Family Size of Children and Women during the Demographic Transition

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Prepared for the 2008 Annual Meetings of the Population Association of America
New Orleans, Louisiana
April 2008

Date of Draft: April 10, 2008

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ABSTRACT

We analyze the links between declines in the family size of women and declines in the family size of children during the demographic transition. We extend Preston's (1976) model in two ways. First, we derive the relationship between the variance of women's family size and children's family size. Second, we analyze family size from the perspective of children of a given age rather than women of a given age. This complicates the analytical model, but the key insights of Preston's results still hold. The mean family size of school-aged children can be approximated by a simple function of the mean and coefficient of variation of fertility for women born 15-40 years earlier. We apply the framework to micro-census data from a number of countries, and show that mean family size for children is a surprisingly constant multiple – around 1.2 to 1.6 – of the mean family size of women across a wide range of countries and time periods. With a few interesting exceptions, it appears that the mean family size of women and children fall at roughly the same rate during the demographic transition.

INTRODUCTION

Rapid fertility decline in most of the developing world has been accompanied by rapid declines in the family size of school-aged children. These declines in children's family size may in turn have led to increased resources for children at the household level. While a link between falling fertility and falling family size for children may seem inevitable, the actual dynamics of this link depend on the change in the variance of fertility. This fundamental demographic point, elegantly demonstrated by Preston (1976), has generally been neglected in discussions of changing family size in developing countries. The goal of this paper is to expand on Preston's result and look empirically at the relationship between declining family size for women and declining family size for children in a number of developing countries throughout the demographic transition.

We begin with a brief review of the literature looking at links between family size and schooling in developing countries. We then discuss Preston's model, extending it in two directions. First, we derive the relationship between the variance of children's family size and the variance of women's family size. Second, we look at family size from the perspective of children of a given age, rather than women of a given age. As we will see, this is a somewhat more complicated problem than the one analyzed by Preston, but nonetheless leads to some simple analytical expressions that can be applied to micro-data. We then analyze changes in family size of women and children in a number of developing countries, using census data from the IPUMS-International project (Minnesota Population Center, 2008). We show that the ration of children's family size to women's family size is surprisingly constant across time and across countries, a result of the fact that the coefficient of variation of women's family size stays within a fairly narrow range. While mean family size of children tends to fall at roughly the same rate as the mean family size of women during the demographic transition, there is a divergence in the variance of family size between women and children. The standard deviation of women's family size falls at roughly the same rate as the mean, but the standard deviation of children's family size falls very little as fertility declines.

RESEARCH ON FAMILY SIZE AND SCHOOLING

Numerous researchers have considered the possible effects of family size on resources available to children, with particular focus on their impact on schooling. As pointed out in the recent National Academy of Sciences' report, *Growing up Global* (Lloyd, 2005), and in earlier reviews by Lloyd (1994) and Kelley (1996), this literature has produced mixed results. Most empirical studies on educational attainment in developing countries have found that children from large families attain less schooling than children with fewer siblings (Ahn, Knodel, Lam, and Friedman 1998; Knodel and Wongsith 1991; Lam and Marteleto, 2005, Marteleto 2001; Parish and Willis 1993, Patrinos and Psacharopoulos 1997, Psacharopoulos and Arriagada, 1989). This is often attributed to a dilution of resources, 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 education (Chernichovsky 1985; Hossain 1988; King et al 1986; Mueller 1984), a result that Kelley (1996) argues could be theoretically plausible if there were large economies of scale in the production of human capital within families. As emphasized in the review by King (1987), whatever the relationship between family size and schooling observed in the data, giving a causal interpretation to the association is difficult, since fertility and children's schooling are choices made jointly by parents.

The purpose of this paper is not to provide any new evidence on the impact of family size on children's outcomes, but to analyze how the family size of school-aged children changes during the demographic transition. Given the rapid declines in fertility in most developing countries in recent decades, and given the potential importance of family size for children's outcomes, we find it surprising that there has not been more systematic analysis of the dynamics of family size from a child's perspective during these fertility declines.

In previous work we analyzed how changes in family size are related to changes in cohort size during the demographic transition (Lam and Marteleto 2005, 2008). We point out that during part of the demographic transition there is a period in which family size is falling while cohort size is increasing. Not until fertility decline catches up with population momentum do both family size and cohort size begin to decline. In this paper we focus on another aspect of changes in family size that we believe has received inadequate attention – the relationship between the family size of women and the family size of children. As Preston pointed out more than three decades ago, the family size of children can change at a different rate than the family size of women (Preston, 1976). Given the dramatic changes in both mean fertility and the distribution of fertility during the rapid fertility declines in developing countries, it is instructive to analyze how those changes are related to changes in the family size of children.

FAMILY SIZE OF CHILDREN AND FAMILY SIZE OF WOMEN

Preston (1976) derived expressions for the mean family size for women of a given age, say 45-49, and contrasted this with the mean family size for the children of those women. Restating his result, if $\bar{s}_W$ is the mean surviving family size for women and $\bar{s}_C$ is the mean surviving family size of their children, Preston derived the surprisingly simple result that

$$\bar{s}_C = \bar{s}_W + \left(\frac{\sigma_W^2}{\bar{s}_W} \right), \qquad (1)$$

where σ_W is the standard deviation of family size for women. A convenient restatement of this result for our purposes is:

$$\bar{s}_C = \bar{s}_W \left(1 + \frac{\sigma_W^2}{\bar{s}_W^2} \right) = \bar{s}_W (1 + CV_W{}^2), \qquad (2)$$

where CV_W is the coefficient of variation of surviving family size for women. Equation (2) says that the mean family size of children will be greater than the mean family size of women by a multiple that is equal to 1 plus the squared coefficient of variation in women's family size. In other words, mean family size for children will always be greater than mean family size for women as long as there is any variation in women's fertility. Looking at historical data from the United States, Preston observed that the variance in fertility falls more rapidly or less rapidly than mean fertility during different stages of fertility decline, causing movements in children's family size that may differ in important ways from movements in fertility. In a recent application to Cambodia, Neupert (2005) shows that the mean family size of children is about 25% higher than the mean family size of women aged 45-49 in 1998.

The divergence between the family size of women and the family size of children may be important in understanding the dynamics of family size for school-aged children during the demographic transition. While we will expect average family size of school-aged children to fall as fertility falls, Preston's result is a warning that the relationship between falling fertility for women and falling family size for children is not necessarily a simple one. It is at least a theoretical possibility, for example, that in some periods there could be a decline in women's fertility that is not accompanied by a decline in the average family size of their children. Looking at Equation (2), this could happen if the decline in mean family size for women were offset by an increase in the coefficient of variation. This would require an increase in the variance coinciding with a decrease in the mean, an unlikely but theoretically possible scenario. Conversely, and more plausibly, mean family size of children could fall without a decline in mean family size of women if there were a decrease in the variance of fertility. The restatement of Preston's result in Equation (2) is helpful since it decomposes the change in children's family size into two components, one reflecting the change in mean fertility and one reflecting the change in the dispersion of fertility as measured by the coefficient of variation. We will use these two components as the framework for our empirical analysis below.

