Reversal in childhood mortality trend in rural KwaZulu-Natal, South Africa[1]

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Abstract

This study uses pregnancy history information from a demographic surveillance site in rural KwaZulu-Natal, along the eastern coastal board of South Africa, to investigate the mortality levels, trends and selected factors associated with childhood mortality. Life table analysis of the data reveals a reversal of the downward trend in mortality rates over time that began around 1990 in this population. Between 1990 and 2000 infant mortality increased from 43 to 65 per 1000 live births and under-five mortality from 65 to 116 per 1 000 live births which translates into a RR of 1.85 over the 10 year period (p-value <0.001). Maternal HIV prevalence in this area is among the highest in South Africa and rose from 4.2% to 26.0% during this period, making it probable that much of the increase in child deaths is attributable to mother to child transmission of HIV. Negative binomial regression identified the source of water, level of maternal education at the time of the survey and being a recipient of the child support grant as important factors associated with child mortality. However, their joint effect is attenuated by the overwhelming impact of HIV which also appears to have swamped the anticipated health benefit expected from various health care reforms.

Key words: Child mortality, rural South Africa, factors associated with child mortality, HIV prevalence, Demographic Surveillance Site

1. This study formed background to Nadine Nannans' research questions towards a PhD thesis supervised by Rob Dorrington and Debbie Bradshaw at the University of Cape Town, South Africa.
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Resume

Renversement de tendance du taux de mortalite infantile dans la zone rurale du Kwazulu Natal en Afrique du Sud.

Cette étude utilise des informations historiques sur les naissances dans un site rural de surveillance démographique au KwaZulu-Natal sur la cote orientale de l'Afrique du Sud pour evaluer le taux de mortalité et leurs tendances et identifier les facteurs associés à la mortalité infantile. L'analyse des table de vie révèle une inversion de la tendance à la baisse du taux de mortalité entre 1990 et 2000 ., Pendant cette periode, la mortalité infantile a augmenté de 43 à 65 par 1000 naissances et celle des moins de 5 ans de 65 à 116 pour 1 000 naissances, ce qui se traduit par un RR de 1,85 pour la periode etudiee. (p-valeur < 0,001). La prévalence du VIH dans cette region est parmi les plus élevées en Afrique du Sud et a augmenté de 4,2 % à 26,0 % pendant cette période, il est donc probable que l'augmentation des décès d'enfants est en grande partie attribuable à la transmission du VIH de la mere a l'enfant. Une régression binomiale négative a identifie l'acces a léau potable , le niveau d'éducation de la mere au moment de l'enquête et à si la mere est bénéficiaire d' allocation sociale pour lénfant comme des facteurs importants associés à la mortalité infantile. Cependant leur effet meme combine, est atténué par l'immense impact du VIH qui semble avoir submerge les bénéfices attendus des diverses réformes de la santé.

Mot clefs: Mortalite infantile, L'Afrique Du Sud rurale, facteurs associes a la mortalite infantile, prevalence du SIDA, Site de Surveillance Demographique.

Introduction

Global trends in child mortality rates throughout the 1970s and 1980s have shown substantial declines (Ahmad *et al.,* 2000; Inter-agency Group for child mortality estimation, 2007). Estimates by Murray *et al,* (2007), for example, show that the global average declined from 110 per 1000 live births in 1980 to 72 in 2005. The decline has been attributed to improvements in a range of factors known to impact on child health such as improvements in nutrition (Gwatkin *et al.,* 2007), housing and environmental conditions (WHO, 2003), the development of health services (WHO, 1979; Claeson & Waldman, 2000) and factors related to economic conditions (Preston, 1975).

Within these general trends, there are variations. Analysis of Demographic and Health Survey (DHS) data shows that some countries in sub-Saharan Africa experienced reversals of the downward trend during the 1990s (Garenne & Gakusi, 2006). South Africa is one of the countries in the southern Africa region that has witnessed reversals of the gains made in child mortality since about 1992. Although the transition to a post-Apartheid society resulted in considerable social and economic changes during this period including improvements in living conditions and considerable restructuring of the health system, much of the increase in childhood mortality has been attributed to mother to child transmission of

HIV (Rollins *et al*., 2007; Nannan *et al.,* 2007) .

Literature review and theoretical framework

The most influential framework to have shifted thinking around improving child mortality is the Mosley and Chen framework which summarises the association of the causal factors of child mortality (Mosley & Chen, 1984). It was the first framework that incorporated both biomedical and social determinants of child health by proposing the operation of five groups of socioeconomic "proximate" determinants that directly influence the risk of morbidity and mortality. These intermediate variables are: maternal factors, environmental contamination, nutrient deficiency and injury and personal control.

