Stages of the Demographic Transition from a Child's Perspective: Family Size, Cohort Size, and Children's Resources

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The demographic transition has played itself out with great regularity in developing countries over the last 50 years. Looking at a broad set of countries, a stylized version of the demographic transition is consistent with the empirical experience of most of the developing world. The transition begins with large and sustained declines in death rates, especially infant and child mortality. The immediate effect of this mortality decline is an increase in the number of surviving children at the family level and an increase in the total number of children at the population level. Mortality decline is eventually followed by the second key element of the transition, a decline in fertility, which in turn has effects on both family size and cohort size. These changes in family size and cohort size over the course of the demographic transition are the focus of this article. We develop a new characterization of stages of the transition, viewing the demographic changes from a child's perspective. As we show, dramatic changes in the numbers of siblings and the size of cohorts can occur during the demographic transition, changes with important implications for children's resources at the family level and the population level. These changes do not always move in the same direction, however, owing to the complex interaction of population momentum with falling fertility and mortality.

We focus on three stages of the demographic transition from a child's perspective, each with different implications for resource competition at the family and population level. In Stage 1 falling infant and child mortality leads to increasing numbers of surviving children within families and increases in the size of birth cohorts. This is the stage in which rapid population growth begins, as seen from both the family and population levels. In Stage 2 falling fertility overtakes falling mortality to produce declining family size, but cohort size continues rising as a result of population momentum. In Stage 3 falling fertility overtakes population momentum to cause declines in the absolute size of birth cohorts. Children, especially school-age children, compete for resources at both the family and the population level. Children born in Stage 1 face increasing competition at both levels. Children born in Stage 2 face increasing competition at the population level, but have fewer siblings and thus face decreasing competition at the family level. Children born in Stage 3 experience declines in both cohort size and family size, implying less competition for resources at both the population and family levels.

After examining past research on cohort size, family size, and schooling, we develop a simple model of the dynamics of cohort size and family size during the demographic transition. Using this model as a framework, we analyze changes in fertility, mortality, surviving family size, and cohort size for eight countries with good census microdata. We first look at trends in fertility and infant survival for eight countries with census microdata for at least two years: Brazil, Costa Rica, Ecuador, Kenya, Mexico, South Africa, Uganda, and Vietnam. We show that in most countries the period in which surviving family size declined the fastest—usually the 1970s and 1980s—was also the period in which the childbearing population grew the fastest. Next we examine trends in cohort size using aggregate data for these countries plus all low- and middle-income countries with a population of at least 25 million in 2005. We show that a large number of countries will experience a peak in the population aged 9–11 years between 2000 and 2010, although many African and South Asian countries will see continued cohort growth for several decades. We then turn to the family-size component of our analysis, using census microdata to look at changes in family size from the perspective of children aged 9–11. We first examine the case of Brazil, where we have data back to 1960. We show that surviving family size was declining in Brazil by the 1960s, while the largest birth cohort was not born until 1982. Looking at the other seven countries for which we have census microdata for multiple periods, we find that with the notable exception of Uganda, the number of siblings of children aged 9–11 declined between the two most recent censuses. This suggests that these countries have entered Stage 2, the stage in which children compete for resources with fewer siblings. Only Brazil had entered Stage 3, the stage at which this decline in the number of siblings coincided with a decline in the absolute number of children aged 9–11 between the most recent censuses, although all of the countries except Kenya and Uganda are likely to have entered that stage by 2010.

Research on cohort size, family size, and children's resources

Numerous researchers have considered the possible effects of family size and cohort size on resources available to children, with particular focus on their impact on schooling.[1] Although negative effects of rapid growth of the school-age population on educational outcomes have frequently been mentioned as one of the potential negative consequences of rapid population growth (Jones 1971; World Bank 1984), empirical evidence has been mixed. Using cross-national data on age structure, school enrollments, and school expenditures, Schultz (1987) found no significant effect on school enrollment rates of the proportion of the population of school age, although he did find a negative relationship between the proportion of the population of school age and public school expenditures per child. Kelley (2001) noted that several other studies based on cross-country data also suggest that there is no impact of relative cohort size on the share of national budgets allocated to schooling, although most of those studies did not look directly at schooling outcomes. In the case of Brazil, Birdsall and Sabot (1996) cited the rapid increase in the number of school-age children as a potential cause of the country's poor educational performance in the 1980s. Lam and Marteleto (2005) showed that declines in the growth rate of the school-age population help explain Brazil's large increases in school enrollment in the 1990s.

An even larger literature looks at the impact of family size on schooling outcomes. As pointed out by Lloyd (1994) and Kelley (1996), this literature has produced mixed results. Most empirical studies in developing countries found that children from large families attained less schooling than children with fewer siblings (Anh et al. 1998; Knodel and Wongsith 1991; Lam and Marteleto 2005; Marteleto 2001; Parish and Willis 1993; Patrinos and Psacharopoulos 1997; Psacharopoulos and Arriagada 1989). This fact is often attributed to resource dilution, with a smaller share of financial and interpersonal resources allocated to each child in larger families. Some studies, however, have found a positive association between family size and schooling (King 1987; Mueller 1984), a result that Kelley (1996) argued could be theoretically plausible if there were large economies of scale in the production of human capital within families. Whatever the empirical relationship between family size and schooling, it is difficult to give a causal interpretation since choices about fertility and schooling are made jointly.

Our purpose is not to provide new evidence on the impact of cohort size or family size on children's outcomes, but to analyze how cohort size and family size change during the demographic transition. Most of the discussion of the dynamics of family size and cohort size during the demographic transition suggests that the two move together. As we show, both empirical evidence and simple models of the underlying population dynamics indicate that family size and cohort size may move in opposite directions for as long as several decades once fertility begins to fall. Understanding these dynamics can provide a clearer picture of how children's competition for resources changes during the demographic transition, with critical implications for countries that have only recently begun to experience fertility decline.

Dynamics of family size and cohort size

We present a stylized model that demonstrates several points about the dynamics of changes in family size and cohort size during the demographic transition. Assume for simplicity that a woman has all her births at the mean age of childbearing μ. This implies that all children born in a given year are born to women at age μ , and that the cohort total fertility rate (TFR) for these women is equal to the period TFR. We define $s(t)$ as surviving family size for children born in year t, $f(t)$ as the number of children born to every woman who gives birth in year t, and $p(t)$ as the probability of a child born in year t surviving from birth to childbearing age.[2] In the limiting case in which there is no variance in fertility across women, f is also the mean completed family size for children born in that year.[3] Under the simplifying assumptions described above (including the assumption of no variance in fertility), surviving family size is simply the product of the fertility rate and the survival rate in a simple multiplicative relationship:

$$s(t) = f(t)p(t). \tag{1}$$

We take the natural logarithm of (1) and differentiate with respect to time to get:

$$\frac{\partial \ln s(t)}{\partial t} = \frac{\partial \ln f(t)}{\partial t} + \frac{\partial \ln p(t)}{\partial t}. \tag{2}$$

Equation (2) simply states that the rate of change in surviving family size is the sum of the rate of change in fertility and the rate of change in survival. During most of the demographic transition, fertility declines while the survival probability increases, so the net change in surviving family size in any given period is ambiguous. While a more complete age profile of fertility would complicate equation (2), it would not change the basic point that declining fertility competes with increasing survival to determine changes in surviving family size during the transition.

We continue with this simple model to introduce the dynamics of cohort size. The number of surviving births in year t, which we denote $N_0(t)$, depends on the number of childbearing-age women in year t and the number of surviving children born to each of those women. In our model the number of childbearing-age women is simply the number of women age μ in year t, $N_\mu(t)$. We can therefore express the number of surviving children born in year t as:

$$N_0(t) = N_\mu(t)s(t) = N_\mu(t)f(t)p(t). \tag{3}$$

Assuming that all surviving births reach the age of childbearing, we link current numbers of childbearing-age women to past births and modify equation (3):

$$N_0(t) = N_\mu(t)s(t) = N_0(t-\mu)f(t)p(t). \tag{4}$$

Equation (4) makes the simple but fundamentally important point that current numbers of surviving births are the product of cohort size one generation in the past multiplied by current fertility and survival rates. As above, it is useful to take logs and differentiate with respect to time to express the dynamics in terms of growth rates:

$$\frac{\partial \ln N_0(t)}{\partial t} = \frac{\partial \ln N_\mu(t)}{\partial t} + \frac{\partial \ln s(t)}{\partial t}. \tag{5}$$

The role of population momentum is clearly evident in equation (5). The first term on the right-hand side is the growth rate of the childbearing-age population in year t, or, equivalently (given our assumptions), the growth rate of numbers of surviving births μ years earlier. While the growth rate of the childbearing-age population is affected by fertility and mortality one generation back, it is not affected by current fertility and mortality, and hence need not move in the same direction as current family size. During the demographic transition the two terms on the right-hand side of equation (5) can clearly move in opposite directions. In particular, surviving family size will start to decline if fertility falls faster than infant mortality, but the childbearing-age population may continue to increase as a result of population momentum.[4] Equations (4) and (5) incorporate the same components of population growth as modeled by Bongaarts and Bulatao (1999), except that we ignore migration and only describe the size and rate of growth of single birth cohorts. Below we present decompositions of cohort growth similar to those of Bongaarts and Bulatao.