Although Preston's analysis focused on historical U.S. data, he pointed out some important implications of his results for developing countries. Preston found that the average family size of women fell by 53% between 1890 and 1950, while the average family size of children only fell by 37% over the same period. The reason for the discrepancy is that the standard deviation in women's fertility fell more slowly than mean fertility over this period. In terms of Equation (2), the coefficient of variation increased, partially offsetting the decline in women's mean family size. Preston suggested that this might be a typical pattern during fertility decline, with fertility falling faster among some groups than others. The resulting increase in dispersion would cause children's mean family size to fall more slowly than women's mean family size during the demographic transition. As Preston put it, "These patterns are a disconcerting precedent for those concerned with issues of population quality in less developed countries; the pace of reductions in family size for children can be expected to lag behind that for women in the process of fertility transition" (1976: 108). While Preston's argument is compelling, and is consistent with historical U.S. data, we will see below that there is surprisingly little evidence of this phenomenon in the countries we analyze. Family size for children tends to fall at roughly the same rate as family size for women as fertility declines. In at least one interesting case where the rates diverge, children's family size actually declines at a faster rate than women's family size.

Another of Preston's interesting results using U.S. data was a difference in the distribution of family size for whites versus nonwhites. Preston found that the difference between the family size of women and the family size of children was much greater for nonwhites than for whites, a result of the fact that non-white women had higher mean-adjusted dispersion in fertility than white women. In terms of Equation (2), the coefficient of variation in women's family size in

1970 was 1.0 for nonwhites and 0.76 for whites. An implication of this difference that is highlighted by Preston is that the mean family size of nonwhite children was 50% higher than the mean family size of white children, even though the mean family size of nonwhite women was only 19% higher than the mean family size of white women. Preston suggested that the greater mean-adjusted dispersion for nonwhites might be due to higher unwanted fertility for nonwhite women. This has important potential implications for developing countries. We might expect to see similar kinds of differences between rural and urban families or between rich and poor families in developing countries as Preston observed between whites and nonwhites in the U.S. Specifically, we might expect to see that the rural-urban gap in family size of children is larger than the rural-urban gap in family size of women. This might, in turn, exacerbate the rural-urban schooling gap. Below we will look at this issue in detail for the case of Brazil, where we can look at differences by race, region, and mother's education. Surprisingly, we find no evidence of the kind of disparities observed by Preston. The racial gap in family size is actually smaller for children than for women in Brazil in most years, the opposite of Preston's result for the U.S.

The variance in family size of women and children

If family size has a significant impact on children's outcomes then we may be interested in what happens to the variance in children's family size as well as the mean. One important question would be whether the variance in children's family size tends to increase or decrease during the demographic transition. Another important question is how the variance in children's family size differs across population subgroups. Building on Preston's simple result for the mean of family size, it is interesting to consider whether there is some analogous relationship between the variance of family size for women and the variance of family size for children. Not surprisingly, just as the relationship between the mean of children's family size and the mean of women's family size depends on the variance of family size for women, the relationship between the variance of children's family size and the variance of women's family size depends on the skewness of family size for women. Specifically,

$$\sigma_C^2 = \sigma_W^2 \left[1 + CV_W (S_W - CV_W)\right], \tag{3}$$

where S_W is the skewness in women's family size.[1]

The result in Equation (3) is somewhat less intuitive than Preston's result for the mean, but some important points can be made. If the distribution of women's family size is symmetric, an assumption that is not entirely unrealistic in high fertility regimes, then Equation (3) reduces to $\sigma_C^2 = \sigma_W^2 \left[1 - CV_W^2\right]$. This means that we need to impose a restriction that $CV<1$ (implying that the standard deviation is less than the mean) in order to avoid a negative variance whenever $S=0$. The inherent connections between the distribution of children's family size and the distribution of women's family size do impose such a restriction. As shown in the appendix, since women's family size has a lower bound of zero, the standard deviation of women's family size must be less than the mean whenever the distribution is symmetric (in the limiting case, half the women have zero children, half the women have $2\overline{s}_W$, S_W =0, CV=1, and $\sigma_C^2 = 0$). Note from Equation (2) that the restriction that $CV<1$ in turn implies that the mean family size of children can never be greater than double the mean family size of women.

Most empirical distributions of women's family size have positive skewness, although the skewness tends to be fairly small and lower than the coefficient of variation in high fertility populations. This implies that the variance in children's family size is smaller than the variance in women's family size in early stages of the demographic transition, a pattern we will see below. When fertility declines the skewness of women's family size tends to increase,

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[1] For a random variable *x*, skewness is defined as $S = \sum f(x)\left(x - \overline{x}\right)^3 / \sigma^3$. $S=0$ implies a symmetric distribution. $S>0$ implies that the right tail falls off less rapidly than the left tail. $S<0$ implies that the left tail falls off less rapidly than the right tail.

eventually surpassing the coefficient of variation (which, as we will see below. stays relatively constant during fertility decline). This can cause the variance in children's family size to exceed the variance in women's family size. We explore these issues in our empirical analysis below.

Family size of school-aged children

The previous results, like the original analysis of Preston, focuses on the family size of women in a given age range (Preston used 45-49), comparing their average family size to the average family size of their children. If we are interested in the family size of school-aged children during the demographic transition, we will want to consider a somewhat different version of the question addressed by Preston. The children of women aged 45-49 cover a broad age range extending from roughly 5 to 30. We are also interested in focusing on children in a narrower age range, say 9-11, and looking at the relationship between the family size of those children and the family size of some corresponding group of women who represent the potential mothers of those children. As we will see, this is a somewhat more complicated problem, although the main insights of Preston's result still apply.

Looking at the problem from the standpoint of children of a given age would be simple if women had all of their children at some particular age μ, with some women having more children than others. In that very unrealistic case, Equation (2) would provide an exact characterization of the relationship between the family size of children born in a given year and the family size of women who give birth in that year (women age μ). More realistically, we must recognize that the children born in a given year have mothers who span a wide age range. If we are interested in tracking something like the mean family size of school-age children, the problem becomes more complicated than in Preston's results. If we are interested in the mean family size of children age 10 in 1980, the mothers of those children could have ranged in age from roughly 25 to 49, representing the experience of a wide range of cohorts. Assume that we can define a group of women who could be considered the potential mothers of children who are age 10 in 1980. All women age 25 to 49 in 1980 might be considered to have been at risk of having a 10-year-old child in 1980 (although women in the middle of the age range are much more likely to have done so than those on the extremes), so this is one logical candidate for the relevant group of women. We can then analyze how the mean family size of women age 25-49 in 1980 compares to the mean family size of children age 10 in 1980.

