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A Comparative Analysis of Determinants of Birth Intervals

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Contents

1 Introduction

The reproductive process can be described as a sequence of events in a woman's life and the ages at which those events take place: the beginning of the biological capacity to reproduce, initiation of sexual relations, occurrence of her first birth, second, etc, and, finally, termination of reproduction either through her death, end of sexual relations, or sterility, whichever happens first. These events are of two kinds, those that affect the length of reproductive life and those, the births themselves, that reflect the speed or pace of childbearing within this reproductive span. It has proved useful to analyse separately those factors influencing the span and those affecting the pace of fertility since, in many cases, they appear to vary quite differently across populations and to be determined in rather different ways. Attention has focused in recent years on the birth interval and on its determinants because, within a given reproductive span, the number of births a woman may have depends upon how quickly births follow one another.

The life-table approach is particularly appropriate to the analysis of birth intervals because one of the major pitfalls of measurement can be avoided. If only intervals beginning with the birth of one child and ending with the next birth are considered, there is a major bias in any results because all information is omitted for women who stopped childbearing within that interval—those who never had a subsequent birth or, in the case of data obtained from surveys, those whose reproductive histories may be incomplete at the time of interview. Both completed and open intervals can be included in the life table; a woman last observed with an open interval of two years since a birth is counted in the life table for those two years as having been exposed to the risk of another birth for that period but contributing no birth. From this type of life table, the proportion of women who have another child within any given period (eg 60 months) subsequent to a live birth and a measure of the average birth interval completed in that period can be calculated. In an illustrative analysis of birth intervals in Colombia, Hobcraft and Rodríguez (1980) found that the proportion having a birth within 60 months (the *quintum*) and the *trimean* were particularly useful summary measures for describing birth interval distributions. The trimean is defined as follows: consider only the intervals completed within 60 months as calculated from the life table. The time when 25 per cent of those intervals are completed, T_{25}, can be located, as can the times when 50 and 75 per cent (T_{50} and T_{75}) have been completed. The trimean is then defined as $T = (T_{25} + 2T_{50} + T_{75})/4$. Hobcraft and Rodríguez (1980) presented birth interval distributions for various birth orders (the interval between first and second birth, between second and third, etc) and for subgroups of the population defined by age at the start of the interval, education, year the interval started, etc. Hobcraft and McDonald (1984) show these distributions and summary statistics (including the quintum and trimean) for 28 WFS surveys.

These analyses demonstrate that birth intervals vary substantially between countries, with birth order, with maternal age, and in many cases, with education and over time. Yet the results remain somewhat unsatisfactory for several reasons. The population can be divided into only relatively few subgroups before the sample size within a group becomes too small for reliable calculation of the life table. Therefore it has not been possible to consider age, education and time period simultaneously. In addition, comparison of a number of life tables, even if that number is relatively small, is difficult. Since the goal of our analysis is to discover regularities and differences among life tables, this difficulty is a major drawback of a tabular approach. Fortunately, new methods have become available quite recently that permit simultaneous analysis of life tables according to several covariates and produce more readily interpretable summary and comparative statistics.

These methods have led us to challenging conclusions regarding the determinants of birth intervals and of the entire reproductive process. In particular, we find that birth intervals for a specific woman result from remarkable persistence of behavioural or biological traits over time. In fact, birth interval lengths depend little upon birth order, but far more upon the length of the previous interval. Starting at least from the second birth, it appears that the reproductive process can be encapsulated as an engine with its own inbuilt momentum whereby early behaviour and socio-economic differences fundamentally determine (along with ageing and secular variation) the remainder of the childbearing experience.

2 Hazard Models

The logic of hazard models is quite straightforward. At each duration, d, measured from a previous birth, a woman is at risk of having another birth. This risk, comparable to the force of mortality in the familiar life tables of survival, is $\lambda(d)$. That is, $\lambda(d)$ is the risk or hazard that a woman who had a baby d months ago (and who had not had a birth since then) will have another birth in month d. In the usual life table, all women are assumed to have the same risk, $\lambda(d)$, at any time. Life tables with covariates relax this assumption: they assume, instead, that the risk *varies* among women according to individual characteristics. In this case, the risk, $\lambda_i(d)$, for a woman with a set i of characteristics at duration d is made up of two parts

$$\lambda_i(d) = u(d)C_i(d)$$

where u(d) is a risk at duration d shared by all women, but $C_i(d)$ is a multiplier that is specific to women with a certain set, i, of characteristics. If $C_i(d)$ is greater than 1, women in group i have relatively high risks ($\lambda_i(d)>u(d)$), if $C_i(d)<1$, there is a *lower* risk for women in group i. For example, consider age as the characteristic and let women be divided into three groups, under 25, 25–34, and 35 and over. If C_3 is the multiplier for women in age group 3 (35+), we might expect C_3 to be less than 1, ie that women over 35 would have *lower* fertility. Thus, $C_i(d)$ is a *proportionality* factor that multiplies the duration-specific risk to reflect the relative risk for women with characteristics i.

It is more convenient mathematically to work with the *log* of the risk:

$$\begin{aligned}\log \lambda_i(d) &= \log u(d) + \log C_i(d)\\ &= \log u(d) + K_i(d)\end{aligned}$$

where $K_i(d) = \log C_i(d)$. The term $K_i(d)$ is assumed to depend upon covariates, such as age, education, etc in a linear fashion, so that

$$K_i(d) = b_1X_{i1}(d) + b_2X_{i2}(d) + \ldots + b_nX_{in}(d)$$

where $X_{ij}(d)$ is the value of covariate j at duration time d (eg age at duration d) for women in group i and b_j is the coefficient that measures the *effect* of that covariate on the log of the baseline risk, log u(d).

The estimated values of b_j, denoted $\hat{b}_j$, will be referred to as the *effect estimates*. Again using age as our example, if age is measured in years and the corresponding value of $\hat{b}$ is negative, then the log risk of a birth at d would decline linearly as age increases. The $\hat{b}$'s then, can be interpreted in ways similar to the coefficients in a standard regression analysis. Again as in regression, the covariates can be categorical and represented by a set of dummy variables. Also, interaction terms can be included as covariates.

A brief example may clarify the assumptions made for these procedures. Consider only five duration categories (completed months 8–17, 18–23, 24–29, 30–41 and 42–59), three age groups (<25, 25–34, 35+) and two education categories (none, some). Then, if there are no interaction terms (a *main effects* model)

$$\log \lambda(d, X_1, X_2, X_3) = \log u(d) + b_1X_1 + b_2X_2 + b_3X_3$$

where $\log \lambda(d, X_1, X_2, X_3)$ is the log of the hazard rate at duration d for women with characteristics X_1, X_2, X_3, log u(d) is the duration effect, X_1 and X_2 are dummy variables for age categories and X_3 is a dummy variable for education so that

$$X_i = \begin{cases} 1 & \text{if the woman is in} \\ & \text{age group } i+1,\ i=1, 2 \\ 0 & \text{otherwise} \end{cases}$$

$$X_3 = \begin{cases} 1 & \text{if the woman is in} \\ & \text{the second education group} \\ 0 & \text{otherwise} \end{cases}$$

Thus b_1 represents the *effect* of being in age group 2 relative to the baseline category of women aged under 25 who are uneducated. The remaining b's are similarly interpretable. If there is an education by duration interaction, then five additional covariates are required, eg $X_4=1$ if the woman is in duration 1 and education group 2 etc.

One other methodological note is in order. If we convert back to $\lambda_i(d)$ by exponentiating, then it can be seen that $\exp(b_1)$ multiplies u(d) if the woman is in age group 2. This factor, $\exp(b_1)$, is called the *relative risk* for women in age group 2 (relative to those in age group 1), given that their other characteristics (in this case, education) are the same. In general, the relative risk of being in any given category compared with any other category is calculated as the ratio of the two relative risks compared with the baseline category.

Models of this type are generally referred to as *hazard* models. A special case occurs when K(d) does not depend upon d. In this case the model is known as a proportional hazards model, since covariates have the same proportional effect at all durations. The techniques for estimating the parameters are described elsewhere (see for example Trussell and Hammerslough 1983). Computer package programs are available for finding the parameter estimates. They, however, require considerable computation and, consequently, computer time. It is important, therefore, to develop efficient ways of determining which models are most likely to describe a particular data set well, so that exact estimation procedures are applied to only a small number of candidates for the final model. Therefore, the discussion of the birth interval analysis is carried out in two parts: screening and final estimation, but we precede this by a brief discussion of the information used in our analysis.

3 Data Choices

While there are some advantages to basing comparative analysis upon results from large numbers of countries, presentation of results in any detail becomes extremely difficult for more than eight to ten countries. In view of this problem, we decided at the outset to limit the number of countries studied and purposively to select countries which represent a range of experience in terms of geographic coverage, fertility levels and trends, marriage patterns and birth interval distribution characteristics. After considering a variety of options we decided to work with the nine countries used by Hobcraft and Casterline (1983) and again by Gilks (1982) in his work on birth intervals. The nine countries are Bangladesh, Colombia, Indonesia, Jamaica, Jordan, Kenya, Korea, Mexico and Sri Lanka. Although these countries were originally selected with no reference to birth interval distributions, they do cover the range of variation in these characteristics quite well. The advantages of comparability with previous work outweighed the marginal benefits of choosing a set of countries with optimal variability in terms of patterns of birth interval distributions. Table 1 gives an indication of the relative positions of each country on the quintum (or proportion having a birth within five years of the previous birth), the trimean (a weighted average of the quartiles with the median receiving double weight), and the spread (or interquartile range = $T_{75}-T_{25}$), when compared with the 28 countries for which results are available from the World Fertility Survey (see Hobcraft and McDonald 1984). It is clear that we do include a variety of patterns.

We decided to use only categorical covariates and thus used elaborate cross-tabulations as the basis for our analysis. All tabulations were produced using the program BIRTHS 1.8 (Rodríguez with Menken 1982). As we use GLIM (Baker and Nelder 1978) to fit the models, we had to limit fairly strictly the number of variables considered and the number of categories on each variable. Time since previous birth (hereafter referred to as duration) is clearly essential for a hazards analysis. There is some evidence that three points on the birth function suffice to capture almost all variation in shape of the birth function within a single country. In view of the distinct variations in shape between countries, we decided to retain five categories for duration and to place boundaries which would divide the average birth function for all 28 countries considered by Hobcraft and McDonald (1983) into approximately equal segments. The categories thus obtained were 8–17, 18–23, 24–29, 30–41 and 42–59 completed months. All births before eight months were assigned to the eighth month.

We wished to retain at least three categories for each other variable considered in order to be able to obtain indications of non-linearity in relationships. But we also wanted to maximize the number of variables considered. By restricting ourselves to only three categories on each

Table 1 Relative positions of the nine countries in terms of the quintum, trimean and spread

Country	Quintum	Trimean	Spread
Bangladesh	Fairly high	High	High
Colombia	Medium	Low	Medium
Indonesia	Low	High	High
Jamaica	Fairly low	Low	Low
Jordan	High	Low	Low
Kenya	High	Fairly high	Low
Korea	Decreasing with order to low	High	Low
Mexico	High	Fairly low	Fairly low
Sri Lanka	Low	High	Fairly high

Table 2 Variables and categories used

Variables	Categories
Duration (completed months since previous birth)	8–17, 18–23, 24–29, 30–41, 42–59
Birth order which would close interval	3, 4–5, 6–8
Period (completed years before survey)	1–5, 6–10, 11–15
Length of previous birth interval (completed months)	6–21, 22–41, 42+
Age (completed years)	15–24, 25–34, 35–49
Education — divided into three categories, except for Bangladesh which has two. Only the second category is identified. (Completed years of schooling)	Bangladesh 1+; Colombia 3–5; Indonesia 1–5; Jamaica 6; Jordan 1–6; Kenya 1–6; Korea 1–5; Mexico 3–6; Sri Lanka 3–6

additional variable it became feasible to operate with five such variables, leading to a maximum of 1215 ($= 5 \times 3^5$) cells with exposure in the table for each country. For each cell, we tabulate the number of births and the woman-months of exposure.

