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Progressive estimation of childhood mortality: the preceding birth technique in Bangladesh.

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Abstract

This paper assesses the value of the Preceding Birth Technique (PBT) for generating current estimates of early childhood mortality from data provided through the health services. Using data from Matlab, Bangladesh (ICDDR,B), the directly measured childhood mortality of the preceding births of two birth cohorts of approximately 5000 second and higher-order index children born in 1984 and 1989 is compared with the proportions of preceding children dead. The PBT approximates q(3) rather than q(2) in Bangladesh due to long birth intervals. The data from mothers seen 3 months before delivery, at birth or 3 months after a birth, all produce estimates of early childhood mortality comparable to those measured directly for the same children through the continuous monitoring system. The PBT successfully identifies socio-economic, sex and other mortality differentials, as well as satisfactorily describing short-term variations in childhood mortality. In Bangladesh, the best source of data for the application of the PBT appears to be immunization centers. Good estimates of early childhood mortality can now be made from the proportions dead among preceding born children obtained from mothers seen some months before or after a birth. This finding extends considerably the potential value of the PBT for estimating trends and differentials in childhood mortality from routine data.

I. INTRODUCTION

In developing countries, the principal source of information on childhood mortality is often a census or a nationally-representative survey rather than routinely reported vital registration data. In censuses, the basic information collected is usually the retrospective data on cumulated numbers of children ever-borne and surviving. From these responses, the proportions dead are calculated by age or by marriage duration which are then converted into life table probabilities of dying by well-known indirect methods (Brass 1975; UN, 1983). In surveys, the source of the mortality information is generally the full birth or maternity history with child mortality calculated by ordinary life table methods (1). The strengths and weaknesses of the various approaches need not be rehearsed here since they are well covered elsewhere (K Hill 1991; Hill and David 1988). With both methods outlined above, the result is a general description of levels, trends and differentials in childhood mortality for the 15 or so years before the survey. From either method, the results for the 5-year period before the census or survey are the least reliable, for reasons again well described in standard references (2). To obtain near-contemporary estimates of childhood mortality, such as are required by UNICEF and other UN agencies for publication in the annual State of the World's Children, these data are often extrapolated on the basis of past trends (UNICEF, 1993).

There is now an alternative method for estimating recent trends and differentials in childhood mortality. It involves extensions to the Preceding Birth Technique (PBT) invented by Brass and Macrae (1984) but extended subsequently by Hill and Aguirre (1990). In this later paper, the key proposal was that good estimates of mortality before age 2 could be obtained at the time mothers were seen not just at the time of delivery but also at the time of an ante-natal visit or soon after the birth of their child. The main reason for this suggestion was that only a small fraction of women in developing countries give birth in hospitals and maternity clinics whereas the majority of women worldwide are seeking some ante-natal care and an even higher proportion are bringing their young children for immunization (3). Leaving aside for the moment the whole problem of the representativeness of the women seen before or after the birth of their children, Hill and Aguirre have shown from models that the departures from the mortality estimates obtained at exactly the time of the birth are very slight. On the one hand, for the ante-natal case, the mortality estimates obtained from the proportions of preceding children dead among women seen 3 months before delivery slightly under-estimates q(2) but the difference is small, especially if the women are seen late in the pregnancy, say in the last trimester (4). On the other hand, when mothers are seen after a birth, provided the delay between delivery and in the interview is not more than a few months, the proportions of preceding children dead will be only slightly affected. Two factors explain this surprising result. One is the prolongation of the exposure period for the preceding born child which will inflate the proportions of preceding born children dead at interview relative to the value obtained at the time of the most recent birth. Working in the other direction, however, is a selection effect related to the kinds of mothers who are seen after the birth. If the information on the survival of the preceding birth is collected at the time of first immunization, say 3 months after delivery, then only mothers whose last-born children survive will attend for immunization of their children. As there is an association between the survival of successive born children, as Hill and Aguirre (1990) have already demonstrated, then the women with children who survive to be immunized will also have lost fewer preceding children than the population at large. The extent of this bias will depend largely on the magnitude of the mortality differentials between the two groups of women - those with surviving last born children and those whose most recent children are dead. Some empirical data on these differences are presented below. By good fortune, it seems that in many cases, these two different biases - extension of the exposure period and dependence between the survival of successive born children - will be almost equal and certainly opposite.

II. THE EXPERIMENT

Until now, these ideas have remained largely theoretical suggestions unconfirmed by empirical evidence. Here we present a confirmation of many of the original suggestions made by Hill and Aguirre (1990) concerning the use of the PBT both in ante-natal and in post-natal encounters with mothers. As part of the assessment of the PBT as a method of obtaining recent childhood mortality estimates from women seen in ante-natal or immunization centers, we ask:

(i) what is the relationship of the proportions dead amongst the previously born children at the time of the third trimester of the current pregnancy, at the time of the succeeding birth, and when the current child is 3 months old (the age when a child is usually brought first to the EPI center), to the directly measured probability of dying by different ages in childhood?

(ii) are the socio-economic differentials in childhood mortality in the direct measures matched by the differentials in the proportions dead amongst the previously born children?

(iii) are the fluctuations in childhood mortality in time being reflected in the proportions of preceding children dead?

(iv) are the estimates of mortality robust to changes in fertility and birth interval length?

(a) Data and methods

The data for this study come from Matlab, the vital registration area of the International Center for Diarrhoeal Disease Research, Bangladesh (ICDDR,B). Details of the Matlab program are available elsewhere (Bhatia et al. 1980; Phillips et al. 1984) so only a brief description follows.

The Matlab demographic surveillance system (DSS) has been maintaining records of vital events of over 200,000 people (1993 population) since 1963. In 1977, a Maternal and Child Health and Family Planning (MCH/FP) project was installed in almost half of the DSS area, later known as the Treatment Area. In the remaining half known as the Comparison Area, only the standard national family planning services are provided. In the beginning, the MCH/FP and the Comparison area had similar socio-economic and demographic characteristics. Now, the two areas have very different demographic attributes. In 1989, the total fertility rate (TFR) in the MCH-FP area was 3.7, but in the Comparison Area, it was 5.2. In that year, infant mortality in the MCH-FP area was 76/1000 and 1-4 year child mortality was 6.4/1000, but in the Comparison area these rates were 90/1000 and 11.3/1000 respectively. Most important, in both areas directly measured mortality and migration rates are available from the continuous recording system. Pregnancies are systematically followed so omission of births and deaths is rare. Data on exact age at birth and death and hence on birth intervals are also available. Altogether, the existence of such detailed information on a large scale is unique in the developing world.

(b) Calculation of measures

Mortality amongst the preceding born children was calculated directly by life table methods using the dates of birth and death as recorded for the previous born siblings of the index children born in the years 1984 and 1989. These are taken as the "true" measures of childhood mortality for the pre-1984 and pre-1989 periods.

Four measures of mortality are calculated from the data on the survival of the preceding born. The simplest, D(0), is the proportion of preceding children dead at exactly the time of birth of the children born in 1984 and 1989. To simulate the effect of collecting the data in ante-natal clinics, the proportions of preceding children dead 3 months before the delivery of the succeeding child, D(-3), were calculated. Finally, two quantities are calculated, D(3) and D'(3), which simulate the results of collecting the PBT data 3 months after delivery, as might occur in immunization clinics. D(3) is the proportion of preceding children dead for all succeeding born children whether they survive or not to 3 months of age. D'(3) excludes the preceding children whose subsequently born siblings die before 3 months of age. D'(3) is thus the quantity which would result from collecting the data only from mothers of index children who survive to at least 3 months. Therefore, the differences between D(3) and D'(3) measure the size of the selection bias attributable to the omission of mothers of succeeding or index children dying before 3 months of age.