Although part of the mortality increase in recent years may be attributed to mother to child transmission of HIV, studies investigating the reversal of trend attribute some of the increase to changes in the intensity of a wide range of determinants that are known to be associated with child survival namely; fertility, nutritional status, maternal and child health, environmental health factors and socioeconomic factors related to household conditions and maternal education (Rutstein, 2000). Wagstaff and others (2004), on the other hand, highlight the inequalities in child mortality generated by conditions of poverty and point out the importance of focusing attention on the role that government programs play in reducing child mortality. Post 1994, South Africa introduced far reaching programmes such as extending the provision of water and providing free health care to pregnant women and children and instituting a number of social remittances including the child support grant. However, this was initiated during a period of limited economic growth and growing unemployment. Economic growth started to improve around 2000, but there has been little change in the unemployment rates (Leibbrandt *et al*., 2010). To date there is little local evaluation of how improvements in social and economic factors have influenced the underlying determinants that act through the proximate determinants of child mortality. A study that used national data (Burgard & Trieman, 2006) to assess the impact of improvements in living conditions on child mortality from 1987-1998 concludes that during this period the introduction of policies have not translated into better socioeconomic and living conditions that have had a beneficial impact on infant mortality.

Basic analysis of the national data from the 1998 South African Demographic and Health Survey (SADHS) shows that most of the differences in under-five mortality occur between population groups with only some of the difference being accounted for by metro/non-metro residence and mother's education (Nannan *et al.*, 2007). Using the same data, provincial investigation of the association between a household asset index and child mortality for African children without adjusting for the effects of other associated covariates show the greatest mortality difference are between the two poorest quintiles. In a rural setting in KwaZulu-Natal the poorest quintiles in the SADHS would represent quite a homogeneous group. In KwaZulu this represented an under-five mortality rate of 139/1000 in the poorest quintile and 82/1000 in the second poorest.

While the national study went some way to explaining the more structural covariates that impact on child health in South Africa, the aim of the present analysis is to explore socioeconomic factors associated with child mortality and their impact in a poor rural setting.

The population of ACDIS has been under surveillance since 2000, a period during which several government programs have been implemented. The retrospective data collected baseline information in 2000 and recorded the details of births in ACDIS that occurred prior to the date of interview and provide an opportunity to investigate a 20 year trend in child mortality over a period of significant societal transformation.

Data and methods

The Demographic Surveillance Area (DSA) is situated in the rural district of Umkhanyakude in the northern part of KwaZulu-Natal. In 2000 the total population was 82,599 with about 80% being resident in the ACDIS area and represented in approximately 11,000 households (Tanser *et al.*, 2007; Muhwava *et al.*, 2008). The ACDIS population is characterized by poor socioeconomic status with poor household conditions, high levels of unemployment, low levels of education and high mobility (Hosegood *et al*., 2005; Hosegood & Timaeus, 2005). At baseline a census was conducted to capture the basic demographic details and a pregnancy history questionnaire was administered to women resident in the area at the 2000 visit to gain knowledge of their fertility experience. Each woman had to recall the dates of all her births, the sex and survival status of the child and if the child died, the child's date of death starting with the youngest child.

We use these retrospective histories spanning births from 1981-2000 to estimate level and trend of childhood mortality indices. Period life table measures of mortality were calculated from the data for single years prior to the dates of interview using the life table methodology proposed by Rutstein (1984). Ages at death and exposure time are categorized into the following intervals in order to capture the change in the risk of dying with age for children under the age of five: < 28 days and 1-2, 3-5, 6-11, 12-23, 24-35 and 36-47 and 48-59 months. The rates for these age intervals were then combined as the product of the conditional probabilities of dying to obtain the standard indices of childhood mortality: neonatal, post-neonatal, infant, child and overall under-five mortality.

An event history file was constructed for children born in the 20 year period prior to the date of the mother's interview. Each child's exposure time from birth until interview or the point of death is divided into age groups and then summed across all children sharing a common set of characteristics up until their fifth birthday, (Yamaguchi, 1991).To this data file the household and individual socioeconomic data were merged using the mother and household unique identifiers to link children to their household circumstance. In this way each woman was matched with her child or children and recorded as woman and child-pairs.