Note that the family size of the *mothers* of children aged 10 will correspond almost exactly to the family size of the children themselves. When we take children of a single age we do not observe the phenomenon discussed by Preston. Preston's result is driven by the fact that a broad age group of children (such as children of women aged 45-49) will over-represent children born in large families. Mothers with eight children will have eight times as many children included in the calculation of children's mean family size as mothers with one child. This will not happen in a sample of 10-year-old children. With the minor exception of twins and other multiple births, each mother of a 10-year old will have only one 10-year-old child, so the family size of 10-year-old children will be the same as the family size of the *mothers* of 10-year-old children. These mothers, however, are not a random sample of all women. They over-represent women with large numbers of children, since those women are more likely to have children of any given age[2]. If we want to understand how changes in the family size of 10-year-old children compare to changes in fertility, we cannot look simply at the mothers of those children, but must look at the fertility of women of a broader age range. If we consider an approximate childbearing span of

[2] In the extreme case, women with no children are never represented among mothers of children of any given age. More generally, the mothers of children of a given age will be more likely to include mothers with large numbers of children. This generates the point commonly demonstrated in statistics and demography courses that "the average child is not from the average family" (Jenkens and Tuten, 1992).

age 15 to 40, then women aged 25 to 49 would be an approximate representation of the potential mothers of 10-year-old children in a given year. We can then compare how changes in the fertility of women aged 25-49 compares to changes in the family size of children aged 10.

As we will see below, empirically it turns out to be the case that the relationship between the mean family size of 10-year-old children and the mean family size of women aged 25-49 can be roughly approximated by the following variation on Equation (2):

$$\overline{s}_{C(10)} \approx \overline{s}_{W(25-49)}\left[1+CV^2_{W(25-49)}\right]. \qquad (4)$$

Equation (4) states that the mean surviving family size of children aged 10 is roughly equal to the product of the mean surviving family size of women aged 25-49 and a term equal to 1 plus the squared coefficient of variation in family size for women aged 25-49. Unlike Preston's result, or its restatement in Equation (2), this is not an exact equality since children aged 10 do not represent all children born to women aged 25-49. They are just one single-year age group drawn out of the children of these women. The intuition behind the expression is in some ways the inverse of the logic behind Preston's result. When we look at children of a single year of age, their mothers are not a random sample of all women, but are overly representative of women who have large numbers of children. The larger the variance in women's fertility, the larger the gap between the average family size of children and the average family size for all women. Although Equation (4) is not an exact equality, it turns out empirically to be a simple and surprisingly accurate approximation, and provides a convenient way of summarizing the relationship between trends in fertility and trends in children's family size.

EMPIRICAL RESULTS

In order to look at changes in family size we require micro data from censuses or surveys at multiple points during the demographic transition in a given country. We will begin by looking at family size from the perspective of women aged 45-49 and the children of those women, following the approach of Preston. We will also look at family size from the perspective of school-aged children in a narrow age range. Age 10 is a somewhat arbitrary but quite interesting age because it represents an age at which most children would be expected to 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 age 7-14 in order to focus on something that is closer to a single birth cohort, providing a better match to the model summarized in Equation (4).

Since we will focus on narrow age groups we need large data sets in order to generate large cell sizes. Our analysis draws on large public use census samples from several 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 data for a number of other countries taken from the Integrated Public Use Microsamples – International (IPUMS-I) project of the University of Minnesota (Minnesota Population Center 2007). Our choice of countries is driven by the availability of large census samples, and is admittedly not a representative sample of countries. These countries are used in order to explore the dynamics of family size using high quality data, and not because they are necessarily the most typical or representative countries. The countries represent most parts of the developing world and reflect a considerable range of demographic experience. Latin America is the best represented, with data for Brazil, Chile, Colombia, Costa Rica, Ecuador, Mexico, and Venezuela. These countries represent the major features of the demographic transition in Latin America. Vietnam is the only Asian country for which we have more than one period of time, but we also include China, Cambodia, and the Philippines in our analysis. In Africa w include Kenya, Rwanda, South Africa, and Uganda.

Family size in Brazil 1960-2000

We begin with the case of Brazil, the country for which we have detailed census data spanning the longest time period. Brazil's demographic transition is fairly typical of those across the developing world. Fertility began a rapid decline in the 1960s, falling to about 2.3 by 2000. The fertility decline occurred during a period of rapid social change that included periods of both economic growth and economic crisis (Martine 1996, Lam and Duryea 1999). There was large regional variation in fertility decline in Brazil, with fertility decline starting later in the poorer northeast region than it did in the higher income southeast region. We will use these two regions as a point of comparison below.

Table 1 analyzes the family size of women aged 45-49 and the family size of their children using Brazilian census data from 1960 to 2000. We include a number of statistics in order to walk through the key components of the mean and standard deviation of family size for women and children. We use both children ever born and children surviving in Table 1. It is useful to begin with children ever born since that was the measure used by Preston (1976) for his analysis of historical United States data. The first row shows that mean number of children ever born for women aged 45-49 fell from 6.3 to 3.6 between 1960 and 2000, with most of the decline taking place after 1980. The second and third rows show that the standard deviation fell at almost exactly the same rate as the mean, with the result that the coefficient of variation remained in a relatively tight range between 0.72 and 0.77 for the entire period. Since, as shown in Equation (2), the mean family size of children is equal to the mean family size of women times one plus the squared coefficient of variation, the fact that the coefficient of variation is roughly constant means that children's family size will closely track women's family size. Line 4 shows the skewness in womens' family size, which rises from 0.6 in 1960 to 1.5 in 2000. As shown in Equation (3), this plays an important role in driving the variance in children's family size.

Line 5 of Table 1 shows the mean family size for children of women aged 45-49. This is calculated by taking the distribution of children ever born for women aged 45-49 and applying

Equation (2). As shown in Line 6, mean family size for children is around 1.5 to 1.6 times the mean family size for women in every year from 1960 to 2000, a result of the narrow range of the coefficient of variation in women's family size in line 3. While the relative constancy of this ratio during a period of rapid fertility decline is surprising, we will see below that it is typical of the ratios we see for a wide range of countries and time periods. It is interesting that the mean family sizes for women and children in Brazil in 1980 are similar to the levels reported by Preston for the United States 1890 census. Preston estimated a mean number of children ever born for women aged 45-49 of 5.0, and a mean family size for their children of 7.8, for a ratio of 1.6. The equivalent numbers in Table 1 for Brazil in 1980 are 5.4 and 8.1, for a ratio of 1.5.

Lines 7 and 8 of Table 1 show the standard deviation and coefficient of variation of children's family size. While the standard deviation of women's family size fell between 1960 and 2000, the standard deviation of children's family size actually increased. Since the mean was falling, the coefficient of variation of children's family size increased substantially over the period, rising from 0.4 in 1960 to 0.7 in 2000. As shown in Equation (3), this is directly related to the rapid increase in the skewness of the distribution of women's family size.

