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Explaining Racial Differences in Child Mortality in South Africa

ABSTRACT

Racial differences in child mortality in South Africa are studied using household-level data from 1987-89 and 1998. Piecewise exponential regression models are estimated to explore the determinants of observed racial disparities in children's survival chances. We conclude that inequalities in the personal and household resources of South Africa's four main racial groups substantially account for racial differences in child survival rates, and that the 1994 dismantling of the *apartheid* system will not eradicate the racial disparity in child mortality unless persisting and dramatic racial inequities in basic levels of living are radically reduced.

INTRODUCTION

Child health and survival in South Africa have been deeply influenced by the system of racial discrimination imposed from the outset of White settlement in the 17th century and institutionalized, codified, and reinforced when the National Party gained power in 1948. Under the *apartheid* system, which began in 1948 and remained in place until the 1994 transition to a non-racial democracy, "Whites" (11% of the population in 1996), "Asians" (mainly from the Indian subcontinent) (3%), "Coloureds" (mixed-race people) (9%), and "Blacks" (the indigenous Bantu-speaking population) (77%) were separated into four official population groups, and virtually all life chances were determined on the basis of group membership. Within this system, educational and occupational opportunities were separate and unequal and there were wide disparities in income (Treiman, McKeever and Fodor 1996); health services were administered separately for each racial group; and racial residential segregation was imposed. Despite its rank as a middle-income country, at the end of *apartheid* 53% of South African children lived in poor households according to the World Bank's definition of poverty, the majority of whom were Black and living in rural areas (National Institute for Economic Policy 1996).

Early in the century, some 13% of the land area of South Africa—mainly the least productive land in the country—had been designated as Black "homelands." During the 1960s and 1970s 3½ million Blacks were "removed" from the cities to their nominal "homelands," often places where neither they nor their ancestors had lived (Davenport 1987; Kaufman 1998; Platzky and Walker 1985). Then, in the 1970s, four of the 10 homelands (the "TVBC" States: Transkei, Venda, Bophutatswana, and Ceskei) were set up as puppet states nominally independent from South Africa. As of 1991, the last date for which there are adequate data, some 38% of the Black population of (internationally recognized) South Africa lived in the six homelands still included within the "South African" polity and 24% lived in the TVBC States. The rural areas of the homelands and TVBC States were, and are, extremely economically marginal. The land is not productive and there were no non-agricultural jobs to speak of, which meant that residents either commuted extremely long distances to work in "White" South Africa or became migrant laborers, leaving behind a population disproportionately comprised of women, children, and the elderly. In addition, especially toward the end of and subsequent to the *apartheid* period, many Blacks migrated as families to the cities, setting up squatter communities of makeshift shacks lacking plumbing and electricity. These conditions are likely to have had strong effects on child survival.

Much of the existing evidence on racial disparities in child survival in South Africa is based on limited data. Under *apartheid*, the TVBC States were excluded from the South African census and sometimes from other surveys, and vital-events data were poor for Nonwhites (Botha and Bradshaw 1985).[1] Data also vary in quality depending on the racial group under study, or have focused on a single racial group or geographically circumscribed area. In this analysis we compare nationally-representative data collected in the late *apartheid* and early post-*apartheid* periods to explore the determinants of observed racial differences in child survival. The central

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[1] A recent study of infant mortality and birth registration data make clear the magnitude of the deficiency in infant and child mortality statistics: completeness of birth registration ranged from 10% in the Eastern Cape, North West and Northern Provinces to 60% in the Western Cape (Nannan et al. 1998). In particular, it has been difficult to assess the validity of an apparent long term secular decline in Black infant and child mortality because of the coincident influence of improvements in environmental and health conditions and changes in the method of calculating infant mortality statistics with changes in the system of birth registration (Unterhalter 1982).

question is to what extent racial differences in child survival can be explained by racial differences in personal and household characteristics, such as mother's schooling, the household economic level, and the quality of the water supply and toilet facilities. The analysis also considers whether the determinants of child survival vary over time and across racial groups. We argue that policies of separate development that disadvantaged nonwhites, and particularly Blacks, under *apartheid* created inequalities in the level of living that help to explain the large racial differences in children's survival in South Africa both at the end of *apartheid* and in the early years of South Africa's new dispensation.

CHILD SURVIVAL IN SOUTH AFRICA

Mortality among infants and children is a key indicator of health status, and specific aspects of *apartheid*, such as inequality in opportunities for socioeconomic advancement (Molteno and Kibel 1989), racial residential segregation into different geographic areas (Louw et al. 1995; Rip, Bourne and Woods 1989a, 1989b; Rip, Keen and Kibel 1986), and migrant labor (Ramphele and Heap 1991), have been shown to affect children's health and survival in South Africa. Institutionalized racial inequality in life chances resulted in the coexistence of distinct child mortality profiles, with Black and Coloured children dying from preventable causes, such as infections or other acquired diseases and accidents, and White children dying from less preventable causes, such as congenital and other non-communicable disorders (Andersson and Marks 1988; Bachmann, London and Barron 1996; Bourne, Rip and Woods 1988; Haffejee 1995; Molteno, Ress and Kibel 1989). Studies across South Africa using a variety of study populations and methodologies repeatedly show significantly higher risk for nonwhite infants and children, particularly Blacks, in the 1970s and 1980s than for Whites (Ramphele and Heap

1991; Rip et al. 1989a). One study found that the IMR for Coloureds declined from 135 deaths per 1,000 live births to 51 over the period from 1970 to 1983, while for Whites the IMR dropped from 22 to 13 over the same period (Herman and Wyndham 1985). Among Blacks in some urban areas, the IMR fell from 124 deaths per 1,000 live births to 86 from 1970 to 1980, while the IMR was still 130 in the rural Transkei area in 1980 (Herman and Wyndham 1985). Child mortality in rural Black areas was concentrated among children under one year of age, with diarrhea identified as an important, and largely preventable, cause of death (Irwig and Ingle 1984). Another study of rural Blacks in the northern Transvaal area that used a direct method of calculating rates found an IMR of 88 deaths per 1,000 live births, with no significant change over the period from 1976 to 1986, in contrast to documented decreases in the rates for other racial groups (Koumans 1992). The Medical Research Council of South Africa reported child mortality rates of between 115 and 120 at the end of *apartheid*, considerably higher than the worldwide average of about 34 deaths per 1,000 live births (National Institute for Economic Policy 1996; SAIRR 1995). The rate for Black children was about six times higher than the rate for Whites (SAIRR 1996). Some evidence suggests that racial group disparities in child mortality have persisted beyond the *apartheid* period, despite an overall secular decline in the IMR (Duncan 1997).