All the quantities are calculated for two time periods, the two Areas (Treatment and Comparison), by maternal education and by sex to test for consistency of the results for sub-populations.

(c) Time references for the estimates

From models, Aguirre (1990) suggested that the PBT estimate of childhood mortality was located about two-thirds of the birth interval before the date of birth of the last born child. Based on simulation exercises for 7 countries, the time location varied between 17.2 and 22.4 months before the next birth. In non-contracepting populations, the birth interval is more likely to be curtailed following an infant death because of the reduction in the subsequent period of post-partum amenorrhoea. Hence, following an infant death, the PBT estimates of childhood mortality will refer to a date closer than otherwise to the time when the data are collected. The time reference of the PBT estimate in months before the data collection will be the average duration of the subsequent birth interval of children dying before the subsequent birth less the mean age of death of the same preceding born children. In the Matlab data, birth intervals are longer than the average for most high fertility populations but following the death of a child before the subsequent birth, the subsequent birth intervals are 30.5 months in the Treatment Area and 26.0 in the Comparison area (Table 1). The birth intervals following an infant death are not very different (26.4 and 23.8 months, respectively) since most of the effects on the duration of post-partum infecundability and hence on the length of the subsequent birth interval result from the curtailment of breast-feeding amongst infants. The mean age at death of the preceding born children dying before the next birth can be calculated directly. For the Treatment Area, this value was 9.0 months, 7.1 months in the Comparison Area (Table 1). The mean age at death for infants is much shorter: 2.5 and 2.1 months respectively. As mortality falls, the mean age at death for childhood deaths will also fall, as inspection of Table 1 bears out. Hence, the reference dates for the PBT estimates collected at the time of the birth in the Treatment Area using the data in Table 1 are 30.5 - 9.0 = 21.5 months before the last birth; 26.0 - 7.1 = 18.9 months before the last birth in the case of the Comparison Area. For most populations in which the PBT is likely to be used, the mean age at death for those dying before their third birthday is likely to be between 4 and 8 months.

III. RESULTS

In Table 2, the distribution of previous birth intervals of second and higher-order birth cohorts of 1984 and 1989 by area is given. The cumulative distribution for the 1989 birth cohort by area is shown in Figure 1. The number of such births in 1984 was 4,878 and in 1989 it was 4,908. The average birth interval remained almost the same in the Comparison area but increased by 1.3 months in the MCH-FP area during the period of 1984-1989. The birth intervals were longer at both dates in the Treatment area than in the Comparison Area due to the combined effects of the family planning program and

Table 1

Mean age at death and subsequent birth interval lengths in months for preceding born children of the 1987 birth cohort (index children) in Treatment and Comparison Areas of Matlab, Bangladesh.

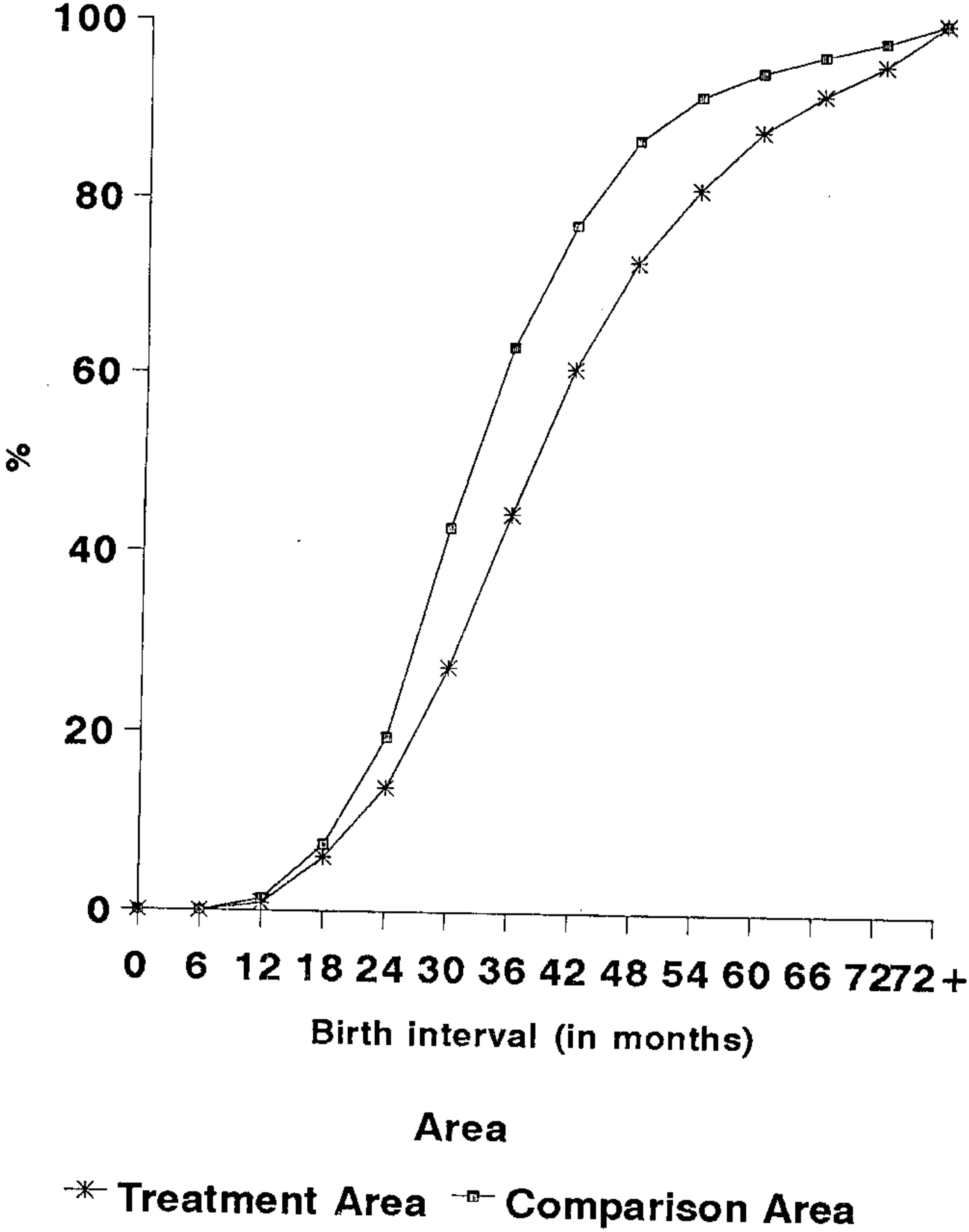
Population	Measures	Mean in months		
		Treatment	Comp.	All
All previous children	Birth interval	41.3	34.6	37.6
Previous children died before birth of index children	Age at death	9.0	7.1	7.8
	Birth interval	30.5	26.0	27.8
Previous children died before 12 months of age and birth of index children	Age at death	2.5	2.1	2.3
	Birth interval	26.4	23.8	24.9
Previous children died before 3 months of age	Age at death	0.7	0.6	0.6
	Birth interval	25.7	22.5	23.7

Table 2

Distribution (%) of Previous Birth Intervals of Second and Higher-Order Births in 1984 and 1989 by Area in Matlab.