Table 2 shows the variables and categories used. It was essential to retain some information about birth order as it is expected that patterns may change with birth order. In particular, the received wisdom is that fertility control is likely to be parity-specific, so that inclusion of birth order might be expected to capture this element of fertility behaviour. Following convention, birth intervals are referred to by the order of the birth which would close the interval. In several countries fertility trends have been substantial, making inclusion of time-period mandatory. Fecundability and other aspects of fertility behaviour are clearly related to age and we use age at start of the relevant interval to capture this aspect. In order to retain observations in most potential cells we maintain a long final age category. Another variable which partially captures fecundability, but also includes effects of breastfeeding and contraceptive behaviour, is the length of the previous birth interval. As this is virtually meaningless in several countries for the interval from marriage to first birth we chose to define this length only subsequent to the first birth, meaning that our analyses could only begin with the transition from second to third birth. Here the categories were chosen to distinguish rather short and rather long previous intervals from those of 'average' length. Our final variable, and the only socio-economic one included, was the woman's education. In view of the very extreme differences in distribution between countries, we felt it best to make the education categories country-specific and the groupings were chosen following Hobcraft and Casterline (1983) in order to give approximately even sample splits.

4 Model Selection

Having chosen the six variables and their categories we were next faced with the problem of choosing a final model. The set of models from which to choose is for all practical purposes infinite. For example, if we limit ourselves just to main effects models there are 15 models with two factors, 20 models with three factors, and so forth. When first, second, or even higher order interactions are allowed, the number of possibilities expands rapidly. Since our goal was to pick as simple a model as possible which would adequately describe the data, we could fortunately eliminate most candidates from consideration. Our criterion strongly suggested that we concentrate our attention on main effects models plus the few most important first order interactions.

Even with this aim, we needed to devise some strategy for screening models, since to fit each model ordinarily requires considerable computer time and expense. One class of models is however very inexpensive (almost free) to estimate since exact solutions involving no iterations are available. This class of models consists of all fully saturated submodels of the fully saturated 6 factor model, where a fully saturated model involving n factors contains all possible interactions of orders up to and including n. One such submodel would be the ordinary life table, which contains the single factor duration. Maximum likelihood estimates (MLEs) are easily obtained from the birth rates in each duration category. Another submodel would be the fully saturated duration by education model, which has ($5 \times 3 =$) 15 parameters, one for each cell in the $D \times E$ matrix. The MLEs are again obtainable from the birth rates in each cell in the $D \times E$ matrix.

Results of such an exercise are shown in table 3. The numerical entries in the table are the likelihood ratio chi-squared, X^2, statistics resulting from a comparison of the given model with the fully saturated 6 factor model. Several important conclusions can be reached by examining these results. First, the most important single factor in every country is duration. This finding was expected, since we felt that there was likely to be far more variation in birth rates at different durations than in different categories of education, age, time period, birth order or length of previous birth interval. The reduction in the X^2 obtained by adding duration to the model is *substantially* greater than that obtained from adding any other factor except in Colombia, but even there adding duration provides the greatest reduction. A second conclusion is that length of the previous birth interval is a powerful predictor of the length of the current interval. It enters the best 2 factor model in all countries except Korea and Sri Lanka, where it first appears in the best 3 factor model. A third substantive result is that birth order is relatively unimportant. It does not appear in the best 5 factor model in any country except Korea and Bangladesh. A fourth conclusion is that the reduction in X^2 caused by adding the single factor duration to a model with only a constant term is in most countries greater than the reduction in X^2 caused by adding any four other factors plus all possible first, second, third, and fourth order interactions to the model with duration. Note that the first step, adding duration, increases the number of parameters by only four, while the second step typically adds about 400 parameters. By contrast, the all main effects model with 15 parameters (14 in Bangladesh) performs about as well as the best 3 factor fully saturated model with typically 45 parameters. Our final model with 31 parameters (described below) in general performs as well as the best 4 factor fully saturated model, which typically has 135 parameters.

We decided on the basis of the screening runs that all variables were good candidates to enter our final model as main effects. The only questionable variable was birth order; as the substantive finding that birth order was inconsequential is of considerable theoretical import it was nevertheless retained. We next needed to discover which interactions were important. We decided for simplicity to limit ourselves to two-way interactions. To find out which were likely candidates for inclusion we compared all 2 factor main effects models with their fully saturated parents. The results, a subset of which is shown in table 4, indicated that the only interactions of importance in several countries were duration by education ($D \times E$) and duration by length of previous interval ($D \times L$). Other interactions were important in one or perhaps even two or three countries, but we thought it worthwhile to estimate a common model on all countries and to keep the number of parameters as small as possible. However, our final model includes all main effects plus the $D \times E$ and $D \times L$ interactions.

Table 3 Comparison of single factor models and best 2, 3, 4 and 5 factor fully saturated models

	BD	CO	ID	JM	JO	KE	KR	MX	SL
Constant	4243	2418	5109	1959	3265	5903	6569	4748	4639
1 factor									
B	4160	2405	5072	1958	3191	5832	6191	4693	4555
L	3866	2063	4674	1844	3040	5719	6321	4220	4119
A	3940	2223	4762	1853	3011	5738	6033	4159	3991
P	3874	2237	4850	1872	3225	5824	6364	4606	4437
E	4240	2236	5101	1930	3138	5881	6501	4436	4604
D	2144	2013	2622	1450	2070	2076	2668	2978	2884
Best 2 factor									
Model	DL	DL	DL	DL	DL	DL	DA	DL	DA
X^2	1507	1638	1877	1301	1696	1650	1919	2196	2118
Best 3 factor									
Model	DLP	DLP	DLA	DLP	DAE	DLA	DLA	DLE	DLA
X^2	1060	1431	1521	1171	1363	1431	1652	1713	1656
Best 4 factor									
Model	DLAP	DLPE	DLAP	DLAP	DLAE	DLAE	DLEB	DLAE	DLAP
X^2	622	1161	1202	1000	1006	1232	1274	1168	1405
Best 5 factor									
Model	DLAPB	DLAPE	DLAPE	DLAPE	DLAPE	DLAPE	DLPEB	DLAPE	DLAPE
X^2	320	741	806	658	683	831	767	758	908
All main effects	1030	1232	1612	1150	1402	1597	1349	1524	1667
Final model[a]	883	1168	1367	1110	1203	1356	1225	1274	1512

[a] Our final model includes all main effects plus the $D \times E$ and $D \times L$ interaction terms.

NOTE: Entries in the table are X^2 statistics resulting from comparison of the given fully saturated model with the fully saturated 6 factor model.

D = duration group in the birth interval,
L = length of last birth interval,
A = age group at the start of the interval,
P = period at the start of the interval,
E = education of the woman and,
B = birth order.

Table 4 Comparison of 2 factor main effects and fully saturated models

Factors	BD	CO	ID	JM	JO	KE	KR	MX	SL
DB	1985	1985	2543	1446	1951	1962	2091	2897	2762
D+B	2038	2001	2578	1449	1973	1973	2131	2910	2780
dif	53	16	35	3	22	11	40	13	18
DP	1728	1797	2395	1333	2026	2017	2475	2830	2674
D+P	1811	1817	2411	1353	2042	2036	2520	2849	2695
dif	83	20	16	20	16	19	45	19	21
DA	1695	1819	2161	1336	1721	1813	1919	2293	2118
D+A	1738	1825	2201	1345	1753	1852	1948	2300	2146
dif	43	6	40	9	32	39	29	7	28
DL	1507	1638	1877	1301	1696	1650	2236	2196	2205
D+L	1659	1674	2074	1335	1796	1827	2322	2361	2284
dif	152	36	197	34	100	177	86	165	79
DE	2136	1819	2549	1414	1818	1960	2557	2533	2773
D+E	2138	1846	2604	1421	1929	2031	2601	2642	2853
dif	2	27	55	7	111	71	44	109	80

NOTE: Entries in the table are the X^2 statistics resulting from a comparison of the given 2 factor model with the fully saturated 6 factor model. The rows labelled 'dif' are also, therefore, X^2 statistics which indicate how well the 2 factor main effects model compares with the 2 factor saturated model. Main effects models are indicated by a plus between the factors.

5 Parameter Estimates

Our discussion of parameter estimates is organized around three tables. Table 5 presents the effect estimates for the two factor main effects models with duration as one of the two factors. We call these models univariate since they are essentially life tables run separately in each category of the single factors considered. The only constraint is that the hazard functions in these life tables for each category must be proportional, with the same proportionality factor at each duration. Table 6 presents the effects estimates from a main effects model including all factors. Table 7 presents the results of our final model, a main effects model with a D × E interaction and a D × L interaction.

Perusal of the univariate estimates shown in table 5 reveals a remarkable commonality of patterns. Recall that the higher the estimate, the higher is the log-hazard, hence the higher is the hazard and the higher the quintum. Birth order effects indicate that women at parity 2 have the highest quintum (except in Jamaica, where there is virtually no difference by birth order), while those at parities 5–7 have the lowest quintums (excepting Colombia). We see that quintums were highest in the most distant period (11–15 years ago) and lowest in the most recent period (1–5 years ago; the omitted group, whose effect estimate is zero). Reduced levels of the quintum are most pronounced in Colombia, and least evident in Kenya and Jordan. In Bangladesh, the estimated parameters indicate a decline only in the most recent period, but this decline may be overstated as a result of reporting errors.

The age effects are extremely consistent, with an older age at the beginning of an interval signifying a lower quintum, as expected. This tendency is most pronounced in Korea followed in order by Sri Lanka, Mexico and Jordan.

Length of previous birth interval effect estimates are also very consistent, with short prior birth intervals associated with more rapid childbearing in the current interval. Effect estimates for education generally indicate that more educated women have lower quintums. The exceptions are Bangladesh, where there is virtually no difference between those in the two education categories; Indonesia, where quintums differ slightly with education; Jamaica, where those in the middle education category have slightly higher quintums than those in the lowest category; and Kenya, where those in the least educated category have lower quintums (almost certainly due to a longer duration of breastfeeding among less educated women).

Estimates from the all main effects models are shown in table 6. Since all effects are estimated simultaneously, they reflect the impact of each factor while the others are controlled. Hence we would expect that parameter estimates would change between the univariate and multivariate models. This expectation is confirmed. Perhaps surprisingly, the effect of birth order is generally very small in the multivariate model. In most countries they are the smallest effect estimates in the table; substantial effects are found only in Korea. The effect of period is smaller in the multivariate models for Korea, Mexico and Sri Lanka. The effect of age is reduced in all countries except Jamaica. The effect of length of last birth interval is somewhat reduced in all countries. Education effects are much the same in both models, except in Korea where they are larger in the multivariate model, reflecting increasing education over time.

The parameter estimates for our final, preferred model are given in table 7. Figure 1 shows the shapes of the baseline hazard ratios. Extreme patterns occur for Colombia and Korea, with substantial differences in the peakedness and the duration of peak risk. Estimates for the categories of birth order, age, and period are virtually the same as those in the main effects model. The fact that they do not change means that the D × E and D × L interactions are not operating through period, age, or birth order. The remaining effect estimates D, E, L, D × L and D × E are difficult to interpret from this table. In table 8 parameter estimates have been converted into relative risks. For all factors the risks are relative to the first category of each factor. Since there are no interactions between duration and birth order, age at start of interval or period, the entries at each duration for categories of these variables are the same; by the same reasoning the relative risks change at each duration for categories of length of the last birth interval and education, since there are such interactions. The risks for duration categories are relative to the category 8–17 months. Entries in this table can be used to calculate any relative risk of interest. For example, relative to the base category (first category of *each* factor), those Colombian women at duration 42–59 months, at parities 5–7, whose previous birth interval was longer than 42 months, aged 35+ at the start of the interval, 11–15 years before the survey and with high education, have a risk of $1.000 \times 0.861 \times 0.935 \times 0.411 \times 0.529 \times 1.636 \times 0.471 = 0.135$. To obtain their estimated monthly *absolute* risk, we need only multiply by the exponential of the grand mean given in table 7: $0.135 \times \exp(-3.36) = 0.0047$, compared with 0.0347 for the base category ($\exp(-3.36)$).

Figure 2 presents the relative risks by birth order, age at start of the interval and by period. This figure shows the striking lack of variation by birth order, with the notable exception of Korea. The relative risks by age at start of the interval show a marked cross-national consistency, with only Kenya departing noticeably from the common pattern. The period relative risks show evidence of radically varying fertility declines over a ten year span.

