked the sensitivity of our parameter estimates for the number of the draws (comparing with larger R) and the nature of the draws (using Halton draws with different seeds) and always got very similar results. The estimation procedure is very similar in spirit to the one used by Bhalotra and van Soest (2008); see also their online appendix for details.

4. **Estimation results**

[2] One might argue that this implies that the error terms in equations (5) and (3) should be correlated. This is an extension we leave for future work.

Table 3 reports the parameter estimates, using the benchmark definition of contraceptive use. The estimates of the specification with an alternative definition of the contraceptive use dummy are presented in Table A2 in the appendix. In the discussion in this section we focus on the benchmark specification; the results in Table A2 will be discussed in Section 6. The top panel of the Table presents the estimates of the parameters in the four main equations; the bottom panel shows the estimates of the covariance structure of the unobserved heterogeneity terms. Estimates for the static equation for mortality of the first child are available upon request; they are very similar to those in Saha and van Soest (2011).

Contraceptive use

The estimates in the contraceptive use equation are in line with existing results on the determinants of contraceptive use in rural Bangladesh; see for example, Koenig et al. (1992) or Rahman et al. (1992). Acceptance of contraception is significantly (at the 5 percent level) higher among Hindus than among Muslims, in line with the bivariate relation in Table 2. The estimated difference in the probability to use contraceptives keeping other observed and unobserved characteristics constant is about 1.7 percentage points.[3] Contraceptive use is increasing in both maternal and paternal education, with larger effects of paternal education. The strong association with parental education levels is in line with Rahman et al. (1992, Table 1), while Koenig et al. (1992, Table 3) find a much weaker relation with maternal education in the ICDDR,B area. If the father is a day-labourer, however, contraceptive use is significantly more likely, which is not in line with the bivariate relationship in Table 2. Perhaps these families have a larger tendency to postpone having more children until the socio-economic position of the breadwinner improves. The likelihood of contraceptive use is increasing in the mother's age at birth, a common pattern in developing country data. Mothers of later birth cohorts exhibit a significantly increasing trend of contraceptive use.

The death of the last born child at infancy substantially reduces the likelihood of contraceptive use (by about 17 percentage points in the benchmark specification), in line with the *replacement hypothesis* that families want to replace a lost child. This is widely regarded in the demographic literature (for example, see Rahman et al. 1992 or Bhalotra and van Soest 2008).

[3] Estimated marginal effects (keeping other observed and unobserved characteristics constant) for the average observation are about 0.19 times the corresponding parameter estimate.

The effects of the numbers of surviving boys and girls are consistent with son preference: having at least one boy has a somewhat stronger (positive) effect on the decision to use contraceptives than having at least one girl (the marginal effects are about 10.0 and 8.4 percentage points), and each additional son in the family increases the likelihood of contraceptive use more than each additional daughter (with, for the average observation, about 6.7 and 3.4 percentage points, respectively). Similar conclusions concerning son preference in family planning have been drawn in other studies for Bangladesh (see for example, Rahman et al. 1992; Koenig et al. 1992).

Birth intervals

The parameter estimates in the log birth-spacing equation show that, keeping constant other factors including the decision to use contraceptives at any time after the previous birth, birth intervals tend to be shorter for high birth orders, which is consistent with the stylized fact that short birth intervals are associated with high fertility. Mothers with more education consistently have longer birth intervals. Birth spacing is increasing in maternal age. In more developed villages with piped/tube well water, birth intervals are longer.

As expected, using contraceptives leads to a large and significant increase in the space between births – it increases the interval by around 60 percent (exp(0.495)-1)*100%). On the other hand, keeping contraceptive use and other factors constant, death at infancy of the previous child shortens the subsequent interval between births by 43 percent (exp(-0.55)-1)*100%), in line with the replacement hypothesis. The effects of the surviving numbers of boys and girls are again consistent with son preference: having a boy increases the birth interval by twice as much as having a girl, and each additional boy has a much larger effect than each additional girl. These findings are consistent with the earlier findings in the contraceptive equation. These results show that the decision to use contraceptives and the length of the birth interval conditional on the decision to use contraceptives (which will depend upon starting and ending date of contraceptive use, which are not explicitly modelled) are both determined by similar family planning considerations.