Age (in months)	Year 1984 Treatment %	Year 1984 Comparison %	Year 1989 Treatment %	Year 1989 Comparison %
5-11	1.0	0.9	0.9	1.4
12-17	5.4	6.4	5.2	6.1
18-23	8.8	9.8	7.8	12.1
24-29	18.3	23.7	13.4	23.3
30-35	17.9	22.7	17.1	20.3
36-41	14.2	15.0	16.3	13.9
42-47	11.3	8.5	12.2	9.6
48-53	7.7	5.6	8.3	5.0
54-59	4.5	2.5	6.5	2.7
60-65	3.8	1.9	4.2	1.9
66-71	1.8	0.6	3.4	1.6
72+	5.5	2.5	4.7	2.3
Total	100.0	100.0	100.0	100.0
Mean (months)	38.4	34.2	39.7	33.9

Figure 1. Cumulative distribution of birth intervals by length: Matlab Treatment and Comparison Areas



the improved child survival in the Treatment Area.

(a) Comparison of D(0) and q(x)

From Tables 3 and 4, it is clear that the D(0), the proportions dead obtained at the time of a subsequent birth, are closer to q(3) than to q(2) for the index children born in 1984 and 1989. The underlying reason is the extra exposure time associated with the long birth intervals in rural Bangladesh. Note that for the Treatment Area in 1989 where family planning was most common (the contraceptive prevalence rate there rose from 19% in 1981 to 40% in 1991) and birth intervals had reached 40 months, D(0) is larger even than q(3). This is a higher value of (x) than the cases studied by Brass and Macrae (1984) where the proportions dead were approximately equal to 0.8 times the average birth interval length of 30 months. The differences between q(2), q(3) and q(4) are small. An additional reason for the high value of (x) estimated from the proportions of preceding children dead may be due to the particular age pattern of mortality which prevails in Bangladesh. As Figure 2 shows for the children born before 1989, the cumulative probabilities of dying in Bangladesh continue to rise steeply beyond age 2 in Bangladesh, a feature not common elsewhere. Overall, from the ratios between the results for the two areas, the last column of Tables 3 and 4, it can be seen that the differentials in childhood mortality as indicated by the q(x) values closely match the ratios of the corresponding D(0) values.

Table 3

Proportions Dead amongst Previously Born Children D(a) by Different Ages of the Most Recent Children (a in months), and the Probability of Dying q(x) for Previous Born Children Before Reaching Age x (in years) by Area in Matlab, 1984.

D(a) or q(x)	Treatment Area (1)	Comparison Area (2)	All	(2)/(1)
D(-3)	0.165	0.176	0.171	1.07
D(0) (birth)	0.174	0.195	0.185	1.12
D(3)	0.179	0.212	0.197	1.18
D'(3)	0.173	0.204	0.190	1.18
q(1)	0.122	0.122	0.122	1.00
q(2)	0.157	0.168	0.163	1.07
q(3)	0.178	0.211	0.196	1.19
q(4)	0.190	0.231	0.213	1.22
q(5)	0.199	0.236	0.220	1.19

D(-3) - Proportion of preceding children dead calculated from data collected 3 months before the birth of the succeeding child.

D(0) - Proportion of preceding children dead calculated from data collected at the time of the birth of the succeeding child.

D(3) - Proportion of preceding children dead calculated at the time the succeeding child had reached 3 months (irrespective of the survival status of the succeeding child at that time).

D'(3) - Proportion of preceding children dead calculated at the time the succeeding born child who was alive and not migrated had reached 3 months.

q(x) - Probability of dying before reaching age x in years.

Table 4

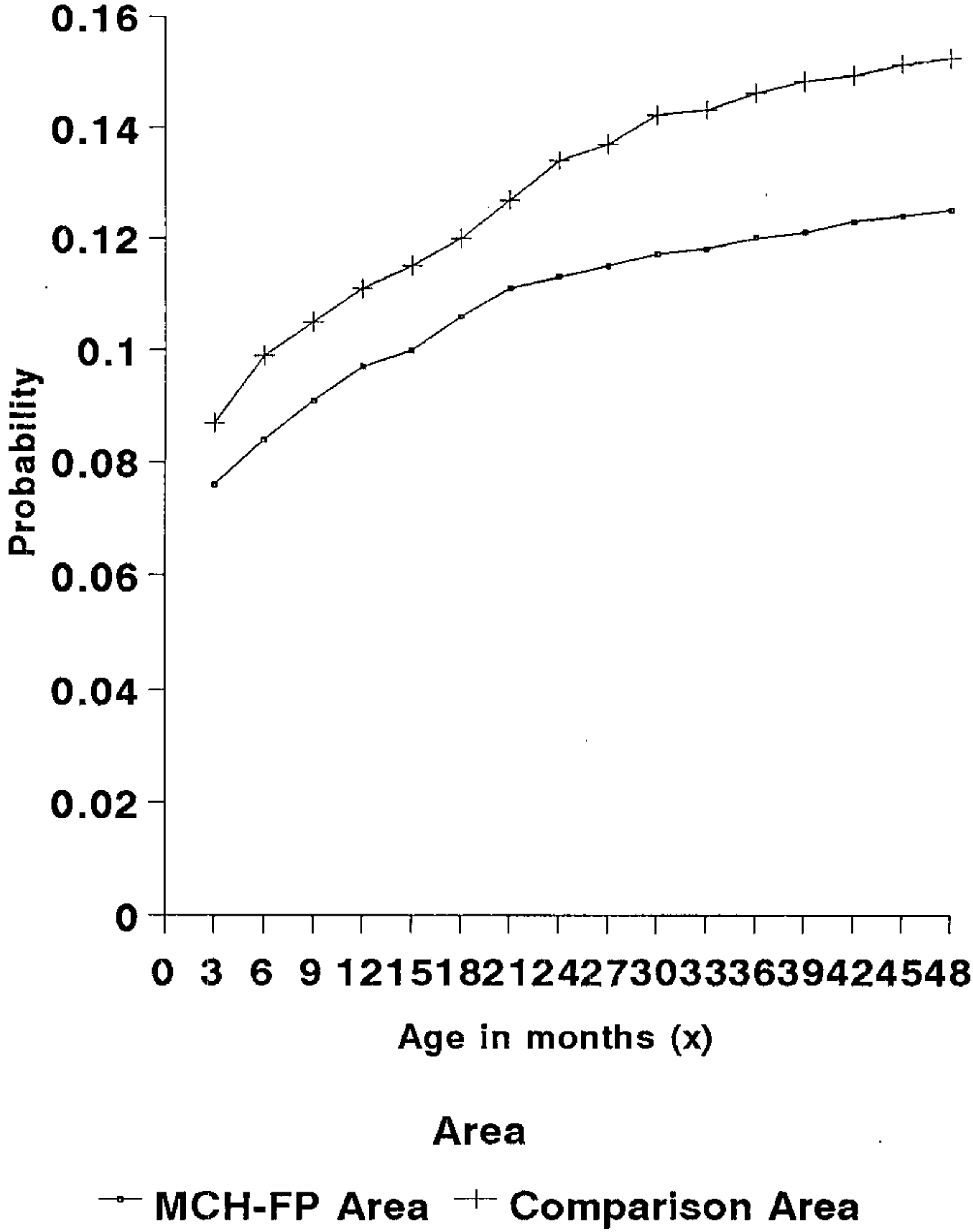
Proportions Dead amongst the Previously Born Children D(a) by Different Ages of the Succeeding Children (a in months) and Probability of Dying q(x) of the Previously Born Children Before Reaching Age x (in years) by Area in Matlab, 1989.