The data file was structured as an

aggregate data file initially for Poisson regression in order to model rates, however the data were fitted with the negative binomial distribution which gave greater variance than the Poisson distribution resulting in a better goodness of fit statistic (STATA 9 manual). The negative binomial regression was therefore used to fit a regression model to the log of the rate calculated as the number of deaths divided by exposure time (measured in person-years):

$$1n(d_{ij}/PYO_{ij}) = 1n(d_{ij}) - 1n(PYO_{ij}) = \beta_0 + \beta_1\chi_i + \beta_2\chi_{1j} + \beta_3\chi_{2j} + \ldots + \beta_n + {}_1\chi_{nj}$$

where d_{ij} is the count of deaths and PYO_{ij} is the person-years of observation for a particular age group *i* and combination of covariates *j*. Exposure times are incorporated in the model as an "offset" term. This model was also fitted excluding the "missing" data, but the goodness of fit indicated that neither the Poisson regression nor a negative binomial distribution fitted these data and is therefore not reported.

Linking ACDIS birth history data with socioeconomic status data, as measured in the form of household assets did not account for the differences in infant mortality observed in a regression analysis, suggesting that the 40% of people represented in the poorest quintiles in the SADHS is quite a homogeneous group within the ACDIS area. Regression models were therefore used to explore mortality by selected socioeconomic covariates at the time of the survey, such as household access to water, the number of household assets and remittances such as the child support grant. Indicators of health care access, demographic variables such as age and sex and the time trend in mortality across seven three-year time periods were also investigated.

The model building strategy involved an initial model including age, sex and the time trend. To this basic model single variables were added to explore the strength of the relationship of a particular variable on child mortality. This was followed by fitting the full model comprising all the socioeconomic and health care access variables. A "post test" was then performed to assess whether there were statistically significant differences for each of the variables. Those that were not significant at the 0.05 level were dropped for a final model. In addition to this, a separate model was fitted in a similar way to data on births in the last 6 years before the survey.

The households were assigned area-type based on the population density. Non-urban population was divided into rural (areas of less than 400 residents per square kilometer) and peri-urban (areas with more than 400 residents per square kilometer) (Tanser *et al*., 2008). Household wealth was measured using an asset index that sums the number of a specified list of household assets and allocates a low, middle or high socioeconomic status to households based on this simple distribution (Hosegood *et al*., 2004).

Results

There were very similar numbers of births for both sexes. Of the 42,609 recorded live-births, 48.9 % were boys and 48.8 % were girls. Sex was either missing or undetermined in 2% of the total live births recorded. The trend in mortality rates for boys and girls combined over the twenty year period (Figure 1) shows substantial declines in overall under-five mortality during the 1980's experienced by children aged 1-4 as well as in the post-neonatal period. Boys had higher numbers of deaths (53%) than the girls (47%). The reversals that began in the early 1990's were most pronounced in the post-neonates, but also noticeable in children age 1-4.

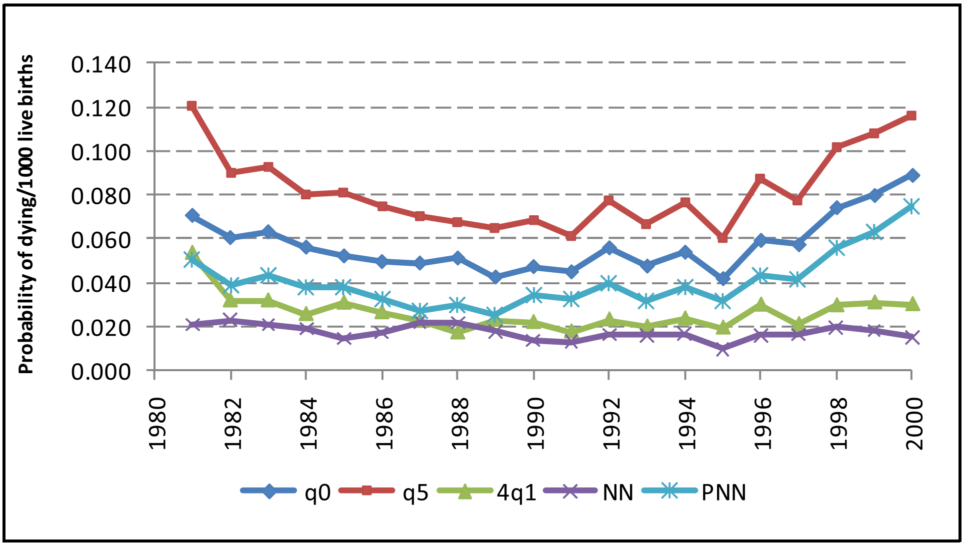

Figure 1 ACDIS age-specific mortality trend from 1981-2000 in single years

A comparison of selected characteristics of women who were asked about a pregnancy history in 2000 with mother (aged 15-49) and child pairs are presented in Table 1.