Rows 9-16 show the same statistics using women's reports of children surviving at the time of the census. Since most child mortality will have occurred in infancy, the number of children surviving is more relevant than the number of children ever born in affecting the resources available to children within the family. We will therefore focus on surviving children in the rest of the paper. One of the surprising results in Table 1 is that the ratio of children's family size to women's family size is very similar whether we use children ever born or children surviving. Looking at Line 11, we see that the coefficient of variation in women's surviving family size remained almost constant at around 0.7 for the entire period from 1960 to 2000, very similar to the results in Line 3 for children ever born. As a result, the mean of children's surviving family size is about 1.5 times the mean of women's surviving family size in every year.

Recalling Preston's results for the United States, there is little evidence in Table 1 that children's family size declined more slowly than women's family size during the demographic transition in Brazil. This is in many ways a surprising result. The fact that the coefficient of variation in women's family size remains roughly constant over 40 years of rapid fertility decline suggests that fertility fell at a much more even rate across the full distribution of family sizes than we might have expected based on diffusion models of fertility decline. The fertility decline essentially takes place at roughly the same rate at all family sizes, with the result that children's family size falls at almost exactly the same rate as women's family size. We are not sure why the pattern observed by Preston for the U.S. is not observed in Brazil, but we will see below that Brazil's pattern is similar to that of the other countries we consider.

Graphical analysis of the distribution of family size for women and children helps illustrate the dynamics of family size during the demographic transition. The top panel of Figure 1 plots the distribution of surviving family size for women aged 45-49 in Brazil from 1960 to 2000. The figure shows the large shift to the left as fertility declines. While only about 10% of women had two children in the 1960 census, almost 25% had two children in the 2000 census. While we know from Table 1 that the standard deviation falls at roughly exactly the same rate as the mean from 1960 to 2000, we can see the increasing skewness of the distribution as fertility declines.

The bottom panel of Figure 1 shows the distribution of surviving family size for the children of women aged 45-49. These are essentially reweighted versions of the distributions in the top panel, where the weighting is based on the number of children. We see, for example, that while the mode of the distribution in 1960 in the top panel was 2 children, the mode in 1960 in the bottom panel is 8 children. While only 4% of women had a family size of 10 in 1960, 8% of children had a family size of 10. If we look at the cumulative distributions (not shown), only

14% of women aged 45-49 had a family size of 8 or more in 1960, while 32% of children of those women had a family size of 8 or more.

Brazil is a good country in which to look for the other pattern observed by Preston for the United States – the fact that the racial gap in children's family size was larger than the racial gap in women's family size. Brazil is well known as a country with high inequality in most dimensions, including race and region. Table 2 presents comparisons of family size for women and children by region, race, and mother's education. The top panel presents estimates of mean family size for the poorer northeast region and the richer southeast region. Comparing column 1 and column 4, we see that mean women's family size is higher in every period in the northeast. Surviving family size actually increased in the northeast between 1960 and 1970, evidence of the impact of improvements in infant and child mortality.[3] Column 3 shows that the ratio of children's family size to women's family size in the northeast is very close to 1.5 in every period, almost identical to the ratio seen for the full country in Table 1. Column 6 shows that the ratio is very similar in the southeast in every period, again around 1.5. Column 7 shows the regional gap in mean family size of women. The mean family size of women is about 15% higher in the northeast than in the southeast in 1960. This gap increases to 50% in 1960, an indication that fertility fell sooner and faster in the southeast than in the northeast. Column 8 shows the same gap for the family size of children. The regional gap in children's family size is almost identical to the regional gap in women's family size. This is in contrast to Preston's analysis of racial differences in family size in the U.S., where children's family size was 1.5 times larger for nonwhites but women's family size was only 1.2 times large for nonwhites.

[3] See Lam and Marteleto (2008) for discussion of the race between falling fertility and falling mortality in determining surviving family size during early stages of the demographic transition.

The second panel of Table 2 shows comparisons between whites and nonwhites. About 55% of Brazilians classify themselves as white in most censuses.[4] Race was not collected in the 1970 census. Family size falls faster for whites than for nonwhites from 1960 to 2000. As shown in column 7, family size of women was only 5% higher for whites than nonwhites in 1960, a reflection of higher infant mortality for nonwhites. Women's family size is 35% higher for nonwhites than for whites in 2000. As with the regional comparison, the racial gap in children's family size is almost identical to the racial gap in women's family size in every year. Once again we see no evidence of the phenomenon observed by Preston in the United States. Children's family size actually declines somewhat faster than women's family size for both whites and nonwhites, as indicated by the fact that the ratio of children's family size to women's family size falls from 1.5 in 1960 to 1.35 in 2000 for both groups. This indicates that the coefficient of variation in women's fertility fell over time for both whites and nonwhites. This is intriguing, since we do not see this same compression for the whole population. The result suggests that there is some compression of fertility within races that is offset by the increasing divergence in mean fertility between races.

The bottom panel of Table 2 shows comparisons between women with low education (less than four years of schooling) and those with high education (four years or more). We take this is a rough proxy for general socio-economic status (SES). In this case we do see some difference between the SES gap in women's family size and the SES gap in children's family size. The direction is the opposite of the differential observed by Preston in the U.S., however. The gap between high-SES and low SES family size for children is *smaller* than the SES gap for women's family size in 1960, 1970, and 1980. This suggests that mean-adjusted dispersion in

[4] The breakdown in the 2000 census is 53% white, 39% brown (pardo), 6% black (preto), 0.4% Asian, 0.4% indigenous, and 0.7% unknown.

fertility was smaller among less educated women with high fertility than it was among better educated women with low fertility. By 2000 this differential has disappeared – the SES gap in women's family size is the same as the SES gap in children's family size. Another implication of these patterns is that family size fell faster for high-SES children than for low-SES children. For children with better educated mothers, mean family size fell by 32% between 1960 and 2000. For children with less educated mothers, mean family size fell by only 14%.

Family size of women and children in other countries

We now look at the same kinds of measure in a large number of other countries. Table 3 shows the mean and standard deviation of women's family size and children's family size for women aged 45-49 in 15 developing countries for which we can get estimates of surviving family size in the IPUMS-International census data. We repeat the results for Brazil in the table to facilitate comparisons across countries. In 11 of the countries we have estimates for more than one time period. In several cases the data cover three decades of rapid fertility decline. The mean family size of women aged 45-49 falls from 4.4 in 1970 to 2.8 in 2002 in Chile, from 5.6 in 1973 to 3.4 in 2000 in Costa Rica, and from 5.2 in 1974 to 3.9 in 2001 in Ecuador. One of the striking features of Table 3 is that the ratio of the mean family size for children to the mean family size of women, shown in column 3, is clustered in the range of 1.2 to 1.5. Looking across time periods within a given country, the ratio shows relatively little change, indicating that the standard deviation in women's family size tends to fall at roughly the same rate as the mean.

The top panel of Figure 2 shows a scatterplot of the ratio in column 3 plotted against the mean women's family size in column 1. The figure shows the relatively narrow range of the ratio of children's family size to women's family size. There is no strong relationship between this ratio and the mean of women's family size, although there is some evidence that the ratio is somewhat lower when fertility is higher. This implies that the coefficient of variation in women's family size tends to increase as fertility falls. This is in contrast to the pattern suggested by Preston's U.S. results, in which the standard deviation of women's family size fell more slowly than the mean as fertility declined.

