J Popul Econ 19:71–97 (2006)
DOI 10.1007/s00148-005-0018-y

ORIGINAL PAPER

Rodrigo R. Soares

The effect of longevity on schooling and fertility: evidence from the Brazilian Demographic and Health Survey

Received: 2 August 2004 / Accepted: 9 December 2004 / Published online: 26 October 2005

Abstract This paper presents microevidence on the effect of adult longevity on schooling and fertility. Higher longevity is systematically associated with higher schooling and lower fertility. The paper looks at the 1996 Brazilian Demographic and Health Survey and constructs an adult longevity variable based on the mortality history of the respondent's family. Families with histories of high adult mortality in previous generations have systematically higher fertility and lower schooling. These effects are not associated with omitted variables and remain unchanged after a large array of factors is accounted for (demographic characteristics, family-specific child mortality, regional development, socioeconomic status, etc.).

Keywords Longevity · Schooling · Fertility

JEL Classification I10 · I20 · J13

Responsible editor: Junsen Zhang

This paper benefited from comments from Gary Becker; Roger Betancourt; Daniel Hamermesh; Steven Levitt; Kevin Murphy; Tomas Philipson; two anonymous referees; and seminar participants at the Universidade Nova de Lisboa, University of Chicago, University of Maryland-College Park, University of Texas-Austin, and LACEA 2002 (Madrid). Financial support from the *Conselho Nacional de Pesquisa e Desenvolvimento Tecnológico* (CNPq, Brazil) and the Esther and T.W. Schultz Endowment Fellowship (Department of Economics, University of Chicago) is gratefully acknowledged. The usual disclaimer applies.

R. R. Soares (✉)
University of Maryland, 3105 Tydings Hall, College Park, MD 20742, USA
Fax: +1-301-4053542, E-mail: soares@econ.umd.edu

R. R. Soares
Catholic University of Rio de Janeiro, Rio de Janeiro, Brazil

1 Introduction

This paper presents individual-level evidence on the effect of adult longevity on schooling and fertility. Higher longevity is systematically related to higher educational attainment and lower fertility. These effects seem to come from two sources: first, gains in adult longevity increase the returns to education, which tends to increase educational investments and reduce fertility via the quantity–quality trade-off; and second, longevity also has an independent direct effect on fertility, which can be understood as coming from the substitutability between number of children and lifetime of each child.

Adult longevity has been pointed out as a possible candidate to reconcile the behavior of fertility in developed countries with economic theory. Countries as culturally diverse as Austria, Canada, Greece, Japan, and Spain have experienced continuous fertility declines, although the total fertility rate is already extremely low (below 1.5 in all cases). Since infant mortality rates are also arbitrarily low in some of these countries, traditional explanations that rely on child mortality changes do not seem to apply. At the same time, from the point of view of theory, adult longevity has gained increased attention as an important determinant of the demographic transition and of the behavior of fertility and schooling thereafter (see Bils and Klenow 2000; Kalemli-Ozcan et al. 2000; Soares 2005). The potential empirical relevance of these theoretical arguments is further supported by recent evidence suggesting that subjective assessments of life expectancy are considerably accurate and react to exogenous events in consistent ways (see Hurd and Mcgarry 1997; Smith et al. 2001).

Cross-country evidence supports the central role of adult longevity predicted by theory. Soares (2003) uses a cross-country panel to show that countries experiencing faster gains in adult longevity also experience faster increases in educational attainment, faster reductions in fertility, and higher economic growth. This result holds after child mortality, old age mortality, income, and country and time fixed effects are taken into account and also after adult longevity is instrumented. His estimates imply that a 10-year gain in adult longevity is usually associated with a reduction of 1.7 points in fertility and an increase of 0.7 year in average schooling. Similar results are obtained by Lorentzen et al. (2004). In the same direction, Kalemli-Ozcan (2001) shows that the spread of AIDS in Africa, which was mostly associated with increases in adult mortality, had a positive impact on fertility. After controlling for a series of factors (female schooling, urbanization, infant mortality, income per capita, and time and country fixed effects), increases in HIV contamination rates were associated with increases in fertility. Simulation exercises performed by Bils and Klenow (2000) and Kalemli-Ozcan et al. (2000) also confirm the role of life expectancy in explaining cross-country differences in schooling, productivity, and fertility.

All these results are probably in part behind the well-known effect of longevity on savings and growth, traditional in the empirical growth literature (summarized and discussed in detail in Barro and Sala-i-Martin 1995). From an international perspective, it is undeniable that there is mounting suggestive evidence indicating that longevity may be an important determinant of the long-run behavior of the economy.