The distributions in the table highlight the high proportion of poor household conditions and low socioeconomic status for the majority of the women in the DSA. The most notable feature from Table 1 is the high proportion of some variables which are missing data. This makes comparison difficult without knowing about these missing data. However, it is clear that the women who have ever been pregnant are younger than those for whom there was matched child-mother data.

The associations of child mortality explored by considering the basic model of age, sex and period and one additional variable at a time are shown in Table 2.

Table 1 Selected basic characteristics of ever pregnant women (33,220) and mother and child pairs (N = 40,842) in 2000

Characteristics of the women	N = 33,220	N = 40,842
Age in 2000	%	%
<15	7.1	-
15-19	18.5	4.2
20-24	15.2	10.5
25-29	12.8	14.3
30-34	9.9	17.2
35-39	8.3	20.0
40-44	7.1	21.2
45-49	4.2	12.6
50+	16.9	-
Education as reported in 2000		
None	14.2	15.8
Incomplete primary	25.6	34.2
Incomplete secondary	29.0	23.6
Metric & above	15.6	12.8
Missing	15.6	13.5
Employment as in 2000		
Full time	20.4	26.4
None	53.5	57.1
Part time	2.6	4.1
Missing	23.5	12.5
Sanitation in the household in 2000		
Flush toilet	5.2	4.2
VIP/chemical	4.5	3.0
Open pit latrine	44.4	38.1
None	35.0	31.3
Missing	10.9	23.2
Water source in household in 2000		
Piped (private/public)	36.8	33.3
Borehole,well,rainwater	25.6	21.2
River,dam	26.0	21.5
Missing	11.6	23.2
Household assets in 2000		
0-6	35.1	31.1
7-9	27.9	24.4
10+	26.2	21.2
Missing	10.9	23.3

Table 2 Association (RR) of child mortality with residence and socioeconomic variables in 2000 adjusted for age, sex and time-period. Mother and child pairs (N = 40,842)

Adjusted for age, sex and time-period			
	N	RR	p-value
Urban in 2000	1,556	1	
Periurban	9,377	1.44	0.014
Rural	20,437	1.43	0.014
Missing	9,472	3.09	<0.001
Piped private or public household in 2000	13,593	1	
Borehole/well/rainwater	8,662	0.99	0.914
River or dam	8,797	1.29	<0.001
Don't know/ missing	9,472	2.19	<0.001
Flush toilet in household in 2000	1,719	1	
VIP/Chemical	1,310	1.11	0.597
Open pit latrine	15,548	1.53	0.003
No toilet	12,793	1.71	<0.001
Don't know/Missing	9,472	3.40	<0.001
Giving birth in a health facility	17,738	1	
Home	3,632	1.17	0.026
Don't know/NA/missing info	17,852	0.74	<0.001
No ANC questionnaire	1,969	0.42	<0.001
Receiving the child grant for at least one child in	5,450	1	
Non-recipients	35,392	1.45	<0.001
Receiving the old age pension for at least one	8,691	1	
Non-recipients	32,151	1.13	0.029
Education			
None	6,465	1	
Incomplete primary	13,979	0.89	0.069
Incomplete secondary	9,655	0.75	<0.001
Completed secondary & above	5,234	0.59	<0.001
Missing SES data	5,509	1.57	<0.001

The relative risks and p-values of the covariates of the basic model of age, sex and period and the same estimates of the final model are shown in Table 3. Evaluation of the full model showed that residence, sanitation and assets all had p-values, from the Chi^2 –test, greater than 0.05. These variables were therefore not included in the final model.

The model building process reveals the strength of the associations and the contribution each has on child mortality. The basic Model (Table 3) exploring the age-sex-pattern of child mortality over time demonstrates that the covariates present in this simple model result in a pseudo-R^2 statistic of 32.5% (methods: calculated using STATA). The final model captures the additional effects of water source, maternal education and being a recipient of the child support grant. The model-building process shows that even after controlling for age, sex and period, all these factors display significant associations with child mortality in 2000.