Infant mortality

The parameter estimates in the mortality equation in Table 3 are largely in line with the general conclusions about the determinants of infant mortality in developing countries (see

Bhalotra and van Soest 2008; Omariba et al. 2008) and Saha and van Soest (2011). A difference compared to our earlier study (Saha and van Soest) is that in the current study, the effect of lagged mortality on the probability of infant death is negative but insignificant, while in Saha and van Soest it was negative and significant at the 5 percent level when the birth interval was controlled for as an exogenous covariate (Table 5). This small and insignificant parameter estimate suggests that a negative learning effect is compensated by a positive scarring effect through, for example, depression induced by the previous infant's death. We allow for a nonlinear relation between birth intervals and infant mortality. The estimates imply that mortality risk falls with the length of the birth interval over most of the relevant range of birth intervals (until about 57 months), a finding which is in line with the existing literature (see, for example, Rutstein, 2005, or Conde-Augudelo et al., 2006). Taking account of the nonlinear relation between birth spacing and infant death, we find that at the average birth interval length, an increase of the birth interval by 10 percent reduces mortality by about 0.11%-points. Since the effect of contraceptive use on the log birth interval is about 0.495, this implies that, for the average observation, using contraceptives reduces the mortality probability by about 5.4 deaths per 1000 live births.

Fertility

The final column of Table 3 presents the estimates of the auxiliary fertility equation explaining whether, after each birth and mortality outcome, a family decides to have another birth or not. Fertility falls with the level of education of both mother and father, with mother's education having the larger effect. Muslims show a higher tendency to continue fertility than their Hindu counterparts, and this finding is consistent with contraception differentials by religion. It is less clear why, keeping other factors constant, the probability to have another birth is highest among the youngest birth cohort of mothers and increases with the mother's age at previous birth. In villages with access to running water (tube well or piped water) mothers are less likely to continue their fertility. The family composition variables again show evidence of son preference in family planning, consistent with the findings in both the contraceptive use and the birth spacing equation.

Unobserved heterogeneity

The bottom panel of Table 3 describes the estimated covariance structure of the unobserved heterogeneity terms. (The covariance matrix is specified as ΛΛ' for a positive semi-definite lower triangular matrix Λ; the estimated auxiliary parameters are not presented to save space) Unobserved mother specific heterogeneity is large and significant in the contraceptive and fertility equations, reflecting 33 percent and 44 percent (denoted in the table by ρ), of the total unsystematic variation (for given values of the observed covariates and endogenous explanatory variables in each equation), compared to only 7 percent in the mortality and birth interval equations.

We find a large negative correlation between the unobserved heterogeneity terms in the fertility and contraceptive use equations, and between the fertility and birth spacing equations. This suggests that, keeping observed factors constant, mothers who desire more children are less likely to use contraceptives ($\text{corr}(\alpha_{fi}, \alpha_{ci})$ = -0.73), and anticipate this by reducing birth-spacing ($\text{corr}(\alpha_{bi}, \alpha_{fi})$ = -0.76). This is consistent with target fertility models discussed in, for example, Wolpin (1997). The negative correlation of the unobserved heterogeneity terms in the mortality and contraceptive equations (-0.31) suggests that mothers whose children have relatively high mortality risks respond to this by planning more children and not using contraceptives. This interpretation contradicts, however, the (modest) positive correlation between unobserved heterogeneity terms in the mortality and birth spacing equations (+0.21).

5. Simulations

To illustrate the importance of family planning for birth spacing, fertility, and infant mortality, we performed some simulations, in a similar way as the simulations in Bhalotra and van Soest (2008, Table 3). These simulations show the benefits of family planning programs that delay second births through lengthening birth intervals and avoid high risk births in the young birth cohorts of mother. It illustrates the main novelty of our approach – the fact that our model incorporates various mechanisms that lead to associations between family planning, birth spacing, fertility, and mortality outcomes, accounting for the effects of endogeneity in contraceptive use decisions, timing of births (and therefore also age at birth etc.), birth intervals, and mortality risks.