A possible contributor to racial differences in infant and child mortality is the dramatic variation in the conditions under which South African women give birth. One study reported that among women reporting for the first time to prenatal clinics in rural areas of northern KwaZulu, 41% had had their last previous birth at home (Buchmann, Crofton Briggs and McIntyre 1992). Children born at home may run greater risks than those who are born at a clinic, while only high risk cases and those with complications are sent to hospitals unless women have the financial resources to give birth there by choice (Richardson and Bac 1987). Women who deliver at private hospitals belong to the most privileged portion of society, and also receive the highest level of neonatal care, adding to the disparity in infant and child outcomes between the wealthy and the poor. For example, stillbirth rates are much lower among private patients, a reflection more of material advantage throughout the pregnancy than of use of private medical services at the time of delivery (Rip, Keen and Woods 1986).

Provision of health care was extremely unequal under *apartheid*. The public health sector was organized into a large number of administrative systems, with a separate National Department of Health for each racial group, homeland, and provincial administration, and health departments for 400 local authorities (Bloom and McIntyre 1998). This highly fragmented and redundant system allocated resources unequally by race, with Whites favored over all other groups and particularly at the expense of Blacks. A strong private medical sector developed in the 1960s and 1970s, with about 40% of the country's doctors providing private care to about 20% of the population. The vast majority of Whites had access to care because they could afford medical insurance (Benetar et al. 1997). Comparison of government health expenditures in the same period shows dramatic regional differences: the per capita expenditure in the developed province of Natal was almost four times that for the adjoining Black homeland of KwaZulu (Jinabhai, Coovadia and Abdool Karim 1986). By the end of *apartheid* in the early 1990s, South Africa had a highly fragmented, curative-focused system of health services, set against a background of extreme racial socioeconomic inequalities. Central cities in former "White areas" feature sophisticated curative services rivaling those available in developed countries, while women living in remote rural areas are often forced to travel great distances to visit a clinic providing only basic services (Abrahams, Jewkes and Mvo 2001; Bloom and McIntyre 1998).

Differences in access translate into large race differences in the utilization of primary care services. While the relatively wealthy private insurance holders visited a general practitioner an average of five to six times per year in the mid 1990s, residents of the poorest districts, inhabited almost entirely by Blacks, averaged one visit per year to outpatient services in public facilities (McIntyre, Valentine and Cornell 1995).

Health services are not the only infrastructures that influence child survival in South Africa, and they may not be the most important sources of inequality. Environmental exposure at the household level, particularly the quality of household sanitation, also influences children's mortality risk. Clean running water and adequate plumbing reduce the likelihood of gastrointestinal diseases that are particularly dangerous for children living in fragile conditions. Gastroenteritis has been shown to be an important cause of death among children living in rural farming areas and informal settlements, areas most likely to be characterized by poor sanitation (Bachmann et al. 1996). As a result of poor sanitation infrastructures, limited provision of medical services, the concentration of disadvantage among families frequently missing members who have migrated for work, and other factors, child mortality rates in rural areas of South Africa are very high (Herman and Wyndham 1985; Irwig and Ingle 1984; Koumans 1992).

Since the end of apartheid in 1994, the South African government has made considerable effort to reduce these dramatic disparities, including signing the United Nations Convention on the Rights of the Child, establishing the National Programme of Action (NPA) to implement a "call for children" commitment, providing free medical care for pregnant women and children under seven years of age, and establishing a family and children section within the Ministry of Welfare, a National Youth Commission, and the Nelson Mandela Children's Fund (Lockhat and Van Niekerk 2000). A plan introduced by the African National Congress supports health for all

South Africans, in the form of an expanded primary care-based system funded by economic growth. Between 1994 and 1996, more than 100,000 homes, 400 clinics and 4,750 health posts were newly built or under construction (Benetar et al. 1997). Despite all of these positive developments, however, some have argued that because of a poorer economic climate since the end of *apartheid*, children may actually be worse off than before (Desmond 1998; Ramashia 1998). The expansion of primary health care has severely strained existing health services, reducing their efficacy (Haffejee 1995). In addition, the health care funds reallocated across provinces were not always wisely utilized, and changes since the end of *apartheid* have required severe budget cuts in historically better-served provinces to create parity with the less well-served areas. This has reduced the effectiveness of existing health care institutions (Benetar et al. 1997).

This analysis assesses child survival in the late-*apartheid* and early post-*apartheid* periods. We expect that under *apartheid*, the risk of child mortality followed the entrenched gradient of privilege, lowest for Whites and increasing, in order, for Asians, Coloureds, and Blacks. We expect Black children to be particularly vulnerable because they faced the multiple handicaps of historical disadvantage, residential segregation in the poorest areas of the country, and segregation and discrimination of their families at school, work, and in health care provision. Despite changes in legislation and the implementation of programs to address disparities, we expect the same mortality gradient in 1998, four years after the official end of *apartheid*. We further expect that household socioeconomic conditions, including mother's education and household wealth and the quality of the water supply, will be independently associated with child survival and will at least partly explain the racial disparities, in both the late *apartheid* and early post-*apartheid* periods.

DATA AND METHODS

Data

We utilize data from the 1987-1989 and 1998 South Africa Demographic and Health Surveys (SADHS), nationally-representative surveys of women 15 to 49 years old that include detailed information about all births in the previous five years (Human Sciences Research Council 1998; South African Department of Health 1998). Despite the shortcomings inherent in retrospective designs (particularly under-reporting of infant deaths and births and misreporting of the age of mortality), in the absence of an adequate vital registration system these data provide the best estimates of child mortality rates available for South Africa (South Africa Department of Health 2002). Descriptive statistics from both surveys are included in the main report on the 1998 Survey (South Africa Department of Health 2002), but that report has no multivariate analysis, which is what we undertake here.