As well as the final model, a separate model explored the associations of the covariates on the mortality of children born in the six years before the survey to address the disjuncture between the current household socioeconomic circumstance and the prevailing conditions of the more distant births. In this model the child grant, instituted in 1998, had a greater protective effect on children living in households receiving the grant in 2000. The relative risk is 1.79 (95% CI 1.39 - 2.29) for non-recipients, but the association with the level of maternal education becomes statistically insignificant with an RR of 1.28, 1.06 and 0.83 for incomplete primary, incomplete secondary and, complete secondary and above, respectively.

Discussion

The 20-year trend of child mortality observed in this setting shows a reversal in the under-five mortality trend. Gains were seen in child survival up until 1991, after which a gradual increase occurred. Infant mortality rose from a minimum of 46 per 1000 live born children in 1990 to 89 in 2000 and under-five mortality from 64 to 116 per 1000 live births.

Although, precise rates are not available from vital statistics because of under-reporting of child deaths, particularly in rural areas (Bradshaw and Dorrington, 2007), and the under-estimation of child mortality due to the omission of deaths in retrospective surveys (Sullivan, 1990), the observed trend is consistent with the national trend measured by the 1998 SADHS (Department of Health, 2001), although the level of mortality is higher in this rural population. Similar trends have been observed in the 1996 census data representative of KwaZulu-Natal (Nannan *et al.*, 2007), and the Agincourt DSA data representing a rural north-eastern part of South Africa (Kahn *et al.*, 2007).

Table 3 Negative binomial regression estimates of risk ratio for childhood mortality

		Basic Model				Full Model			
Covariate	Deaths	RR	lower	upper	P-value	RR	lower	upper	P-value
Years before survey	**1998-2000**	**1.00**				**1.00**			
	1995-1997	0.77	0.67	0.89	<0.001	0.75	0.65	0.87	<0.001
	1992-1994	0.69	0.60	0.80	<0.001	0.66	0.57	0.77	<0.001
	1989-1991	0.54	0.46	0.63	<0.001	0.50	0.42	0.59	<0.001
	1986-1988	0.71	0.60	0.83	<0.001	0.66	0.56	0.78	<0.001
	1983-1985	0.69	0.59	0.81	<0.001	0.64	0.54	0.76	<0.001
Sex	**Girl**	**1.00**				**1.00**			
	Boy	1.18	1.08	1.29	<0.001	1.19	1.08	1.31	0.001
Age group	**<28 days**	**1.00**				**1.00**			
	1-2 months	0.16	0.01	0.02	<0.001	0.16	0.01	0.02	<0.001
	3-5 months	0.07	0.14	0.18	<0.001	0.07	0.14	0.18	<0.001
	6-11 months	0.04	0.01	0.01	<0.001	0.04	0.01	0.01	<0.001
	12-23 months	0.01	0.00	0.01	<0.001	0.01	0.00	0.01	<0.001
	24-35 months	0.01	0.06	0.09	<0.001	0.01	0.06	0.09	<0.001
	36-47 months	0.00	0.00	0.00	<0.001	0.00	0.00	0.00	<0.001
	48-59 months	0.00	0.03	0.05	<0.001	0.00	0.03	0.05	<0.001
Water source	**Piped private/public**					**1.00**			
	Borehole/well/rainwater					0.95	0.83	1.09	0.448
	River/dam					1.21	1.06	1.38	0.001
	Missing socioeconomic data					1.77	1.51	2.08	<0.001
Mother's education	**No Education**					**1.00**			
	Complete primary					0.94	0.81	1.08	0.379
	Complete secondary					0.78	0.67	0.91	0.002
	Matric & above					0.59	0.49	0.72	<0.001
	Missing socioeconomic data					1.28	1.05	1.56	0.014
Child support grant	**Receiving the child grant**					**1.00**			
	Non-recipients					1.36	1.17	1.58	<0.001

In an era that has seen significant reversals in child mortality trends in sub-Saharan Africa, various efforts have been made to understand the factors that have lead to the change. Rutstein (2000) investigated the effect of a range of variables on child mortality in a comparative country study. Of the five key areas of determinants that he considered, little of the improvement in mortality in this era is attributed to fertility behavior or breastfeeding. However, the reversal of child mortality is attributed to a lapse in progress on all the determinants, but could also partly be explained by deterioration in health seeking behavior for fever. Not included in his study was the impact of increased prevalence of HIV or increasing resistance to malaria drugs. Adetunji (2000) and Zaba *et al.*, (2003) have reported data indicating significant population-level reversals in under-5 mortality that are attributed to HIV.