Nevertheless, at present, there is no microlevel study confirming the effects of longevity estimated in the cross-country literature.[1] The goal of this paper is to provide such evidence in relation to schooling and fertility. The most difficult challenge in this direction is to obtain individual specific measures of life expectancy or mortality that are exogenous and have enough variation within the sample.

We use the 1996 Brazilian Demographic and Health Survey to construct a proxy for adult longevity that is based on the mortality history of the previous generation of the respondent's family. We then analyze how this variable is related to a woman's decisions regarding her own education and number of children. Ideally, this variable captures family characteristics—maybe related to genetics—that reveal information about the woman's life expectancy that is otherwise unobservable to the researcher and, in some cases, previously unobservable to the woman herself.[2]

The paper shows that women born in families that experienced higher adult survival end up with a higher level of schooling and with fewer children. These results hold even after a large array of factors is accounted for and do not seem to be generated by omitted variables nor by imperfect measures of income and wealth. In fact, they remain virtually unchanged once we control for the following characteristics of the woman: education (in the case of fertility), family-specific child mortality (history from the previous generation), socioeconomic status (household characteristics), state of residence, total number of siblings (or fertility in the previous generation), occupation, working status, and job characteristics, among others.

Once age is accounted for, changes in our proxy for adult survival explain between 3.1 and 2.2% of the variation in educational attainment in the sample and between 3.7 and 2.5% of the variation in complete fertility. These numbers should not be regarded as particularly small since our goal here is simply to present microlevel evidence that longevity has an independent effect on fertility and schooling. We do not claim that, in any given country at a point in time, adult longevity is the main determinant of cross-sectional variations in these two variables. Indeed, the exogenous variation in adult longevity in such a setting is small, so the results should not be surprising. In addition, since Brazil has a high degree of income inequality and great regional and population heterogeneity, there are certainly many other factors that affect the cross-sectional distribution of fertility and schooling. Nevertheless, the results support the idea that, once large exogenous changes in adult longevity take place due to technological advances in medical and biological sciences, we should also expect to observe changes in schooling and fertility.

---

[1] Bleakley and Lange (2003) show that the eradication of hookworm disease in the American South was associated with increases in school attendance and literacy and reductions in fertility. Nevertheless, hookworm disease was in general associated with morbidity rather than mortality and seemed to have a direct effect on the costs of investments in human capital. Ram and Schultz (1979) analyze, in the case of India, the effects of health interventions on schooling and productivity, but it is also likely that morbidity was an important issue in this case. Our focus here is on the effects of longevity on the incentives to invest in human capital, from the perspective of its impacts on the horizon of productive life.

[2] Existing evidence suggests that the most important event determining updates in individuals' assessments of their own life expectancies is the death of a relative (see Hamermesh 1985; Hurd and Mcgarry 1997; Smith et al. 2001).

The remainder of the paper is structured as follows. Section 2 summarizes the theoretical arguments linking adult longevity to educational attainment and fertility and discusses the empirical specification of the model. Section 3 describes the 1996 Brazilian Demographic and Health Survey, the variables used, and the general features of the data. Section 4 discusses the main concerns in the estimation of the model. Section 5 presents and analyzes the results. The final section concludes the paper.

2 Theory and specification

2.1 Theoretical arguments

This section summarizes the theoretical arguments linking longevity to fertility and educational attainment. Typically, these arguments relate expected longevity (or probability of survival) to certain levels of desired lifetime investments in human capital and lifetime completed fertility. The next section discusses the empirical specification of this type of relation, when the only kind of information available is fertility observed up to a given age.

The most basic effect of adult longevity in terms of incentives faced by individuals is probably the one related to human capital investments. As adults live longer and their productive horizon is enhanced, the period over which the gains from investments in human capital can be reaped is extended. Therefore, the rate of return to investments in human capital increases and educational attainment tends to rise. This very simple mechanism is explored in Kalemli-Ozcan et al. (2000) and Tamura (2001), where the long-run consequence of higher longevity in terms of income and growth rates is discussed.

Once the effect of longevity on investments in human capital is acknowledged, it is natural to infer that the change in educational attainment will bring together an indirect effect on fertility via the opportunity cost of children and the traditional quantity–quality trade-off.[3] Galor and Weil (1999) discuss informally the possibility of this indirect effect of adult mortality on fertility. This quantity–quality interaction is also behind the reduction in fertility triggered by adult longevity gains, which characterizes the transition between the “Malthusian” equilibrium and the steady state with growth in Meltzer (1992). Ehrlich and Lui (1991) explore this relation in another context, where investments of parents in their children are driven mainly by an “old-age support” reason.