Equation (5) provides a useful framework to describe the dynamics of family size and cohort size during the demographic transition. Assume that before the transition begins there is a stationary population with constant numbers of surviving births in every year, implying that $\partial N_\mu(t)/\partial t = 0$ in equation (5). We can characterize the beginning of the demographic transition as an unexpected increase in the survival probability, $\partial p(t)/\partial t > 0$, in some year t_1. Since this will not cause any change in the childbearing-age population for the first μ years, all effects on numbers of surviving children operate through increased survival probabilities. This increase in child survival must increase both the average size of families, s, and the number of surviving births in each year, N_0, during the initial years of the transition. From the perspective of children, generations born in some initial set of years after year t_1 experience both an increase in surviving numbers of siblings and an increase in cohort size relative to previous years. This is what we call Stage 1 of the demographic transition from a child's perspective.

Following the standard pattern of the demographic transition, assume that with some lag a sustained fertility decline begins, $\partial f(t)/\partial t < 0$. Recalling equation (2), surviving family size may continue to increase or begin to decline, depending on whether fertility falls fast enough to offset increasing child survival. It is entirely an empirical question whether and for how long surviving family size continues to increase after fertility begins to decline. We assume that at some point, possibly quite a few years after the onset of fertility decline, fertility begins to fall fast enough to offset increased child survival, leading to decreasing family size.

Once surviving family size begins to fall, it need not (and generally will not) imply a decline in the number of surviving births in the population. As equation (5) shows, population momentum resulting from the growth in cohort size during the first stage of the transition will cause continued growth in the childbearing population for at least one generation. While it is not a mathematical necessity that cohort size continues growing after family size has begun to fall, the typical empirical pattern is continued growth in total numbers of births for two or three decades after family size begins to decline. This is what we call Stage 2 of the demographic transition from a child's perspective. Children born in this period experience declining family size but increasing cohort size relative to previous cohorts. They compete with fewer siblings at home, but compete with more children of the same age in the overall population.[5]

Assuming that declines in fertility continue to be faster than increases in child survival, an eventual reduction in the impact of population momentum is inevitable. Stage 1 of the transition from a child's perspective is a race between falling fertility and falling mortality to determine when surviving family size begins to fall. Stage 1 ends when falling fertility overtakes falling mortality and family size declines. As equation (5) makes clear, Stage 2 is similarly a race between falling fertility and population momentum to determine when the absolute number of births in the population begins to fall. Stage 2 ends when falling fertility overtakes population momentum to produce a decline in the absolute number of births. The decline in surviving family size must precede any decrease in cohort size.

The stages as we have defined them may not be sharply defined. Family size may fall but then rise again if improvements in child survival once again overtake declines in fertility. Similarly, the absolute number of births may reach a peak, decline for a few years, then rise again as "waves" of population momentum work their way through the childbearing population. We may therefore observe a long flat peak or oscillations around a turning point in both family size and cohort size, rather than sharply defined peaks. Although the model outlined above makes a number of simplifying assumptions, it is a useful heuristic guide for understanding the short-run dynamics of family size and cohort size during the demographic transition. Using the model as a framework for looking at trends in fertility, infant survival, and the size of the childbearing population, we will see that the basic stages as we have defined them are clearly evident for countries undergoing the demographic transition in recent decades.

Data

Fundamental to our analysis is an interest in both macro-level and micro-level demographic changes during the demographic transition. Below we present data at both levels. Macro-level data on cohort size and age structure are more readily available than micro-level data on family size. Estimates of age distributions such as those made by the United Nations Population Division (2005) provide a reasonably accurate picture of changes in cohort size back to 1950. We use these data to describe trends in the size of the population aged 9–11, including projections for future decades. We use the 9–11 age group at both the macro and micro levels for several reasons. We want to focus on a narrow age range of children who would be affected by both family size and cohort size. Age 10 represents an age at which most children should be in school. We use the 9–11 age group rather than age 10 alone in order to reduce problems that might result from age misreporting or small cell sizes. We prefer 9–11 over a broader group such as 7–14 in order to focus on a group that is closer to a single birth cohort, providing a better match to the model outlined above.

To look at changes in family size, we need microdata from censuses or surveys at multiple points during the demographic transition. Since we focus on the number of siblings of children aged 9–11, we need large samples to generate large cell sizes for this age group. Our analysis draws on large public use census samples from eight countries. We pay special attention to Brazil, where we have excellent micro-samples of the census for 1960, 1970, 1980, 1991, and 2000. We also use census samples from the Integrated Public Use Microdata Series-International (IPUMS-I) project (Minnesota Population Center 2007) for Costa Rica (1973, 1984, and 2000), Ecuador (1974, 1982, 1990, and 2001), Kenya (1989 and 1999), Mexico (1990 and 2000), South Africa (1996 and 2001), Uganda (1991 and 2002), and Vietnam (1989 and 1999). While these censuses do not extend as far back in the demographic transition as the data for Brazil, they allow us to look at recent changes in family size from the perspective of school-age children.

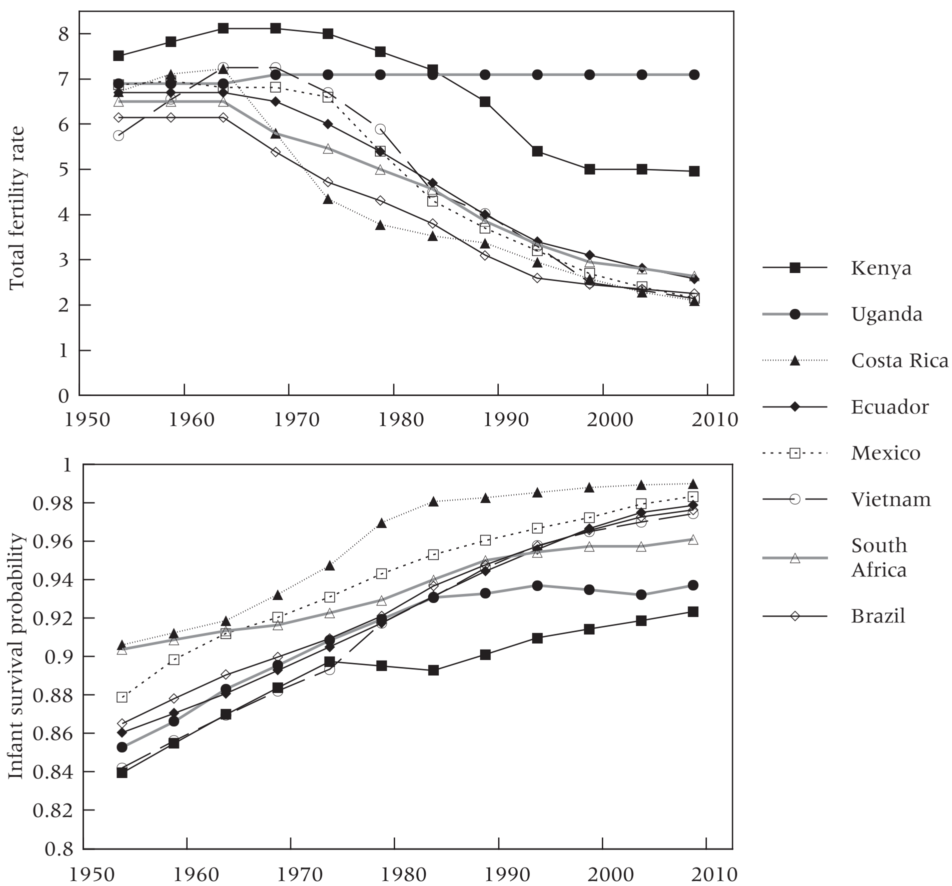
Our choice of countries is dependent on the availability of large census samples and is admittedly not a representative sample of countries. Nevertheless, these countries reflect a considerable range of demographic experience. The four Latin American countries reflect the major features of the demographic transition in the region, with Brazil having had an earlier and faster fertility decline than Mexico, Costa Rica, and Ecuador. Vietnam has a unique history that makes it not entirely typical of Southeast Asia, but its fertility decline has been similar to the experience in much of the region.