The SADHS conducted from 1987 to 1989 during the late *apartheid* era was implemented by the Human Sciences Research Council (HSRC) of South Africa, modeled on the USAID/Macro International DHS studies that were conducted at about the same time in other parts of the world but, due to international sanctions, with no assistance from these organizations or the demographic community (Kaufman 1997, 1998).[2] These were the only data collected

[2] The 1987-89 SADHS was controversial (Caldwell and Caldwell 1993) because it was conducted during a period of considerable political unrest, the HSRC researchers were under suspicion due to their connections with the state, questionnaires were not identical across geographic areas and population groups (separate surveys were conducted in each of the 10 Black "homelands" and, within "White" South Africa, separate surveys were conducted of each of the four race groups), the questionnaires were not translated into all of the major languages,

during the period that contain information about women from all race groups and across all areas of South Africa, including the homelands and TVBC States. The sample consists of women age 12 to 49 years who were currently in a union or living with someone, had been in a union or living with someone previously, or had ever given birth or were currently pregnant. We focus on the information collected about children of women who had ever given birth. In the 1987-89 SADHS, information was collected from nearly 22,000 women. After restricting the sample to women 15 to 49 years of age (to be consistent with the age range of the 1998 DHS) who had had a birth in the previous five years and were not missing information on their race, and on singleton births, we arrived at an analytic sample of 11,651 women and 14,912 births, our unit of analysis for the study. Twins and higher multiple births are omitted from the analysis because they have poorer survival probabilities and differ in other ways from singletons.

Fieldwork for the 1998 SADHS was conducted between January and September, 1998, utilizing conventional survey procedures and with technical assistance from Measure DHS (formerly Macro International) (Department of Health of South Africa 2003). The 1998 SADHS used a multistage, clustered sampling frame stratified by province and by urban vs. non-urban settlement type, based on the 1996 South African census. The 1998 SADHS sample includes

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and the sample design, training, and fieldwork were not well documented (Kaufman 1997). Nonetheless, quality checks indicate that distributions of characteristics of each racial group in the pooled (national) sample are consistent with expectation, and sampling design and fieldwork difficulties probably do not introduce substantial bias into the sample (Caldwell and Caldwell 1993). We use these data because they provide a very useful *apartheid*-era baseline against which to explore changes in infant and child mortality over the period of transition to the post-*apartheid* era.

information about 5,066 births of 4,148 women, but we consider only the 4,891 singleton births in the sample, born to 4,069 mothers.

Our outcome measure is whether a child born within the five years prior to each survey had died, based on the mother's report. Mothers also provided information about the age of death of deceased children. National under-five mortality rates decreased dramatically from around 90 in the late 1970s to about 55 in 1991, but apparently have increased slightly since then (South Africa Department of Health 2002:Fig. 6.1). The reasons for this reversal are considered below. Our data also lack information about the children of otherwise eligible women who died in the five years preceding the survey; these women probably have the highest rates of under-five mortality. However, even among Blacks, mortality rates for women age 15-49 are low, and hence can have little impact on our results.[3]

Explanatory Variables

Characteristics of children, their mothers, and their households are displayed in Table 1, which shows the percentage in each category for categorical variables and means and standard deviations for characteristics measured as continuous variables. Figures are presented separately for Black, Coloured, Asian, and White children to document the disparities in resources that characterize these groups in South Africa. Mother's race is the key independent predictor of

[3] Even if maternal mortality is higher among Black women than others, and women who died were also probably more likely to have experienced an infant or child death, the selection out of our analytic sample of these women would only make our estimates of racial differences in infant and child mortality more conservative.

child mortality in this analysis because, as discussed above, race is the major axis of differential advantage in South Africa, with racial distinctions institutionalized under the *apartheid* system.

A child's age is a key determinant of mortality risk, and we specify a series of child age intervals that capture changes in the risk of death over the early life course: less than one month (neonatal), 1-5 months, 6-11 months, 12-23 months, and 24-59 months. These categories were chosen both to reflect substantive differences in risk (e.g., a child's risk of contamination from crawling and weaning is greater around the age of two years than in the neonatal period) and to allow for enough deaths per age group.[4] There are small differences in the distribution of children across age groups by race but, except for Blacks (where there were proportionally fewer very young children and more children aged 2-4 years in 1998), the distribution of children by age does not differ significantly between the 1987-89 sample and the 1998 sample.

The child's sex is included because there is some evidence that in South Africa male infants and children have a higher mortality risk than do females (Koumans 1992). About half the children in the sample are male, with no important differences by mother's race, and no significant changes between the earlier and later samples.

We include a measure that combines information about the child's birth order and the length of the preceding birth interval. First births occur to mothers with presumably little experience at caring for infants, which increases the risk of mortality, while higher-order births occur to women who presumably have more familiarity with child care, which decreases the risk of mortality, but might also result in fewer resources for the new child, which increases the risk. Also, the demographic literature has established that children born after a relatively short interval

[4] We tested other age categorizations to ensure that our results were not driven by heaping of reported ages at death, but found no differences worthy of note.

are at greater risk of mortality than those who are spaced further apart (Sastry 1997). We created measures that distinguished first births, second births up to (and including) three years after the first birth, second births more than three years after the first birth, third and higher-order births up to three years after the second birth, and third or higher-order births more than three years after the second birth. The modal category across racial groups and survey years is first births, but there were significant differences in the samples for 1987-89 and 1998 for both Black and Coloured births, with Black births less likely to be first-order and Black and Coloured births more likely to have long preceding intervals in 1998.

We also include a dichotomous measure of whether the child preceding the index child died. This was coded 1 for children whose immediately preceding sibling had died by the interview date, and coded zero for first births and for children whose preceding sibling was still alive. Having a preceding sibling who died could increase the index child's mortality risk either because of shared genetic predisposition or because the children share the same household environment. At the same time, being born after a sibling who died could increase a child's survival probability if parents changed their behavior or environment in response to the death. Black children were most likely to have had their preceding sibling die and Asian and White children were least likely, but significantly fewer Coloured and Black children had a deceased preceding sibling in the 1998 sample than in the 1987-89 sample.