Columns 4 and 5 of Table 3 show the standard deviation in family size for women and children, with column 6 showing the ratio. In this case there are much clearer trends over time, as was the case for Brazil in Table 1. While the standard deviation of women's family size tends to fall at roughly the same rate as the mean, the standard deviation of children's family size falls much slower than the mean, often staying constant or even increasing over time. In Ecuador, for example, while the standard deviation of women's family size falls 3.3 to 2.5 from 1974 to 2001, the standard deviation in children's family size rises from 2.4 to 2.7. Looking at the ratio of the two in column 6, the ratio tends to be well below 1.0 at high levels of fertility, then rises to above 1.0 at lower levels of fertility. This is shown graphically in the bottom panel of Figure 2, which plots the ratio against women's mean family size. The explanation of how the standard deviation of children's family size can increase while the mean and standard deviation of women's family size are decreasing is the increased skewness in women's family size as fertility declines during the demographic transition. As demonstrated in Equation (3), increasing skewness tends to increase the standard deviation in children's family size, especially since the coefficient of variation in women's size remains relatively constant.

Family size of school-aged children

If we are interested in the impact of family size on an outcome like schooling, it probably makes more sense to look at family size for children of a given age, rather than to look at family size of all children born to mothers of a given age. As discussed above, this is a somewhat more complicated problem than the one originally analyzed by Preston (1976). Equation (4) provides a useful approximation that links the family size of potential mothers of 9-11 year-olds to the family size of children aged 9-11.

Table 4 looks at all women aged 25-49, a group that will encompass most of the mothers of children aged 9-11, as well as mothers of children of many other ages. We use a selected set of the countries used in Table 3, focusing on countries for which we have at least two observations and for which we have sufficient family relationship detail to link children with their mothers. Instead of simply calculating the distribution of family size for children using the distribution of family size for women, as was done in the previous sections, we directly estimate the family size for children aged 9-11. These estimates are based on the number of surviving children reported by the mothers of 9-11 year-old children in each census.[5] Column 1 shows the mean number of surviving children to women aged 25-49. Column 2 uses Equation (2) to calculate the mean surviving family size for children of these women, exactly the same calculation that was done for women aged 45-49 in Tables 1 and 2. Column 3 shows the mean surviving family size of 9-11 year-olds, based on the number of surviving children born to their mothers.

An important feature of Table 4 is the similarity of the numbers in column 2 and column 3. This indicates that Equation (4) is a very close approximation – the mean family size of 9-11 year-old children is very close to the mean family size of children of women aged 25-49. One way to think of this is that while 9-11 year-olds represent only one small set of the children born to women aged 25-49, they are roughly a representative sample of all children born to women aged 25-49, at least in terms of family size. We will consider the comparison of column 2 and 3 as having established that Equation 4 is an accurate approximation, and we will proceed with comparisons of the family size of 9-11 year-olds with the family size of women aged 25-49.

[5] 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 there are inevitably likely to be some errors in matching.

This consistency gives us a convenient way to compare changes in fertility with changes in the family size for children. We will use the mean family size of women aged 25-49 as an indicator of mean fertility at the time our focal children were born, and will compare this to the mean family size of children aged 9-11.

Looking at column 4 of Table 4, we see that the ratio of the family size for children aged 9-11 to the family size of women aged 25-49 stays within a fairly narrow range both within and across countries. The ratio in Brazil is between 1.6 and 1.74 from 1960 to 2000. This means that the average family size of children falls at roughly the same rate as fertility declines over this period of rapid fertility decline. One useful way to think of the ratio in column 4 is as a multiplier for translating fertility decline into declining family size for children, with a 1 child decline in fertility translating into a 1.6-1.7 decline in the number of siblings of school-aged children. In Brazil, the family size of 25-49 year-old women fell by 1.2 between 1960 and 2000, while the family size of 9-11 year-old children fell by 2.1.

In some cases a reduction in the coefficient of variation in women's family size significantly increases the speed at which children's family size declines. In Costa Rica, women's family size fell by 1.5 children between 1973 and 2000, while the number of siblings of 9-11 year-olds fell by 3. If the multiplier in column 4 had remained at its 1973 level of 1.65, children's family size would have fallen by 2.5. More precisely, if we take the total derivative of Equation (2), the change in children's family size can be described as $d\overline{s}_c = d\overline{s}_w(1+CV^2) + 2\overline{s}_w CVdCV$. Using the average of the 1973 and 2000 values for $\overline{s}_W$, $\overline{s}_C$, and *CV*, the first component is 2.4 and the second component is 0.6. In other words, the decline in mean family size of children in Costa Rica between 1973 and 2000 fell was about 80% (2.4 siblings) due to a decline in average fertility of women aged 25-49 and about 20% (0.6 siblings) due to the decrease in dispersion in fertility of women aged 25-49. In most other countries in Table 4, the ratio in column 4 is relatively constant across periods, implying that the change in children's mean family size between periods is almost entirely due to the decline in mean fertility of women aged 25-49.

Columns 5 and 6 of Table 4 show the standard deviation of family size for women aged 25-49 and children aged 9-11. As we saw for women aged 45-49, the standard deviation of women's family size falls at roughly the same rate as the mean when we look across years in any given country. This means that the coefficient of variation of women's family size is roughly constant over time, which we know must be the case from the relatively constant ratios in column 4. The standard deviation of family size for children aged 9-11 does not fall as fast as mean children's family size, however. The ratio of children's standard deviation to women's standard deviation tends to begin below 1 and then rise above 1 over time, consistent with the pattern in Figure 2. The coefficient of variation in children's family size increases over time, and tends to be higher in low-fertility populations. In other words, mean-adjusted dispersion in children's family size tends to increase as fertility declines, even though mean-adjusted dispersion does not increase in women's fertility.

Figure 3 shows the cumulative distributions of family size for women 25-49 and children 9-11 for three countries for which we have at least three periods – Brazil, Costa Rica, and Ecuador. The cumulative distributions provide a detailed summary of the decline in family size for both women and children during the demographic transition. The percentage of Brazilian women aged 25-49 who had less than four surviving children was 55% in 1960. This actually declined slightly in 1970, a reflection of improving child mortality. It then increased rapidly from 1970 to 2000, reaching 80% in 2000. As we have shown, children aged 9-11 are roughly representative of the children of these women. Comparing the panel for children 9-11 with the panel for women 25-49 illustrates the large differences in the family size of women and children. For

Brazilian children aged 9-11, the percentage in families with less than four surviving children was only 19% in 1960 and 1970. This increased to 58% in 2000, similar to the percentage of women with less than four surviving children in 1960.