The simulations use the covariates (including, for example, date of first birth) as observed for each mother in the actual sample. We then generated, for each mother in the sample, unobserved heterogeneity terms, error terms, and new outcomes (the dependent variables in our model) using the estimated parameters of each equation. The outcomes were generated recursively, using the timing of the events as sketched in Section 4.3. For example, for a given mother, we take the date of first birth as given and first generate the mortality outcome of the first child (using equation (2)). Given simulated mortality, we then generated the contraceptive use decision and the fertility decision after the first birth (equations (3) and (5)). If the fertility decision is positive, we then generate a birth interval, and update calendar time and age of the mother at the second birth. Given these variables and the other covariates and the previous mortality outcome, we then generate the mortality outcome of the second born child, etc. In this way we generate complete contraceptive use, fertility, and mortality patterns for each mother in the sample. To reduce simulation variance, this is repeated 25 times for each mother.[4]

Column 1 summarizes the simulation outcomes according to a benchmark simulation where all mechanisms at work in the estimated model are active. This simulation reproduces the means in the raw data, showing that the model is able to reproduce these basic features of the data. This simulation also reproduces the substantial difference between mortality of first born children (simulated at 67.2 per 1000 live births) and mortality of higher order births (39.6 per 1000 births on average; 40.4, 37.9, 39.0, 42.2 and 46.8 per 1,000 live births for birth orders 2, 3, 4, 5 and 6, respectively).

The other columns present the deviations from the benchmark considering the two hypothetical extreme cases of contraceptive use: in column 2, everyone is always assumed to use contraceptives. In column 3, no contraceptives are used at all. The latter is a more dramatic change compared to the benchmark than the former, since in the benchmark simulation contraceptives are used in 88.6 percent of all cases.

[4] The simulations take the parameter estimates as given. In principle, it would be possible to compute a standard error for each simulation outcome by repeating the simulations for other draws of the model parameters from their estimated (asymptotic) distribution but this would require a substantial computational effort.

The simulation in column 2 shows that, according to our model estimates, if contraceptives were used after each birth, the average birth interval length would increase by about four months. Since short birth intervals are then more often avoided, it would also reduce the mortality risk of higher order births. The estimated reductions in mortality of children of birth order two and higher would be substantial: 7.9 percent for all birth orders of 2 and higher. It is particularly large for birth order 2 with a reduction of 9.2 percent (3.7 per 1000 live births – from 40.4 to 36.7; these figures are not shown in the table). The longer birth intervals would also reduce total fertility, by about 2.4 percent. This implies that the weight of first born children in the total infant mortality rate will increase. Since the infant mortality risk for first born children is higher than for higher birth orders (and since contraceptives do not affect this mortality rate), this composition effect tempers the favourable effect of contraceptives on survival chances of higher order births: the total infant mortality rate still falls compared to the benchmark situation, but by much less than the mortality rate for higher birth orders.

Results by maternal education level (not shown in the table) show that the benefits of complete contraceptive use would be particularly large for the lowest socio-economic status group, mothers without any education. This is because they have the lowest contraceptive use in the benchmark situation (84.4% compared to 88.6% for the complete sample) but also because they have shorter birth intervals and the most vulnerable children (their infant mortality rate among children of birth order 2 and higher is 49.5 per 1000 births in the benchmark situation, compared to 39.6 per 1000 for the complete sample). If everyone would use contraceptives after each birth, birth interval lengths in the no education group would increase by 6 months on average, and infant mortality among higher order births would fall by 8.7% (compared to 7.9% for the complete sample). Their total infant mortality rate would fall by 3.2% (2.9% for the whole sample).

The simulation in column 3 indicates that, if contraceptives were never used after any birth, the average birth interval length would shorten by more than 13 months, and this would raise the mortality risks in higher order births by 10.6 percent (from 39.6 to 43.8 per 1000 births). Particularly for second order births the effect would be large (6.3 per 1000). The shorter birth intervals lead to an increase of the total fertility rate by 19.3 percent, implying that the weight of first born children in the total infant mortality rate will fall. This leads to a negative composition effect on the total infant mortality rate, that almost completely compensates for the rise in mortality of higher order births – the total infant mortality rate increases by 1.6 percent only (from 51.2 to 52.1 per 1000 live births) compared to the benchmark situation.

6. Alternative model specification

Table A2 presents the estimation results for the alternative definition of the contraceptives use dummy – considering whether a mother uses contraceptives at a specific point in time: exactly 12 months after a given birth. Most of the parameter estimates are similar to those in Table 3, but there are exceptions, particularly, as expected, in the coefficients of the contraceptives equation. Muslim mothers are much less likely to use contraceptives after exactly one than Hindu mothers and the difference is now significant at the 5 percent level. Contraceptive use after one year also increases significantly with birth order. On the other hand, mother's education plays a much smaller role than in Table 3. The effect of lagged mortality is still somewhat stronger than in Table 3, but, unexpectedly, the effects of the family composition variables (surviving boys and girls) are much smaller and less significant. These variables still have the expected strong and significant effects on birth intervals and fertility decisions, but not on the decision to use contraceptives at the chosen specific point in time.