Mother's age is associated with child mortality because the youngest and oldest mothers are at highest risk for complications (Pebley and Stupp 1987). We indicate mother's age at the time of the child's birth with a set of dummy variables, distinguishing women under 20 years of age, those age 20 to 29, and those age 30 or older. The modal category is 20-29 for women from all groups and across survey years, but there were significantly fewer mothers under age 20 and significantly more older than age 30 among Black children in the 1998 survey than in the 1987-89 survey.

Mother's education, a key indicator of household socioeconomic standing, is also a strong predictor of mortality. More educated women may have better access to health-related information and may be more efficient at using the resources they have to raise healthy children (Cleland 1990; Cleland and Van Ginneken 1988). We measure mother's education by the number of years of schooling. In the 1987-89 sample, Coloured and Black mothers had an average of about seven years of schooling, compared to 9.8 years among Asian mothers and 12.4 years among White mothers.[5] Average educational attainment was significantly higher in the 1998 sample for all groups except Whites, with averages of 7.9 years, 8.5 years, 11.1 years, and 12.6 years for Black, Coloured, Asian, and White mothers, respectively.

A household's economic level may strongly affect child health by determining the quality of housing and nutrition and the ability to pay for medical care. The DHS generally does not

[5] In our 1997 data, the average education of Black and Coloured women is essentially equal, while the same figures for ever married women 15 to 49 years of age from the 1985 South African census are 4.6 years for Blacks and 6.6 years for Coloureds, and the figures from the 1991 census are 7.2 years for Blacks and 7.8 years for Coloureds. The SADHS sample was conducted between 1987 and 1989, falling closer to the 1991 census on the whole, and these numbers do not seem greatly dissimilar. The lack of a Coloured advantage in educational attainment in the SADHS may result from the fact that births occurring to young Coloured women may keep them from returning to school, while many Black adolescents return to school after a birth (Kaufman, de Wet and Stadler 2001); this would result in a lower average educational attainment among Coloured women in a sample of women who had given birth.

collect information on household income or wealth (an unfortunate omission), and neither of the two surveys we utilized included such information. Thus, we constructed a linear index of possession of a radio, television, or refrigerator, and whether there was electricity in the dwelling to represent the household's economic level (Filmer and Pritchett 2001). We used principle components analysis to derive weights across indicators over the pooled samples for the two years, then summed the weighted values and rescaled them to range from 0 to 1. Black children live in households with the fewest economic resources, and Whites and Asians live in the wealthiest households, with Coloured children intermediate between these groups. Black and Coloured children in the 1998 sample were significantly better off, on average, than those in the 1987-89 sample, while Asian children's average standing did not change and the standing of White children was slightly, but significantly, lower (which could have resulted from selective emigration of Whites).

Living in a rural area in South Africa indicates only limited access to educational and occupational opportunities, health-producing resources, and access to health care services and information. However, rural-to-urban migration also may be deleterious to child health for Blacks, because many such migrants live in squatter settlements with inadequate warmth or hygiene. We measure the effect of place of residence via a typology formed by crossing place of residence at age 12 (urban or rural) with place of residence at the date of the interview (urban or rural). In all four racial groups, but particularly for Blacks and Coloureds, the proportion who were lifetime rural residents declined, and for all but Whites the proportion who were rural-to-urban migrants increased between the two survey periods. Oddly, the 1998 data also show smaller proportions of lifetime urban residents among Blacks and Coloureds than do the 1987-89 data. This may reflect variations in sampling procedures in the two years, although we are unable to check it since we have no measure of type of childhood residence in the corresponding census data.

Household sanitation is a marker both of the environmental conditions in which a child is raised and of the level of infrastructure development in a community. We distinguish categories that denote combinations of clean water (piped or bottled water versus other sources) and toilet facilities (flush toilet or latrine versus other facilities or none) available to the household. Black children are most likely to live in households with less-than-optimal sanitation conditions: in the 1987-89 sample, only about 60% lived in household with both clean water and a toilet, compared with 88% of Coloured children, 99% of Asian children and 97% of White children. For Black and Coloured children, there was a significant increase between the two survey periods in the likelihood of living in households with both clean water and a toilet.

Since community resources are known to affect child mortality (e.g., Sastry 1996, 1997), we considered including community indicators of level of living, and did some exploratory analysis using measures derived from the 1985 and 1996 South African censuses. Ultimately, however, we dropped the community indicators because they produced results that were more confusing than enlightening. The main difficulties were, first, that the 1985 census includes only a few variables and, moreover, did not include the TVBC States, which means that we have no community-level information for a quarter of the Black population in the 1987-87 survey; and that community poverty is highly correlated with household variables already in the model, particularly mother's education, the household economic level, and the sanitation measures.

Methods

We estimate piecewise exponential regression models with shared frailty to explore the relative contributions of the various determinants of child survival. Piecewise exponential regression models are a variant of the hazard model developed initially by Cox (Cox 1972) in which relatively rare death events occurring at individual months of age are considered within broader, discrete age ranges, for which the hazard of death is held constant. Frailty models, originally introduced by Clayton (1978) and by Vaupel, Manton, and Stallard (1979), are hazard models with unmeasured heterogeneity, or frailty, that is introduced as an unobservable multiplicative effect on the hazard of a child dying. The frailty is a random positive quantity assumed to have a mean of 1 and variance θ, and we use the gamma distribution to define the frailty distribution. Shared frailty models are used in this analysis because we believe that children born to the same mother are subject to more similar conditions than are children chosen at random.[6] Differences in genetic predispositions, environmental conditions, mother's behavior, local norms, or the availability of high-quality health care services, for example, could exert similar effects on children born to the same mother. Using Stata 8.0 software (Clayton 1978; StataCorp 2003;

[6] Some models of child survival have examined frailty at the levels of the family and the community simultaneously. In one such study (Sastry 1996), both family- and community-level frailty effects were individually insignificant, while in another (Sastry 1997), family-level frailty had a large and significant effect, but was almost completely explained by unmeasured factors at the community level. Our measure of shared frailty among children born to the same mother captures all unmeasured factors that create clustering of child mortality within families (Kuate-Defo and Diallo 2002; Sastry 1997), including family-specific differences in reproductive behavior and community differences in health resources and conditions.