South Africa had an earlier and faster fertility decline than most of Africa, with a pattern similar to many Latin American countries. Kenya's late fertility decline is similar to much of Africa, as is its continued rapid growth in the size of birth cohorts. Uganda is of interest as one of the few remaining countries with high fertility levels.[6]

Trends in fertility and infant survival

Figure 1 shows the total fertility rate and the probability of infant survival for all eight countries based on United Nations estimates (United Nations Population Division 2005). The infant survival rate, which corresponds to *p(t)* in equation (1), is one minus the infant mortality rate (expressed as a proportion). While the basic trends in fertility and mortality shown in Figure 1 are

FIGURE 1 Total fertility rate and infant survival rate, eight countries, 1950–2010



SOURCE: Estimates based on United Nations 2005.

well known, several points are worth noting in the context of our framework. Fertility in all of these countries is high and relatively stable through the 1950s and 1960s. In most of the countries, this is followed by a period of rapid fertility decline and a subsequent leveling off. Kenya has a later and slower fertility decline, while Uganda shows no decline. The probability of infant survival shows more constant rates of change, in spite of having an upper asymptote of one. The growth rate of infant survival is around 0.2 percent to 0.3 percent per year in most of the countries between 1955 and 2000, taking the average rate of change between five-year periods. This compares to growth rates of fertility that begin around zero, fall to as fast as –4 percent to –5 percent per year during the period of most rapid fertility decline, then level off. Most of the change in surviving family size, then, is driven by falling fertility, with increasing child survival providing only a small offsetting effect.

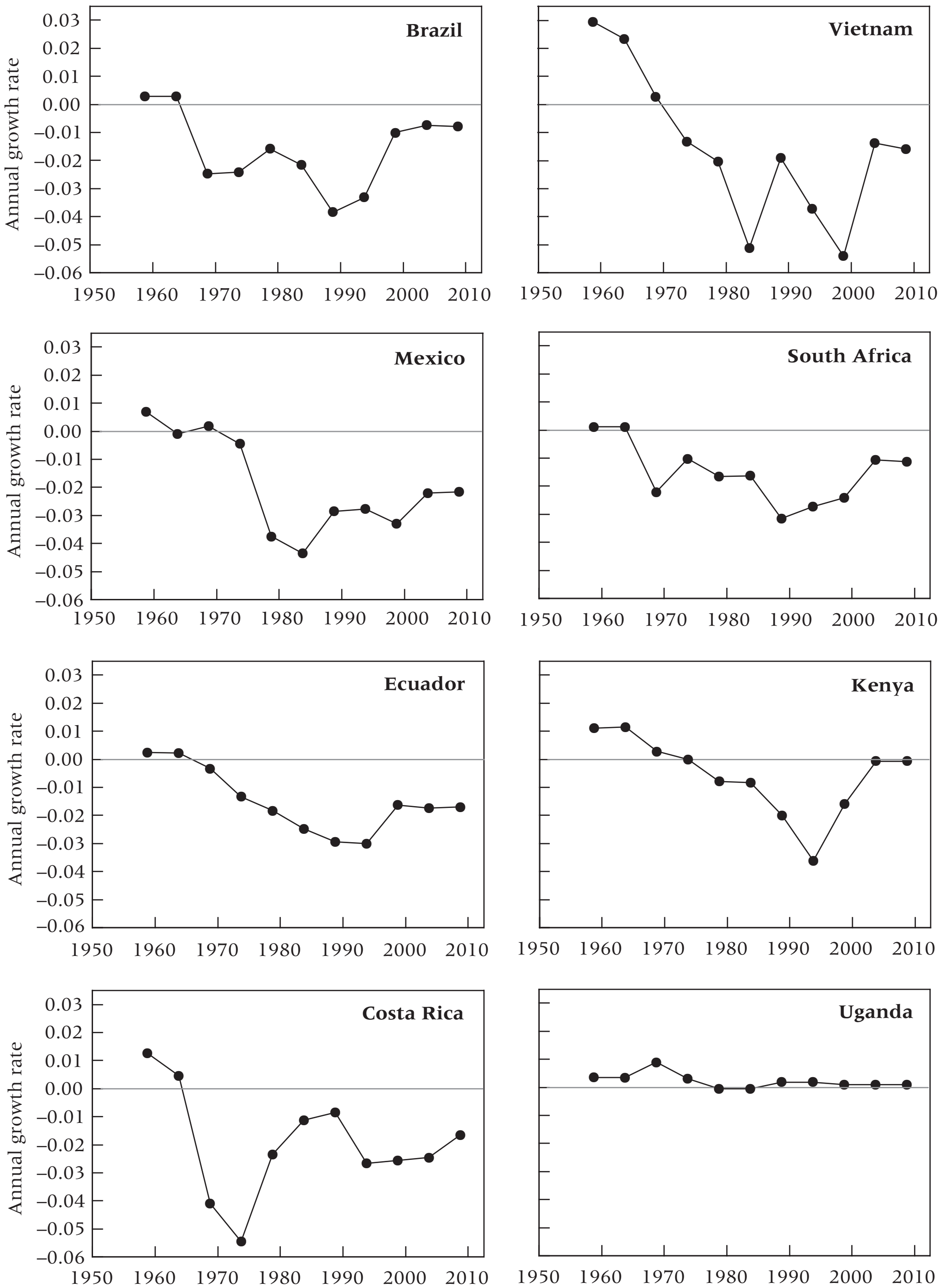
Figure 2 shows estimates of the rate of change in surviving family size. These are calculated by plugging the annual rate of change for fertility and survival into equation (2), which shows the predicted growth rate in surviving family size as the sum of the growth rate of fertility and the growth rate of survival.[7] As seen in Figure 2, this prediction implies positive growth of surviving family size in the 1950s and 1960s for most countries, turning to a decline in family size in the 1970s and 1980s. These growth rates are very close to the growth rates of the TFR, since the growth rates of infant survival are much smaller in magnitude and thus have little impact on the growth rates of surviving family size. The general pattern is for family size to reach its maximum rate of decline in the 1980s or 1990s, falling at about 3 percent to 5 percent per year. These growth rates rebound toward zero by the 1995–2005 period, a result of the slowdown in fertility decline.

Trends in cohort size

As our model demonstrates, cohort size need not move in the same direction as family size during the demographic transition. The growth rate of cohort size depends on both the growth rate of surviving family size and the growth rate of the childbearing population. Figure 3 shows the annual growth rate of the childbearing population in our eight countries.[8] The general pattern is that the growth rate hovers around 2 percent to 3 percent per year in the 1950s and 1960s, increases to around 3 to 4 percent per year during the 1970s and 1980s, then falls in the 1990s. All eight countries are projected to have positive growth rates of the childbearing-age population in 2010, although most are approaching zero at that point. Uganda's childbearing population continues to grow rapidly, with a current growth rate of about 4 percent per year.