Other papers present a somewhat different type of quantity–quality trade-off. Cigno (1998), for example, develops a model where longevity and fertility may move in opposite directions due to the possibility of parental investments in the health and nutrition of children. Zhang et al. (2001) show that, depending on preference parameters, increases in longevity may lead to lower fertility and increased investment in human capital of children. However, the changes in

---

[3] Note that these two potential effects are completely distinct: (1) as adult longevity increases, female schooling rises, increasing the opportunity cost of having children; and (2) as adult longevity increases, the returns to investments in children’s human capital rises, increasing the investments in each child and the shadow price of number of children.

longevity that they analyze are of a different nature, corresponding to increases in the probability of survival from productive life into retirement years (therefore, longevity does not affect directly the rate of return to human capital investments).

In addition to the indirect effect of longevity on fertility through changes in the level of schooling or other types of human capital, evolutionary arguments suggest that longevity should also have a direct effect on fertility, possibly built into preferences. In our case, the two key arguments are: (1) parents care for the life expectancy of children, possibly including ages beyond reproduction; and (2) parents see number of children and lifetime of each child as substitutes. Both arguments derive directly from evolutionary biology (see discussion in Bergstrom 1996; Robson 2001, 2003; Robson and Kaplan 2003; Soares 2005). Intuitively, these assumptions are extensions of the widely accepted effect of child mortality on fertility to later ages. Once one considers that individuals are not only concerned with the survival of their children but also with the continuing survival of their whole lineage, it becomes relevant to know whether the offspring will have enough time to have their own offspring and raise them. As discussed at length by Robson (2003), this type of consideration in an evolutionary context gives rise to a trade-off between number of children and lifetime of each child and generates dominant preferences that regard fertility and life expectancy as substitutes.

Soares (2005) develops a model that brings together several of the dimensions discussed above. In his model, parents care directly for the life expectancy of children and, in addition, invest in their own (adult/productive) human capital and in the human capital of their children (basic human capital). He shows that, in this context, gains in adult longevity increase educational attainment, reduce fertility, and increase the stock of basic human capital given to each child. Gains in adult longevity increase the horizon over which benefits from investments in human capital can be enjoyed, therefore increasing the returns to education. This eventually raises educational attainment and increases the productivity of individuals in the labor market and in the household sector. In addition, higher adult longevity reduces the benefits from having a large number of children, shifting the quantity–quality trade-off towards fewer and better-educated offspring. Lower fertility and higher investments in children and adults lead to faster human capital accumulation and higher growth. In his model, gains in longevity can also trigger the transition from an equilibrium without investments in human capital and no growth to an equilibrium with investments in human capital and the possibility of sustained growth.

The papers mentioned above provide a wide spectrum of arguments linking gains in adult longevity (τ) to increases in educational attainment (e) and reductions in fertility (n). In addition to this, traditional economic analysis also links these variables to child survival (s) and preference and technology parameters (broadly understood, so as to include family income and characteristics, unobserved ability, etc.; from now on, all these factors are summarized by a vector Z). From the individual perspective, we can think of lifetime fertility and educational attainment as being determined ultimately by reduced-form equations of the general type: $n=n(\tau,s,Z)$ and $e=e(\tau,s,Z)$. As argued before, these solutions have the following properties: $\frac{dn}{d\tau} < 0 \; and \; \frac{de}{d\tau} > 0$. Longevity gains reduce fertility and increase educational attainment.

The final goal of this paper is to estimate the functions $n=n(\tau,s,Z)=n(X)$ and $e=e(\tau,s,Z)=e(X)$, for $X=(\tau,s,Z)$. Given the existing and accepted knowledge regarding the relation between child mortality and fertility, our attention is focused on the effects of adult longevity. In addition, since the fertility literature has extensively discussed the role of education in determining fertility decisions, we also look at the effects of longevity on fertility, conditional on educational attainment—as summarized by $n=n(X|e)$.

2.2 Empirical specification

The theories discussed above uncover the effect of adult longevity on educational attainment and ideal lifetime fertility. Educational attainment is a variable that varies over a wide range and for which most of the decisions will be completed for the women included in our sample. Therefore, we use standard OLS techniques in analyzing the determinants of educational attainment. The same will not be possible for ideal lifetime fertility.

Theory explains how the total number of children—or complete fertility—tends to vary with changes in life expectancy. Complete fertility is typically a very small number, which varies discretely within a relatively narrow range. In addition, instead of complete fertility, our data set gives the number of children ever born to a woman of certain age and demographic characteristics. Both these issues raise certain challenges for the estimation of the fertility equation from the theories outlined above.