D(a) or q(x)	Treatment Area (1)	Comparison Area (2)	All	(2)/(1)
D(-3)	0.121	0.139	0.131	1.15
D(0) (birth)	0.123	0.145	0.135	1.18
D(3)	0.125	0.149	0.138	1.19
D′(3)	0.122	0.145	0.135	1.19
q(1)	0.097	0.111	0.105	1.14
q(2)	0.113	0.134	0.125	1.19
q(3)	0.120	0.146	0.135	1.22
q(4)	0.125	0.152	0.140	1.22
q(5)	0.126	0.154	0.142	1.22

Notes:

D(-3), D(0), D(3), D′(3) and q(x) as defined as in Table 3.

Figure 2: Cumulative probability of dying by age (x) for preceding born children by Area: Matlab 1989



(b) Comparison of D(-3) and q(x)

In Table 3 for the index children born in 1984, we see that the D(-3) values are closer to q(2) than to q(3) for both the Treatment and the Comparison Areas. For the index children born in 1989, D(-3) is a better estimator of q(3) as before. Birth intervals had lengthened in the Treatment Area between 1984 and 1989. The differences between D(-3) and D(0) are very small, as predicted. The largest difference is less than 10% for the Comparison Area in 1984. For both dates, D(-3) still over-estimates q(2) for both areas and for both time periods, indicating the relatively small effect of the reduction in the exposure period of the preceding born children on the probability of dying by age (x).

(c) Comparison of D(3), D'(3) and q(x)

First, it is clear from the comparisons of D(3) and D'(3) in Tables 3 and 4 that the effect of omitting mothers whose children died before 3 months of age has only a small effect on the D values. The D'(3) values, calculated only from data provided by mothers whose children survive to 3 months, is never more than 4% below the D(3) value based on all mothers. In rural Bangladesh, especially in 1984, childhood mortality was relatively high (infant mortality was 122/1000) and so in most other circumstances with similar or lower infant mortality rates, we would not expect the differences between the biased and the unbiased case to be much larger than those shown here.

Table 5

Proportions Dead amongst the Previously Born Children D(a) by Different Ages of the Succeeding Children (a in months) and Probability of Dying q(x) of the Previously Born Children Before Reaching Age x (in years) by Mothers Education (year of schooling) in Matlab, 1984.

D(a) or q(x)	Mother's Education 0 (1)	1-5 (2)	6+ (3)	All	(1)/(2)	(1)/(3)
D(-3)	0.181	0.132	0.131	0.171	1.37	1.38
D(0) (birth)	0.196	0.141	0.144	0.185	1.37	1.36
D(3)	0.208	0.154	0.152	0.197	1.35	1.37
D'(3)	0.204	0.143	0.149	0.190	1.43	1.37
q(1)	0.127	0.097	0.088	0.122	1.31	1.44
q(2)	0.172	0.131	0.123	0.163	1.31	1.40
q(3)	0.208	0.158	0.142	0.196	1.32	1.46
q(4)	0.228	0.167	0.146	0.213	1.37	1.56
q(5)	0.235	0.173	0.151	0.220	1.36	1.56

Notes:

D(-3), D(0), D(3), D'(3) and q(x) as defined as in Table 3.

Table 6

Proportions Dead amongst the Previously Born Children D(a) by Different Ages of the Succeeding Children (a in months) and Probability of Dying q(x) of the Previously Born Children Before Reaching Age x (in years) by Mothers Education (year of schooling) in Matlab, 1989.

D(a) or q(x)	Mother's Education 0 (1)	1-5 (2)	6+ (3)	All	(1)/(2)	(1)/(3)
D(-3)	0.142	0.121	0.113	0.131	1.17	1.26
D(0) (birth)	0.146	0.125	0.118	0.135	1.17	1.24
D(3)	0.149	0.126	0.121	0.138	1.18	1.23
D′(3)	0.148	0.117	0.109	0.135	1.26	1.38
q(1)	0.111	0.099	0.096	0.105	1.12	1.16
q(2)	0.134	0.118	0.106	0.125	1.14	1.26
q(3)	0.145	0.124	0.113	0.135	1.14	1.17
q(4)	0.151	0.130	0.113	0.140	1.16	1.34
q(5)	0.153	0.132	0.113	0.142	1.16	1.35

Notes:

D(-3), D(0), D(3), D′(3) and q(x) as defined as in Table 3.

Table 7

Proportions Dead amongst the Previously Born Children D(a) by Different Ages of the Succeeding Children (a in months) and Probability of Dying q(x) of the Previously Born Children Before Reaching Age x (in years) by sex of the previous children in Matlab, 1984.

D(a) or q(x)	Male (1)	Female (2)	All	(2)/(1)
D(-3)	0.170	0.173	0.171	1.02
D(0) (birth)	0.179	0.193	0.188	1.08
D(3)	0.186	0.209	0.197	1.12
D′(3)	0.175	0.206	0.190	1.18
q(1)	0.126	0.118	0.122	0.94
q(2)	0.162	0.164	0.163	1.01
q(3)	0.182	0.208	0.196	1.14
q(4)	0.198	0.228	0.213	1.15
q(5)	0.205	0.235	0.220	1.15

Notes:

D(-3), D(0), D(3), D′(3) and q(x) as defined as in Table 3.