Using table 8 and figure 3 we are in a better position to examine the pattern of the interaction between education and duration. The duration effects shown in figure 1

Table 5 Parameter estimates from univariate models (2 factor main effects models with duration as one factor)

		BD	CO	ID	JM	JO	KE	KR	MX	SL
Birth	3	0	0	0	0	0	0	0	0	0
orders	4–5	−0.07	−0.12	−0.04	0.02	−0.12	−0.02	−0.46	−0.13	−0.13
	6–8	−0.25	−0.11	−0.16	−0.02	−0.29	−0.20	−0.77	−0.22	−0.29
Years	1–5	0	0	0	0	0	0	0	0	0
before	6–10	0.41	0.26	0.28	0.24	0.10	0.08	0.14	0.17	0.17
survey	11–15	0.43	0.53	0.36	0.45	0.15	0.15	0.38	0.29	0.39
Age at	<25	0	0	0	0	0	0	0	0	0
start	25–34	−0.30	−0.25	−0.24	−0.17	−0.29	−0.12	−0.54	−0.35	−0.36
	35+	−0.87	−0.83	−0.79	−0.73	−1.00	−0.53	−1.44	−1.10	−1.20
Length of	<22	0	0	0	0	0	0	0	0	0
previous	22–41	−0.24	−0.25	−0.14	−0.15	−0.22	−0.14	−0.27	−0.23	−0.23
interval	42+	−0.70	−0.89	−0.65	−0.57	−0.71	−0.47	−0.81	−0.82	−0.81
Education	Low	0	0	0	0	0	0	0	0	0
	Mid	0.07	−0.20	0.07	0.07	−0.11	0.12	−0.06	−0.13	−0.05
	High		−0.62	0.14	−0.16	−0.48	0.13	−0.31	−0.71	−0.17

NOTE: Estimates for the duration parameter are omitted.

Table 6 Parameter estimates from the main effects model with six factors

		BD	CO	ID	JM	JO	KE	KR	MX	SL
Grand mean		−4.17	−3.39	−4.43	−3.81	−3.15	−3.96	−4.73	−3.50	−4.10
Birth	3	0	0	0	0	0	0	0	0	0
orders	4–5	−0.02	−0.14	0.00	0.05	−0.08	−0.01	−0.39	−0.08	−0.06
	6–8	−0.03	−0.07	0.00	0.13	−0.19	−0.13	−0.65	−0.06	−0.07
Years	1–5	0	0	0	0	0	0	0	0	0
before	6–10	0.43	0.27	0.30	0.23	0.04	0.07	0.12	0.13	0.16
survey	11–15	0.47	0.50	0.33	0.40	0.03	0.12	0.23	0.20	0.30
Age at	<25	0	0	0	0	0	0	0	0	0
start	25–34	−0.24	−0.19	−0.17	−0.22	−0.17	−0.02	−0.17	−0.25	−0.24
	35+	−0.70	−0.63	−0.61	−0.70	−0.77	−0.33	−0.82	−0.89	−0.92
Length of	<22	0	0	0	0	0	0	0	0	0
previous	22–41	−0.20	−0.21	−0.11	−0.11	−0.19	−0.13	−0.20	−0.21	−0.19
interval	42+	−0.60	−0.74	−0.57	−0.41	−0.55	−0.41	−0.65	−0.64	−0.65
Education	Low	0	0	0	0	0	0	0	0	0
	Mid	0.05	−0.19	0.05	0.08	−0.16	0.09	−0.20	−0.15	−0.04
	High		−0.63	0.10	−0.15	−0.54	0.06	−0.56	−0.72	−0.15
Duration	<18	0	0	0	0	0	0	0	0	0
group	18–23	0.81	0.57	0.81	0.81	0.69	0.96	1.45	0.84	0.90
	24–29	1.16	0.59	1.28	0.88	1.04	1.49	2.37	1.13	1.28
	30–41	1.26	0.24	1.35	0.42	0.88	1.28	2.52	0.86	1.18
	42+	0.94	−0.21	0.93	−0.15	0.44	0.87	1.86	0.43	0.71
Deviance		1030	1232	1612	1150	1402	1597	1349	1524	1667
DF		674	1057	1076	982	936	971	926	1052	1129

Table 7 Parameter estimates from the final model—all main effects plus D×L and D×E interactions

	BD	CO	ID	JM	JO	KE	KR	MX	SL
Grand mean	−3.90	−3.36	−3.96	−3.70	−3.10	−3.65	−4.68	−3.48	−3.94
B2	−0.02	−0.13	0.00	0.06	−0.08	−0.01	−0.38	−0.07	−0.05
B3	−0.03	−0.07	0.00	0.14	−0.18	−0.13	−0.64	−0.05	−0.06
P2	0.43	0.27	0.30	0.23	0.04	0.07	0.13	0.13	0.17
P3	0.46	0.49	0.33	0.40	0.04	0.12	0.24	0.19	0.31
A2	−0.24	−0.18	−0.17	−0.22	−0.17	−0.02	−0.17	−0.24	−0.25
A3	−0.72	−0.64	−0.61	−0.70	−0.78	−0.33	−0.84	−0.90	−0.93
L2	−0.69	−0.38	−0.75	−0.36	−0.46	−0.57	−0.51	−0.50	−0.53
L3	−0.91	−0.68	−0.98	−0.40	−0.41	−0.41	−0.27	−0.59	−0.64
E2	0.03	−0.16	−0.23	0.04	−0.08	−0.13	−0.14	−0.05	−0.12
E3	—	−0.41	−0.19	−0.17	−0.28	0.05	−0.18	−0.21	0.01
D2	0.40	0.52	0.32	0.68	0.56	0.62	1.55	0.86	0.73
D3	0.89	0.41	0.73	0.73	0.84	1.11	2.24	0.97	1.09
D4	0.84	0.34	0.69	0.31	0.89	0.84	2.33	0.77	0.90
D5	0.63	−0.15	0.32	−0.61	0.49	0.51	1.91	0.44	0.54
LD22	0.72	0.13	0.62	0.21	0.23	0.51	−0.10	0.16	0.27
LD23	0.50	0.52	0.73	0.42	0.56	0.55	0.33	0.63	0.35
LD24	0.67	0.19	0.91	0.32	0.41	0.65	0.58	0.47	0.57
LD25	0.53	0.22	0.76	0.65	0.41	0.52	0.28	0.33	0.53
LD32	0.41	−0.09	0.45	0.03	−0.06	0.10	−0.60	−0.27	−0.11
LD33	0.16	0.14	0.42	−0.04	0.06	−0.07	−0.48	−0.01	−0.08
LD34	0.53	−0.15	0.53	0.10	−0.39	−0.02	−0.19	0.11	0.16
LD35	0.43	−0.21	0.66	−0.18	−0.40	0.10	−0.43	−0.02	0.04
ED22	−0.01	0.09	0.28	0.11	0.14	0.20	0.09	−0.11	0.09
ED23	0.06	0.01	0.32	−0.08	−0.04	0.30	0.05	−0.34	0.15
ED24	0.06	−0.30	0.33	−0.02	−0.45	0.34	−0.16	−0.35	0.08
ED25	−0.05	−0.20	0.36	0.39	−0.42	0.28	−0.17	−0.43	−0.01
ED32		−0.18	0.58	0.05	−0.01	0.26	0.02	−0.54	0.13
ED33		−0.45	0.44	−0.01	−0.61	−0.12	−0.26	−0.88	−0.08
ED34		−0.40	0.25	−0.05	−0.51	−0.25	−0.62	−0.67	−0.41
ED35		−0.35	−0.07	0.25	−0.58	−0.04	−0.56	−0.64	−0.61
Deviance	883	1168	1367	1110	1203	1356	1225	1274	1512
DF	662	1041	1060	966	920	955	910	1036	1113

indicate the intervals during which monthly probabilities are highest, namely when the duration effects are highest. The peak rate occurs fairly early in Colombia and Jamaica and quite late in Bangladesh, Indonesia, Jordan and Korea. It is against this pattern for the least educated group that we place the variation in the relative risks by duration for women with higher levels of education. The most common tendency we observe is for the relative risks to be lower with increasing education and for these differences to increase at the higher durations. This occurs fairly clearly in Colombia, Jordan, Korea, Mexico and, to a lesser extent, Sri Lanka. This pattern partly reflects stronger fertility control among the more educated. The tendency for differences between education groups to become greater at higher durations can be attributed to two likely explanations. The first is that more educated women typically breastfeed for shorter periods (see Ferry and Smith 1983), with consequent shortening of the period of post-partum infecundity. This breastfeeding behaviour almost certainly leads to higher proportions of educated women being at risk of conception during the earliest durations (see Richards 1982, Gilks 1982 and Trussell *et al* 1983, for more direct linkage of birth interval analysis with breastfeeding and contraception). The second likely explanation is one of progressive selection. Less effective users of contraception or non-users will progressively be more likely to become pregnant, leaving increasingly higher proportions of effective contraceptors at the later durations. As use of effective methods is often related strongly to level of education, this progressive selectivity would probably lead to increasing differentials with lengthening of the interval. There is no especial indication that more educated women are more likely to be deliberately spacing their births: spacing behaviour would be indicated by a narrowing of differences between education groups, probably in the 24–41-month range.

The patterns of the duration–education interaction for the remaining four countries are more varied. In Bangladesh, differences are negligible. The interaction term achieves little explanatory power for Jamaica, although the

Table 8 Relative risks in the final model

Subgroup	Hazard ratio at duration 8–17	18–23	24–29	30–41	42–59	Hazard ratio at duration 8–17	18–23	24–29	30–41	42–59	Hazard ratio at duration 8–17	18–23	24–29	30–41	42–59
	Bangladesh					**Colombia**					**Indonesia**				
Duration effect	1.000	1.485	2.444	2.326	1.883	1.000	1.675	1.505	1.400	0.861	1.000	1.379	2.077	1.984	1.384
Birth order															
3			1.000					1.000					1.000		
4–5			0.981					0.875					1.002		
6–8			0.968					0.935					1.000		
Last interval															
<22	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
22–41	0.503	1.032	0.826	0.984	0.852	0.684	0.777	1.147	0.831	0.851	0.474	0.881	0.979	1.180	1.012
42+	0.404	0.606	0.472	0.685	0.618	0.508	0.463	0.586	0.436	0.411	0.376	0.593	0.570	0.637	0.729
Age at start															
<25			1.000					1.000					1.000		
25–34			0.788					0.831					0.844		
35+			0.485					0.529					0.541		
Period															
1–5			1.000					1.000					1.000		
6–10			1.532					1.309					1.347		
11–15			1.586					1.636					1.384		
Education															
Low						1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Middle None	1.000	1.000	1.000	1.000	1.000										
Middle Some	1.031	1.022	1.095	1.098	0.981										
Middle						0.856	0.935	0.867	0.634	0.703	0.797	1.055	1.102	1.107	1.144
High						0.666	0.556	0.423	0.444	0.471	0.825	1.479	1.277	1.099	0.769
	Jamaica					**Jordan**					**Kenya**				
Duration effect	1.000	1.974	2.074	1.362	0.542	1.000	1.755	2.317	2.434	1.635	1.000	1.849	3.034	2.312	1.657
Birth order															
3			1.000					1.000					1.000		
4–5			1.057					0.926					0.987		
6–8			1.147					0.833					0.879		
Last interval															
<22	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
22–41	0.696	0.862	1.059	0.957	1.328	0.633	0.798	1.111	0.949	0.951	0.565	0.936	0.977	1.084	0.947
42+	0.668	0.686	0.640	0.738	0.556	0.662	0.622	0.705	0.451	0.446	0.665	0.737	0.618	0.649	0.735
Age at start															
<25			1.000					1.000					1.000		
25–34			0.807					0.843					0.982		
35+			0.495					0.458					0.717		
Period															
1–5			1.000					1.000					1.000		
6–10			1.254					1.043					1.071		
11–15			1.495					1.041					1.124		
Education															
Low	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Middle	1.042	1.160	0.963	1.023	1.540	0.921	1.058	0.881	0.588	0.602	0.877	1.071	1.185	1.230	1.160
High	0.846	0.886	0.838	0.802	1.090	0.759	0.749	0.413	0.458	0.423	1.055	1.367	0.935	0.825	1.018
	Korea					**Mexico**					**Sri Lanka**				
Duration effect	1.000	4.721	9.403	10.237	6.733	1.000	2.369	2.631	2.155	1.556	1.000	2.078	2.977	2.462	1.710
Birth order															
3			1.000					1.000					1.000		
4–5			0.680					0.929					0.952		
6–8			0.526					0.948					0.944		
Last interval															
<22	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
22–41	0.600	0.543	0.832	1.072	0.797	0.608	0.713	1.136	0.973	0.843	0.589	0.773	0.833	1.043	0.998
42+	0.764	0.419	0.474	0.634	0.497	0.557	0.427	0.551	0.620	0.547	0.529	0.474	0.487	0.622	0.552
Age at start															
<25			1.000					1.000					1.000		
25–34			0.841					0.784					0.780		
35+			0.434					0.408					0.396		
Period															
1–5			1.000					1.000					1.000		
6–10			1.136					1.136					1.180		
11–15			1.273					1.213					1.357		
Education															
Low	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Middle	0.867	0.949	0.909	0.739	0.733	1.052	0.944	0.745	0.743	0.683	0.890	0.976	1.033	0.969	0.883
High	0.838	0.824	0.649	0.449	0.478	0.808	0.473	0.334	0.415	0.426	1.014	1.150	0.934	0.673	0.553