Traditionally, the empirical literature on the economics of fertility has been concerned mostly with the timing and spacing of births (see, for example, Newman and Mcculloch 1984; Heckman and Walker 1990). The demographic literature has looked specifically at fertility at a point in time as the outcome of some exposure risk and time of exposure (see, for example, Rodriguez and Cleland 1988; Blau and Robbins 1989). This is the approach adopted here and, although the theories and concepts used are quite distinct, the logic underlying our empirical model is similar to the discussion in Rodriguez and Cleland (1988).

In a deterministic setup, a woman's fertility history can always be obtained from the complete lifetime fertility, the interval of time over which this fertility has to occur (fertile period), and the optimal timing of births inside this interval (Newman and Mcculloch 1984). If, additionally, we assume that the ideal timing of births is only a function of the total number of desired births and of the fertile period, these two variables will be enough to represent a woman's fertility history. For simplicity, we maintain this assumption throughout the paper.

Suppose that a woman's fertile period is given by the age interval $[\underline{a}, \bar{a}]$ and the woman's age is given by $a \in [\underline{a}, \bar{a}]$, such that $a = \underline{a} + t$, where $0 \leq t \leq \bar{a} - \underline{a}$. The complete desired family size is given by $\eta=n(X)$, where $n(X)$ is the function discussed in the previous section, and X includes life expectancy measures, demographic characteristics, and other factors.

η is the ideal lifetime fertility of the woman, and this determines her behavior towards fertility throughout life. In a deterministic world, the time of exposure together with the behavior towards fertility would uniquely determine the outcome (number of births) up to a given period. Assume that these factors determining behavior towards fertility up to age $a = \underline{a} + t$ can be summarized by the following function:

$$N = g(\eta, t). \tag{1}$$

In other words, in this deterministic world, the desired number of births and the time of exposure (time within the fertile period) summarize all the relevant information regarding a woman's behavior towards fertility up to that point in her reproductive life.

However, in reality, fertility outcomes are uncertain, and these behavioral factors will simply determine the probability of occurrence of different outcomes at age a. For biological reasons, individuals cannot perfectly control the number and timing of births, and the actual number of births observed up to any given age will be a function of a latent variable $\Upsilon = N + \varepsilon$, where ε is a random term. The actual outcome observed up to any given period (age) will be:

$$\begin{array}{cc}
0 \text{ birth, if} & \Upsilon \leq c_0; \\
1 \text{ birth, if} & c_0 < \Upsilon \leq c_1; \\
2 \text{ births, if} & c_1 < \Upsilon \leq c_2; \\
3 \text{ births, if} & c_2 < \Upsilon \leq c_3; \\
\ldots & \ldots \ldots \ldots \\
m \text{ births, if} & c_{m-1} < \Upsilon \leq c_m; \\
m+1 \text{ birth, if} & c_m < \Upsilon;
\end{array}$$

where $m + 1$ is the maximum number of births possible, and the c's are constant parameters.

The effect of the variables in X on the probability of different outcomes will depend on the functional form of $g(.,.)$ and on the density function of ε. For simplicity, we assume that $g(.,.)$ takes on the simple form $g(\eta(X), t) = X\theta + \delta_t$, where δ_t is an additive age-specific factor. Since the variables in X will affect the number of births via the probability of different outcomes, this nonparametric specification on age allows for a very general nonadditive relation between the marginal effects of X and the age-specific factors. This is a welcome feature of the model, given the dynamic nature of the childbearing process. In addition, this set up explicitly takes into account the discrete nature of fertility outcomes.

Assuming additionally that ε is normally distributed, this model becomes an ordered probit, which can be immediately estimated by standard maximum-likelihood techniques. In this case, the probability of an outcome n at age $a = \underline{a} + t$ is given by:

$$\begin{aligned} \mathrm{P}(n) = \mathrm{P}(c_{n-1} < X\theta + \delta_t + \varepsilon \leq c_n) = \Phi(c_n - X\theta - \delta_t) \\ - \Phi(c_{n-1} - X\theta - \delta_t), \end{aligned} \tag{2}$$

where $\Phi(.)$ is the cumulative function of the normal distribution.

Again, given the nonlinear nature of the probability model, the marginal effects of changes in the independent variables will vary with age (because of the presence of the age-specific constants δ_t's). This amounts to allowing for age-specific marginal effects—or, in other words, interactions with age—for all the variables in X.

3 The data

3.1 The Brazilian Demographic and Health Survey

The data used here are from the 1996 Brazilian Demographic and Health Survey (*Pesquisa Nacional sobre Demografia e Saúde*). This survey follows the standards of the Demographic and Health Surveys conducted worldwide by MEASURE DHS +, a program supported by the Center for Population, Health, and Nutrition (US Agency for International Development/Bureau for Global Programs, Field Support, and Research). The Brazilian survey was executed by BEMFAM. Additional data, related to state per capita income, were obtained from the Brazilian Ministry of Planning.