Table 8

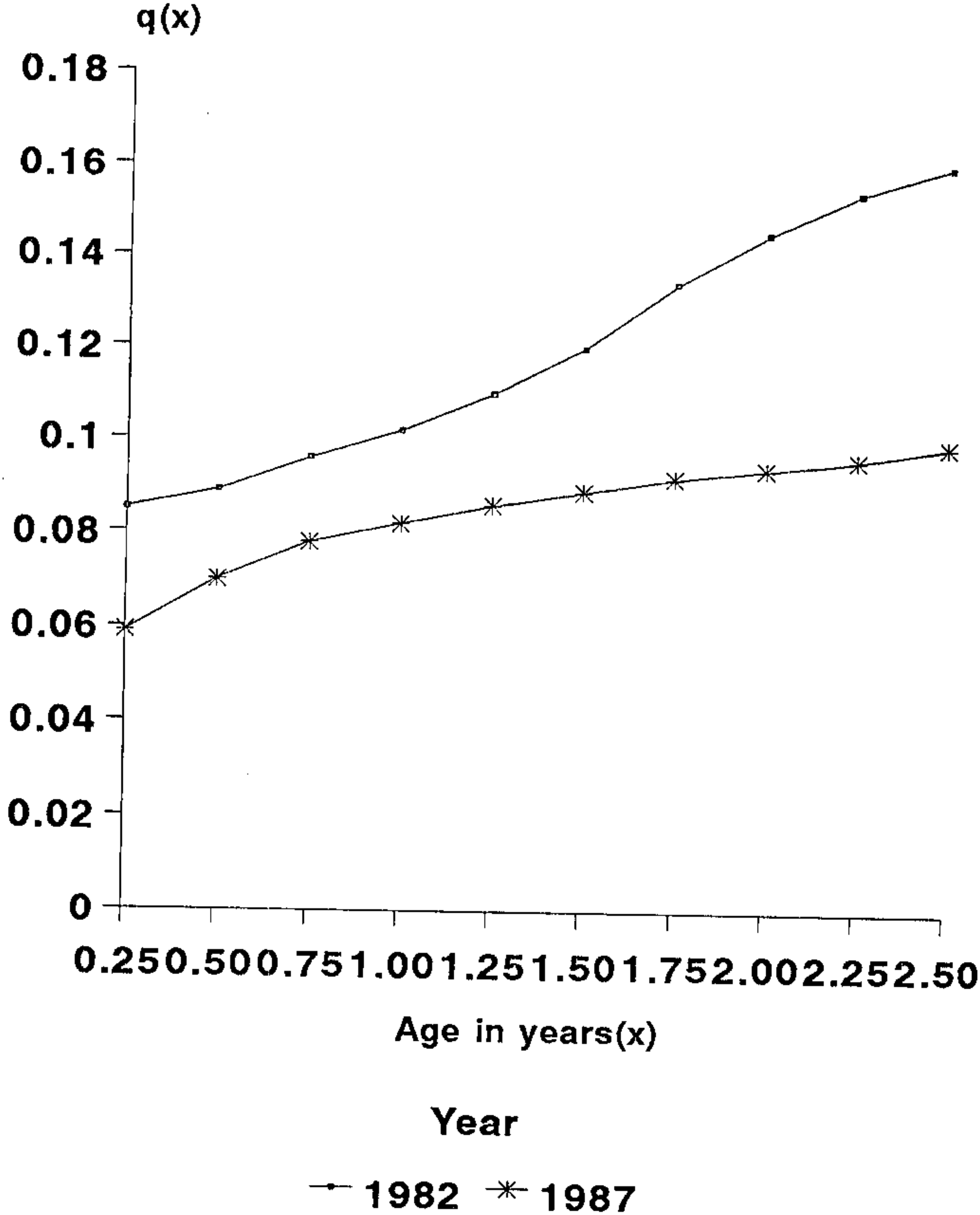
Proportions Dead amongst the Previously Born Children D(a) by Different Ages of the Succeeding Children (a in months) and Probability of Dying q(x) of the Previously Born Children Before Reaching Age x (in years) by sex of the previous children in Matlab, 1989.

D(a) or q(x)	Male (1)	Female (2)	All	(2)/(1)
D(-3)	0.129	0.133	0.131	1.03
D(0) (birth)	0.131	0.140	0.135	1.07
D(3)	0.132	0.145	0.138	1.10
D′(3)	0.127	0.142	0.135	1.12
q(1)	0.108	0.102	0.105	0.94
q(2)	0.122	0.127	0.125	1.04
q(3)	0.129	0.140	0.135	1.09
q(4)	0.133	0.148	0.140	1.11
q(5)	0.135	0.148	0.142	1.10

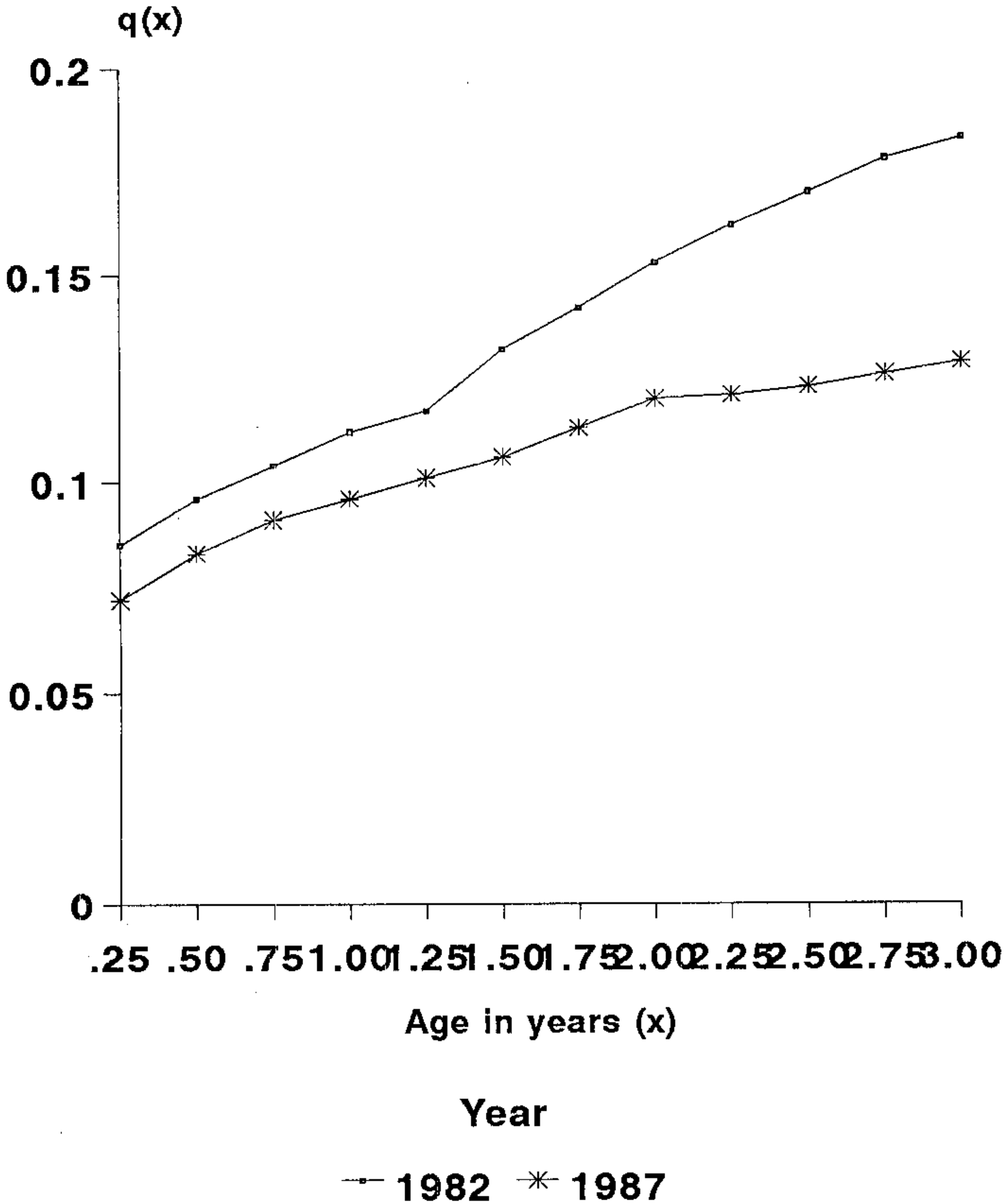
Notes:

D(-3), D(0), D(3), D′(3) and q(x) as defined as in Table 3.

Figure 3. Cumulative probability of dying by age (x) for the birth cohorts of 1982 & 1987: Matlab Treatment Ar



gure 4: Cumulative probability of dying by age for the birth
rth cohorts of 1982 & 1987: Matlab Comparison Area



(d) Differences by maternal education and gender

In Tables 5, 6,7 and 8, we compare the directly calculated q(x) values with the D values by education and sex. Broadly the same conclusions as before hold for the sub-groups examined in these tables. That is, in rural Bangladesh, D(0) is generally a better predictor of q(3) than q(2), especially for the later date. There is a relatively small proportional difference between the values of D(-3) and D(0), indicating the small biases which would result from collecting the data at ante-natal clinics. This generalization holds even when controlling for maternal education and the sex of the child. Finally, we see that D(3) and D'(3) are even closer, showing that the effects of interviewing only mothers with children surviving to at least 3 months are again small. In almost every case, the D values correctly predict the rank order of the differentials in childhood mortality and the trend in the ratios of the Ds are similar to the ratios in the q(x) values for different values of (x).