The effect of contraceptive use defined in this alternative way on birth spacing remains positive and significant, but is much smaller than in Table 3 (0.341 instead of 0.495), suggesting that contraceptive use after exactly 12 months does not capture the full effect of contraception decisions on birth spacing; this is the main reason why we prefer the definition of using contraceptives at any time instead of the alternative.

Table 5 gives the results of the simulations discussed in the previous section for the estimated model in Table A2, using the alternative dummy on contraceptive use. The benchmark simulation predicts that contraceptives are used at exactly one year after birth in 58 percent of all cases. The other outcomes of the benchmark simulation are similar to those in Table 4 and reproduce the corresponding statistics in the sample.

The simulation in column 2 of Table 5 shows that, according to our alternative model estimates, if everyone always used contraceptives at one year after each birth, the average birth interval length would increase by about 7.5 months. The effect seems larger than in Table 5, but that is because the change from not using to using contraceptives affects many more cases now (42 percent rather than 12 percent). As a consequence, mortality of children of birth orders two and higher would fall by 6.9 percent (from 39.4 to 36.7 per 1000 live births). Again, the reduction is relatively high for second order births (8.2 percent; not shown in the table). The longer birth intervals would reduce total fertility by about 6.0 percent. This implies that the weight of first born children in the total infant mortality rate will increase. This composition effect tempers the favourable effect of contraceptives on survival chances of higher order births if the total infant mortality rate is considered: the total infant mortality rate falls by only 1.5 percent (from 51.0 to 50.3 per 1000 live births) compared to the benchmark situation.

Column 3 of Table 5 gives the simulation results when no one would use contraceptives one year after birth. The average birth interval length would fall by about 5.7 months. As a consequence, mortality of children of birth orders two and higher would rise by a modest 1.4 percent (3.8 percent for children of birth order 2, but smaller effects for higher birth orders), while total fertility would increase by 8.6 percent. This induces a negative composition effect on total infant mortality including first children since the weight of relatively vulnerable first born children falls. This composition effect is larger than the direct effect through birth intervals so that the sum of the two effects is also negative: total infant mortality falls by 1.1 percent compared to the benchmark situation.

7. Discussion and conclusion

Several studies using Matlab data investigated the determinants of infant mortality (DaVanzo and Starbird 1991; Hale et al. 2006; DaVanzo et al. 2007 and 2008). However, these studies did not assess explicitly the magnitude of the effect of family planning programs on birth intervals and thereafter on infant mortality. The major motivation of our current study is the conclusion drawn by Bongaarts (1987) and a recent review paper by Yeakey et al. (2009). We use the prospective pregnancy-history data from Matlab, Bangladesh where community health workers (CHWs) through their monthly routine visit record episodes of contraceptive use, pregnancies, conceptions, and morbidity and mortality outcomes for mothers and children younger than five.

Exploiting dynamic econometric panel data modelling, our analysis allows for taking into account endogeneity of birth intervals in the mortality equation, reverse causality of mortality and fertility (probability of having further birth), and identifies the causal effect of contraceptive use on birth intervals.

The covariate effects on infant mortality, contraceptive use, and birth intervals are generally in line with expectations and associations observed in the existing demographic literature. Some remarkable findings are: contraceptive use after a given birth is likely to increase the length of log birth intervals by about 60 percent Feeding this effect in the mortality equation shows that it is also likely to reduce the effects of maternal depletion in child births. We find evidence of son preference in both contraceptive use decisions and log birth interval choices conditional on using contraceptives or not.

Contraceptive use may be related to breastfeeding, since breastfeeding also can delay a new pregnancy. The effects of breastfeeding on birth intervals and childhood deaths in the literature are mixed; see, e.g., Smith (1985) and Retherford et al. (1989). We have investigated the associations of breastfeeding with birth intervals and, surprisingly, found no significant differences in birth spacing by breastfeeding status. However, a large and significant difference in birth spacing by contraceptive use status exists and this difference does not vary by breast feeding status. This finding is in line with van Ginneken (1974) who found that lactation is less adequate as a birth spacing method than modern contraceptives. Still, it can be seen as a limitation of our study that we did not explicitly incorporate breastfeeding in our model.