Brazil is an interesting case for analysis because the demographic transition has been underway for a long time, and significant variation is present due to population heterogeneity. In the end of the 1990s, Brazil was in the last stage of its demographic transition, with health and fertility numbers similar to those of other middle range developing countries. Life expectancy at birth was roughly 68 years, with infant mortality rates (before age 5) equal to 44 per 1,000 and adult morality rates (between ages 15 and 60) equal to 170 per 1,000. At the same time, the total fertility rate had reached 2.3, and the average schooling in the population aged 15 and above was 4.9 years (numbers from the World Bank Development Indicators and the Barro and Lee data set).

The exercise proposed will not try to capture the extent of the changes in fertility experienced by the Brazilian population during the process of demographic transition. Instead, we want to identify one independent source of variation in mortality and show that this variation, no matter how small, is systematically related to choices regarding schooling and number of children. Brazil remains an interesting case from this perspective because the fact that demographic transition has long been underway supports the idea that fertility is being actively chosen and is not set to a corner solution at the maximum number of children possible. In addition, the great diversity of population and geography may help generate enough variation in the family-specific variable within the sample.

Our sample is composed of 12,612 women between ages 15 and 49, from all Brazilian states, and both urban and rural areas. The Demographic and Health Survey contains variables related to observed fertility, individual characteristics, household characteristics, and mortality history of the respondent's family. This last set of variables is of special interest, for it allows the construction of family-specific measures of adult longevity and child mortality. The main drawback of this data set is the absence of any explicit income or wealth variable. In the empirical analysis, we try to overcome this problem by controlling for household characteristics related to its socioeconomic status.

3.2 Variables

The fertility variable used in the analysis is the "number of children ever born to the respondent." To check consistency of the results, the variable "number of children born to the respondent who are still alive" is also used at a later point in the discussion.

The adult longevity variable tries to capture dimensions of adult mortality that are related to family-specific characteristics. The variable is the "survival rate of the respondent's adult siblings." It is defined as the fraction of the respondent's siblings that reached 10 who were still alive at the moment of the interview. This indicates the adult mortality history in the previous generation of the woman's family. Previous studies have consistently shown that death of a relative is the single most important factor determining updates on individuals' life expectancy assessments (see Hamermesh 1985; Hurd and Mcgarry 1997; Smith et al. 2001). Even if this was not the case, siblings' mortality may reveal information available to the individual that would be otherwise unobservable to the researcher. These two possibilities give credit to the key identifying assumption of the estimation: individuals who lost adult siblings tend to have lower assessments of their own life expectancy, be it because they update their expectations due to the event or because the event reveals to the outside observer some condition previously known to the individual (a family condition of genetic origin, for example).

The other variables used include years of education of the respondent (mother) and a number of controls that try to encompass all sorts of factors that affect schooling and fertility decisions and that may be correlated with family-specific factors. Among these, the most important control is probably the "family-specific child survival rate," defined as the fraction of respondent's siblings born who reached 10. This variable is constructed in a way completely analogous to the "family-specific adult survival rate," and it indicates the child mortality history in the previous generation of the woman's family. Other controls include: age; total number of siblings (fertility in the previous generation); demographic characteristics associated with tastes (race, religion, and urban residence); marriage history; fecundity status (menopausal or sterile); work-related variables (whether respondent works, is self-employed, works in an unpaid job, and her occupation); socioeconomic characteristics of the household (whether it has electricity, piped water, flush toilet, and number of cars); and state of residence (fixed effects). The durable goods chosen as household characteristics are more or less ordered in terms of income so as to represent different socioeconomic statuses, as opposed to differences in tastes. What we mean is that the presence in the household of electricity, piped water, a flush toilet, and a car, in this order, denotes increasingly higher socioeconomic statuses. This can be seen from the fact that the vast majority of households with piped water have electricity (99%); the vast majority of households with flush toilet have piped water (92%) and electricity (98%); and the majority of households with at least one car have flush toilet (51%), piped water (86%), and electricity (99%). When using these household variables, we will think of them as representing different socioeconomic groups.

The role of each of these variables will be discussed in later sections. Detailed definitions are contained in the Appendix.

3.3 Descriptive analysis

Table 1 presents basic statistics for all the variables. The typical woman in the sample is 30 years old, has two children, and has 6 years of formal education. She has electricity and piped water in the household, is Christian, had six siblings, lost

20% of her born siblings before they reached ten, and has virtually all siblings who reached 10 still alive (96%).