It is well established that HIV-infected children have a substantially increased risk of death. This cohort of children has been exposed to a rapidly progressing HIV epidemic through their mothers. In the Hlabisa health district in 1997 overall prevalence among pregnant women was 26% (95% CI 24%-28%) having risen from 4.2% in 1992 to 14.0% in 1995 (Wilkinson *et al.*, 2000). The increasing child mortality trend is consistent with the increasing HIV prevalence among pregnant women, and it is therefore probable that much of the increase in child deaths (Figure 1) was due to mother to child transmission.

The increase observed in this study is also consistent with model based estimates of child mortality in the ASSA2003 model for African children living in KZN (Dorrington *et al.*, 2006). Furthermore, Garrib and colleagues (Garrib *et al.*, 2006) found a continued increase for the period 2000-2002 from the ACDIS prospective data, indicating that the overall under-five mortality rate was still rising in this population.

From the socioeconomic variables explored in this study, water source, maternal education and being a recipient of the child support grant at the time of the survey were significantly associated with child mortality in the fully adjusted model. The modeling strategy showed that controlling for urban-rural residence makes sanitation less important than water source, but maternal education remains important and has a greater effect on child mortality, as does being a recipient of the child support grant. Although some of the effect of an incomplete secondary education is due to motherhood at an early age, this is small as there were only 4.2% of mother and child pairs represented in the 15-19 year old age group. Restricting analysis to births in the last 6 years shows that while the relative risk of being a recipient of the child grant remains statistically significant, the effect of maternal education at the time of the survey on child mortality disappears. The attenuation in the relationship with maternal education status is likely to be due to better access to grants by more educated women given the well established fact that education acts as a proxy for socioeconomic status of the family (Desai and Alva, 1998). Possible interaction effects of maternal education and receiving a child grant were explored, but none of the effects were statistically significant.

Although only 14% of the women were accessing this remittance two years after it's introduction, demonstrating an association with child mortality is relevant, given the South African government's commitment to the provision of the child grant and the fact that this proportion is increasing with time and has been extended to reach older children (Children's Institute, 2006). A systematic review of studies to assess the impact of conditional cash transfers in low income settings concludes that grants have been associated with improvement in anthropometric and nutritional outcomes as well as preventive behavior, however the overall effect on health status remains unclear (Lagarde *et al*., 2009). Less research has evaluated the effects of unconditional grants such as the child support grant programme implemented in South Africa from 1998. In a KwaZulu-Natal based study, Woolard *et al.,* (2006) demonstrate that the nutritional status (height-for-age) of children receiving the grant for at least two-thirds of the first 26 months of life improved. Assessment of the impact of unconditional cash transfer programmes on child health farther afield, in rural Ecuador and Mexico, using other indicators of child health, are consistent with the South African findings (Paxson & Schady, 2007). However, more research is needed to verify the effectiveness of the child grant and understand how the programme impacts on child mortality.

There are some important limitations to this study that must be mentioned. First, the paper attempts to describe the net socioeconomic effects on child mortality during a period when HIV became the leading underlying cause of death in children under-five in South Africa (Bradshaw *et al.,* 2003), but it was not possible to include individual level HIV status information in this analysis. Second, the extent of the missing socioeconomic data is problematic. About 15% of the mothers' information in the individual level data is missing, and about 23% of the household information is missing. Health service indicators such as giving birth in a health facility suffered even more missing data and were therefore not investigated further. It is noteworthy that the mortality of the children in the categories with missing data had significantly higher mortality compared with children in the other categories (see Table 2). However, the coefficients from the model excluding the missing data were similar to the model reported but the confidence intervals were wider, possibly as a result of the poor statistical fit achieved with the data excluding missings. Third, the pregnancy history instrument delivers a cross-sectional estimate at a single point in time. The retrospective nature of the data limits the investigation of socioeconomic factors to a snap-shot centered on 2001 information as it relates the household conditions at the time of the survey. Notwithstanding this, there are general relationships that can be observed from the historical mortality trend and the socioeconomic characteristics of the households, particularly for variables not likely to have changed rapidly over the time.

The fully adjusted model only accounts for one-third of the variability, suggesting that there are other contributing factors that have not been captured. This analysis nonetheless, demonstrates the clear reversal in the child mortality trend between 1990 and 2000 which it is argued is largely related to maternal HIV transmission. Of the socioeconomic factors, water source, maternal education and receiving the child grant all display a protective effect on child mortality, but their joint impact is attenuated due to the overwhelming impact of HIV. HIV has probably also swamped the potential health benefit that was expected from the health care reform introduced in 1994 (Benatar, 2004).

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