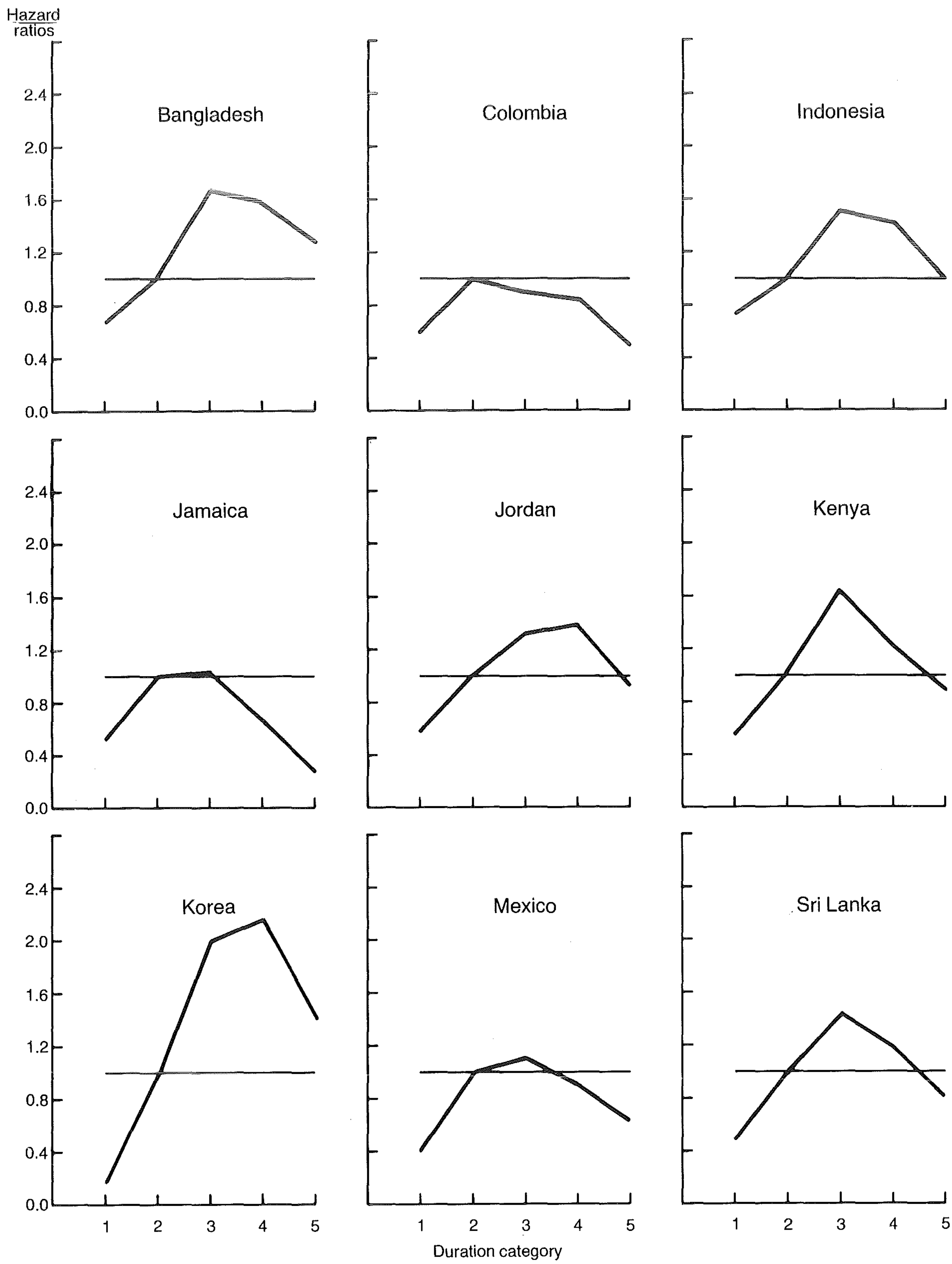
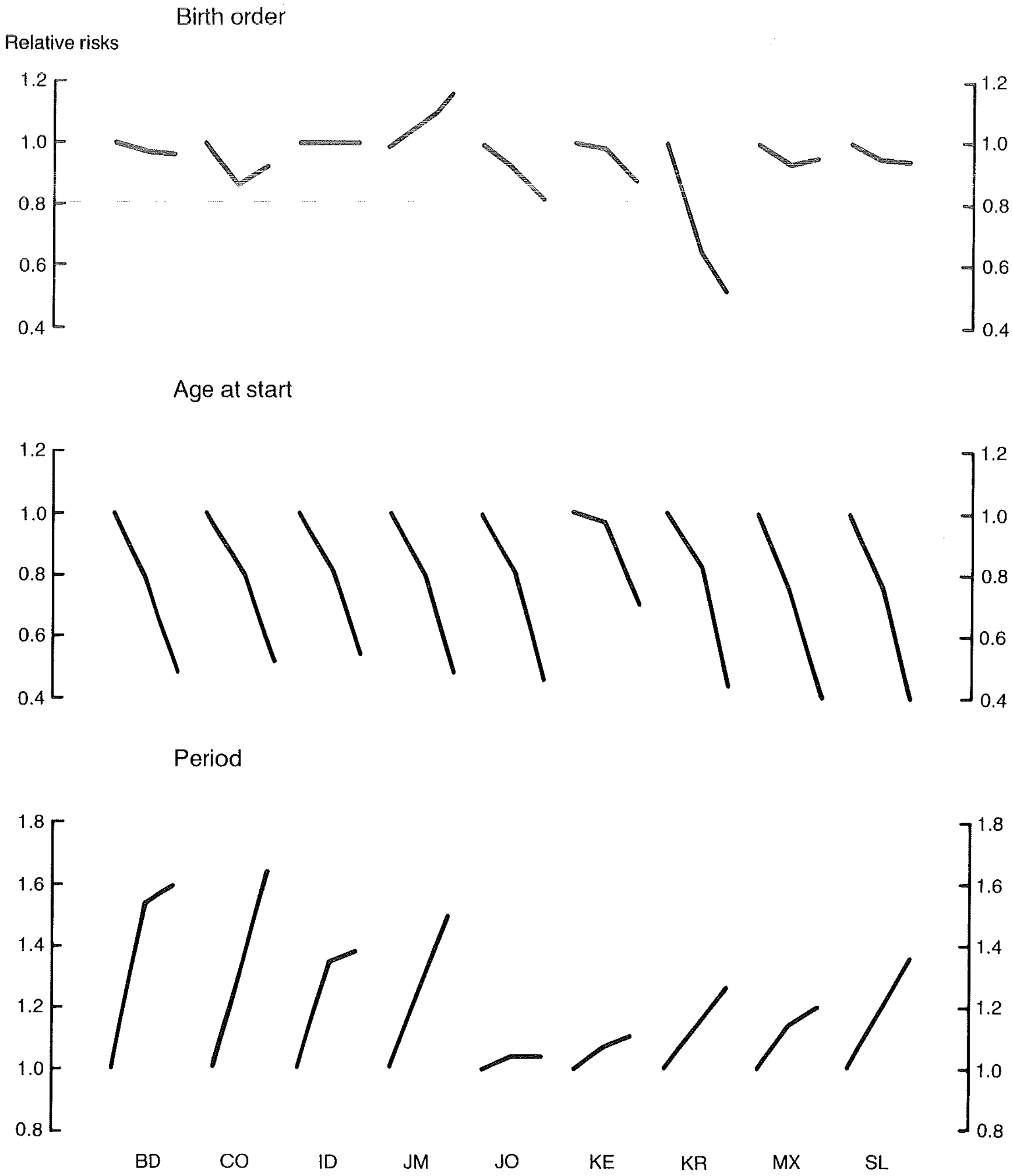


Figure 1 Baseline hazard ratios for final model (18–23 months = 1.00)



Key

	Values		
	1st	2nd	3rd
Birth order	3	4–5	6–8
Age at start	<25	25–34	35+
Period	1–5	6–10	11–15

Figure 2 Relative risks for birth order, age at start and period for final model

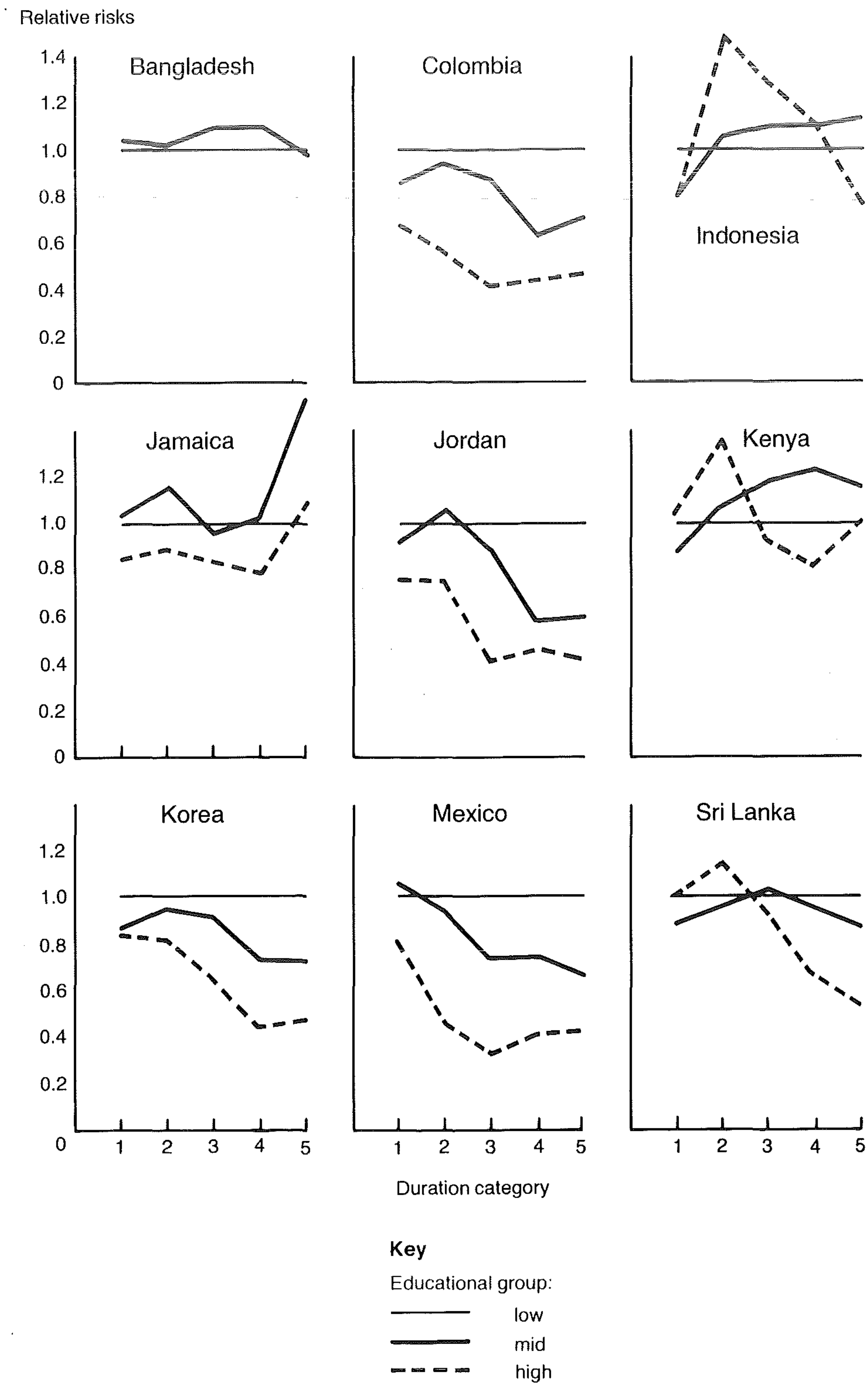


Figure 3 Relative risks for education by duration for final model

most educated group generally exhibits lower propensities to have a birth at each interval length. Kenya and Indonesia provide different results. These are both countries where marital fertility tends to increase with increasing education, rather than decrease. This tendency is generally explained by the fertility increasing effects of shorter breastfeeding by more educated women not being fully offset by the increased contraceptive use with increasing education (see Casterline *et al*, forthcoming). Our analysis does not contradict these findings. For Indonesia, the least educated appear to have the highest risk of births within 18 months of the previous birth, perhaps partly reflecting higher infant mortality which interrupts breastfeeding and shortens the period of infecundity with consequent increased risks of pregnancy, but also perhaps attributable to more frequent imputation of exact dates for the least educated. Once past the 18-month duration, the middle and higher education groups achieve more rapid childbearing. This result may be due to breastfeeding and contraception differences but could also reflect a differing incidence of marital dissolution, which is more frequent among the least educated, or higher fecundability. It is likely that the very rapid childbearing of the most educated group over the durations 18–29 months is at least partly a reflection of shorter periods of post-partum infecundity consequent upon reduced length of breastfeeding. The subsequent relative decline for the most educated will partly be attributable to selection effects, including differences in use of contraception and in fecundity.