These average numbers are very much consistent with the aggregate numbers observed in Brazil since the 1960s. The women included in our sample are all above 15 years of age; therefore, the previous generation fertility and child mortality experiences are, in the vast majority of cases, already completed. If we take the average age in the sample to denote the average interval between these generations, we should compare our family-specific child mortality variable and the number of siblings (fertility in the previous generation) to the child mortality and total fertility rates observed in the mid-1960s. Total fertility rate in 1965 was around 6, as compared to the typical family size of 7 in our sample (six siblings plus the respondent). Child mortality before age 5 in that same year was around 160 per 1,000 (or 16%), while our family-specific child mortality has an average value of 20% (remember that we measure child mortality up to age 10). In relation to educational attainment, our sample includes only women between 15 and 49, and since older cohorts tend to have lower educational attainment, average schooling in the sample should be higher than that of all women above 15. This is what we obtain when comparing average schooling in our sample (6 years) with

Table 1 Descriptive summary of variables

Variable	Mean	Standard error of the mean	Observations	Min	Max
Children born	1.94	0.0273	12,612	0	18
Adult survival	0.96	0.0012	11,822	0	1
Child survival	0.80	0.0038	12,315	0	1
Age	30	0.0949	12,612	15	49
Educ	6.5	0.0818	12,608	0	19
Urban	0.82	0.0159	12,612	0	1
Christian	0.92	0.0036	12,559	0	1
Church	0.39	0.0070	12,612	0	1
Black	0.0474	0.0031	12,612	0	1
Mixed	0.5102	0.0089	12,612	0	1
Asian	0.0033	0.0010	12,612	0	1
Nevermar	0.31	0.0051	12,612	0	1
Infecund	0.08	0.0029	12,612	0	1
Number siblings	5.94	0.0565	12,612	0	20
Work	0.51	0.0065	12,591	0	1
Electric	0.95	0.0060	12,594	0	1
Water	0.82	0.0127	12,274	0	1
Toilet	0.47	0.0157	12,563	0	1
Cars	0.38	0.0137	12,576	0	6

Variables are, respectively, number of children born, mother's siblings adult survival rate, mother's siblings' child survival rate, age, mother's years of education, urban residence dummy, Christian dummy, religious service once a week dummy, race dummies (black, mixed, and Asian), never married dummy, infertile woman dummy, number of siblings of the mother, work dummy, electricity in the household dummy, piped water in the household dummy, flush toilet in the household dummy, and number of cars in the household. Means weighted by sampling weights, and standard errors adjusted for survey clustering the 1995 average years of education in the female population aged 15 and above (4.2 years) from the Barro and Lee data set. Finally, given that the typical woman in the sample is relatively young from the perspective of adult mortality experiences, the history of mortality of her adult siblings gives a picture somewhat different from that obtained in the aggregate data (96% adult survival rate, against 83% survival rate between ages 15 and 60 in 1995, from the World Bank Development Indicators).

Table 2 presents pair-wise correlations between the main variables. The typical relation between fertility and standard socioeconomic variables is present in the raw data: women with higher educational attainment, living in urban areas, and with higher wealth (as captured from the household characteristics) have, on average, lower fertility. Furthermore, more developed areas have lower average fertility, and families with higher child mortality history have higher fertility. These correlations are widely accepted in the profession, both empirically and theoretically.

However, we want Table 2 to stress a couple of additional points that will be very important in the following discussion. First, in principle, the indicators of family-specific mortality can be somewhat endogenous to the socioeconomic variables. Women born in richer families could experience lower siblings'

Table 2 Correlations between main variables

	Children born	Adult survival	Child survival
Adult survival	−0.17		
	0.00		
Child survival	−0.12	0.11	
	0.00	0.00	
Age	0.60	−0.22	0.02
	0.00	0.00	0.09
Educ	−0.38	0.09	0.22
	0.00	0.00	0.00
Urban	−0.16	0.01	0.09
	0.00	0.23	0.00
Electric	−0.15	0.01	0.08
	0.00	0.28	0.00
Water	−0.13	0.02	0.06
	0.00	0.08	0.00
Toilet	−0.11	0.00	0.08
	0.00	0.66	0.00
Cars	−0.12	0.03	0.13
	0.00	0.00	0.00
ln(GDP)	−0.75	0.04	0.60
	0.00	0.83	0.00

Pair-wise correlations. Numbers below correlation coefficients are p values. Variables are, respectively, number of children born, mother's siblings' adult survival rate, mother's siblings' child survival rate, age, mother's years of education, urban residence dummy, electricity in the household dummy, piped water in the household dummy, flush toilet in the household dummy, number of cars in the household, and state per capita GDP. No weights used. For ln(GDP), correlations calculated with respect to the within-state averages of the other variables (27 observations) mortality both at early and older ages. This factor is partly responsible for the correlations between family-specific child mortality and education and wealth mentioned above. However, the correlation between family-specific adult mortality and these same variables is rather weak: family-specific adult mortality is only significantly correlated with one of the four household characteristics (cars), and the correlation is quantitatively very small (0.03). Furthermore, while the correlation between regional development and family child survival is very strong (0.6) and significant, the correlation between state GDP and family adult survival is very small (0.04) and far from significant (*p* value of 0.83).