Our findings are in line with the argument of Bongaarts (1987) that the direct effects of contraceptive use on mortality are largely offset due to changes in the composition of births by age, birth order, and birth interval, particularly the rise in the proportions of high-risk first births. These effects are disentangled in the simulation analysis. It shows that, as Bongaarts argued, the net effect of family planning on reducing total infant mortality is small. At the same time, the results confirm the favourable effects of family planning programs on child survival for second and higher birth orders that work through birth spacing – and our simulations imply that further increase of contraceptive use has the potential or reducing infant mortality among second and higher order births by about 7.9 percent. (11 infant deaths per 1000 live births). This leads to the policy implication that strengthening family planning programs helps to reduce infant mortality. Since this is particularly the case for lower socio-economic groups, it also improves equity across socio-economic groups.

In our analysis, the date of the first birth is given and not explained. Children of very young mothers (age at birth less than 20 years) have a much larger risk of infant mortality and thus it remains important for further study to analyze how contraceptive use plays a role in increasing age at first birth. This information will be important for strengthening family planning programs for newly married couples. Increasing the age at first birth may also lead to fertility reductions through reducing the total reproductive span of women, something that is already on the policy agenda.

Our current analysis has several other limitations. Due to availability of data we could not model the decision to discontinue the use of contraceptives and the births that are due to such discontinuation or failure of the contraceptive method. That these events are common in Bangladesh is known from contraceptive use history data (see Steele and Diamond 1999; Bairagi et al., 2000; Saha et al., 2004). Saha et al, (2004), for example, estimate that about 50% of all mothers discontinue using a contraceptive method within two years of initiating it, and discontinuation is particularly large for pills and condoms. Different rates are found in other studies that use the calendar data from the Bangladesh Demographic and Health Surveys (BDHS), where injection users are more likely to discontinue than pill or condom users. This is possible because the method mix observed in the nationally representative BDHS is different from that of Matlab. A study conducted in Matlab by Bairagi et al. (2000) found that the cumulative probability of first method failure within one year of method acceptance during 1990-1994 was, for example, 12.9% for pills and 22.0% for condoms. Our alternative specification is a first crude attempt to take account of how long contraceptives are used instead of just whether they are used or not. Future research can look at the timing in more detail.

Moreover, our model uses one dummy of contraceptive use and does not distinguish between the various methods, avoiding the need to complicate the model further with the choice of method in an already intricate model. Modelling the choice of the type of contraceptives may give more insight in the effectiveness of method-mix in lengthening birth intervals, and thus seems interesting topic for future research.

Finally, it would be interesting to extend the current analysis to a setting without extensive health and family planning services such as the comparison area in Matlab. This can disentangle the effects of family planning programs on the duration of birth intervals and on infant mortality in a society where only government health services are available and contraceptive use is less prevalent.

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Table 1. Distribution of contraceptive use and birth intervals.

Birth interval	**<-24 months**	**25-36 months**	**37 + months**	**Total (N)**
Contraceptive Use		Row Percentage		
No	41.13	35.03	23.84	3,460
Yes	6.47	16.58	76.94	14,472
Total (N)	2,360	3,612	11,960	17,932

Notes: observations on contraceptive use (after each birth) are missing for total 1,524 birth records where 804 birth records after first-borns and excluded from this analysis, and due to first-borns 13,232 observations are excluded from this analysis.

Table 2. Descriptive statistics (%) of different predictors of infant mortality and contraceptive use in Matlab, Bangladesh, birth cohort 1982-2005.

	Children	Infant mortality	Contraceptive use after birth
Birth order			
1	41.39	6.70	79.46
2-3	46.55	3.86	86.39
4+	12.06	4.28	89.68
Gender of child			
Male	16,294	5.43	84.43
Female	15,674	4.73	83.38
Preceding birth interval (excluding first-born)			
<=24 months	7.61	7.27	
25-36 months	11.71	4.12	
37+ months	39.29	3.26	
Mother's age at birth (years)			
<=19	10.89	8.13	79.89
20-24	47.03	5.55	81.60
25-29	22.23	3.79	86.26
30-34	16.23	3.70	88.98
35+	3.62	4.06	87.04
Religion			
Muslim	83.03	4.97	83.72
Not Muslim	16.97	5.68	84.86
Maternal education level			
No education	48.48	6.28	81.84
At least primary education	24.86	4.53	86.32
At least secondary education	26.66	3.44	85.45
Mother's birth cohort			
Before 1966	6,304	6.44	74.11
1966-1970	9,416	5.62	83.60
1971-1975	7,306	4.71	89.46
1976+	8,942	3.88	86.62
Paternal educational level			
No education	55.67	5.53	80.59
At least primary education	22.65	5.58	86.98
At least secondary education	21.68	3.43	89.25
Paternal occupation			
Day laborer	19.61	7.53	77.21
Not day laborer	80.39	4.49	85.55
Source of drinking water			
Pipe/tube-well	87.76	4.68	85.15
Other	12.24	8.0	75.03
Distance to nearest health facility			
$\leq$ 1 km	35.80	4.97	84.84
1-2 km	42.44	5.06	83.72
>2 km	21.76	5.32	82.78