The interaction of duration with education for Kenya has similar features. Thus the most educated initially bear children relatively rapidly, but subsequently exhibit a substantial relative reduction. This almost certainly reflects a combination of effects of shorter breastfeeding together with higher contraceptive use. Once again, though, the pattern for the middle education group is generally one of relatively more rapid childbearing than for the least educated at all durations beyond the shortest. This differential cannot be attributable to differences in breastfeeding behaviour or post-partum abstinence (since these effects would operate in the reverse direction, see Ferry and Smith 1983) and may reflect higher fecundability or greater exposure.

The interactions between duration and length of previous interval shown in figure 4 are again quite informative. Almost without exception, those women who had a short previous interval are more likely to have a further short interval, usually having about twice the risk of closing the interval per month before 18 months of those whose previous interval was over 42 months. Those women whose previous interval was a mainstream 22–41 months are also relatively unlikely to have a subsequent interval of under 18 months. Generally, those women who had a previous interval of less than 22 months reproduce more rapidly at all durations than do women whose previous interval was long. The large group of women whose previous interval fell in the 22 to 41-month category usually show a tendency for their rate of childbearing, relative to those with the shortest previous intervals, to increase steadily with duration; and usually this group achieves a slightly higher rate in one of the duration intervals, but then falls away again. Thus, those whose previous intervals were neither unduly short nor unduly long seem to maintain a propensity to achieve medium length intervals for their subsequent births. Women who experienced a previous interval of over 42 months are far less likely to proceed to a subsequent birth at all durations.

In general, those factors for which relative risks do not differ a great deal among categories are not demographically important covariates of fertility. A more precise estimate of their statistical significance can be obtained by omitting the factor (or interaction) from the final model and noting that the increased deviance is asymptomatically distributed as a chi-squared variate with degrees of freedom equal to the decrease in the number of free parameters. When such an exercise is performed, we can clearly demonstrate the lack of importance of birth order. This factor does not statistically improve the fit of the model (at the 1 per cent level) in Bangladesh, Indonesia, Jamaica, Mexico or Sri Lanka. The fit is only moderately improved in Colombia, Jordan and Kenya, and vastly improved in Korea. Only in Korea can birth order be said to be a demographically important covariate relative to the other factors investigated. Period is significant in all countries except Jordan. Age is everywhere significant, as is length of the previous birth interval. Both education (and the education–duration interaction) add no explanatory power to the model in Bangladesh and the education by duration interaction adds little explanatory power in Jamaica.

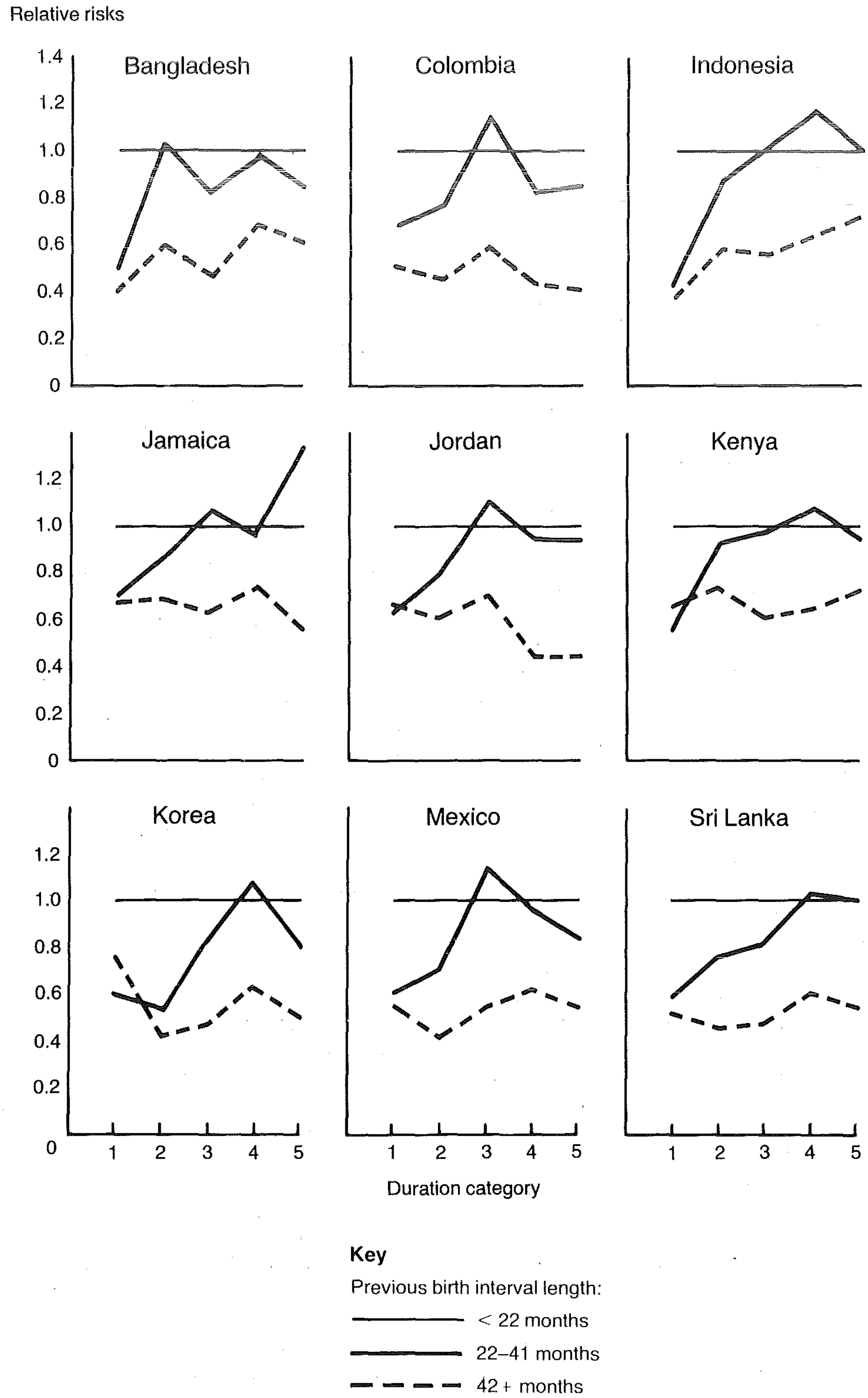


Figure 4 Relative risks for previous birth interval by duration for final model

6 Adjusted Quintums and Trimeans

In chapter 1 we stressed that our analysis would be truly multivariate and noted that many prior studies had simply estimated covariate effects by constructing life tables for categories of covariates. Moreover, we cited the work of Hobcraft and Rodríguez (1980), which showed that population differences in birth intervals can be largely captured by two summary statistics: the trimean and the quintum. It is, therefore, useful to document the fact that the effect of any one variable changes if the effects of others are simultaneously controlled; we do so by presenting *unadjusted* and *adjusted* estimates of the trimean and the quintum for each of the covariates. These are displayed in table 9.

Unadjusted effects are derived from separate life tables constructed for each category of a factor considered alone. Calculation of the adjusted effects for the categories of the target factor proves considerably more difficult, since it requires calculating a life table for each category of this factor adjusted for all other factors in the model. If only one category is selected for each of the other factors (eg its mode or reference category), the model permits estimation of the risk at any duration for a subject with this given set of characteristics. The estimated risks can easily be converted to complete life tables, which apply to the *homogeneous* subgroups of the individuals with these characteristics. Therefore, we could compare individuals in different categories of a factor who have a common value on each of the other factors considered. The nature of the model, which has no interactions among substantive factors (it only has interactions involving duration and one substantive factor), assures us that the hazard ratios would be the same at any given duration whatever categories are chosen for this type of adjustment. The same is not true, however, for the levels of the hazard or the life-table survivorship function and hence the quintum and trimean, all of which will in general depend on the value assigned to the remaining covariates.

A more realistic form of adjustment recognizes that each category of the factor of interest contains a *heterogeneous* subgroup, resulting from a mixture of individuals in different categories of the other factors considered. Thus, for example, each age category contains a mixture of women who have different lengths of previous birth intervals, varying levels of education, have reached different parities and start the interval at different periods. One form of adjustment which seems particularly appealing is to fix the mixing proportions to be the same for all categories of the factor of interest, as is usually done in the calculation of standardized rates (see Pullum 1978). An interesting consequence of viewing subgroups as heterogeneous mixtures is that hazard ratios do not remain constant over time even if the model has no interactions with duration. Essentially a form of selectivity operates, where individuals drawn from high risk subgroups, such as those with shorter previous intervals and lower educational levels, tend to conceive more rapidly, leaving a subset exposed to risk which is progressively selected from those subgroups with lower hazard rates. This selection affects the comparison of categories of a factor, since high fertility categories will more quickly lose their high risk members. In the course of time the hazard ratios will therefore be closer to unity than suggested by table 8.