Vaupel, Manton and Stallard 1979) we estimate the frailty, θ, and obtain the results of likelihood ratio tests of θ=0; when θ is not significantly different from zero, we accept the null hypothesis that there is no unmeasured correlation across children born to the same mother. In this case, results can be interpreted in the same way as for ordinary piecewise hazard models.

We begin by estimating, in Model 1, the hazard of death before age five that considers only mother's race and the child's key social and biological characteristics: age and sex. Here our primary interest is in the effect of mother's racial group, net of the child's age and sex. In Model 2 we add indicators of socioeconomic characteristics—mother's years of education and household economic resources—to examine how much of the racial disparity in child mortality is accounted for by the differential distribution of these resources. In Model 3 we add measures of the conditions prevailing at the time of the birth and socio-demographic characteristics of the mother, including the child's birth order and preceding birth interval, whether the mother's prior child died, mother's age, and her place of residence in childhood and at the time of the survey. Some of these covariates, such as place of residence, may explain pathways through which socioeconomic resources exert their effects. Model 4 adds information about household sanitation, which reflects both household environmental conditions and community-level infrastructure. We examine whether inclusion of sanitation indicators modifies the effects of household socioeconomic resources and sociodemographic characteristics of mothers and children. All of these models are estimated from pooled data for 1987-89 and 1998, weighted to equalize the sample sizes in the two years, and including a dummy variable for survey year. Our final model tests the assumption that child mortality is determined by the same factors in both years by including interactions between year and each of the other variables in the model. As we will see, as a set the interactions are not significant, which justifies our decision to pool the data.

We also tested for interactions between mother's race and other key covariates, such as mother's education, household economic resources, and the current and former residence typology, but none added significantly to the models, and they are not discussed here.

RESULTS

The results of the multivariate analysis are shown in Table 2. The hazard ratios show the net effect of a one-unit change in the independent variable on the hazard of death before reaching age five. Of course, for categorical predictors, the hazard ratios give the expected ratio of the hazard for those in each category shown and those in the corresponding reference (omitted) category. For example, in Model 1 the hazard ratio for Whites is 0.170, which indicates that, among children of the same age and sex, White children are slightly less than one-fifth as likely as Black children to have died in the five years prior to the survey. The figures in parentheses give the p-values associated with each hazard ratio. Thus, in Model 1 the hazard ratio for children in each of the nonblack groups is significantly lower than for Black children, by conventional standards. Wald chi-square tests of the significance in the improvement of fit as we add successive variables in Models 2-5 are shown at the bottom of the table, as are results of likelihood-ratio tests that $\theta = 0$ — that is, that there is no unobserved heterogeneity in the model.

Model 1 shows a clear racial gradient in the hazard of under-5 mortality. Taking the reciprocals of the coefficients shown in the table, we see that, net of children's age and sex, the hazard is about five times as great for Black children as for White children, about three times as great for Black children as for Asian children, and about 1 ½ times as great for Black children as for Coloured children. This gradient mirrors exactly the system of relative racial advantage institutionalized during the apartheid period. The change in these coefficients in successive models makes clear how, at least in part, the racial gradient is created. Controlling for the socioeconomic status of the household and the adequacy of plumbing reduces the Black-Coloured distinction to non-significance and sharply reduces the hazard ratios for Blacks relative to Asians and Whites.

Model 1 also shows, as expected, that the mortality hazard declines with age (Irwig and Ingle 1984): mortality in the first through fifth month is much lower than neonatal mortality and the ratio declines still further with each successive age interval. Under-5 mortality is about a third higher for male children than for female children, a pattern also found in other settings that do not display gender-discriminatory allocation of resources and care for children (Waldron 1987). Finally, there is no difference between the survey years in the under-5 mortality rate, which means that hoped for reductions in child mortality as a consequence of greater investments in child health had not yet materialized by 1998. Of course, since the regime change occurred in April 1994, it may simply be the case that too little time had elapsed for improvements in the health infrastructure or the quality of housing—which, after all, take some time to implement—to have had much effect, especially since we are considering child deaths in the 1993-1998 period. The non-zero θ tells us that unmeasured factors account for shared frailty among children in the same household—that is, there is greater than expected similarity in the mortality hazard among children living in the same household.

Model 2 adds mother's years of schooling and an index of household economic resources. Both have a significant, although modest, impact on child mortality. For example, if the average education of Black women in 1998 were increased to the White level (an increment of 4.7 years), the hazard of mortality for their young children would be reduced by about 15% ($=1-0.965^{4.7}$), net of all other factors. Similarly, the net under-5 mortality rate for children living in households with the highest level of economic resources is less than 60% of that for children living in households with the lowest level of economic resources. Since our economic resources measure does a better job of differentiating at the low end of the distribution (fully 28% have the highest score on the scale), the coefficient is best interpreted as indicating the increased hazard of child mortality experienced by the economically most marginal portion of the population relative to those with an adequate standard of living.

As was noted above, including measures of mother's education and the household economic level substantially reduces the racial differential in mortality: the Black-Coloured ratio becomes only marginally significant, the Black-Asian ratio is reduced from about 3:1 to about 2:1, and the Black-White ratio is reduced from about 5:1 to about 3:1. Thus, it appears that a substantial fraction of the racial differential in child mortality is due to race differences in mother's education and the economic resources of households. However, in Model 2 θ remains nearly as large as in Model 1, which suggests that neither mother's education nor household economic level accounts for the shared frailty.