The distributions in Figure 3 demonstrate how large families continue to be prevalent for children even after they have become relatively rare for women. For example, in Brazil in 2000 only 7% of women aged 25-49 had more than five surviving children, but 20% of children aged 9-11 were in families with over five surviving children. The mathematics that drives the relationship between women's family size and children's family size mean that discrepancies between the two can be very large in the tails of the distribution. In Ecuador in 2001, the proportion of children aged 9-11 in a family with 8 or more surviving children (10.6%) was three times larger than the proportion of women aged 25-49 with 8 or more surviving children (3.2%).

CONCLUSIONS

Preston's (1976) provided an elegant and insightful way of understanding the links between the family size of women and the family size of children. In this paper we have extended his mathematical results in two directions. First, we derived results that link the standard deviation of women's family size with the standard deviation of children's family size. The result, which depends on the skewness of women's family size, is useful in understanding how dispersion in children's family size changes with fertility decline. Second, we analyzed family size from the perspective of children in a narrow age range, rather than looking at all children born to women in some given age range. This is useful in understanding how the family size of school-aged children evolves during the demographic transition.

Several interesting patterns emerge from our empirical analysis of census data from 15 different countries. First, we find a surprisingly constant relationship between the mean family size of women and the mean family size of children. Looking at women aged 45-49, mean family size of their children tends to be in a range of 1.2 to 1.5 times the women's mean family size. This multiplier, which is equal to one plus the squared coefficient of variation of women's family size, is also relatively constant over time within a given country. In Brazil, where our data cover the longest time period, the ratio of the mean family size for children to the mean family size for women is between 1.49 and 1.53 for every year from 1960 to 2000. An important implication of this result is that the mean family size of children falls at roughly the same rate as the mean family size of women as fertility declines during the demographic transition. This is in contrast to Preston's speculation based on the U.S. trends that family size of children would fall slower than family size of women during the demographic transition as a result of increased dispersion in fertility.

A second result is also at odds with one of Preston's results for the United States. While Preston found that the racial gap in children's family size was larger than the racial gap in women's family size, we find no such difference in our analysis for Brazil. Looking at differentials by race, region, and mother's education, we find that the gaps in children's family size are very similar to the gaps in women's family size. While the overall differentials in family size by race, region, and education tend to increase over time, there is no evidence that the gaps in family size for children are larger than the gaps in family size for women. In results not reported here, we find similar results when we look at rural-urban differences in all of the countries for which we have data on rural-urban location.

While the insights of Preston's model demonstrate that we might expect to see children's family size evolve quite differently than women's family size during the demographic transition, it is intriguing that we find the two changing at very similar rates in the diverse set of countries we consider. As Preston shows in historical U.S. data, the standard deviation in fertility might fall much more slowly than the mean during the early stages of fertility decline, then fall at a faster rate in later stages. We might expect that the upper tail of the fertility distribution changes more slowly than the middle of the distribution, causing increased dispersion as mean fertility declines. We find no evidence of these kinds of patterns. Our results suggest that fertility decline has taken place at similar rates across the complete distribution of family sizes, with almost no change in the coefficient of variation over as long as four decades. As a result, children's family size has fallen at the same rate as women's family size.

APPENDIX

An important point in understanding the implications of Preston's original result is that the standard deviation in women's family size must be lower than the mean if the distribution is symmetric, given that fertility has a lower bound of zero. This imposes limits on the possible differences between the mean of children's family size and the mean of women's family size. It also affects the relationship between the variance in women's family size and the variance in children's family size. To see why the condition holds assume that the mean of women's fertility is $\bar{s}_W$, which for a symmetric distribution implies that all observations lie between 0 and $2\bar{s}_W$. This implies that $\sigma^2 = \sum_0^{2\bar{s}_W} f(x)x^2 - \bar{s}_w^2$, and means that we can focus on a comparison of the mean of the squared *x* values and the squared mean.

Consider two possible extreme cases for the distribution of *x* over the interval $[0, 2\bar{s}_W]$. The first is that all the mass is located at the mean, $\bar{s}_W$. In this case $\sum_0^{2\bar{s}_W} f(x)x^2 = \bar{s}_w^2$, implying that the variance is zero. It is easy to show that any symmetric redistribution of *x* values away from the mean causes an increase in the sum of squared *x* values. The most extreme case that preservers symmetry and maximizes the sum of squared *x* values is to put half the mass at zero and half the mass at $2\bar{s}_W$. In that case we get $\sum_0^{2\bar{s}_W} f(x)x^2 = 2\bar{s}_w^2$ (the average of zero and $4\bar{s}_W^2$), implying that $\sigma = \bar{s}_W$. In this case the variance in children's family size is zero, the limiting case of Equation (3). For any symmetric distribution that has less than half the distribution at $2\bar{s}_W$, the sum of squared *x* values will be smaller, implying that $\sigma < \bar{s}_W$. Given Equation (2), this implies that the mean family size of children will be less than double the mean family size of women for any symmetric distribution. As discussed in the text, the distribution of women's family size is never literally symmetric, since there will almost almost be some mass beyond $2\bar{s}_W$. In practice, however, the distributions have relatively low skewness in high fertility populations.

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Table 1. Family size of women aged 45-49 and family size of their children, Brazil 1960-2000

Measure	1960	1970	1980	1991	2000
All Brazil - Children ever born					
1 Mean number of children ever born, women 45-49	6.29	5.99	5.30	4.80	3.63
2 Standard deviation, women's family size	4.58	4.34	3.88	3.55	2.80
3 Coefficient of variation, women's family size	0.73	0.72	0.73	0.74	0.77
4 Skewness, women's family size	0.58	0.70	0.84	1.05	1.50
5 Mean family size for children of women 45-49	9.63	9.13	8.14	7.43	5.79
6 Ratio, children's family size/women's family size	1.53	1.52	1.54	1.55	1.59
7 Standard deviation of children's family size	4.09	4.25	4.18	4.31	4.29
8 Coefficient of variation of children's family size	0.43	0.47	0.51	0.58	0.74
All Brazil - Children surviving					
9 Mean number of surviving children, women 45-49	4.65	4.73	4.44	4.17	3.31
10 Standard deviation, women's family size	3.34	3.35	3.14	2.90	2.40
11 Coefficient of variation, women's family size	0.72	0.71	0.71	0.70	0.73
12 Skewness, women's family size	0.51	0.59	0.67	0.88	1.27
13 Mean family size for children of women 45-49	7.05	7.10	6.67	6.19	5.06
14 Ratio, children's family size/women's family size	1.52	1.50	1.50	1.49	1.53
15 Standard deviation of children's family size	2.83	3.08	3.05	3.26	3.35
16 Coefficient of variation of children's family size	0.29	0.34	0.37	0.44	0.58

**Table 2. Surviving family size for women aged 45-49 and their children,
Brazil 1960-2000, by region, race, and mother's education**