Table 3: Estimation Results.

Variable	Contraceptive use		Log birth space		Infant mortality		Prob (next birth)	
Panel A	parameter	s.e	parameter	s.e	parameter	s.e	parameter	s.e
Male	-0.070	0.041	0.002	0.010	0.025	0.037	-0.031	0.045
Muslim	-0.092*	0.042	-0.008	0.010	-0.023	0.052	0.602**	0.064
Birth order	0.057	0.071	0.084**	0.018	0.064	0.103	-0.072	0.086
Birth order square	-0.011	0.010	-0.019**	0.002	-0.007	0.014	0.005	0.009
Mother's age at birth (years)/10	0.005*	0.002	0.003**	0.001	-0.012**	0.003	-0.001	0.003
Mother's age at birth/10 square	0.230**	0.047	0.048**	0.012	0.193**	0.060	0.228**	0.059
Maternal education level								
At least primary education	0.116**	0.037	0.027**	0.008	-0.047	0.047	0.024	0.050
At least secondary education	0.181**	0.045	0.043**	0.010	-0.023	0.060	-0.366**	0.071
Mother's birth cohort								
1966-1970	0.565**	0.038	-0.007	0.009	-0.026	0.047	0.033	0.046
1971-1975	1.208**	0.0467	0.017	0.011	-0.133*	0.058	0.007	0.064
1976+	1.841**	0.057	0.052**	0.012	-0.159*	0.069	0.574*	0.258
Paternal educational level								
At least primary education	0.200**	0.037	-0.024*	0.008	0.056	0.044	-0.011	0.050
At least secondary education	0.291**	0.041	-0.024*	0.009	-0.205**	0.059	-0.129*	0.056
Father is day labourer	0.194**	0.052	-0.022	0.011	0.131*	0.055	-0.508**	0.064
No tubewell/piped water	0.052	0.037	0.031**	0.009	-0.163*	0.056	-0.100	0.053
Distance to health centre (in km)	-0.009	0.015	0.006	0.003	0.005	0.020	-0.018	0.017
Lagged contraceptive use			0.495**	0.010				
lagged infant mortality	-0.880**	0.060	-0.554**	0.016	-0.020	0.072	-0.139	0.089
First boy surviving	0.528**	0.062	0.126**	0.016			-0.955**	0.105
First girl surviving	0.440**	0.063	0.085**	0.016			-0.873**	0.096
After first boy, # of boys surviving	0.353**	0.056	0.079**	0.015			-0.678**	0.085
After first girl, # of girls surviving	0.178**	0.052	0.027	0.015			-0.298**	0.072
Preceding log birth interval					-1.586**	0.373		
Preceding birth interval square					0.196**	0.052		
Constant	-0.226	0.293	2.899**	0.073	3.131**	0.750	4.472**	0.462
Panel B								
P	0.328		0.067		0.066		0.435	
Correlation (row1)			0.184		-0.306		-0.727	
Correlation (row2)							-0.764	
Correlation (row3)			0.205				-0.153	

Notes: * 2 < t-value < 3; ** t-value ≥ 3
Reference category: gender is female, religion is Muslim, mother and father have no education, father is not day-labourer, source of drinking water is tube-well/pipewater, and mother's birth cohort before 1966.

Table 4. Simulation results.