Model 3 adds mothers' and children's characteristics other than those that directly index socioeconomic status: mother's age; the birth order and birth interval; whether the previous child had died; and mother's migration experience. The mortality hazard is significantly elevated for very young mothers (those under age 20 at the time of birth) but is no different for those age 30 or older, relative to those in their twenties. Second or third and higher-order births that took place more than 36 months after the previous birth have a significantly lower risk of mortality than first births, while third or later children born less than 36 months after the previous child have a significantly greater risk of mortality, though this effect is significant only at the .087 level. No other combination of birth order and birth interval has a mortality hazard significantly different from that for first borns. These findings are in accordance with expectation that later births occur to mothers with greater experience with childbearing and rearing, and that longer inter-birth intervals are protective. As expected, the death of the previous child more than doubles the mortality hazard. This may imply either genetic frailty or poor childrearing practices; out data do not allow us to distinguish between the two. Despite our predictions to the contrary, it turns out that migration patterns of mothers have no effect on the hazard of under-5 mortality, net of other factors. This is true even though we have not yet included quality of the water supply and toilet facilities in the model, which we would have expected to be affected by migration patterns because of the disproportionate likelihood that rural-to-urban migrants reside in squatter settlements. None of the coefficients also included in Model 2 is much changed by introduction of the additional variables, except that for survey year. Oddly, net of all other factors, the hazard of under-5 mortality is about 20% higher in 1998 than in 1987-89. This result gives credence to the claim that one of the costs of the transfer of power was a degradation of health services. But this is a fairly indirect inference, which needs to be documented precisely before being taken very seriously. Finally, there is a radical reduction in the size of the shared frailty coefficient, θ. This suggests that the major reasons for the shared frailty of children in the same household are sociodemographic; either they have disproportionately young mothers, or many and closely-spaced siblings, or share other, unmeasured, conditions that also increased the propensity for their next eldest sibling to have died.

Model 4 adds indicators of the quality of plumbing facilities—whether a household has piped or bottled water, or a toilet or latrine, or neither, with the reference category households that have both. Households that lack clean water and toilet facilities are at increased risk of child mortality relative to households with both; net of all factors the hazard for such households increases by about one-third. However, controlling for plumbing hardly changes any of the remaining coefficients, suggesting that the character of plumbing is substantially orthogonal to the variables already in the model. The one exception is the coefficient associated with survey year, which becomes non-significant once the adequacy of plumbing is controlled. In Model 4, the shared frailty coefficient, θ, is reduced still further and becomes only marginally significant.

Model 5, our final model, tests the hypothesis that the factors affecting under-5 mortality changed between 1987-89 and 1998, by including interactions between the survey year and each of the remaining variables. What is striking is the almost complete lack of change between the late *apartheid* period and the early post-*apartheid* period. We cannot reject the null hypothesis that the interaction terms are collectively = 0 and only one of the 19 individual coefficients is statistically significant at conventional levels, and implies a doubling of the hazard of under-5 mortality in 1998 compared to 1987-89 among households lacking both clean water and a toilet. It is unclear what to make of this, since we have no adequate way of studying possible shifts in the character of households lacking clean water and toilets, for example, an increase in the proportion of the population living in squatter settlements (the proportion of Black children living in such households increased slightly, from 9.7% to 13.4%, between the two surveys). Moreover, we are vulnerable to a simultaneous inference problem since, by definition, 1 in 20 coefficients should be significant by chance at the $p < 0.05$ level. To correct for this possibility, we make a Bonferroni adjustment by dividing 0.025 (for a two-tailed test) by the number of possible comparisons, 19, to get an adjusted critical p-value of 0.0013. By this criterion, not a single interaction coefficient is significant. Thus, the reasonable conclusion is that there has been no change either in the factors affecting under-5 mortality in the 10 year period straddling the end of *apartheid* or, since the main effect of survey year also is not significant, in the overall hazard of child mortality.

DISCUSSION

At the end of the *apartheid* era, Black children faced many disadvantages, relative to other children. Their mothers had relatively low schooling, they lived in households with few economic resources and very poor sanitation, and many lived in underserved rural areas. These conditions were central determinants of the poorer survival prospects of Black children, relative to others, captured in the 1987-89 SADHS survey. But they changed little in the decade between surveys. Although the *apartheid* system of institutionalized discrimination and separate development was dismantled, Black children in the 1998 SADHS continued to have poorer living conditions, resources, and survival prospects than others in their first five years of life. The present analysis has shown that the same characteristics that increased the risk of child mortality for Black children in the late *apartheid* period continued to be key determinants a decade later. Moreover, this was true not only for Blacks. The *apartheid*-era gradient of racial advantage, with Whites on top, followed, in order, by Asians, Coloureds, and Blacks, remained in place in 1998, at least with respect to its impact on the hazard of child mortality. What is striking is that we cannot distinguish between the late *apartheid* period and the early post-*apartheid* period with respect either to the rate of child mortality or its determinants; a single model fits the data from both years.

The very substantial racial gradient in the hazard of mortality (five times greater for Blacks than for Whites, with the other groups falling in between) is partly but not completely explained by racial differences in mother’s education, the level of household economic resources, the adequacy of plumbing (the availability of clean water and toilet facilities), the age of the mother, the timing and number of births, and the mortality of the previous child. Controlling for these factors reduces the Black-Coloured hazard ratio to non-significance, the Black-Asian ratio from more than 3:1 to less than 2:1, and the Black-White ratio from about 5:1 to about 3:1.

Racial disparities in South Africa are long-standing, and persist despite the repeal of *apartheid* legislation. As in other societies, but even more so in South Africa (Treiman, McKeever and Burgard 1998), socioeconomic position is passed from parents to their children, which means that the children of the severely disadvantaged, who are mainly Black, are likely to persist in their disadvantage, inheriting unhealthy conditions for reproduction and child rearing. Only when education is made much more widely available than it is now is there likely to be much increase in the chance for socioeconomic mobility across generations. Moreover, families living in the poorest regions, which would benefit most from relocation to areas with better infrastructure and economic opportunities, are least able to migrate from their current residences. Thus it is unlikely that there will be much reduction in racial differentials in child mortality and other aspects of reproductive health in the near future.

Limitations of the data used here mean that some of the measures we include are not optimal. The indicator of household economic resources used in this analysis is only a proxy for actual economic resources that could influence children's health and mortality, and does not make fine distinctions between individual households, especially at the higher end of the distribution. Better measures of income or wealth might show stronger associations with child survival. Similarly, we have no direct measures of health services or health behaviors, which could enrich future studies. Nonetheless, these findings suggest that equalizing health care access will not alleviate racial differences in child survival in South Africa unless persisting vast inequities in socioeconomic profiles and conditions of living are addressed.