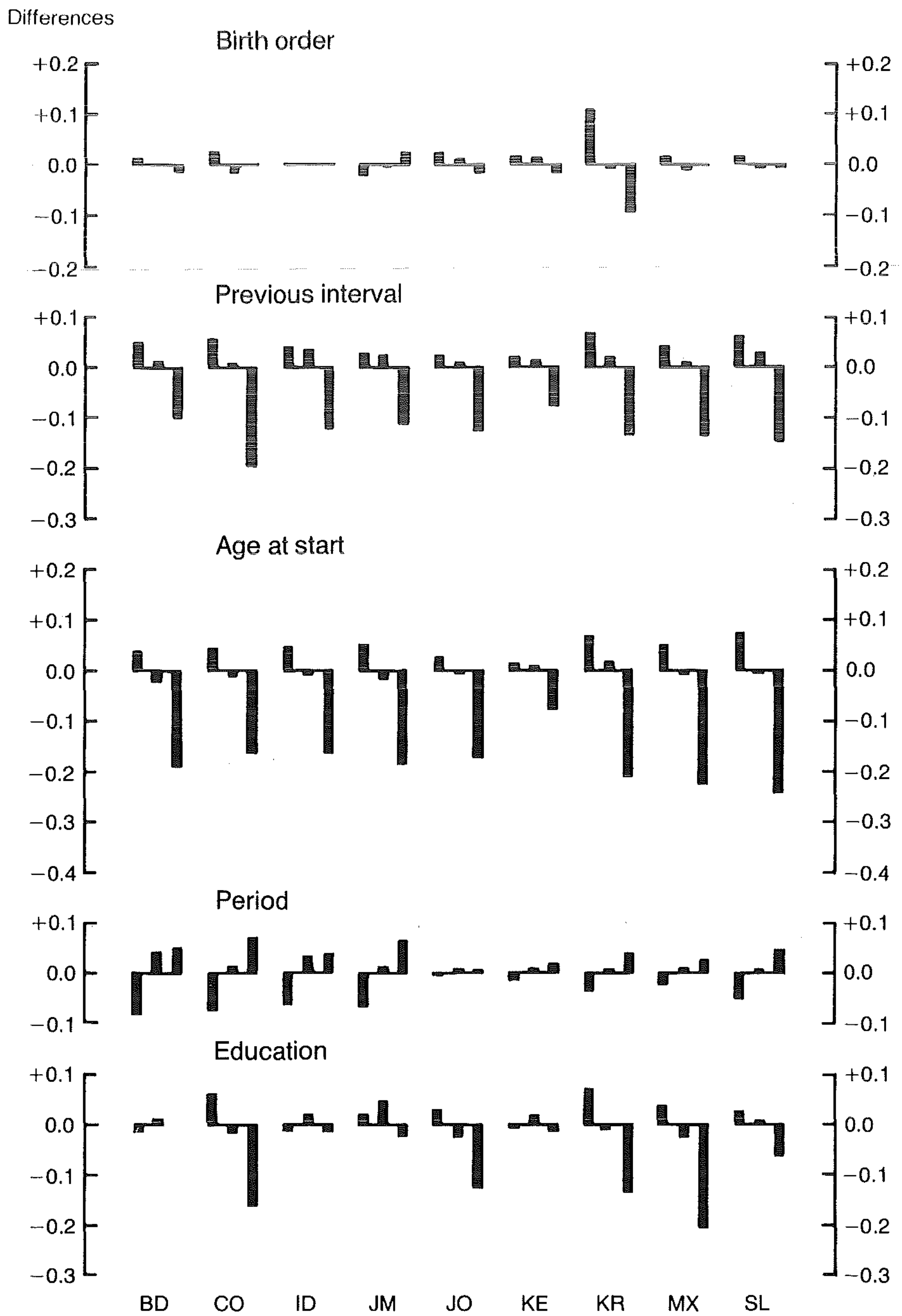
The strategy adopted in this analysis is as follows. We use the parameter estimates of table 7 to build life tables for each possible subgroup defined by the five substantive factors (that is all factors but duration). We then estimate the initial proportion of cases in each subgroup (ie at duration 0) and use these proportions to mix the life tables, obtaining a total sample estimate which recognizes heterogeneity. This estimate will in general be similar but not identical to the total sample life table, which assumes homogeneity. To obtain adjusted life tables for a factor (say age) we build a life table for each category mixing the subgroup tables (defined by all five factors) with the same proportions as the marginal joint distribution of the other factors (in this case birth order, last birth interval, period and education). The resulting category life tables always bracket the total sample estimate, but relative risks vary over time as a result of the process of selectivity described earlier. The methodology used as well as the more general issues involved are described at greater length in Rodríguez (1983).

A general conclusion that can be drawn from table 9 is that the effects of a factor when considered singly are usually somewhat reduced when other factors are simultaneously controlled. Within the table, however, there are many exceptions. Differentials in the quintum are most reduced for the age at start of the interval by the multivariate adjustment. Reductions in Jordan, Korea and Sri Lanka are the most pronounced. Jamaica is the only country for which the reduction is not substantial. Differentials in the trimean are most reduced for the birth order factor in Mexico and Sri Lanka; for age at start in Korea; and for period in Bangladesh and Colombia. On the other hand, differentials are sometimes widened in the multivariate analysis: a moderate widening of differences for the quintum after adjustments occurs for the factor birth order in Jamaica, where the ordering of the effects of the categories is also changed. The period effects become noticeably more dispersed for Bangladesh. And the biggest increase of all is for the factor education in Korea. Increased differentials are more evident, although usually small, for the trimean. The most dramatic example is the factor age at the start of the interval in Bangladesh, Indonesia and Jordan. Age at start of the interval also shows a small widening of differences for Mexico and Sri Lanka,

Table 9 Unadjusted and adjusted differences from total sample values for each factor on the quintum and trimean

	Bangladesh		Colombia		Indonesia		Jamaica		Jordan		Kenya		Korea		Mexico		Sri Lanka	
Subgroup	Un	Adj	Un	Adj	Un	Adj	Un	Adj	Un	Adj	Un	Adj	Un	Adj	Un	Adj	Un	Adj
Quintums (Δ = difference × 1000)																		
Total sample	0.854	0.838	0.789	0.780	0.775	0.765	0.773	0.765	0.922	0.917	0.903	0.900	0.735	0.724	0.853	0.845	0.754	0.743
Birth order																		
3	+47	+6	+35	+21	+31	−1	0	−22	+25	+18	+20	+13	+153	+107	+45	+12	+55	+13
4−5	+24	+1	−17	−17	+14	0	+9	−5	+18	+6	+16	+10	−7	−8	−1	−6	+8	−3
6−8	−55	−3	−5	+2	−39	0	−9	+21	−28	−13	−28	−16	−133	−94	−21	−1	−46	−5
Last interval																		
<22	+53	+46	+63	+51	+49	+39	+40	+26	+27	+20	+20	+18	+90	+63	+46	+38	+74	+55
22−41	+10	+11	+2	+3	+37	+33	+24	+22	+1	+4	+9	+9	+24	+19	+10	+5	+30	+25
42+	−132	−106	−246	−195	−144	−123	−161	−114	−181	−127	−94	−79	−179	−137	−198	−136	−194	−148
Age at start																		
<25	+53	+36	+57	+39	+66	+44	+53	+49	+40	+22	+26	+9	+183	+68	+68	+47	+108	+73
25−34	−46	−28	−20	−14	−19	−10	−14	−19	−23	−7	−6	+5	−3	+14	−26	−12	−19	−5
35+	−274	−189	−233	−163	−238	−165	−213	−189	−289	−172	−141	−77	−313	−211	−304	−225	−323	−242
Period																		
1−5	−56	−81	−72	−77	−72	−67	−80	−66	−17	−4	−7	−13	−97	−38	−57	−25	−60	−50
6−10	+14	+41	−14	+8	+13	+30	−4	+10	0	+3	−4	+3	−22	+3	+5	+8	−15	+4
11−15	+35	+49	+75	+68	+40	+39	+70	+63	+16	+3	+13	+13	+74	+38	+36	+24	+60	+47
Education																		
Low	−3	−1	+60	+55	−10	−8	+20	+16	+28	+30	−15	−11	+38	+71	+35	+36	+25	+23
Middle	+13	+10	−22	−19	+28	+19	+54	+43	−27	−27	+24	+19	+4	−3	−29	−27	+4	+6
High	—	—	−172	−165	+9	−2	−25	−23	−125	−127	−1	−14	−100	−135	−223	−209	−78	−67
Trimeans (Δ = difference × 10)																		
Total sample	28.5	28.4	23.4	23.3	30.1	30.0	24.5	24.4	24.0	23.9	26.5	26.5	31.7	31.8	25.3	25.3	28.6	28.5
Birth order																		
3	−1	−1	−4	−5	+1	0	0	+3	−17	−8	−5	−4	−10	−13	−9	−3	−7	−2
4−5	+2	0	−1	+3	+1	−1	0	0	+1	−2	−3	−3	+5	+3	0	+1	−1	+1
6−8	−1	+1	+5	−1	−4	0	0	−4	+7	+7	+6	+4	+7	+12	+7	0	+8	+1
Last interval																		
<22	−22	−19	−13	−10	−26	−24	−16	−14	−16	−14	−14	−12	−22	−17	−19	−17	−22	−18
22−41	+4	+4	+13	+12	+2	+3	+10	+11	+12	+12	+4	+4	+3	+2	+9	+8	+8	+8
42+	+37	+33	+26	+20	+28	+25	+7	+4	+12	+8	+15	+13	+16	+12	+34	+28	+23	+18
Age at start																		
<25	−4	−6	−9	−7	−5	−6	−3	−8	−10	−8	−4	−2	−13	−6	−10	−8	−9	−8
25−34	+7	+9	+7	+5	+3	+3	0	+4	+8	+6	+1	−1	+2	+1	+8	+6	+4	+5
35+	+7	+34	+31	+28	+2	+23	+23	+23	+14	+43	+14	+18	+32	+22	+29	+37	+21	+31
Period																		
1−5	+35	+19	+28	+16	+15	+11	+12	+10	+4	+2	+7	+3	−5	+5	+5	+6	+15	+8
6−10	−17	−7	−5	+1	−6	−5	−4	0	−3	−1	−3	−1	0	0	0	−1	−2	+1
11−15	−7	−9	−15	−13	−10	−6	−8	−11	−2	−1	−7	−4	0	−5	−6	−5	−9	−7
Education																		
Low	+1	+1	−1	−2	0	−1	−8	−6	+2	0	+1	0	+4	−2	+1	0	+4	+4
Middle	−3	−3	−3	−3	+4	+4	−6	−6	−11	−6	−1	0	−2	−1	−6	−4	+3	+3
High	—	—	+15	+15	−23	−19	+5	+4	+8	+14	−15	−11	−2	+2	+19	+20	−17	−16

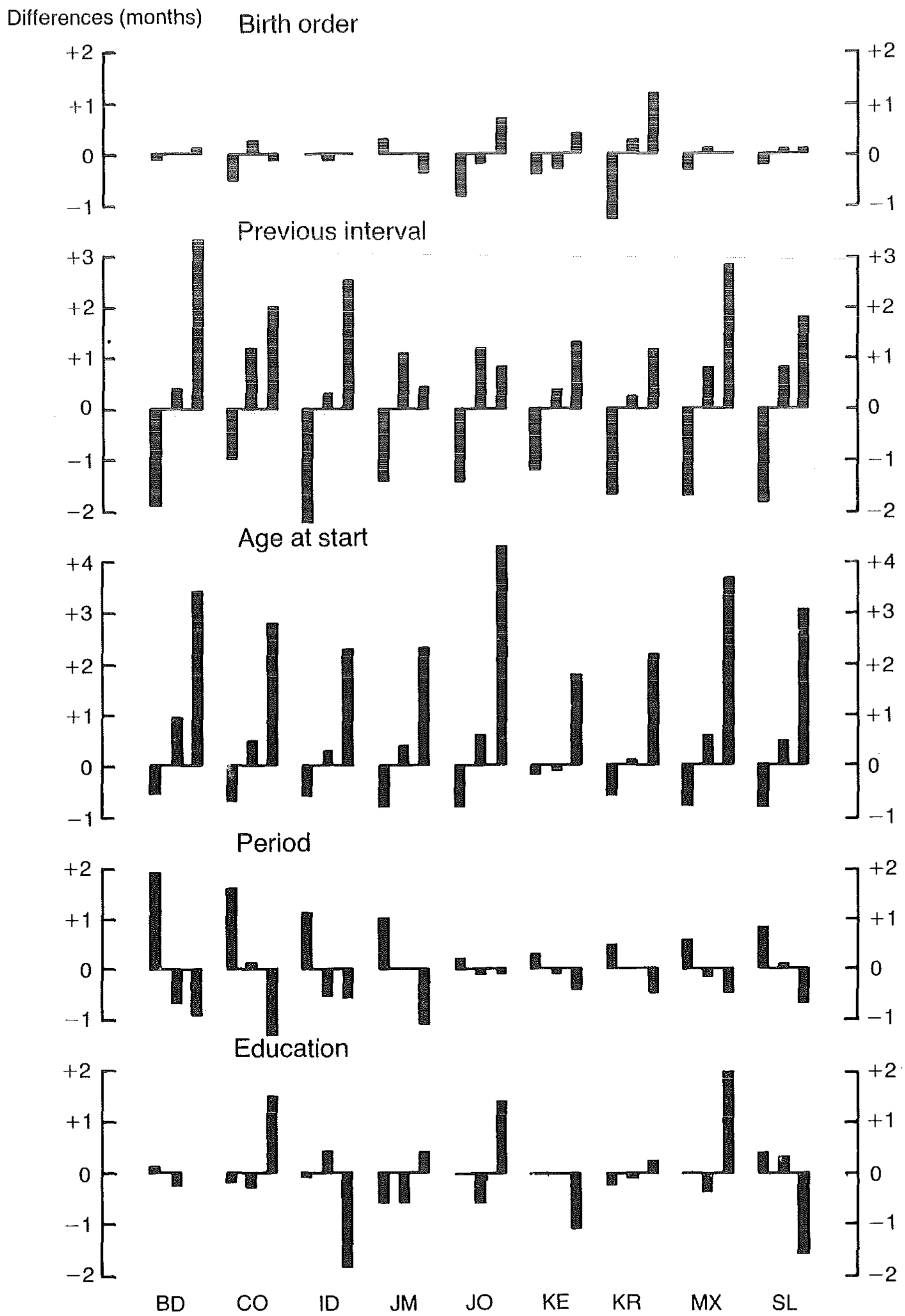
Un = Unadjusted.
Adj = Adjusted for effects of all other factors.