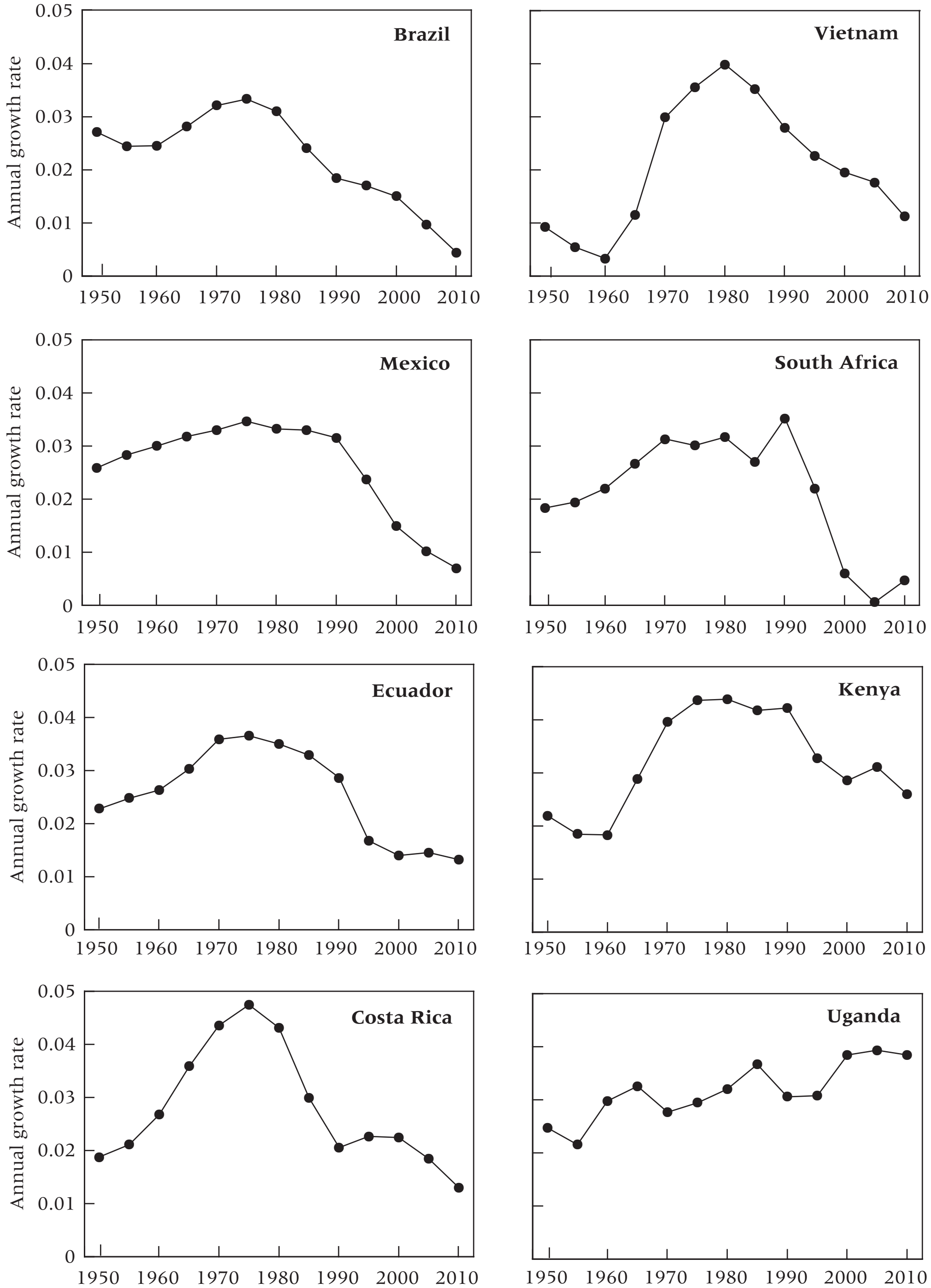
The growth rates of the childbearing population in Figure 3 interact with the growth rates of surviving family size in Figure 2 to produce the net growth rate in the size of surviving birth cohorts. Comparing the two figures, the

FIGURE 2 Annual growth rate of surviving family size, eight countries, 1950–2010



SOURCE: Calculations based on UN population estimates (United Nations 2005) using equation 2 above.

FIGURE 3 Annual growth rate of the childbearing population, eight countries, 1950–2010

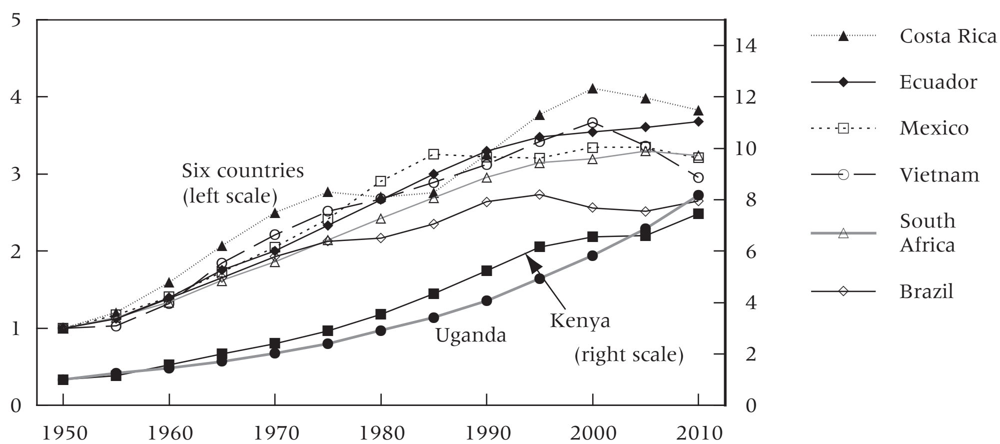


SOURCE: Estimates based on United Nations 2005.

maximum rate of increase of the childbearing population in most countries occurred around the 1980s, at roughly the same time as the maximum rate of decrease of surviving family size. This was the period in which the race between falling fertility and population momentum was at its most extreme, with the childbearing population growing at about 3 percent to 4 percent per year at the same time that surviving family size was falling at roughly similar rates. The combined effect of changes in the size of the childbearing population and changes in surviving family size is seen in Figure 4. Rather than looking at the size of cohorts at birth, Figure 4 shows the size of cohorts at ages 9–11, when most of the cohort should be enrolled in school. Figure 4 presents UN estimates and projections of the number of 9–11-year-olds from 1950 to 2010, using 1950 = 1 as a benchmark. Brazil shows a peak in the 9–11 age group around 1995, corresponding to a peak in births ten years earlier. Many countries have a peak around 2000–2010. Kenya and Uganda are far off the scale of the other countries and are shown using a different scale. The projected number of 9–11-year-olds in 2010 is about eight times its 1950 level in Kenya and Uganda.

Comparing these patterns to the predicted change in family size in Figure 2, the implied peak in the number of births comes 10 to 30 years after the year in which we predict that surviving family size started to decline. The reason for the delay is population momentum driven by growth of the childbearing population. Also note in Figure 4 that the size of the population aged 9–11 does not necessarily have a single peak. In Mexico and Brazil, for example, the number of births begins to decline but then increases for a period of time. This is not surprising given the theoretical dynamics shown above. As falling

FIGURE 4 Index of the size of the population aged 9–11, eight countries, 1950–2010 (1950 = 1)



SOURCE: Estimates based on United Nations 2005.

fertility competes with population momentum, the total number of births may well increase even after a period in which it was decreasing, and even though fertility continues to fall. The number of women of childbearing age grows at somewhat uneven rates owing to fluctuations in numbers of births in the past. Even if fertility falls at a steady rate, an increase in the rate of growth of the childbearing population could cause the number of births to increase again after an initial period of decline.

Recalling equations (4) and (5), we can decompose the growth rate of the population aged 9–11 as the sum of the growth rate of the childbearing population, the growth rate of child survival, and the growth rate of fertility, all lagged ten years. A few examples are instructive. In Brazil the population aged 9–11 grew at 0.8 percent per year from 1980 to 1985. Looking at Figures 2 and 3, we see that this resulted from a combination of 3.2 percent annual growth of the childbearing population and 2.4 percent annual decline in surviving family size in 1970–75.[9] As previously noted, the growth rate of surviving family size is driven almost entirely by fertility decline, with increasing child survival having a very small offsetting effect. Kenya's 9–11 population grew 3.7 percent per year in 1990–95, the result of 4.4 percent annual growth in the childbearing population and 0.7 percent annual decline in surviving family size in 1980–85. While these decompositions are instructive about the dynamics of cohort size and family size, they are based on imprecise UN estimates of fertility, mortality, and cohort size that are not necessarily perfectly consistent. Rather than presenting a full set of these decompositions, we focus below on more precise estimates of family-size dynamics based on direct analysis of micro-level census data.

Using the UN population projections, we can estimate the year in which every country in the world experiences a peak in population aged 9–11. Since it is impossible to have a decline in cohort size at the macro level without having a decline in family size at the micro level, the year of the peak in the 9–11 population must be the year in which these countries enter our Stage 3 from the perspective of 9–11-year-olds. Table 1 summarizes the results for low- and middle-income countries with populations of at least 25 million in 2005.[10] Column 2 shows the year in which the population aged 9–11 reaches its peak within the 1950–2050 period of the UN projections. China and Thailand reached a peak around 1980, indicating that the largest birth cohort was born around 1970. Other large countries that had a peak in the 9–11 population before 2000 were Indonesia, Brazil, Iran, and Algeria. Many countries have a peak between 2000 and 2009, including Vietnam, Costa Rica, Mexico, and South Africa. The current peak in youth populations in many developing countries was a major theme of the *World Development Report 2007* (World Bank 2006; Lam 2006). Looking at column 4, which shows the size of the 9–11 population at its peak (using 1950 = 1 as a baseline), many of the countries with a peak between 2000 and 2009 have a peak 9–11 population

TABLE 1 Year of the peak in the population aged 9–11, total fertility rate, and infant survival probability for selected countries