(e) Mortality change and the PBT

From the Matlab surveillance system, we have a good description of age-specific mortality trends from 1982 onwards for both the Treatment and the Comparison Areas. As Figures 3 and 4 show, mortality between 1 and 3 decreased more rapidly than did infant mortality. Is the PBT capable of detecting such changes in level, especially when the ratios of the age-specific mortality rates is changing?

The aggregate data are shown in Table 9. Broadly, there is good agreement between the directly calculated values of q(3) and the corresponding values for all of the sub-divisions of the population shown. One notable feature is that the correspondence did not worsen from 1984 to 1989 when major demographic changes had begun, especially in the Treatment Area.

We have calculated by direct methods the probabilities of dying by age 1 and 3 for eight birth cohorts and the proportions dead of the corresponding preceding born siblings of index children born from 1982 to 1989. The PBT estimates have been centered at the time corresponding to the mean period of death of those who died before age 3. The direct estimates are centered at the mid-point of the time when the deaths occurred. The results are plotted in Figures 5 and 6.

The trend in q(3) in both graphs is clearly mimicked by both the level and trend in D(0). D(0) provides a poor description of the trend in q(1) for reasons explained earlier (see Figures 3 and 4). The divergent trends in infant and under 3 mortality mean that extrapolating the trends in q(3) or D(0) to describe infant mortality may be misleading when infant mortality and 1-3 year-old mortality are changing at different rates. If the Bangladesh experience is compared to that of other developing countries, then the PBT estimates of early childhood mortality should not be used to estimate infant mortality but should be retained as good estimators of q(2) when birth intervals are less than 30

Table 9

Proportions Dead among the Previously Born Children at the time the Succeeding Child reaches 3 months of age and Probability of Dying of the Previous Children before Reaching Age 3 Years by Area, Mother's Education and Sex in 1984 and 1989 in Matlab, Bangladesh

		1984 (1)	1989 (2)	(1)/(2)
Area				
Treatment	D'(3)	0.173	0.122	1.42
	q (3)	0.178	0.120	1.48
Comparison	D'(3)	0.204	0.145	1.41
	q (3)	0.211	0.146	1.45
Mother's Education (Year of Schooling)				
0	D'(3)	0.204	0.148	1.38
	q (3)	0.208	0.145	1.43
1-5	D'(3)	0.143	0.117	1.22
	q (3)	0.158	0.124	1.27
6+	D'(3)	0.149	0.109	1.37
	q (3)	0.142	0.113	1.26
Sex of the Previous Child				
Male	D'(3)	0.175	0.127	1.38
	q (3)	0.182	0.129	1.41
Female	D'(3)	0.206	0.142	1.45
	q (3)	0.208	0.140	1.49
All	D'(3)	0.190	0.135	1.41
	q (3)	0.196	0.135	1.45

D'(3) - Proportion of preceding children dead when the succeeding child who was alive and not migrated at that time had reached 3 months.

q(3) - Probability of dying before reaching 3 years of age.

Figure 5. Life table probabilities of dying by age 1 and 3 compa
with the proportions of siblings dead D(0): Treatment Area

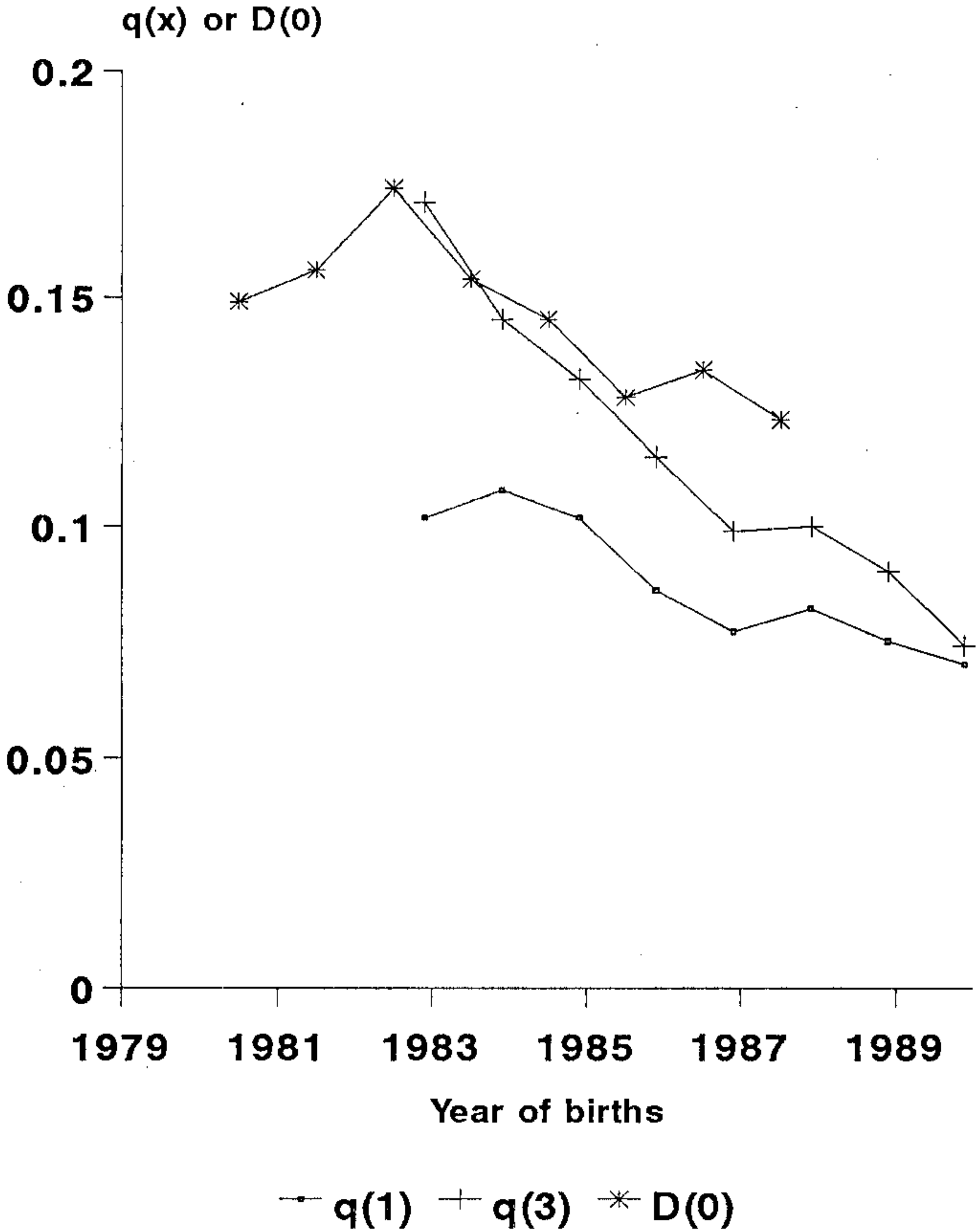
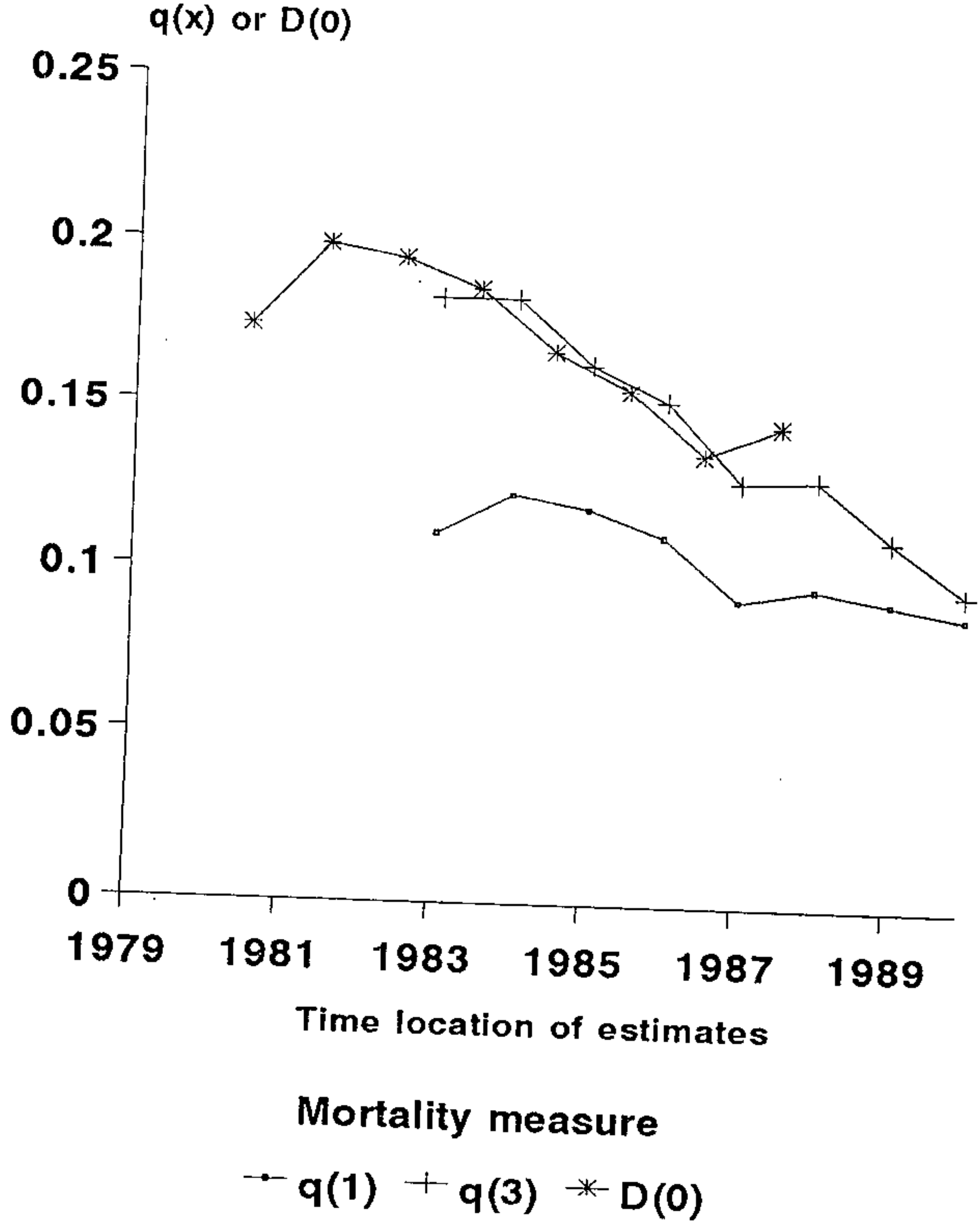