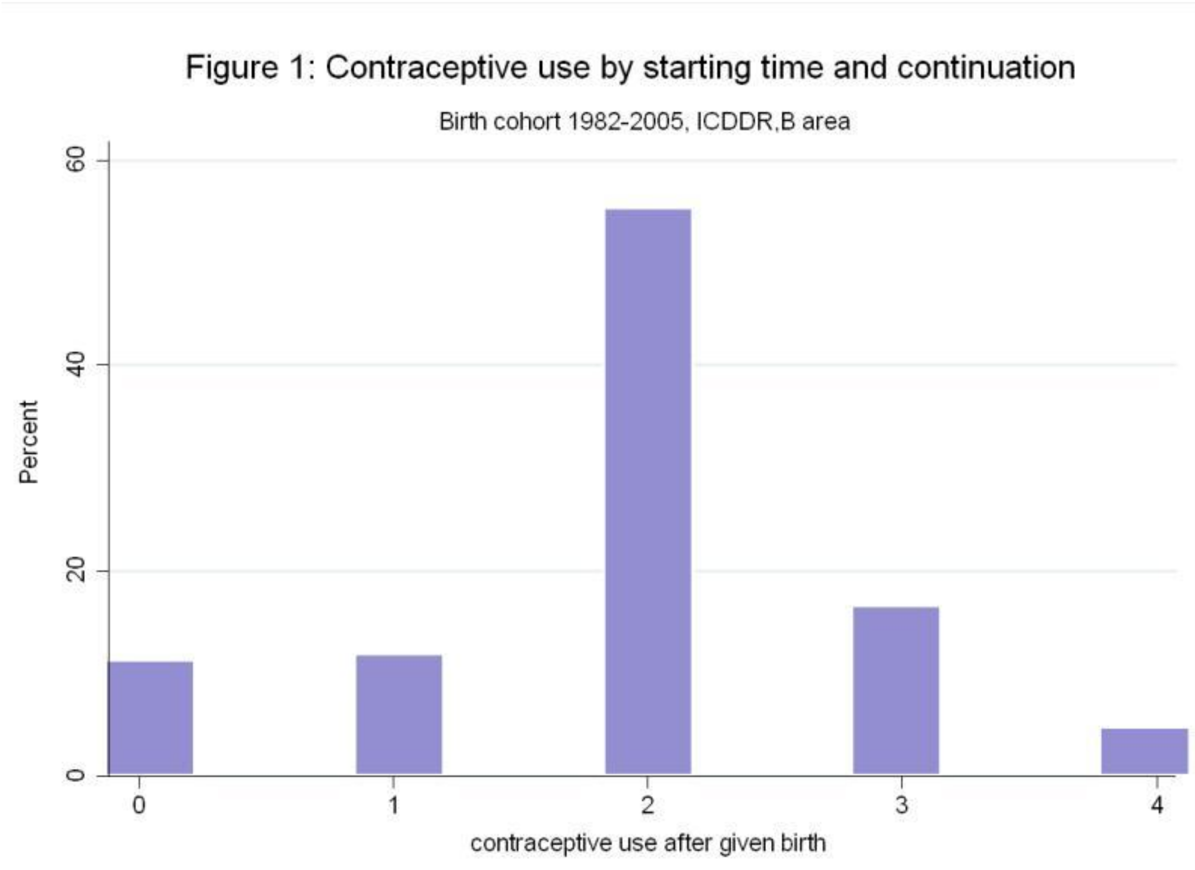
	Column 1	Column 2	Column 3
	Benchmark	**Contraceptive use**	**Contraceptive non-use**
Birth interval	43.82 months	+4.13 months	-13.25 months
Number of births (fertility)	2.37	-2.43%	+19.36%
Number of survivors	2.25	-2.28%	+19.26%
For all children			
Infant mortality	51.3/1000	-2.88%	+1.62%
For children after first born			
Infant mortality	39.6/1000	-7.86%	+10.61%

Note: column1: Outcomes benchmark simulation, columns 2 and 3: deviations from the benchmark simulation if everyone uses contraceptives (column 2) or noone uses contraceptives (column 3)

Table 5. Simulation results (alternative definition of contraceptives use).

	Column 1	Column 2	Column 3
	Benchmark	**Contraceptive use**	**Contraceptive non-use**
Birth interval	43.43 months	+7.53 months	-5.67 months
Number of births (fertility)	2.41	-6.01 %	+8.65 %
Number of survivors	2.28	-5.93 %	+8.72 %
For all children			
Infant mortality (%)	51.0/1000	-1.48 %	-1.13 %
For children after first born			
Infant mortality (%)	39.4/1000	-6.89 %	+1.44 %

Note: column1: Outcomes benchmark simulation, columns 2 and 3: deviations from the benchmark simulation if everyone uses contraceptives (column 2) or noone uses contraceptives (column 3)



Note: 0 = non-use
1 = start one year after birth or later
2 = start within one year after birth and continue until more than one year after birth
3 = start within one year after birth and stop before one year after birth
4 = missing

Annex

Table A1. Infant mortality of previous child, Contraceptive use, and Infant mortality of the next child.