Country and period of peak	Year of peak	Population aged 9–11 (1950=1)		Total fertility rate		Infant survival probability	
		2005	At peak	1965	2005	1965	2005
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Before 2000							
China	1979	1.84	2.48	6.06	1.74	0.919	0.969
Thailand	1982	2.06	2.44	6.00	1.87	0.926	0.983
Indonesia	1993	2.10	2.22	5.57	2.20	0.856	0.966
Brazil	1994	2.51	2.74	5.38	2.24	0.900	0.976
Iran	1996	3.94	5.15	6.80	2.04	0.868	0.973
Algeria	1996	3.22	3.70	7.38	2.39	0.852	0.969
2000–09							
Vietnam	2000	3.36	3.67	7.24	2.14	0.882	0.975
Uzbekistan	2000	4.30	4.58	6.60	2.48	0.906	0.945
Costa Rica	2001	3.98	4.12	5.80	2.10	0.932	0.990
Mexico	2003	3.35	3.37	6.82	2.15	0.921	0.983
Argentina	2003	2.15	2.15	3.05	2.25	0.943	0.987
Myanmar	2003	2.82	2.86	6.00	2.08	0.868	0.934
Colombia	2006	3.16	3.17	6.18	2.46	0.918	0.978
Malaysia	2006	3.78	3.81	5.94	2.62	0.950	0.991
South Africa	2006	3.30	3.30	5.80	2.64	0.916	0.961
India	2007	2.84	2.85	5.69	2.76	0.855	0.940
Philippines	2009	3.82	3.85	6.50	2.84	0.912	0.977
2010–35							
Ecuador	2010	3.61	3.68	6.50	2.58	0.893	0.979
Morocco	2021	2.76	3.00	7.09	2.58	0.867	0.969
Egypt	2022	3.12	3.78	6.56	2.99	0.830	0.970
Venezuela	2022	4.46	4.78	5.91	2.55	0.940	0.984
Peru	2026	3.27	3.28	6.56	2.66	0.874	0.971
Pakistan	2029	4.73	5.66	6.60	3.73	0.862	0.929
Bangladesh	2030	3.52	3.84	6.60	2.96	0.841	0.950
Tanzania	2030	5.09	6.07	6.79	4.45	0.865	0.896
Nepal	2034	3.53	4.06	5.92	3.30	0.827	0.945
After 2035							
Sudan	2041	3.87	4.77	6.67	3.95	0.856	0.935
Iraq	2045	5.66	7.92	7.20	4.24	0.903	0.918
Nigeria	2048	4.43	5.89	6.90	5.32	0.846	0.892
Kenya	2049	6.60	11.88	8.12	4.96	0.896	0.937
Dem. Rep. Congo	2050	5.06	13.23	6.30	6.70	0.862	0.888
Afghanistan	2050	4.11	10.60	7.70	7.07	0.809	0.858
Ethiopia	2050	4.60	7.02	6.82	5.42	0.852	0.909
Uganda	2050	6.87	25.90	7.10	7.10	0.884	0.923

NOTE: Countries included are all countries classified as low to middle income by the World Bank with a population of at least 25 million in 2005, plus Costa Rica and Ecuador.
SOURCE: Estimates based on United Nations 2005.

that is about three times larger than the 1950 level. Kenya and Uganda join a number of other African countries that are projected to have continued growth of the 9–11 population beyond 2040. While projections to that distance are imprecise, these countries will almost surely have continued growth of the 9–11 population for at least two more decades.

Table 1 also shows UN estimates of the TFR and the infant survival probability for each country in 1965 and 2005. Not surprisingly, countries with earlier peaks in the 9–11 population tend to be those with larger fertility declines. Also, while all countries had significant increases in infant survival between 1965 and 2005, these increases only partially offset the decreases in fertility. In Indonesia, for example, the decline of 3.4 births in the TFR is reduced to a decline of 2.6 births if we adjust for infant survival, suggesting that children experienced a large decline in the number of surviving siblings over this period. Most of the countries in the first three panels of Table 1, and even some of those in the last panel, clearly had substantial declines in surviving family size between 1965 and 2005. This means that they entered Stage 2 at some point in the period, in many cases in the 1970s or 1980s. While column 2 gives a fairly good estimate of the year in which these countries enter Stage 3, it is much harder to identify the year in which countries enter Stage 2. In order to see when countries begin to experience a decline in surviving family size (the beginning of Stage 2), we need microdata at the household level, preferably covering a large part of the demographic transition. In the following sections we use large census samples from the eight countries shown in Figures 1–4 to see how changes in family size compare to changes in cohort size during the demographic transition. We begin with Brazil, the country for which we have the most complete set of census microdata covering the demographic transition.

Cohort size and family size in Brazil

Brazil's demographic transition is fairly typical of transitions across the developing world and is documented with excellent census data. As shown in Figure 1, the TFR began a rapid decline in the 1960s, falling to about 2.3 births per woman by 2000. The fertility decline occurred during a period of rapid social change that included both economic growth and economic crisis (Martine 1996; Lam and Duryea 1999). There was large regional variation, with fertility decline starting later in the poorer north and northeast regions than in the higher-income south and southeast. Brazil's rapid population growth in the 1960s and 1970s, evident in the size of birth cohorts, was also fairly typical. As shown in Figure 4, the number of 9–11-year-olds more than doubled between 1950 and 1975, reflecting the size of birth cohorts ten years earlier. Using overlapping age distributions from the 1960–2000 censuses, Lam and Marteleto (2005) showed that the largest cohort was born in 1982. As seen in Figure 4, the growth rate of birth cohorts varies over time, with much slower growth in the 1960s than the 1970s. These fluctuations in cohort size result from the interaction between falling fertility and the growth of the childbearing population. The decline in cohort size after the peak in the early 1980s is also uneven, with cohort size increasing again in the 1990s, producing the growth of the 9–11 age group around 2005 seen in Figure 4.

The changes in fertility and mortality that caused the changes in cohort size also caused large changes in family size. Table 2 shows estimates of the

TABLE 2 Number of siblings of children aged 9–11 ever born and surviving and change per year, Brazil 1960–2000

	Siblings ever born		Siblings surviving	
Sample and year (1)	Mean (2)	Change per year (3)	Mean (4)	Change per year (5)
All Brazil				
1960	6.43		4.96	
1970	6.13	–0.03	5.03	0.01
1980	5.25	–0.09	4.50	–0.05
1991	4.12	–0.10	3.61	–0.08
2000	3.16	–0.11	2.88	–0.08
Northeast				
1960	7.62		5.41	
1970	7.28	–0.03	5.59	0.02
1980	6.55	–0.07	5.26	–0.03
1991	5.56	–0.09	4.65	–0.06
2000	4.28	–0.14	3.73	–0.10
Southeast				
1960	5.73		4.58	
1970	5.43	–0.03	4.57	0.00
1980	4.47	–0.10	3.97	–0.06
1991	3.19	–0.12	2.90	–0.10
2000	2.44	–0.08	2.30	–0.07
Mother's schooling <4 years				
1960	6.83		5.19	
1970	6.63	–0.02	5.37	0.02
1980	6.01	–0.06	5.05	–0.03
1991	5.54	–0.04	4.74	–0.03
2000	4.76	–0.09	4.22	–0.06
Mother's schooling ≥4 years				
1960	4.67		3.94	
1970	4.42	–0.02	3.89	–0.01
1980	3.74	–0.07	3.39	–0.05
1991	2.71	–0.09	2.50	–0.08
2000	2.19	–0.06	2.07	–0.05

SOURCE: Estimates from Brazilian census microsamples.

mean number of siblings of children aged 9–11 based on Brazilian censuses from 1960 to 2000. Column 2 shows the mean number of siblings ever born, and column 4 shows the mean number of siblings surviving at the time of the census. These figures are based on the number of children ever born and children still alive reported by their mothers in the census.[11] Columns 3 and 5 show the absolute change per year (simplifying comparisons when the intercensal interval is not ten years). The mean number of siblings ever born in column 2 indicates that Brazil's fertility decline was already underway before 1970.[12] The mothers of 9–11-year-olds reported 0.3 fewer children ever born in 1970 than did their counterparts in 1960. The mean number of surviving siblings (column 4) shows a different pattern, however, with an increase of 0.07 between 1960 and 1970. This is an increase of 0.007 per year, which is rounded in column 5 to 0.01 siblings per year. While this increase in surviving siblings is very small, it suggests that Brazil was still in Stage 1 of the demographic transition in 1970: increasing infant and child survival was leading to increasing family size, even though fertility had already begun to decline.