Figure 6. Life table probabilities of dying by age 1 and 3 compared with the proportions of siblings dead D(0): Comparison Area



atlab Comparison Area

months and of q(3) when birth intervals are longer. In many cases, the trends in q(1) and ${}_3q_1$ may be found directly from birth histories as a check on whether the time trends in the two indices are divergent or not.

(f) Effects on the estimates due to incomplete coverage of births

So far, we have discussed only the systematic biases related to variations in the exposure period of previous born children when their mothers are interviewed at different durations since the last birth. A different set of biases, probably more important, are introduced when the mothers providing the data are only a small proportion of all mothers. Again, we can show from models that the extent of the over- or under-estimation of childhood mortality in the population at large is related to the size of the differences between the mortality of the two populations (omitted and covered) and the ratios of the two proportions. Broadly, when 80% of women are covered and the uncovered women have childhood mortality 1.5 times as large as the covered, then the under-estimation of the true rate will be around 10%. A more general explanation of the effects of incomplete coverage appears in Appendix A.

An empirical assessment of the biases is provided by a comparison of the data on Tables 3 to 8. The D(3) and D'(3) values represent the values obtained from first, all women and second, only from women whose last born child survives at least 3 months. These tables show that the effect of omitting reports from mothers whose children die before 3 months is quite small.

An additional perspective on these biases is provided by some additional Matlab data. We lack direct data on the mortality of the survival and vaccination status of siblings of children brought to clinics compared to those who are not, but we can estimate the relationships indirectly. A survey conducted in the Matlab area in 1990 provides the information on childhood mortality by maternal education and on the educational status of those attending immunization clinics. The results are given in Table 10. As can be seen in this table, more children of educated parents were immunized than those of uneducated parents. We calculated adjusted mortality rates by assuming that the mortality differences by education are the same as those for immunization status. We found that in Bangladesh, these educational differentials had little effect on the proportions of preceding children dead and hence on the resulting estimates of childhood mortality. The same is true for the differentials by dwelling space, a rough proxy for wealth.

In practice, the effect of the biases introduced by the incomplete coverage of all mothers giving birth are difficult to predict. The data from both Bamako and Mopti in Mali showed some surprising effects by maternal age and order as well as much higher proportions dead for women delivering in hospitals (Hill 1992; Hill and Dollimore, 1991). We cannot assume that the children of mothers in contact with the health

Table 10

Percentage of Children aged 1-3 years immunized at least once by socio-economic characteristics, Comparison Area, Matlab 1990.

Mother's Year of Schooling	Boys % immunized	N	Girls % immunized	N
0	74	542	69	533
1-5	78	219	77	215
6-10	90	68	92	61
11+	100	1	100	1
All	76	830	73	810
Father's Year of Schooling				
0	73	420	68	383
1-5	79	214	74	216
6-10	83	161	77	172
11+	80	35	87	39
All	76	830	73	810
Dwelling Space				
20-100 sq ft	80	44	74	58
101-200 sq ft	73	307	71	293
201-300 sq ft	74	234	72	221
301-400 sq ft	83	87	69	104
401+ sq ft	82	158	78	134
All	76	830	73	810

services will always have better health and mortality than those not covered by the health system because of the referral system for at risk cases.