	Previous child died (n=1,353)	**Previous child did not die (n= 17,383)**	**All children (n=18,736)**
Contraceptive use	Infant mortality next child	Infant mortality next child	Infant mortality next child
Yes	81.0/1000 (n= 617)	32.0/1000 (n=14,482)	34.0/1000
No	77.7/1000 (n= 734)	58.3/1000 (n= 2,884)	62.2/1000
Total	79.2/1000 (n=1,351)*	36.4/1000 (n=17,366)**	39.5/1000

Notes: observations on contraceptive use (after each birth) are missing for total 1,524 birth records where

*2 birth records after first-borns and excluded from this analysis. ** 17 birth records after first borns and excluded from the analysis

- Due to first-borns 13,232 observations are excluded from the analysis, and the remaining missing birth records are in the first obsrevations

Table A2. Estimation results with alternative definition of contraceptive use.

Variable	Contraceptive use		Log birth space		Infant mortality		Prob (next birth)	
Panel A	parameter	s.e	parameter	s.e	parameter	s.e	parameter	s.e
Male	-0.091**	0.027	0.003	0.010	0.024	0.036	-0.041	0.041
Muslim	-0.188**	0.026	-0.008	0.010	-0.021	0.050	0.491**	0.050
Birth order	0.211**	0.052	0.081**	0.020	0.060	0.101	-0.044	0.084
Birth order square	-0.006	0.005	-0.018**	0.002	-0.007	0.014	0.006	0.008
Mother's age at birth (years)/10	0.002	0.001	0.002**	0.001	-0.011**	0.003	-0.002	0.003
Mother's age at birth/10 square	0.060*	0.026	0.043**	0.012	0.178**	0.060	0.186**	0.052
Maternal education level								
At least primary education	0.043	0.025	0.030**	0.008	-0.047	0.045	0.029	0.042
At least secondary education	0.062*	0.028	0.053**	0.010	-0.023	0.058	-0.312**	0.057
Mother's birth cohort								
1966-1970	0.337**	0.028	0.015	0.009	-0.023	0.045	0.042	0.039
1971-1975	0.656**	0.032	0.050**	0.011	-0.133*	0.057	0.035	0.056
1976+	0.688**	0.034	0.079**	0.013	-0.148*	0.067	0.208	0.141
Paternal educational level								
At least primary education	0.168**	0.025	-0.022*	0.008	0.056	0.042	0.025	0.042
At least secondary education	0.237**	0.026	-0.024*	0.009	-0.200**	0.057	-0.070	0.047
Father is day labourer	0.238**	0.032	-0.034*	0.012	0.128*	0.053	-0.397**	0.050
No tubewell/piped water	0.175**	0.029	0.031**	0.009	-0.165*	0.055	-0.126*	0.046
Distance to health centre (in km)	-0.007	0.010	0.005	0.004	0.005	0.019	-0.016	0.014
Lagged contraceptive use			0.341**	0.008				
lagged infant mortality	-1.109**	0.057	-0.574**	0.017	0.007	0.069	-0.141	0.081
First boy surviving	0.117*	0.050	0.146**	0.018			-0.765**	0.094
First girl surviving	-0.014	0.049	0.103**	0.018			-0.702**	0.087
After first boy, # of boys surviving	0.0001	0.044	0.092**	0.016			-0.536**	0.078
After first girl, # of girls surviving	-0.082*	0.042	0.032*	0.016			-0.218**	0.069
Preceding log birth interval					-1.627**	0.365		
Preceding birth interval square					0.203**	0.051		
Constant	-0.587**	0.175	3.082**	0.075	3.103**	0.735	3.961**	0.381
Panel B								
ρ	0.225		0.015		0.028		0.242	
Correlation (row1)			0.025		-0.439		-0.489	
Correlation (row2)							-0.811	
Correlation (row3)			0.086				-0.168	

Notes: * 2 < t-value < 3; ** t-value ≥ 3
Reference category: gender is female, religion is Muslim, mother and father have no education, father is not day-labourer, and source of drinking water is tube-well/pipewater, mother's birth cohort before 1966.
Alternative specifications: refer contraceptive use=1 if mother initiated method use within one year after birth and continued until at least one year after birth, otherwise contraceptive use=0.