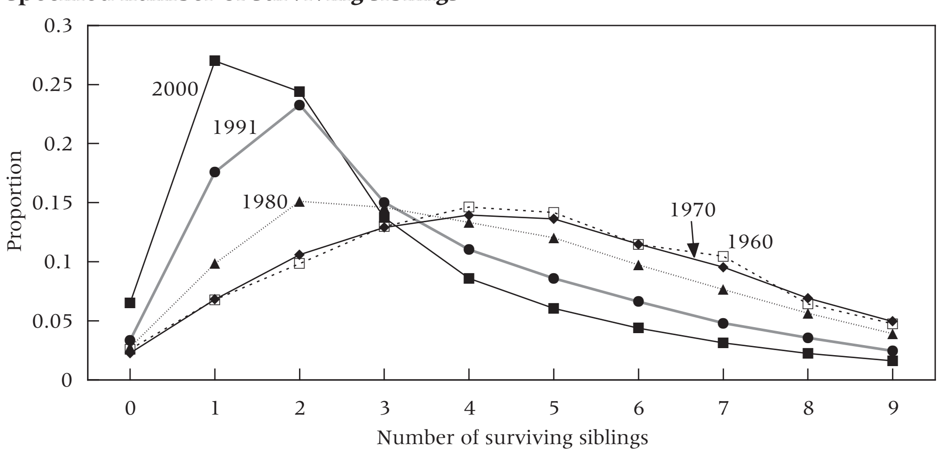
The decline in children ever born between 1970 and 1980 is substantially larger than the 1960–70 decline. Children aged 9–11 in 1980 had almost one less sibling ever born than their 1970 counterparts. This decline was large enough to cause a 0.5 decline in the number of surviving siblings. The fact that the number of siblings ever born declined by 0.88 while the number of surviving children declined by only 0.53 indicates that increasing child survival continued to play an important role. The number of siblings ever born continued to fall rapidly in the next two decades, with a decline of 1.13 from 1980 to 1991 and 0.96 from 1991 to 2000. The net impact of declining fertility over these four decades was that 9–11-year-olds in 2000 had more than two fewer surviving siblings than their counterparts in 1960, a decline of over 40 percent.

The next two panels of Table 2 present separate estimates for two large regions of Brazil, the less developed northeast and the higher-income southeast. Fertility decline began later in the northeast, making it informative to compare the evolution of family size in the two regions. Fertility decline was already evident in the northeast in 1960–70, with a decline of 0.34 between 1960 and 1970 in the mean number of siblings ever born to children aged 9–11. As was the case for all Brazil, increased infant and child survival more than offset this decline, however, leading to a 0.18 increase in surviving family size in the northeast between 1960 and 1970. The southeast, on the other hand, had already moved out of Stage 1 by 1970, with a slight decrease in the mean number of surviving siblings between 1960 and 1970. In the 1970–80 period we see a decline in surviving family size in the northeast, indicating that the northeast moved into Stage 2 of the transition sometime between 1970 and 1980. Children aged 9–11 in the northeast had 0.33 fewer surviving siblings in 1980 than they did in 1970.

Table 2 also compares trends in family size for mothers with high and low education. Low education is defined as less than four years of schooling (roughly the median level of schooling for women aged 30 in 1980). Lam and Duryea (1999) showed a strong negative relationship between women's schooling and fertility in Brazil, with increases in women's schooling playing a major role in the fertility decline. Here we use mother's schooling as a proxy for socioeconomic status (SES) that reflects a number of variables in addition to mother's schooling, including husband's schooling and family income. As with the regional breakdown, we observe an increase between 1960 and 1970 in the number of surviving siblings for the low-SES children, but a decrease for high-SES children. After 1970 family size fell for both groups, but fell at a much faster rate for the high-SES children. The number of surviving siblings fell by 0.98, or 19 percent, between 1960 and 2000 for the low-SES children, while it fell by 1.87, or 47 percent, for high-SES children.

Figure 5 shows the frequency distribution of numbers of siblings of children aged 9–11 in each Brazilian census, providing a clear picture of the evolution of small families in Brazil. The peak of the density moved from four siblings in 1960 to one sibling in 2000. The percentage with three siblings stays roughly constant across the five censuses, with the percentage above three falling rapidly over time. Over 25 percent of 9–11-year-olds had only one sibling in 2000, compared to 7 percent in 1960. Looking across the five censuses, some of the largest changes in family size of 9–11-year-olds take place between the 1980 and 1991 censuses. These changes reflect the rapid declines in fertility in Brazil between 1970 and 1981, declines that far offset improvements in child survival.

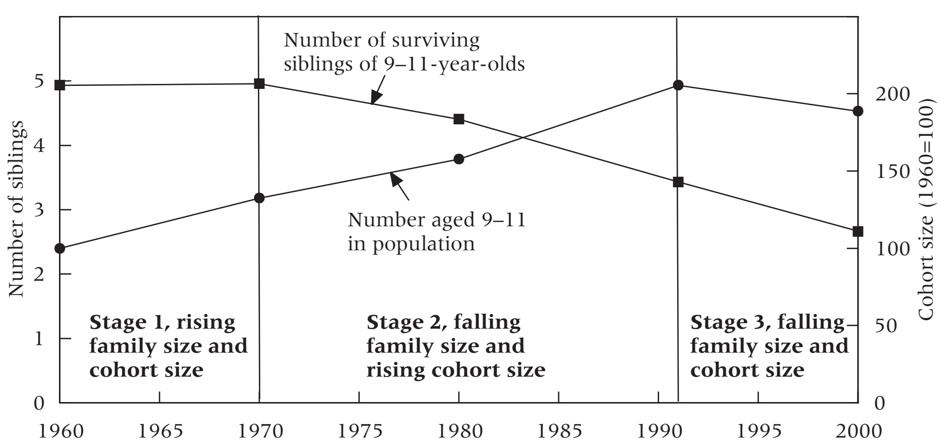
FIGURE 5 Frequency distribution of the number of siblings of children aged 9–11, Brazilian censuses, 1960–2000: Proportion with specified number of surviving siblings



SOURCE: Estimates from Brazilian census microsamples.

Figure 6 combines the estimates of cohort size and family size for children aged 9–11 in the five censuses from 1960 to 2000, providing a concise summary of the stages of the demographic transition from a child's perspective. As noted above, the number of surviving siblings rises slightly between the 1960 and 1970 censuses. The total number of 9–11-year-olds in the population increases by about 30 percent between 1960 and 1970. From the perspective of 9–11-year-olds, Brazil was still in Stage 1 of the demographic transition between 1960 and 1970, with both family size and cohort size increasing. Between 1970 and 1980 the number of surviving siblings declined, while the total number of 9–11-year-olds in the population continued to grow, increasing by 19 percent during the decade. Although we cannot specify the turning point, which could have occurred either during the 1960s or 1970s, Brazil was clearly well into Stage 2 by 1980, with falling numbers of siblings and rising cohort size. These trends continued between the 1980 and 1991 censuses. Children aged 9–11 in 1991 had one less sibling than their counterparts in 1980, but the total number of 9–11-year-olds in the population increased by 30 percent, almost as large as the increase of the 1960s. With the largest cohort born in 1982, the number of 9–11-year-olds declined between the 1991 and 2000 census by about 10 percent. The timing of the entry into Stage 3 of the demographic transition is much easier to see than the boundary between Stage 1 and Stage 2, since it only requires identification of the year in which the largest cohort is born. From the perspective of a 9–11-year-old, 1992 marks the year in which there is both a decline in the absolute number of 9–11-year-olds in the population and a (continuing) decline in the average number of siblings.

FIGURE 6 Number of surviving siblings of 9–11-year-olds and total number of 9–11-year-olds in the population, Brazilian censuses 1960–2000



SOURCE: Number of siblings estimated from Brazilian census microsamples; number of 9–11-year-olds based on United Nations 2005.

Changing family size in other countries

We can perform the same kind of analysis on other countries for which we have multiple censuses. We use the large census samples for Costa Rica, Ecuador, Kenya, Mexico, South Africa, Uganda, and Vietnam provided through the IPUMS-International project, each of which has at least two censuses. Table 3 shows the mean number of siblings ever born and mean number of siblings surviving for children aged 9–11, based on mothers' reports of children ever born and of children surviving. The table also shows the absolute number of 9–11-year-olds relative to 1950 and the annual growth rate of 9–11-year-olds for each intercensal period, based on UN estimates.