IV. Discussion

One of the criticisms of the PBT is that the mortality estimates are biased due to selection effects related to clinic attendance. Selection by socio-economic status, residence, and previous child loss are all undeniable, but the key question is whether the selection is significant or not. Two main factors are important: the initial proportion of the whole population covered by the health services, and the magnitude of the mortality differentials between the covered and the uncovered parts of the population. For example, if in Bangladesh, we were to apply the PBT to data obtained at the time of delivery in maternity clinics or hospitals, the estimate would refer to a very highly selected group of mothers, because barely 10% to 15% of the births take place in the hospitals or in facilities from which PBT data can be collected. In addition, the direction of this selection bias is uncertain since it may be that only the difficult deliveries are being seen in hospitals. Obtaining the data from Traditional Birth Attendants, midwives and relatives is not possible since these people are mostly illiterate and data collection from individual households by trained workers will be very expensive. In such situations, one must think of alternative sources. For Bangladesh, as mentioned before, collection of data on the survival of preceding children seems to be most appropriate at the time of immunization since the coverage of the vaccination program is much higher than the coverage of the ante-natal services. In a recent study of mothers in immunization clin· over 80% had received tetanus toxoid immunization during the pregnancy - an unrepresentative figure but still lower than the proportion of children receiving at leas' one vaccine. In a trial conducted by Shuaib in immunization clinics in both urban and rural parts of Dhaka division, the PBT approach produced childhood mortality estimat compatible with those from Matlab (Shuaib, 1993). In the study in which data were obtained from nearly 9000 attending mothers with at least 2 births, the proportions of preceding children dead was 0.126 for the urban areas, 0.149 in rural areas, and 0.143 for both areas combined. For Matlab in 1989, the corresponding figure was 0.145. In other countries, with varying coverage rates for the different health services, data collection at the time of birth or at the time of antenatal care may be more appropria'

Overall, the results of this study suggest that the Preceding Birth Technique will generate reliable estimates of early childhood mortality when the data are collected fr mothers attending immunization clinics with their last born children. These estimates will refer to a period from about one year to 20 months before the date of the data collection. The time location will vary with the length of the birth interval following a early childhood death, with the level of mortality and with the prevalence of contraceptive use. Broadly, when mortality is high and contraception rare, the time reference will be close to 16 months before the time the data are collected. When mortality is low and contraception more common, the time reference will be close to 21 months before the time of data collection. The PBT in Bangladesh estimates q(3) more closely than q(2).

V. CONCLUSIONS

The results of this study can be summarized as follows:

1) with birth intervals as long as 34 (Comparison Area) and 40 months (Treatment Area), the proportions of preceding children dead, whether collected at birth, before delivery or 3 months after, are better estimators of q(3) than q(2) in Bangladesh. As shown elsewhere, however, q(2) is generally around 90% of q(3) so one can be readily estimated from the other (Hill and Aguirre 1990). In some situations, in which 1-4 mortality remains high in relation to infant mortality due to diarrhoea and acute respiratory infections (diseases for which we have no effective vaccine), q(3) may in any case be preferable to q(2) as a measure of program impact.

2) The PBT was able to detect the differences in childhood mortality in the two areas with different and changing birth intervals.

3) The PBT picked up the socio-economic differentials (by mother's education) and the sex differentials in childhood mortality.

4) The PBT accurately described the changes in childhood mortality over time.

5) The deaths of some live-born infants before the age at first immunization will not have any substantial effect on the mortality estimates.

6) Simulation work (Appendix A) suggests that change of coverage rate in the immunization coverage with time will have little effect on the usefulness of the PBT for monitoring childhood survival when the initial coverage rates are already quite high (62 % of children fully immunized in 1992; over 90% receiving at least one dose).(EPI coverage data for Bangladesh).

The experiment described above has demonstrated that collection of data on the survival of preceding children from pregnant mothers seen at ante-natal clinics as well as from mothers with index children brought to vaccination centers can both provide reliable measures of recent childhood mortality at least for the population in contact with the health services. The results here show that the PBT estimates of childhood mortality are sensitive enough to detect socio-economic differentials, differences by sex and time trends even when birth intervals are changing as a result of the introduction of family planning programs.

Appendix A

Effects of incomplete coverage of mothers on PBT estimates of early childhood mortality when the data are collected at the time of first immunization.

There are two separate biases associated with incomplete coverage of mothers when the data for the PBT are collected some months after a birth, for example at immunization centers when children might be 3 months old when first seen. One bias arises due to omissions of reports on the survival of preceding born children from mothers of infants who die before reaching 3 months of age. In Bangladesh, the proportion who die before 3 months is 7% of births. For the preceding born siblings of these children, the risks of dying was 1.9 times as large as for all children - very close to the figure of 2 estimated by Hill and Aguirre on the basis of 7 different country analyses. A second source of bias arises because some surviving children are not immunized. But not all surviving children are immunized and not all children who die are missed. What are the contributions of each of these two different types of omission on the PBT results?

Let q be the probability of death of all preceding births measured when the succeeding birth is 3 months old, and let q′ be the probability of dying for those surviving to at least 3 months of age. Then:

$$q = k \cdot c \cdot q' + q' \quad \text{..................} \qquad (1)$$

where k = the ratio of the probability of dying amongst children whose succeeding siblings die before 3 months of age to the mortality of all children; and c = the proportion dying before 3 months of age. In Bangladesh, the figures are k = 1.9 and c = 7% of births.

Let P be the proportion of surviving children who come to be immunized; 1-P is the proportion who do not. Let the probability of dying among preceding children whose succeeding siblings do not come to be immunized be R times higher than that of children who are immunized. Let q* be the proportion dead amongst preceding children whose younger siblings come to be immunized. Then, q* depends on P as follows:

$$q' = P \cdot q^* + R \cdot (1 - P) \cdot q^* \qquad (2)$$

Assuming q = 0.140, R = 1.15 and P = 80%, we obtain the values q′ = 0.132 and q* = 0.128 from equations (1) and (2). The following table shows the values of q, q′ and q* for different values of R and P:

Coverage rate: P (%)	True q(3) measured at 3 months	q′ measured at 3 months for children surviving to be immunized	Values of q* for different R:		
			1.15	1.10	1.05
60	0.140	0.132	0.125	0.127	0.129
70	0.140	0.132	0.126	0.128	0.130
80	0.140	0.132	0.128	0.129	0.131
90	0.140	0.132	0.130	0.131	0.131
95	0.140	0.132	0.132	0.131	0.132
100	0.140	0.132	0.132	0.132	0.132

The effect of incomplete coverage will be the same for q(3) and for the D values. For Matlab, the indications are that R will not exceed 1.10 except in unusual circumstances. As the table above shows, the incomplete coverage of children either because they are not immunized at all or because of deaths under 3 months, has little effect on the values of D and hence q(2) or q(3). Even when immunization coverage rates are changing, the effect on the PBT estimates of childhood mortality will be slight.

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NOTES

1. Note that several trials with short birth histories and PBT estimates of childhood mortality have produced promising results. See A.G. Hill and P.H. David, 'Assessing childhood mortality in the Third World: neglected sources and novel approaches', IUSSP General Conference Proceedings, New Delhi, 1989, vol. 2, pp. 33-45.

2. See, for example, pages 73 ff. in the UN (1983) Manual; and J. E. Potter, 'Problems in using birth-history analysis to estimate trends in fertility', Population Studies, 31: 335-64, (1977).

3. One index of ante-natal coverage is that in 1990-91, 57% of women in developing countries received tetanus toxoid whilst pregnant. Almost the same proportion (55%) of deliveries in these countries were attended by a trained health person. But vaccination against tuberculosis, a vaccine normally given soon after birth, was reaching some 84% of all children. All the figures are lower for sub-Saharan Africa. See UNICEF, State of the world's children 1993, tables 3 and 7, Oxford University Press, New York and Oxford.

4. When birth intervals are very long, as in Bangladesh, the mortality measure estimated is likely to be closer to q(3) than to q(2) but the basic point about the

truncation of the period of exposure for the preceding birth remains.

5. Note that this includes all women whether they subsequently deliver a live birth or a still born child.

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