In other words, even in the raw data, there seems to be little correlation between adult survival and the other variables. The exceptions are precisely the ones predicted by theory: fertility and educational attainment. This is quite different from what the table suggests in terms of child survival. Child survival is strongly correlated with all the variables that are related to income and wealth and particularly so with the level of regional development. In short, while family-specific child mortality seems to be highly affected by socioeconomic status, family-specific adult mortality seems to be largely independent of it. This supports our reading of the latter variable as revealing family-specific characteristics—maybe related to genetics—that affect adult longevity. In terms of the analysis to be performed later on, this evidence indicates that the endogeneity of adult survival should not be much of a concern.

4 Estimation

We start with very basic specifications, which follow closely the theoretical discussion in Section 2. In this initial specification, educational attainment and the latent variable determining the probability of different fertility outcomes ($N=g(\eta, t)=X\theta+\delta_t$) are functions only of adult longevity, child mortality, and taste and technology parameters. After that, we include additional variables to account for possible endogeneity problems and check the robustness of the results to different alternative hypotheses. We discuss these in detail when the results are presented in the next section. The basic equations estimated are the following:

$$\text{educ} = \phi_0 + \phi_1\text{adult survival} + \phi_2\text{child survival} + \text{demographics} + \psi_t + \omega; \tag{3}$$

and

$$\begin{aligned}\text{P(child born} = n) = \text{P}(c_{n-1} \leq \theta_0 + \theta_1\text{adult survival} \\ +\theta_2\text{child survival} + \text{demog} + \delta_\text{t} + \varepsilon \leq \text{c}_\text{n});\end{aligned} \tag{4}$$

where educ is number of years of schooling; child born is the number of children ever born to the respondent; adult survival is the family adult survival rate; child survival is the family child survival rate; demog include dummies for race, religion, urban residence, and, in the case of fertility, marriage history and fecundity status; ψ_t and δ_t are age-specific constants (fixed effects); and ω and ε are random terms. The fertile period for every woman is assumed to be between ages 15 and 49, so that the whole sample is used in the estimation. The demographic variables included in the basic specification account for racial, cultural, and biological factors that may be thought to affect educational and fertility outcomes.

The variables measuring schooling, fertility, and family-specific adult survival are naturally correlated with age since older individuals are more likely to have completed their educational investments, to have children, and to have lost siblings. Since the specification already includes age effects (35 age dummies), this issue should not be a problem. In addition, as mentioned before, the nonlinearity of the distribution function in the fertility model allows for marginal effects of the independent variables that are age-dependent. In other words, the inclusion of age dummies in this context amounts to allowing for nonadditive marginal effects of age, as if interaction terms (of age with the other independent variables) were included. This is a nice feature of the model, considering the dynamic nature of the childbearing process (exogenous variables should have distinct effects in the different moments of the life cycle).

Following the basic specification, we introduce several additional controls. In the fertility equation, we first introduce a control for the mother's educational level (educ). Female education has been extensively studied as one of the main determinants of fertility, in a context where women are endowed with a level of education strictly exogenous to fertility decisions. From a broader perspective, this cannot be an accurate picture of reality: long-term plans—such as educational investments and fertility choices—are made simultaneously, in light of lifetime prospects and preferences. Therefore, observed correlations do not fully reflect causation. Nevertheless, although education is an endogenous variable in the theory discussed in Section 2, its inclusion in the right-hand side also constitutes an interesting exercise from the perspective of our model. Estimating the relation between adult longevity and fertility conditional on schooling can help distinguish between the direct effect of longevity on fertility (via the substitutability hypothesis) and the indirect effect (through educational attainment, and the ensuing quantity–quality trade-off). Generally, we can decompose the effect of longevity on fertility as

$$\frac{dn}{d\tau} = \frac{\partial n}{\partial \tau} + \frac{\partial n}{\partial e}\frac{de}{d\tau}. \tag{5}$$

The first effect is the direct impact of longevity on fertility, determined by the substitutability between number of children and lifetime of each child. The second effect is similar to the quantity–quality trade-off common in the traditional fertility literature, which appears here due to the increase in educational attainment that follows increases in longevity. Including educational attainment in the equation, we can tell how much of the effect estimated in the basic specification comes from the direct impact of longevity on fertility and how much comes from the indirect impact via education.