Year	Northeast			Southeast			Northeast/Southeast	
	Mean for women	Mean for children	Ratio (2)/(1)	Mean for women	Mean for children	Ratio (2)/(1)	Women (1)/(4)	Children (2)/(5)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1960	4.94	7.50	1.52	4.28	6.64	1.55	1.15	1.13
1970	5.18	7.64	1.48	4.23	6.57	1.55	1.22	1.16
1980	5.01	7.43	1.48	3.97	6.09	1.53	1.26	1.22
1991	5.15	7.32	1.42	3.52	5.32	1.51	1.46	1.38
2000	4.23	6.28	1.49	2.81	4.19	1.49	1.50	1.50
	Nonwhite			**White**			**Nonwhite/White**	
Year	**Mean for women**	**Mean for children**	**Ratio (2)/(1)**	**Mean for women**	**Mean for children**	**Ratio (2)/(1)**	**Women (1)/(4)**	**Children (2)/(5)**
1960	4.81	7.30	1.52	4.56	6.91	1.51	1.05	1.06
1980	4.71	7.11	1.51	3.94	6.16	1.56	1.19	1.16
1991	4.66	6.80	1.46	3.53	5.39	1.53	1.32	1.26
2000	4.22	5.79	1.37	3.12	4.24	1.36	1.35	1.37
	Mother low education			**Mother high education**			**High ed/Low ed**	
Year	**Mean for women**	**Mean for children**	**Ratio (2)/(1)**	**Mean for women**	**Mean for children**	**Ratio (2)/(1)**	**Women (1)/(4)**	**Children (2)/(5)**
1960	5.03	7.31	1.46	3.39	5.68	1.68	1.48	1.29
1970	5.18	7.43	1.43	3.51	5.71	1.63	1.48	1.30
1980	4.99	7.15	1.43	3.56	5.53	1.55	1.40	1.29
1991	5.02	6.99	1.39	3.23	4.79	1.48	1.55	1.46
2000	4.34	6.27	1.44	2.71	3.89	1.44	1.60	1.61

Note: Mother's education low is less than 4 years of schooling; high is 4 years of schooling or more.

Table 3. Mean and standard deviation of surviving family size for women aged 45-49 and their children

		Mean Family Size			Standard Deviation		
		Women	Children	Ratio	Women	Children	Ratio
Country	**Year**	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Brazil	1960	4.65	7.05	1.52	3.34	2.83	0.85
Brazil	1970	4.73	7.10	1.50	3.35	3.08	0.92
Brazil	1980	4.44	6.67	1.50	3.14	3.05	0.97
Brazil	1991	4.17	6.19	1.49	2.90	3.26	1.12
Brazil	2000	3.31	5.06	1.53	2.40	3.35	1.39
Cambodia	1998	4.50	6.02	1.34	2.62	1.91	0.73
Chile	1970	4.40	6.13	1.39	2.76	2.64	0.96
Chile	1982	4.28	5.82	1.36	2.57	2.98	1.16
Chile	1992	3.09	4.43	1.44	2.04	2.50	1.23
Chile	2002	2.80	3.55	1.27	1.45	1.80	1.24
China	1982	4.51	5.21	1.16	1.78	1.46	0.82
Colombia	1973	5.46	7.72	1.42	3.52	2.83	0.80
Colombia	1985	5.25	6.85	1.31	2.90	2.94	1.01
Colombia	1993	4.36	5.86	1.35	2.56	3.07	1.20
Costa Rica	1973	5.56	8.27	1.49	3.88	3.03	0.78
Costa Rica	1984	5.11	7.16	1.40	3.23	2.83	0.88
Costa Rica	2000	3.42	4.82	1.41	2.19	2.73	1.25
Ecuador	1974	5.22	7.32	1.40	3.31	2.38	0.72
Ecuador	1982	5.49	7.17	1.31	3.04	2.51	0.83
Ecuador	1990	4.79	6.57	1.37	2.92	2.44	0.84
Ecuador	2001	3.85	5.48	1.42	2.50	2.70	1.08
Kenya	1989	6.23	7.83	1.26	3.16	2.57	0.81
Kenya	1999	5.85	7.37	1.26	2.98	2.39	0.80
Mexico	1990	5.05	6.93	1.37	3.08	2.63	0.85
Mexico	2000	4.36	6.08	1.40	2.74	2.83	1.03
Philippines	1990	4.71	6.24	1.33	2.69	2.30	0.86
Rwanda	1991	5.83	6.94	1.19	2.54	1.87	0.74
Rwanda	2002	5.09	6.16	1.21	2.33	1.76	0.75
South Africa	1996	3.49	4.86	1.39	2.19	2.21	1.01
South Africa	2001	3.26	4.60	1.41	2.09	2.18	1.04
Uganda	1991	5.22	6.95	1.33	3.00	2.06	0.69
Uganda	2002	5.74	7.39	1.29	3.07	2.29	0.74
Venezuela	1990	4.94	7.04	1.43	3.22	3.01	0.93
Vietnam	1989	4.64	5.97	1.29	2.49	2.09	0.84
Vietnam	1999	3.51	4.71	1.34	2.05	1.95	0.95

Table 4. Mean and standard deviation of surviving family size for women aged 25-49 and children aged 9-11

		Mean Family Size				Standard Deviation		
		Women age 25-49	Children of women 25-49	Children age 9-11	Ratio (3)/(1)	Women age 25-49	Children age 9-11	Ratio (6)/(5)
Country	**Year**	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**
Brazil	1960	3.55	5.78	5.96	1.68	2.81	2.72	0.97
Brazil	1970	3.77	5.95	6.03	1.60	2.87	2.80	0.98
Brazil	1980	3.17	5.34	5.50	1.74	2.62	2.78	1.06
Brazil	1991	2.82	4.69	4.61	1.64	2.29	2.64	1.15
Brazil	2000	2.39	3.96	3.88	1.62	1.94	2.42	1.25
Costa Rica	1973	4.14	6.72	6.84	1.65	3.27	3.03	0.93
Costa Rica	1984	3.23	5.09	4.96	1.54	2.45	2.76	1.12
Costa Rica	2000	2.61	3.93	3.84	1.47	1.86	2.00	1.07
Ecuador	1974	4.03	6.03	6.21	1.54	2.84	2.48	0.87
Ecuador	1982	3.89	5.62	5.69	1.46	2.59	2.54	0.98
Ecuador	1990	3.23	5.02	5.00	1.55	2.40	2.40	1.00
Ecuador	2001	2.76	4.33	4.31	1.56	2.08	2.30	1.10
Kenya	1989	4.57	6.20	6.23	1.36	2.73	2.49	0.91
Kenya	1999	3.95	5.74	5.58	1.41	2.66	2.46	0.92
Mexico	1990	3.35	5.24	5.12	1.53	2.51	2.58	1.03
Mexico	2000	2.96	4.67	4.63	1.56	2.25	2.44	1.08
South Africa	1996	2.55	3.91	4.10	1.61	1.86	2.00	1.07
South Africa	2001	2.37	3.71	3.79	1.60	1.78	1.86	1.05
Uganda	1991	4.06	5.67	5.78	1.42	2.56	2.31	0.90
Uganda	2002	4.42	5.95	5.78	1.31	2.60	2.37	0.91
Vietnam	1989	2.88	4.40	4.53	1.57	2.09	1.93	0.92
Vietnam	1999	2.37	3.53	3.48	1.47	1.66	1.66	1.00