Key

	Values		
	1st	2nd	3rd
Birth order	3	4–5	6–8
Previous interval	<22	22–41	42+
Age at start	<25	25–34	35+
Period	1–5	6–10	11–15
Education	Low	Mid	High

Figure 5 Adjusted differences for quintum



Key

	Values		
	1st	2nd	3rd
Birth order	3	4–5	6–8
Previous interval	<22	22–41	42+
Age at start	<25	25–34	35+
Period	1–5	6–10	11–15
Education	Low	Mid	High

Figure 6 Adjusted differences for trimean

as does the factor birth order in Jamaica and Korea. Another general finding is that with few exceptions, the effects of education are not greatly altered by multivariate analysis. The country with biggest differences between adjusted and unadjusted effects is Korea. However, this is also the country with the largest adjusted differences in the quintum: Korea has a range in excess of 0.2 on each factor except period even after adjustment for all other variables.

The adjusted overall differences in the quintums across each of the variables considered are shown in figure 5 and give a summary indication of their demographic significance. Differences between quintums in excess of 0.1 are undoubtedly of demographic importance. Even after adjustment for all other terms in the models, the range of differences is greater than 0.2 for age at start of the interval in all countries except Kenya and, marginally, Jordan. The range of variation across the previous interval lengths is also considerable, exceeding 0.14 in all but Kenya. Period variability is less consistent across countries, as should be expected. The range of adjusted differences exceeds 0.1 in Bangladesh, Colombia, Indonesia and Jamaica. Equally, education effects on the adjusted quintums are not always large, although the range exceeds 0.2 for Colombia, Korea and Mexico, and is also large in Jordan. On the other hand, the range in the adjusted quintums across birth orders only exceeds 0.05 for Korea, where it exceeds 0.2.

The range of variation in the trimeans is, as stated earlier, fairly small. The differences for the adjusted trimeans across each of the factors are shown in figure 6. After adjustment, the range always equals or exceeds two and a half months for the length of the previous birth interval effects. The length of the current interval typically steadily increases with lengthening of the previous interval. A range in excess of two and a half months across categories of age at start of the interval is also the norm, occurring in all but Kenya: older women unsurprisingly tend to have longer intervals. Differences between extreme categories of two and a half months in the trimean are rare for the other three factors, the only exceptions being for period effects relating to Bangladesh and Colombia and birth order effects for Korea.

In order to illustrate the effects of heterogeneity when mixing life tables to get adjusted survival functions, we show in table 10 the adjusted relative risks for the final model. The difference between table 10 and the earlier table 8 is that we now present the estimates based upon mixing the various life tables according to the distribution of cases at duration zero. (With discrete categorisation, the setting of other variables at their mean value, which is a common approach to obtaining adjusted effects, is not a tenable procedure.) Because we are now mixing the various life tables in continuously changing proportions, it is no longer possible to present hazard ratios for a range of durations. Instead, we show the achieved hazard ratios at the end of each category of the duration variable. The effect of heterogeneity is to constantly push the hazard ratios nearer to unity than in a homogeneous population. A comparison between the values shown in tables 8 and 10 gives an indication of the overall impact of heterogeneity. Thus, as an illustrative example for Korea, the adjusted hazard ratio at exact duration 60 months for the birth order 6–8 group becomes 0.600 once heterogeneity is taken into account, compared with the incorrect homogeneous constant ratio across all durations of 0.526 of table 8. We shall not dwell on these adjusted hazard ratios at any great length, but it is an instructive lesson to discover how important heterogeneity is as a factor in the process.

Table 10 Adjusted relative risks for the factors in the final model

Subgroup	Hazard ratio at exact duration 18	24	30	42	60	Hazard ratio at exact duration 18	24	30	42	60	Hazard ratio at exact duration 18	24	30	42	60
	Bangladesh					**Colombia**					**Indonesia**				
Birth order															
3	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
4–5	0.982	0.982	0.982	0.983	0.985	0.880	0.885	0.889	0.902	0.911	1.002	1.002	1.002	1.002	1.002
6–8	0.969	0.969	0.971	0.972	0.974	0.938	0.941	0.943	0.950	0.955	1.000	1.000	1.000	1.000	1.000
Last interval															
<22	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
22–41	0.506	1.039	0.836	0.997	0.871	0.690	0.789	1.161	0.850	0.875	0.476	0.885	0.984	1.181	1.013
42+	0.407	0.615	0.485	0.716	0.661	0.514	0.477	0.614	0.475	0.458	0.379	0.598	0.578	0.652	0.754
Age at start															
<25	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
25–34	0.793	0.793	0.799	0.804	0.814	0.836	0.842	0.846	0.861	0.872	0.848	0.847	0.849	0.855	0.855
35+	0.493	0.492	0.502	0.510	0.525	0.538	0.548	0.556	0.585	0.604	0.548	0.546	0.550	0.561	0.562
Period															
1–5	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
6–10	1.515	1.519	1.497	1.482	1.447	1.300	1.290	1.282	1.253	1.232	1.338	1.339	1.332	1.315	1.310
11–15	1.566	1.571	1.546	1.528	1.489	1.613	1.587	1.566	1.493	1.443	1.374	1.376	1.368	1.348	1.342
Education															
Low						1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Middle						0.861	0.943	0.877	0.662	0.752	0.801	1.057	1.101	1.099	1.132
Middle None	1.000	1.000	1.000	1.000	1.000										
Middle Some	1.030	1.021	1.090	1.087	0.972										
High						0.675	0.574	0.443	0.490	0.543	0.829	1.474	1.264	1.044	0.766
	Jamaica					**Jordan**					**Kenya**				
Birth order															
3	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
4–5	1.056	1.055	1.053	1.051	1.048	0.928	0.929	0.931	0.943	0.956	0.987	0.987	0.987	0.988	0.988
6–8	1.143	1.140	1.136	1.131	1.120	0.837	0.839	0.844	0.868	0.894	0.880	0.880	0.882	0.887	0.888
Last interval															
<22	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
22–41	0.700	0.868	1.066	0.964	1.328	0.636	0.804	1.118	0.959	0.966	0.566	0.938	0.979	1.084	0.949
42+	0.671	0.694	0.651	0.757	0.574	0.665	0.629	0.722	0.485	0.509	0.666	0.740	0.622	0.659	0.750
Age at start															
<25	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
25–34	0.810	0.812	0.816	0.819	0.829	0.845	0.846	0.850	0.868	0.888	0.983	0.982	0.983	0.983	0.983
35+	0.500	0.504	0.509	0.516	0.531	0.463	0.465	0.470	0.505	0.545	0.720	0.718	0.721	0.729	0.729
Period															
1–5	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
6–10	1.250	1.247	1.242	1.237	1.221	1.041	1.041	1.039	1.033	1.026	1.070	1.070	1.069	1.065	1.064
11–15	1.485	1.477	1.467	1.454	1.418	1.040	1.039	1.038	1.032	1.025	1.122	1.122	1.120	1.113	1.111
Education															
Low	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Middle	1.041	1.155	0.960	1.019	1.498	0.923	1.059	0.884	0.616	0.669	0.879	1.071	1.181	1.215	1.144
High	0.849	0.891	0.846	0.815	1.107	0.764	0.757	0.422	0.498	0.501	1.054	1.364	0.933	0.828	1.020
	Korea					**Mexico**					**Sri Lanka**				
Birth order															
3	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
4–5	0.682	0.686	0.694	0.722	0.743	0.931	0.934	0.937	0.943	0.951	0.953	0.954	0.956	0.959	0.963
6–8	0.527	0.533	0.541	0.574	0.600	0.949	0.951	0.954	0.959	0.964	0.946	0.947	0.949	0.952	0.957
Last interval															
<22	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
22–41	0.602	0.550	0.850	1.086	0.820	0.611	0.724	1.148	0.986	0.866	0.592	0.780	0.843	1.055	1.010
42+	0.765	0.426	0.493	0.681	0.554	0.560	0.436	0.577	0.667	0.613	0.532	0.481	0.500	0.651	0.596
Age at start															
<25	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
25–34	0.842	0.845	0.848	0.859	0.867	0.788	0.793	0.800	0.811	0.829	0.782	0.785	0.788	0.793	0.806
35+	0.435	0.441	0.447	0.469	0.486	0.413	0.421	0.429	0.445	0.471	0.400	0.403	0.408	0.415	0.433
Period															
1–5	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
6–10	1.135	1.131	1.126	1.114	1.104	1.132	1.127	1.121	1.109	1.095	1.177	1.173	1.168	1.159	1.143
11–15	1.271	1.262	1.251	1.224	1.203	1.207	1.198	1.188	1.169	1.144	1.349	1.341	1.329	1.309	1.273
Education															
Low	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Middle	0.868	0.952	0.916	0.769	0.785	1.051	0.945	0.755	0.764	0.723	0.892	0.978	1.034	0.972	0.894
High	0.839	0.830	0.666	0.494	0.554	0.813	0.485	0.350	0.450	0.489	1.014	1.146	0.933	0.686	0.584

7 Discussion

Some care has to be taken in interpreting results from analyses based on hazards models. As an example take the contrast between the periods 11–15 years and 1–5 years before the survey for Colombia. Our effect estimate for this contrast is 0.492. This implies that the hazard rate is 63.6 per cent (= exp(0.492) − 1) higher for the earlier period at all durations. Yet the adjusted quintums for the two periods are 0.848 and 0.703, with a difference of 21 per cent. It is clear that this latter measure is more appropriate for judging the impact on overall fertility: the rate of transition to the next birth for women at parities 2–7 was about 21 per cent higher ten years earlier. We now abstract by assuming all women have at least two births and these estimated adjusted quintums by period are actually parity progression ratios which apply to transitions from parities 2–7. We then find that 37.2 per cent of women experiencing the quintum of 0.848 ($0.848^6 = 0.372$) for the period 11–15 years before the survey would progress to an eighth birth. Use of the quintum of 0.703 for the period 1–5 years before the survey would only result in 12.1 per cent of women progressing to parity 8. Assuming all women ceased childbearing at parity 8 we would get synthetic average family sizes of 5.50 and 4.08 respectively, suggesting that fertility between parities 2 and 8 was 68 per cent (= (3.50 − 2.08)/2.08) higher ten years before and overall fertility was 35 per cent higher. It is evident that considerable care is needed in interpreting results and that judging the impact of differences on one scale of measurement for another scale is not simple. Quite small changes in quintums at all birth orders can have a substantial overall fertility impact. As a rough rule a reduction in the quintum of 0.05 for all intervals 3–8 reduces overall fertility between parities 2 and 8 by about one-sixth (17 per cent): a substantial reduction.

In view of the impact of fairly small changes in the quintum on overall fertility, the magnitude of several of the effects we observe is very substantial indeed. Even after controlling for all the factors in our final model, the adjusted quintums show large variations between subgroups. For age at start of the interval, we recall that the differences in the adjusted quintums between the youngest and oldest groups is in excess of 0.2 for all countries except Kenya and, marginally, Jordan and is around 0.3 for Korea, Mexico and Sri Lanka. At the other extreme differences between adjusted quintums by birth order exceed 0.05 only for Korea, which has a large range of 0.20. These findings suggest that age is of far greater importance in determining fertility behaviour than is birth order, even where there is known to be substantial fertility control, although Korea is a striking exception. A partial explanation of the unusual pattern of Korea is undoubtedly the implementation of sex preferences. Rindfuss *et al* (1984) show this quite clearly in a birth interval analysis.