TABLE 3 Number of siblings ever born and number of surviving siblings of children aged 9–11, and size of the population aged 9–11, seven countries

	Siblings ever born		Siblings surviving		Cohort size	
Country and year (1)	Mean (2)	Change per year (3)	Mean (4)	Change per year (5)	Level (1950=1) (6)	Annual growth rate (%) (7)
Costa Rica						
1973	6.73		5.84		2.66	
1984	4.34	–0.22	3.96	–0.17	2.75	0.28
2000	2.95	–0.09	2.84	–0.07	4.11	2.52
Ecuador						
1974	6.36		5.21		2.27	
1982	5.53	–0.10	4.69	–0.06	2.80	2.65
1990	4.56	–0.12	4.00	–0.09	3.30	2.05
2001	3.59	–0.09	3.31	–0.06	3.56	0.68
Kenya						
1989	6.02		5.23		5.06	
1999	5.21	–0.08	4.57	–0.07	6.47	2.46
Mexico						
1990	4.57		4.12		3.22	
2000	3.99	–0.06	3.63	–0.05	3.34	0.37
South Africa						
1996	3.60		3.10		3.16	
2001	2.99	–0.12	2.79	–0.06	3.22	0.38
Uganda						
1991	6.16		4.78		4.24	
2002	5.63	–0.05	4.78	0.00	6.24	3.50
Vietnam						
1989	3.86		3.59		3.08	
1999	2.62	–0.12	2.48	–0.11	3.62	1.62

SOURCE: Number of siblings estimated from IPUMS-International census microsamples (Minnesota Population Center 2007); cohort size based on United Nations 2005.

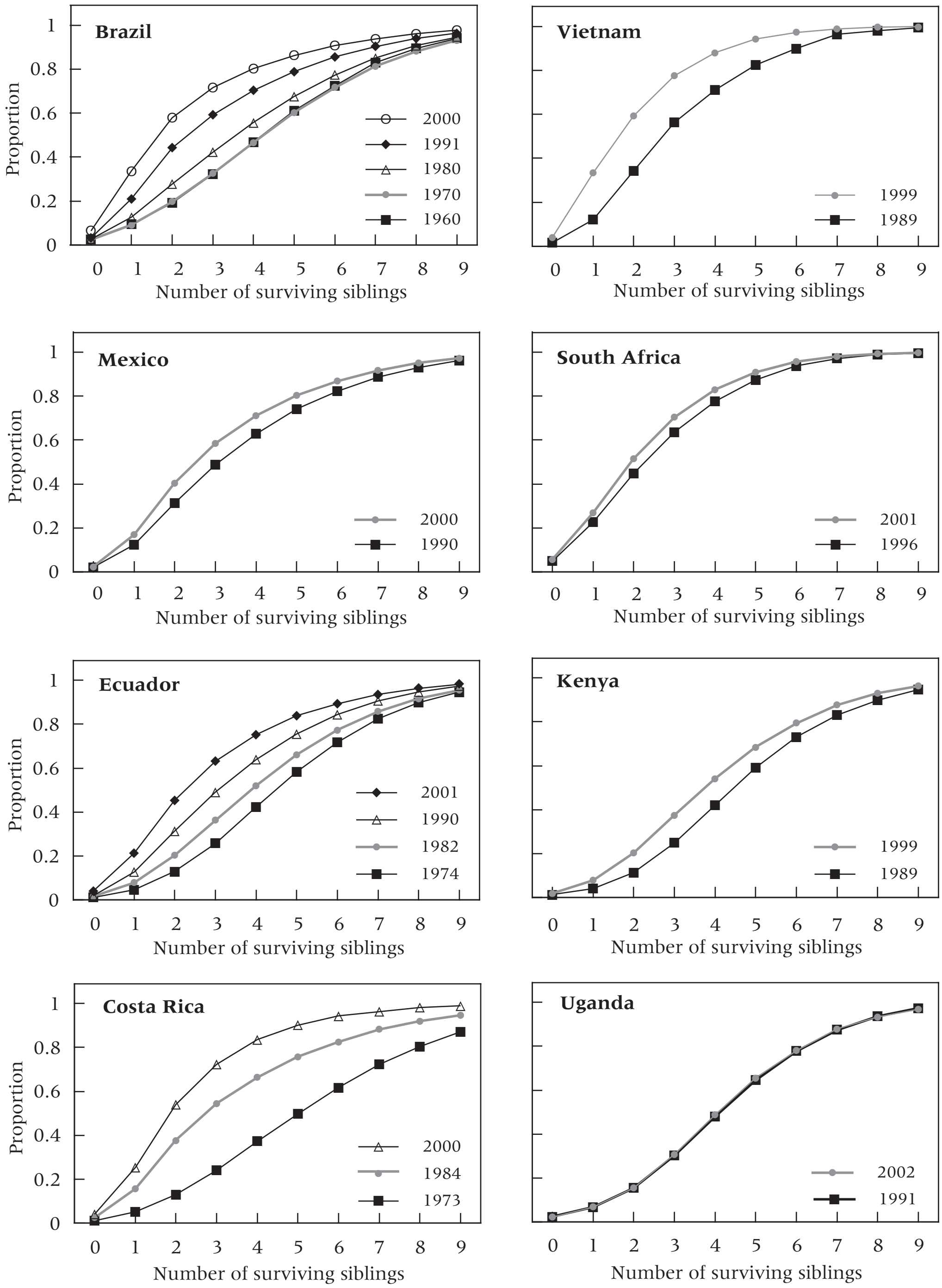
Table 3 indicates that the change in siblings ever born is negative for every period in every country. This is not surprising, since at least modest fertility decline had begun to reduce children ever born for all of these countries in the periods considered. The largest annual decline was 0.22 siblings per year in Costa Rica from 1973 to 1984. The unweighted mean for all countries and periods is a decline of 0.1 per year, or 1 sibling per decade. The change in surviving siblings is also negative for every country except Uganda, where the mean number of surviving siblings is identical in the 1991 and 2002 censuses. This suggests that increasing child survival exactly offset the small fertility decline in Uganda in this period. The unweighted mean for all periods and countries is a decline of 0.06 per year, or 0.6 surviving siblings per decade. Unlike Brazil, where we saw an increase in the number of surviving siblings in 1960–70, the data for other countries do not go back far enough to see Stage 1, when children experienced both increasing family size and increasing cohort size. For the periods we observe, all countries had entered Stage 2 with the exception of Uganda, which was on the border between Stage 1 and Stage 2.

Looking at the evidence on cohort size in columns 6 and 7 of Table 3, all of the countries experienced an increase in the absolute number of 9–11-year-olds in the periods shown. This suggests that none of these countries had entered Stage 3 by the most recent census reported in Table 3. Several had reached a point at which the number of 9–11-year-olds was approaching its peak, however. As shown in Table 1, Vietnam, Costa Rica, Mexico, South Africa, and Ecuador are all projected to have entered Stage 3 by 2010. Kenya and Uganda, in which the number of 9–11-year-olds grew at annual rates of 2.5 percent and 3.5 percent in the last intercensal period, are projected to have continued growth of the population aged 9–11 until after 2040.

While we would like to construct the equivalent of Figure 6 for all countries, the data for countries other than Brazil do not allow us to go back far enough into the early stages of the demographic transition. There is every reason to think that other countries would demonstrate patterns similar to Brazil, with 25 or 30 years spent in Stage 2. Costa Rica, for example, had declining numbers of siblings for 9–11-year-olds between 1973 and 1984, but did not reach a peak in the population aged 9–11 until 2001. Many of the countries for which we only observe sibling size after 1980 almost surely had declines in the number of surviving siblings for at least one decade earlier than that. If we could observe the year in which surviving family size began to decline in these countries, we expect that there would be at least 20 or 30 years between that year and the year in which cohort size begins to decline.

Figure 7 shows the cumulative distribution of numbers of siblings of children aged 9–11 in all eight countries. The distributions clearly demonstrate the decline in family size over time in each country and the large differences between countries. One powerful summary measure of the decline in family size is the change in the proportion of children with two or fewer siblings.

FIGURE 7 Cumulative distribution of siblings of children aged 9–11, eight countries: Proportion with specified number of surviving children or fewer



SOURCE: Estimates from IPUMS-International census microsamples (Minnesota Population Center 2007).

Looking at the three countries where our data cover long time spans, the proportion of 9–11-year-olds with two or fewer surviving siblings rose from 20 percent to 58 percent between 1960 and 2000 in Brazil, from 13 percent to 45 percent between 1974 and 2001 in Ecuador, and from 13 percent to 54 percent between 1973 and 2000 in Costa Rica. In Vietnam the proportion with two or fewer siblings rose from 34 percent to almost 60 percent from 1989 to 1999, a dramatic emergence of small families in just one decade.

Kenya and Uganda stand out with cumulative distributions that continue to be dominated by high fractions of children with many surviving siblings. The proportion with two or fewer surviving siblings was only 20 percent in Kenya in 1999 and 16 percent in Uganda in 2002, levels last seen two or three decades earlier in Latin America. Family size nonetheless changed substantially in Kenya between 1989 and 1999. The percentage with three or fewer siblings increased from 25 percent to 37 percent, while the percentage with more than five siblings fell from 41 percent to 32 percent. The distributions for Uganda in 1991 and 2002 are virtually indistinguishable from each other. Not only was there no change in mean surviving family size in Uganda, as documented above, but there appears to have been no significant change at any point in the distribution.