Figure 1. Distribution of family size of women aged 45-49 and their children, Brazilian censuses 1960-2000

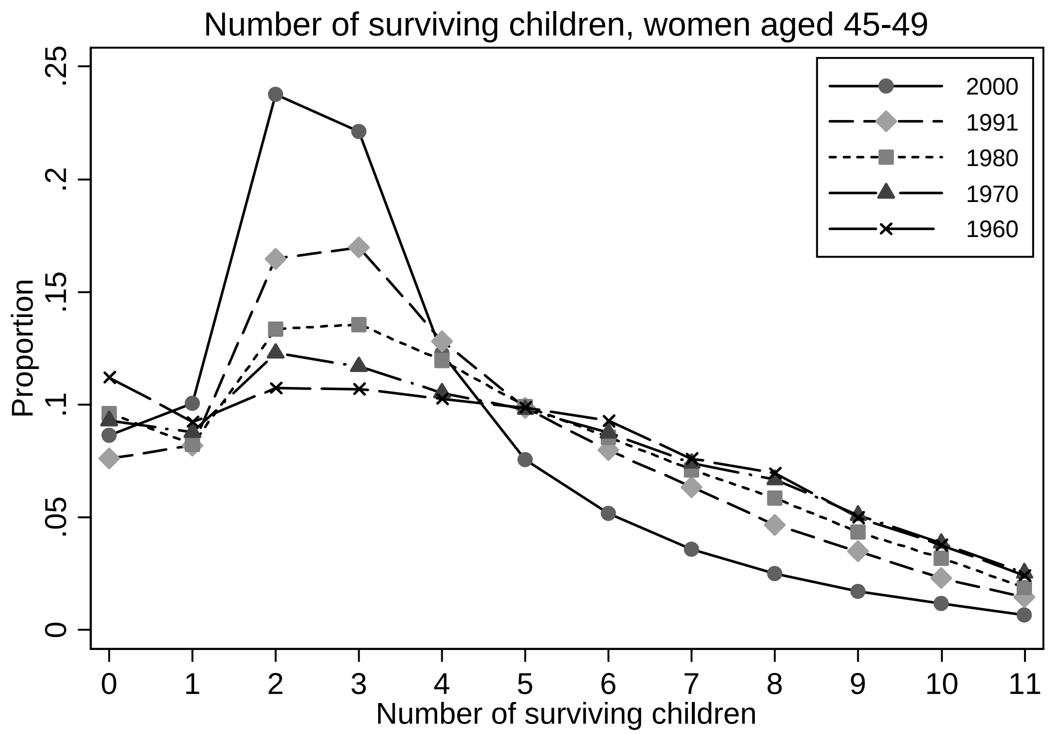

Figure 2. Surviving family size of women aged 45-49 and their children, Countries and years in Table 3

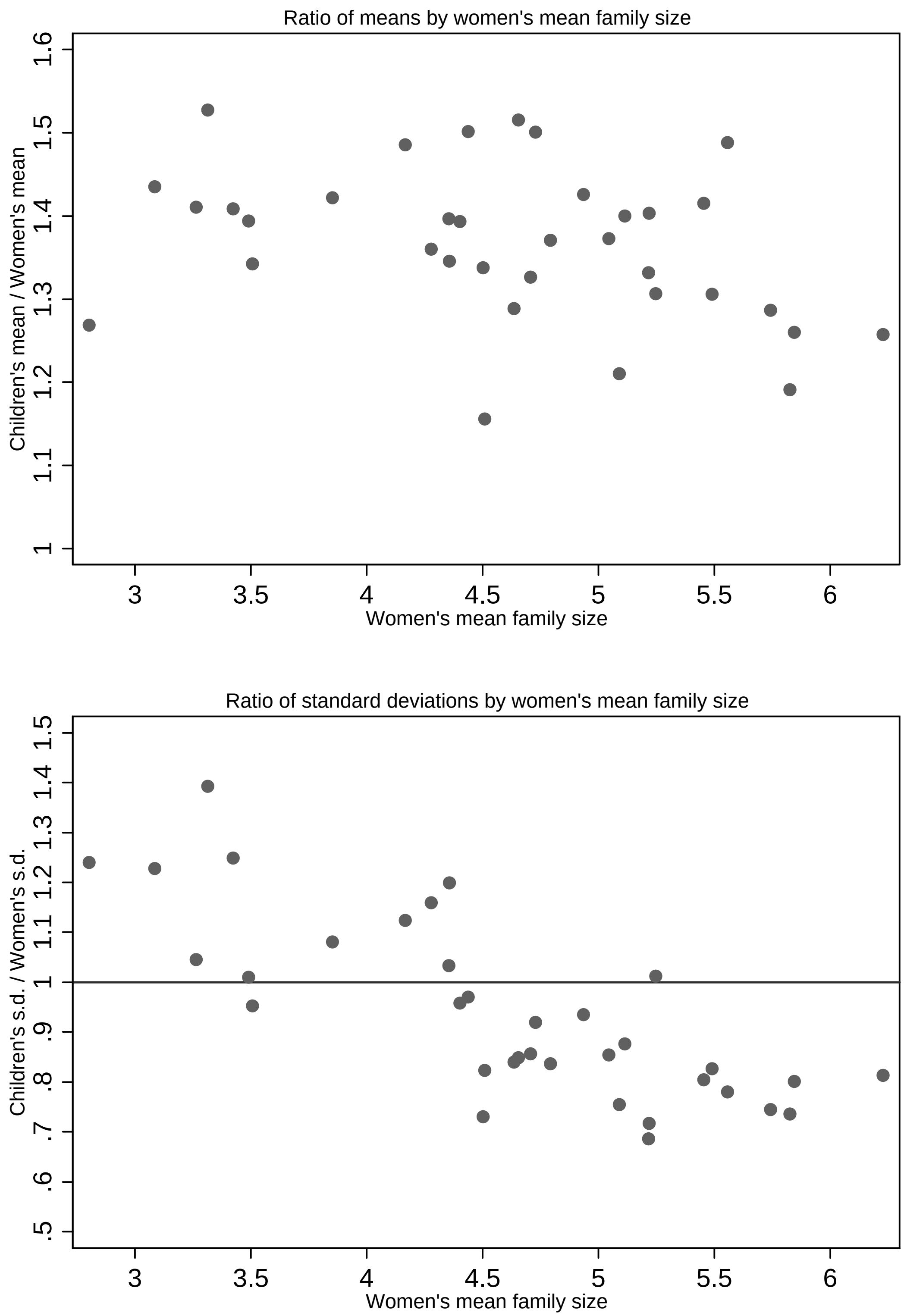

Figure 3. Distribution of family size, women 25-49 and children 9-11