A final limitation of the present analysis is our inability to ascertain the importance of various causes of death for differentials in infant and child mortality. A particularly salient issue when considering child mortality in South Africa is the HIV/AIDS epidemic, which is not addressed in the present study. It would be useful to distinguish the contributions of the various preventable causes of death, such as malnutrition or diarrheal disease, which have long headed the list of causes of death, and HIV/AIDS, a relatively new influence. The actions necessary to improve outcomes depend on the causes contributing to the mortality rates, and the recent actions taken by the state to improve infant and child survival are targeting HIV/AIDS rather than basic preventative care, such as immunization (Romani and Anderson 2002).

Regardless of the distribution of causes of death, wide-ranging improvements in infant and child survival will likely follow from expansion of basic infrastructure in the underserved areas of the country. Without clean water and sanitation, for example, improving women's schooling or the quality of available medical delivery services may not have a great effect. There has been some improvement in the provision of clean water for rural Black households since 1994, but little if any change in the availability of modern sanitation (Romani and Anderson 2002). Further development of these resources will bring children across the country to parity in basic environmental influences, which is likely to increase the relative importance of other household and community resources. In general, the dismantling of the legal system governing unequal opportunities for the population groups of South Africa will not have an impact on child health until inequities in basic level of living are addressed.

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Table 1. Summary Statistics for Individual and Community Variables Used in Statistical Analysis of Child Survival by Mother's Race, South Africa 1987-89 and 1998.

	Black/African			Colored			Asian			White		
Variable	**1987-9**	**1998**	**Test[a]**	**1987-9**	**1998**	**Test**	**1987-9**	**1998**	**Test**	**1987-9**	**1998**	**Test**
Child's age (%)												
> 1 month	3.05	2.41	0.033	2.83	2.12	0.820	1.49	0.86	0.879	0.84	2.04	0.823
1-5 months	12.0	11.2		8.46	9.21		8.30	6.99		10.1	10.3	
6-11 months	12.2	11.2		11.1	11.8		9.07	6.61		8.26	6.16	
12-23 months	21.3	20.4		18.6	20.5		20.4	19.0		18.2	17.1	
24-59 months	51.5	54.8		59.0	56.4		60.8	66.5		62.6	64.5	
Child's Sex Male (%)	50.6	50.4	0.940	51.1	50.8	0.832	50.1	46.0	0.980	49.6	51.3	0.823
Birth order / length of preceding birth interval												
First birth	40.7	32.9	<.001	35.3	35.2	<.001	39.3	36.5	0.246	36.1	39.9	0.324
Second birth, <= 36 months	10.1	7.31		10.1	5.88		17.7	15.5		20.7	22.0	
Second birth, > 36 months	12.5	16.1		17.5	26.9		12.2	18.7		15.0	15.3	
Third + birth, <= 36 months	18.3	16.5		12.9	8.21		11.2	11.8		12.7	10.6	
Third + birth, > 36 months	18.1	27.2		23.1	23.8		18.4	17.4		15.4	12.2	
Missing	0.33	0.00		1.00	0.00		1.24	0.00		0.17	0.0	
% Previous child died	5.12	1.61	<.001	3.74	0.23	<.001	2.38	0.00	0.123	2.36	1.07	0.215
Mother's Age			<.001			0.380			0.322			0.083
< 20 years	24.4	17.8		18.9	16.3		11.9	8.47		9.11	4.89	
20 – 29 years	54.5	48.3		54.8	55.4		67.5	61.1		68.3	68.9	
30 + years	21.2	33.9		26.3	28.3		20.6	30.4		22.6	26.3	
Mother's Years Education	7.07	7.88	<.001	6.98	8.50	<.001	9.76	11.1	<.001	12.4	12.6	0.177
	(3.71)	(3.98)		(3.30)	(3.21)		(2.61)	(2.40)		(2.44)	(2.35)	
Household Wealth	0.278	0.474	<.001	0.602	0.762	<.001	0.966	0.955	0.296	0.984	0.945	0.005
	(.329)	(.378)		(.405)	(.320)		(.131)	(.125)		(.086)	(.136)	
Mother's Residence: Childhood and Current												
Lifetime Urban (%)	29.6	24.7	<.001	68.3	64.5	<.001	89.2	89.0	<.001	76.9	78.2	0.351
Rural-to-Urban Migrant (%)	7.04	18.3		3.65	11.7		1.99	11.0		6.41	5.77	
Urban-to-Rural Migrant (%)	2.59	2.81		2.01	5.38		4.93	0.00		10.6	11.4	
Lifetime Rural (%)	60.8	53.2		26.0	17.6		3.85	0.00		6.07	4.65	
Missing	0.00	1.12		0.00	0.82		0.00	0.00		0.00	0.00	

Table continued below.

Table 1, continued. Summary Statistics for Individual and Community Variables Used in Statistical Analysis of Child Survival by Mother's Race, South Africa 1987-89 and 1998.

	Black/African			Colored			Asian			White		
	1987-9	**1998**	**Test**	**1987-9**	**1998**	**Test**	**1987-9**	**1998**	**Test**	**1987-9**	**1998**	**Test**
Household Sanitation												
No Clean Water, No Toilet	9.72	13.4	<.001	3.47	1.41	0.032	0.00	0.00	<.001	0.00	0.00	0.002
Clean Water, No Toilet	5.56	5.64		4.66	2.90		0.00	0.00		0.00	0.00	
No Clean Water, Have Toilet	25.1	12.7		3.93	1.12		1.37	0.00		3.04	0.97	
Clean Water, Have Toilet	59.7	65.1		87.9	93.8		98.6	98.3		97.0	97.3	
Missing	0.00	3.22		0.00	0.76		0.00	1.71		0.00	1.75	
Average years of schooling of women in magisterial district	3.69 (1.28)	5.97 (1.98)	<.001	4.88 (1.12)	7.96 (1.48)	<.001	5.66 (1.00)	8.04 (1.38)	<.001	5.20 (1.30)	8.24 (1.66)	<.001
Number of Births	12,435	3,996		1,096	579		788	108		593	208	
Number of Deaths	662	213		41	19		14	1		5	3	

Source: From authors' calculations of SADHS 1987-89 and SADHS 1998 data.

a. Tests for difference conducted using Chi-square tests for categorical variables and t-tests for continuous variables.