Discussions of the implications of this work must begin with the most striking of our findings, namely the general lack of importance of birth order in the reproductive process (see figure 5). Even without any other controls the within-country range of variation in the quintums is fairly small, reaching 0.1 only for Bangladesh, Sri Lanka and Korea (with a range of 0.29). Once we have controlled for other factors, even using very broad groupings, we find even less indication of significant variation in the timing or quantity of transitions to the next birth, for orders 3–8.

Almost all theoretical statements about childbearing behaviour are rooted in statements about individual 'target' levels of fertility. The more extreme of such theoretical statements assume targets are immutably fixed early in the reproductive career. Weaker versions assume an element of sequential decision-making, perhaps with decisions made about each pregnancy in turn. Yet our results suggest a distinct lack of pattern in cessation of childbearing by birth order (or in timing for that matter), at least beyond the second birth.

A better description of the reproductive process, excepting Korea for the moment, might focus on this continuity of behaviour. At the societal level it seems that achieved parity exerts little independent influence on the decision to cease childbearing. On the contrary, there seems to be an inbuilt momentum to the reproductive process, whereby earlier behaviour and socio-economic differences fundamentally determine the remainder of childbearing experience. Thus, increased education often substantially reduces the proportions having births of any order between 3 and 8. Education also commonly affects the timing of such births, almost certainly through changes in breastfeeding and contraceptive behaviour. Yet we must note that our observed education effects do not seem to operate through an association between successive intervals, as the education effects do not get substantially reduced by a control for length of the previous interval. Previous rapidity of childbearing, as captured by length of the previous interval, is associated with both the timing and quantity of subsequent childbearing. This relation reflects a variety of influences, including perhaps variations in individual propensities to breastfeed and use of contraception for spacing purposes. However, we note that the analysis of Trussell *et al* (1983) finds strong effects of length of previous interval, even after controlling for breastfeeding duration and contraceptive use in the interval, which suggests other factors are responsible for this link between intervals. In addition, the length of the previous interval contains some information about individual variation in fecundability and coital frequency. As prior birth interval length is a function of several unobserved factors which introduce random variation, it will only poorly proxy for these unobserved factors. It is well known that the effect of a variable (or collection of variables) measured with error is to attenuate statistical relationships. This implies that we fail to capture anything like all variation due to the underlying factors (see Gilks (1982) for further discussion). Despite this caveat, we consistently find strong and interpretable relations with the length of the previous interval (for a discussion of other related controls, including especially duration of motherhood or time since first birth, see Gilks 1982). The final and important element identified in the reproductive process is age of the woman at the start of the interval. In the aggregate, onset of sterility is closely associated with ageing and clearly exerts an ultimate force which causes reproduction to cease. Although further work is required which delineates more age categories, especially above age 35, the import of our results is clear.

Our tentative interpretation of the results of the models considered here would run as follows. Once women have begun the process of childbearing, education seems to affect the overall tendency to go on to a further birth equally for all births beyond the second. There is a strong correlation between behaviour in successive intervals, probably reflecting variations in fecundity, coital frequency, contraceptive use and efficacy, and breastfeeding propensity, with those having long previous intervals being less likely to progress to a further birth. Ultimately, it seems that childbearing may stop as a result of the ageing process, with women gradually ceasing through sterility or, perhaps, normative pressures related to age but not to achieved parity. Such a description undoubtedly over-interprets our fairly simple models, but is clearly much more consistent with the findings than is an idea of deliberate parity-related behaviour beyond the second birth.

Perhaps the above argument is not a great surprise to those who are familiar with patterns of parity progression ratios from the most developed societies, where values are usually fairly constant for transitions to all births beyond the second. Thus in countries with very highly controlled fertility, decisions are taken about the timing and occurrence of the first two births, but transitions to higher orders include many accidental births and reflect, in part, contraceptive failures. For such analyses, socio-economic factors such as education, housing tenure, race and religion may also be useful and important controls.

Pre-transitional societies are usually assumed to have natural fertility, which presumes no change in behaviour by birth order. Post-transition societies seem also to exhibit such patterns beyond the second birth. The implication of our models seems to be that several transitional societies maintain a process whereby behaviour is not heavily conditioned by achieved parity, but rather reflects the outcome of a variety of other determinants, including age, fecundability, breastfeeding practices and socio-economic factors. The only exception among our nine countries is Korea, although among the other eight countries considered only Colombia, Jamaica and Sri Lanka have well-established fertility declines. It is clearly of considerable theoretical import to pursue these aspects further in other transitional societies and to improve the model specification. Very closely related findings, which lend support to the arguments presented here, are reported in Hobcraft and McDonald (1984) and Gilks (1982).

This encapsulation of the reproductive process as an engine with its own inbuilt momentum, albeit strongly affected by period changes in attitudes, behaviour and contraceptive availability, suggests a very important role for age at entry. Age at beginning childbearing is usually quite strongly related to education and other socio-economic characteristics. These also affect the pace of subsequent childbearing, usually but not always by altering the length of interval and almost always affecting the general propensity to stop. However, insofar as age is important in determining cessation, the later starters will end up at lower final parities.

The conclusions about lack of importance of birth order in reproductive behaviour are undoubtedly challenging to conventional wisdom. Thus, we are all familiar with findings that show variations by birth order in contraceptive use and in proportions wanting no more births. These results seem consistent with theories dependent upon stopping rules determined mainly by birth order. Yet under our hypothesised patterns of reproductive behaviour, which are independent of birth order, we would observe similar patterns. Even without educational differences in rapidity of childbearing once started, later ages at beginning would lead to slower reproduction at higher birth orders, simply from the age effects. This process in turn implies higher proportions stopping at lower birth orders. This result can be achieved in a natural fertility population. Once control is introduced, the propensity to stop may vary between subgroups but stays essentially constant across birth orders, once other factors are controlled. A higher propensity to stop naturally leads to higher proportions stopping at lower birth orders. Hence, observed patterns in contraceptive use and wanting no more births can be achieved accompanied by no change in behaviour with increasing birth order beyond the second birth.

Conceivably, the regularities observed could purely reflect a patterning of independent individual decisions about desired family size, which happen in the aggregate to give the appearance of lack of association with birth order. We think such an explanation probably less tenable than the following argument. It appears to us that couples probably do think that they take decisions about childbearing one birth at a time. These individual decisions are the source of a large component of the stochastic variation in childbearing. However, when viewed in the aggregate, external factors essentially determine the underlying parameters of the reproductive process for those individuals. These factors strongly and commonly influence reproductive behaviour across all birth orders above the second. They are essentially the societal and biological factors which determine the overall outcome in the fertility process. Once set on a reproductive pathway, the biological, behavioural and chance aspects of the previous interval may contribute to varying the outcome. Similarly, there may be secular changes in the parameters of the reproductive process, as the societal pressures change, for example through more widespread contraceptive availability, economic hardship or changes in the manifestly temporary norms about reproduction. It seems, though, that it is relatively rare for these parameters of the reproductive process beyond the second birth to change across birth order.

Further research clearly needs to focus on the beginning of the reproductive process. Thus, if as much of reproduction as seems to be the case is determined early on in the reproductive career, it is the variation there which requires explanation. Does the 'reproductive engine' start with marriage? Or does it start with the first or second birth? Questions then arise as to whether the same determinants are responsible for variations in age at first marriage or age at first birth as are linked with subsequent reproductive behaviour. Rindfuss *et al* (1984) suggest that this is not the case for the south-east Asian countries they study: they find education an important determinant of age at first birth, with rural/urban residence fairly unimportant; but the reverse occurs for subsequent birth intervals, with residence being the more powerful predictor.

The first relevant information about birth interval length as a determinant of subsequent reproductive performance becomes available after the second birth. The rate and quantity of transition to a third birth is demonstrably strongly related to the length of this second birth interval. It may be useful to focus upon this particular linkage, at the beginning of the process we term the reproductive engine. The length of any birth interval is determined to a significant extent by behaviour of the couple, including breastfeeding, contraception, abstinence, union dissolution, induced abortion and coital frequency. But the outcome is also strongly affected by chance factors, including timing of resumption of ovulation and waiting times to conception, capacity to breastfeed, propensity to abort spontaneously and other aspects of biological fecundity. These behavioural and chance factors are interlinked, and their joint effects determine the interval length. We need to know whether it is the chance or behavioural elements which predominate in bringing about the links with subsequent fertility behaviour and then to clarify which of the individual behavioural or chance elements are most important.

Let us first consider the chance elements. One important but largely unmeasurable determinant of the waiting time to conception is the fecundability of the couple. Insofar as fecundability varies across couples, it may be an important factor in the relationship between successive birth intervals. Although the waiting time has a large chance element, some information about underlying fecundability may be contained in a single observed interval. Any characteristic of a couple that is fixed, by chance, at a certain level would affect each interval in a similar fashion. This characteristic would then provide a plausible mechanism for some of the observed strong linkage between successive intervals. What of the remaining chance elements that are not fixed for an individual couple? Suppose the second birth interval just happens to be unusually long for a particular couple. By what mechanism might we expect this long interval to lengthen subsequent intervals? We could think of none. On the whole, we think it more likely that such a chance outcome may cause the couple to adopt behaviour to ensure this does not happen again, thus inducing a negative rather than a positive association.

A further chance element can have a crucial effect on interval lengths and could be an important component of the observed linkage: infant mortality. An infant death brings an abrupt cessation to breastfeeding, where this method of feeding is used for lengthy periods. This, in turn, is likely to shorten the period of infecundity, at least on an average basis. A short previous birth interval has been well documented as being closely linked with higher infant mortality for the child born at the end of that interval (Hobcraft, McDonald and Rutstein 1983). This higher mortality will shorten the period of infecundity and thus shorten the next interval. However, the link between successive intervals persists even after a control for length of breastfeeding. What may remain as a mortality consequence would therefore have to be associated with replacement-linked behaviour.

We now briefly consider the behavioural determinants of birth interval length which may induce the observed auto-correlation. Provided her children survive, a mother may breastfeed each of them for a fairly fixed length of time, including those women who are physically unable to breastfeed. This tendency would cause variation between women in their typical length of post-partum infecundity and induce an auto-correlation between successive intervals. Yet Trussell *et al* (1983) demonstrate that this linkage between successive intervals is barely attenuated by a control for breastfeeding duration. Similarly, at least at birth orders above two or three, couples may consistently use contraception for spacing or stopping purposes with varying degrees of efficacy. But the previous interval effects were again barely attenuated by a control for contraceptive use in the interval in the analysis by Trussell *et al* (1983). Variations in typical length of use or efficacy of use between couples could still be linked with the observed auto-correlation, provided couples remain fairly consistent in their behaviour. Other uncontrolled and usually unmeasured factors which may be partly responsible for the strong relationship between successive intervals include variations in coital frequency between couples and seasonal migration or other regular exposure reduction (eg visiting unions in the Caribbean).

Clarification of the relative importance of these possible determinants of the observed auto-correlation between intervals seems worthwhile. Insofar as the links between successive intervals are behavioural this would imply the need for better measurement for input into analyses and fuller attempts to discover the more remote determinants of these variations between couples in the measurable proximate determinants. The mortality–fertility linkage is more mechanistic, although any conscious replacement-oriented behaviour would make this less so. Once again the lesson would be of the need to include this information explicitly in any analysis. If the linkages between successive intervals persisted after the more elaborate analysis, which included controls for survivorship and a full range of measurable behavioural proximate determinants, the likely remaining explanation would involve unmeasurable (or unmeasured) proximate determinants such as fecundability. Further clues and precision could perhaps be obtained by using controls on earlier interval lengths or average interval lengths.

A conclusion which emerges from this work is that it may be misleading to break down the reproductive process too finely. It is clear that reproductive performance in any one birth interval is intimately linked to that of the previous interval. This result implies the need for a more holistic approach to modelling the transitions in the child-bearing process than is implied by separate models for each birth order. There are clearly many aspects of reproductive behaviour which are common to many, if not all, birth intervals. Without further progress towards such holistic models of the process, we are slightly sceptical about the merits of work with birth intervals. The fragmentation of the process may not give useful gains over models which use fertility rates without a birth order component (eg Rodríguez and Cleland 1981; Hobcraft and Casterline 1983). The proliferation of parameters from birth interval based analyses makes presentation and interpretation inevitably more complex. At the present, though, we would welcome further attempts to develop more integrated models with a birth order component, if only to elucidate the nature of the reproductive process, the role of reproductive norms and the interplay of chance and deterministic factors in determining individual and societal fertility behaviour.

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