The distributions in Figure 7 document the remarkable declines in family size experienced by the typical school-age child during the demographic transition. The decline in the prevalence of large families is particularly striking. In Costa Rica, the percentage of 9–11-year-olds with more than five siblings fell from 50 percent to 10 percent between 1973 and 2000, roughly within one generation. We also see the large diversity in family size observed in the 2000 round of censuses. The percentage of 9–11-year-olds with more than four siblings in the census closest to 2000 ranged from 51 percent in Uganda to 25 percent in Ecuador and 12 percent in Vietnam.

Summary and conclusions

While the basic empirical regularities of falling mortality, falling fertility, and resulting patterns in population growth rates are well known, little attention has been paid to the implications of these changes for the dynamics of family size and cohort size. These dynamics have a number of intriguing features, the most important of which is the tendency for family size and cohort size to move in opposite directions during a significant part of the demographic transition.

We have proposed a characterization of the demographic transition from a child's perspective that has three stages. Children born in Stage 1 face increases in both family size and cohort size, the result of increased child survival. Children born in Stage 2 experience declining family size, as falling fertility overtakes falling mortality, but face continued increases in cohort size as the result of population momentum. Children born in Stage 3 experience declines in both cohort size and family size and face less competition for resources at both the population and family levels. Using a simple model of the demographic transition, we demonstrate the key components of these stages: a race between falling fertility and falling mortality in Stage 1, a race between falling fertility and population momentum in Stage 2, and concurrent declines in cohort size and family size in Stage 3. This model suggests that Stage 2 will be a typical feature of the demographic transition, usually lasting two or three decades.

Seven of the eight countries we examined— Brazil, Costa Rica, Ecuador, Mexico, Kenya, South Africa, and Vietnam—moved into Stage 2 long enough ago that we see a clear decline in the number of surviving siblings for children aged 9–11 between the two most recent censuses. In Brazil, where we have census data back to 1960, we see a movement from Stage 1 to Stage 2 sometime in the 1960s or 1970s. For the other countries it is impossible to tell when they moved from Stage 1 to Stage 2 in the absence of comparable microdata for earlier years. However, in all cases we know there had to be a Stage 1, since there had to be a period in which family size increased in order to create the rapid population growth and resulting population momentum seen in all seven countries. We also know that these seven countries had moved from Stage 1 to Stage 2 by at least the 1990s, and probably well before then. Uganda is the exception to the rule, with the 1991 and 2002 censuses showing identical numbers of surviving siblings for children aged 9–11.

While seven of the eight countries had entered the stage in which we observe declines in the number of surviving siblings for school-age children by the 2000 census round, only Brazil had entered Stage 3, the stage in which this decline is matched by a decline in the absolute number of school-age children. UN estimates suggest that Costa Rica, Mexico, South Africa, Vietnam, and Ecuador will have entered this stage by 2010, while Kenya and Uganda will continue to have rapid growth of the 9–11 age group until after 2035.

Declines in the absolute numbers of 9–11-year-olds have come later than the decline in the number of surviving siblings of 9–11-year-olds in all the countries we considered. This is the pattern we would expect from our model of the demographic transition. Declines in surviving family size are a necessary condition for declines in cohort size. While it is not a mathematical necessity that cohort size will continue to grow for some period after family size declines, we believe the basic patterns shown for these eight countries will be typical of most other countries during their demographic transition. Specifically, there will be a period of two or three decades in which school-age children experience declining numbers of siblings but increasing numbers of same-age children in the population. Most countries in East Asia and Latin America experienced this stage during the 1970s, 1980s, and into the 1990s. As shown by Lam and Marteleto (2005), it was not until declining family size was accompanied by declining cohort size in the 1990s that Brazil began to experience significant rates of improvement in educational attainment. As shown in Table 1, many countries are experiencing their peak number of 9–11-year-olds during 2000–09. While these children compete with the largest cohort sizes ever born in their countries, they have significantly fewer siblings than did their parents.

The implications of these changes in family size and cohort size depend on the interaction between these two variables and such outcomes as schooling, health, and eventually labor market experience. How children fare on a given outcome during each stage of the transition depends on the impact of family size versus cohort size for that outcome. Child health and nutrition may be more affected by competition with siblings than by competition with other members of the cohort, although provision of clinics and other services may be affected by cohort size. Schooling may be more affected by rapid growth of cohorts than by competition with siblings. During the two or three decades of the demographic transition that most countries spend in Stage 2, children benefit from reduced competition for resources inside the family, but face increased competition at the population level. In terms of schooling, the cohort growth during this stage may imply larger class sizes, crowded schools, and lower funding per pupil. It is critical to take these dynamics into account in order to understand the trends in education in the many countries that have just moved from Stage 2 to Stage 3. These dynamics are even more important for understanding the educational challenges faced by many African and South Asian countries that will have continued cohort growth for several more decades.

Notes

Support for this research was provided by the US National Institutes of Health (NICHD Grant Number R01HD031214, Fogarty International Center Grant Number D43TW00657), the Mellon Foundation, and the Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq), Brazil. A previous version of this paper was presented at the XXV International Population Conference of the International Union for the Scientific Study of Population, Tours, France, July 2005.

1 A valuable review of this literature is provided in the National Academy of Sciences' report, *Growing Up Global* (Lloyd 2005). See also Jones (1971), Lloyd (1994), and Kelley (1996, 2001).

2 For simplicity we use $p(t)$ to indicate survival to childbearing age. Infant mortality is by far the major component of this survival, especially during the early part of the demographic transition, so changes in infant survival will be a reasonably good proxy for changes in $p(t)$.

3 As pointed out by Preston (1976), if there is variance in fertility across women, then the mean family size of children will be larger than the mean family size of women. We abstract from this discrepancy in this analysis, but analyze the issue in detail in Lam and Marteleto (2008).

4 We use the term "population momentum" in a broader sense than it is usually used. The term generally refers to the fact that a population continues to grow for some time after replacement fertility has been reached. We use it to refer to the fact that the number of surviving births continues to increase after surviving family size declines,

the result of increasing numbers of women of childbearing age. As we will see, cohort size begins to decline in the countries we analyze before replacement fertility has been reached, the result of the short-run dynamics from the competition between falling fertility and increasing numbers of childbearing-age women. We use the term population momentum to describe the component of the dynamics that is driven by increasing size of the childbearing population resulting from higher fertility rates in the past.

5 Ryder (1975) pointed out that dependency ratios in the population need not move in the same direction as dependency ratios within families for reasons similar to the points we make here.

6 Although Uganda's high fertility has persisted throughout the last decades, some predict that the prospects for a future fertility decline are high because of high HIV/AIDS prevalence and because of evidence of fertility decline among urban, better-educated women (Blacker et al. 2005).

7 The growth rates of family size in Figure 2 are for the ten-year period surrounding each point. For example, the point for 1955 is based on the rates of growth of fertility and child survival between the 1950–55 period and the 1955–60 period.

8 The size of the childbearing population is calculated by weighting the number of women in each age group by the contribution each age group makes to overall fertility, using an average age-specific fertility schedule for Brazil around 1980. We use this weighting scheme rather than simply taking the number of women aged 15–44, in order to more accurately reflect the impact of changing age structure on the actual childbearing population. In practice the growth rates in Figure 3 are almost identical if we use the number of women aged 15–44 or some alternative weighted aggregation of those age groups.

9 This decomposition is similar in approach to Bongaarts and Bulatao's (1999) decompositions of future population growth into components related to fertility, mortality, and population momentum. While they decompose the change in total population between 2000 and 2010, our model decomposes the growth rate of surviving births over short intervals. It is important to do the analysis over short intervals since the growth rates of the components change sign during the demographic transition.

10 Although Costa Rica and Ecuador have populations below 25 million in 2005, we include them in Table 1 since they are two of the eight countries we analyze in detail throughout the article.

11 As is usual in census data, children are linked to their mothers using the relationship of children to the household head. With the exception of female-headed households, this requires assumptions about whether the head's wife is the mother of the head's children. We have excluded cases in which the wife is not plausibly the child's mother, but inevitably there are likely to be some errors in matching.

12 As mentioned in endnote 3, the mean family size of children does not necessarily track the mean family size of women. The differences in family size of children and family size of women during the demographic transition are analyzed empirically in Lam and Marteleto (2008). Here we focus only on family size from the perspective of children.

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