Table 2. Hazard Ratios For Piecewise Exponential Models of Child Survival with Mother-level Frailty, South Africa 1987-1989 and 1998.[a]

		Model 1	Model 2	Model 3	Model 4	Model 5
Mother's Race (Black omitted)						
	Colored	0.654	0.779	0.832	0.833	0.834
		(.003)	(.085)	(.194)	(.199)	(.289)
	Asian	0.298	0.494	0.530	0.517	0.542
		(<.001)	(.012)	(.022)	(.018)	(.038)
	White	0.170	0.306	0.340	0.332	0.283
		(<.001)	(.001)	(.003)	(.003)	(.007)
Age (0 Months omitted)						
	1-5 Months	0.147	0.147	0.144	0.144	0.144
		(<.001)	(<.001)	(<.001)	(<.001)	(<.001)
	6-11 Months	0.101	0.100	0.0963	0.0962	0.0963
		(<.001)	(<.001)	(<.001)	(<.001)	(<.001)
	12-23 Months	0.0383	0.0381	0.0359	0.0359	0.0359
		(<.001)	(<.001)	(<.001)	(<.001)	(<.001)
	24-59 Months	0.00846	0.00838	0.00778	0.00777	0.00779
		(<.001)	(<.001)	(<.001)	(<.001)	(<.001)
Child's Sex Male		1.33	1.34	1.32	1.32	1.36
		(<.001)	(<.001)	(<.001)	(<.001)	(<.001)
Survey year 1998		0.987	1.13	1.18	1.14	0.835
		(.876)	(.143)	(.040)	(.112)	(.635)
Mother's Years of Education			0.965	0.967	0.969	0.972
			(<.001)	(.001)	(.002)	(.012)
Household Economic Resources			0.575	0.651	0.693	0.651
			(<.001)	(.001)	(.007)	(.011)
Mother's Age (20 – 29 years omitted)						
	< 20 years			1.31	1.31	1.29
				(.004)	(.005)	(.017)
	30 + years			1.04	1.05	1.08
				(.675)	(.620)	(.462)
Birth Order/ Previous Birth Interval (1st birth omitted)						
	2nd, <=36 months			0.908	0.900	0.871
				(.439)	(.398)	(.330)
	2nd, >36 months			0.676	0.677	0.619
				(.003)	(.004)	(.003)

Table 2, continued. Hazard Ratios For Piecewise Exponential Models of Child Survival with Mother-level Frailty, South Africa 1987-1989 and 1998.[a]

	Model 1	Model 2	Model 3	Model 4	Model 5
Birth Order/ Previous Birth Interval (1st birth omitted)					
3rd +, <=36 months			1.21	1.20	1.28
			(.087)	(.110)	(.051)
3rd +, >36 months			0.786	0.782	0.798
			(.051)	(.047)	(.115)
Missing			1.63	1.62	1.64
			(.222)	(.228)	(.224)
Previous Child Died			2.17	2.18	2.17
			(<.001)	(<.001)	(<.001)
Mother's Place of Residence: Childhood and Current (Lifetime Urban omitted)					
Rural-to-Urban Migrant			1.14	1.15	1.01
			(.315)	(.277)	(.960)
Urban-to-Rural Migrant			0.780	0.766	0.669
			(.216)	(.187)	(.086)
Lifetime Rural			1.11	1.03	0.986
			(.286)	(.744)	(.900)
Missing			0.329	0.342	0.446
			(.271)	(.288)	(.429)
Household Sanitation (Clean Water, Have Toilet omitted)					
Clean Water, No Toilet				1.13	1.05
				(.506)	(.614)
No Clean Water, Have Toilet				1.13	1.14
				(.348)	(.367)
No Clean Water, No Toilet				1.39	1.16
				(.003)	(.289)
Missing				0.742	0.874
				(.517)	(.773)
Interactions with Survey Year					
1998 * Mother's race Colored					1.03
					(.911)
1998 * Mother's race Asian					0.547
					(.568)
1998 * Mother's race White					1.69
					(.492)
1998 * Child's sex Male					0.870
					(.361)

Table 2, continued. Hazard Ratios For Piecewise Exponential Models of Child Survival with Mother-level Frailty, South Africa 1987-1989 and 1998.[a]

	Model 1	Model 2	Model 3	Model 4	Model 5
Interactions with Survey Year					
1998 * Mother's Years of Education					0.993 (.761)
1998 * Household Economic Resources					1.33 (.323)
1998 * Mother's age < 20 years					1.02 (.924)
1998 * Mother's age 30 + years					0.911 (.660)
1998 * 2^{nd}, <=36 months					1.18 (.571)
1998 * 2^{nd}, >36 months					1.31 (.353)
1998 * 3^{rd} +, <=36 months					0.703 (.203)
1998 * 3^{rd} +, >36 months					0.902 (.721)
1998 * Previous Child Died					1.05 (.900)
1998 * Rural-to-Urban Migrant					1.66 (.079)
1998 * Urban-to-Rural Migrant					1.70 (.254)
1998 * Lifetime Rural					1.22 (.445)
1998 * No Clean Water, No Toilet					1.91 (.011)
1998 * Clean Water, No Toilet					0.970 (.929)
1998 * No Clean Water, Have Toilet					1.53 (.076)
Model Chi-Square	1549.8 (<.001)	1598.3 (<.001)	1673.0 (<.001)	1682.7 (<.001)	1702.8 (<.001)

Table 2, continued. Hazard Ratios For Piecewise Exponential Models of Child Survival with Mother-level Frailty, South Africa 1987-1989 and 1998.[a]

	Model 1	Model 2	Model 3	Model 4	Model 5
Likelihood-ratio Test that Theta=0	50.4	44.8	2.80	2.35	1.97
	(<.001)	(<.001)	(.047)	(.063)	(.080)
<u>Wald tests of Groups of Additional Covariates</u>					
Model 2 – Model 1		46.6			
		(<.001)			
Model 3 – Model 2			80.4		
			(<.001)		
Model 4 – Model 3				9.86	
				(.043)	
Model 5 – Model 4					20.3
					(.442)

Source: From author' calculations of SADHS 1987-89 and SADHS 1998 data.
a. p-values in parentheses