It is important to stress that this is indeed a very strong test of the model since theory does predict that longevity should affect educational attainment, and, therefore, this variable is endogenous. Controlling for educational attainment, we could partly capture effects ultimately due to longevity since the former is certainly better measured than the latter.

Other variables included in the education and fertility equations try to control for potential sources of bias. They consist of variables reflecting socioeconomic status of the household (electric, water, toilet, and cars), regional development (state-fixed effects), fertility in the previous generation (number siblings), and, in the case of fertility, working status (work, self, unpaid, and occupation fixed effects). The different alternative hypotheses are discussed in detail in the next section.

In all the results reported, regressions are weighted by sampling weights, and standard errors are adjusted for survey clustering (for details on these issues, see Deaton 1997).

5 Results

5.1 Main results and robustness

Table 3 presents the results of OLS regressions of years of education on adult longevity (adult survival) and a large set of controls (Eq. 3). In the largest specification, controls include age fixed effects, family-specific child mortality, socioeconomic characteristics of the household, urban residence dummy, demographic variables related to religion and race, number of siblings, and state fixed effects. Family-specific adult longevity has a positive and significant effect on educational attainment. The results show that women born in families with higher longevity tend to have higher educational attainment. The other independent variables are also significant and have the expected effects. The inclusion of the wealth-related variables in the regression reduces the magnitude of the longevity coefficient by roughly 20%, but leaves the statistical significance unchanged. This hints at the presence of credit constraints limiting investments in human capital, as is commonly believed to be the case in developing countries. Therefore, it seems to be the case that the relation between adult longevity and educational attainment captures, to some extent, the effect of family wealth on investments in education. However, specification 4 shows that, even after socioeconomic characteristics are controlled for, there still remains a significant effect of adult longevity on educational attainment. In addition, the quantitative effect of adult longevity is reduced only by a modest magnitude as wealth-related variables are introduced. This is quite different from what happens with the coefficient on child survival. The coefficient on child survival is reduced by more than 60% once the health related variables are accounted for. As before, child mortality seems to be much more sensitive to family wealth than adult mortality.

The control variables also generate some interesting results, which illustrate the degree of inequality in Brazilian society. For example, individuals in the highest socioeconomic group in our sample—corresponding to someone who has a car and lives in a household with electricity, piped water, and flush toilet—have, on average, an advantage of 4.4 years of education over someone in the lowest socioeconomic group. The results also corroborate the presence of a quantity–quality trade-off. Even after controlling for all the wealth-related variables and individual characteristics, each additional sibling is associated with a reduction of 0.2 year in educational attainment. Since these women belong to a generation where the average number of siblings was equal to six, substantial variation in educational attainment can be attributed to differences in family size, due maybe to differences in taste for children or in access to contraceptive techniques.

Table 3 Effect of adult longevity on schooling of the mother; OLS regressions; Brazilian Demographic and Health Survey (1996)

	(1)	(2)	(3)	(4)
Adult survival	1.0818[a]	0.8443[a]	0.7876[a]	0.7504[a]
	0.3254	0.3140	0.3026	0.2939
Child survival	2.6034[a]	2.0297[a]	2.0277[a]	1.0508[a]
	0.1705	0.1621	0.1604	0.1563
Electric		1.1897[a]	1.3070[a]	1.2313[a]
		0.1609	0.1720	0.1681
Water		0.9422[a]	1.0637[a]	1.0295[a]
		0.1360	0.1366	0.1322
Toilet		0.4622[a]	0.6627[a]	0.6195[a]
		0.1007	0.1061	0.1037
Cars		1.5965[a]	1.6496[a]	1.5306[a]
		0.0820	0.0804	0.0765
Urban	2.6121[a]	1.3007[a]	1.1042[a]	0.9765[a]
	0.1411	0.1562	0.1677	0.1605
Christian	−1.1258[a]	−0.8911[a]	−0.8368[a]	−0.7443[a]
	0.1686	0.1586	0.1571	0.1522
Church	0.4628[a]	0.3620[a]	0.3972[a]	0.4132[a]
	0.0820	0.0758	0.0754	0.0737
Black	−1.7485[a]	−1.0073[a]	−1.1363[a]	−1.0784[a]
	0.1901	0.1796	0.1779	0.1739
Mixed	−1.3668[a]	−0.8442[a]	−0.9760[a]	−0.8996[a]
	0.0934	0.0874	0.0894	0.0871
Asian	2.8353[a]	2.1014[a]	2.3631[a]	2.2852[a]
	0.9703	1.0520	1.0654	1.0490
Number siblings				−0.2146[a]
				0.0117
_cons	2.3117[a]	0.8473[a]	1.0125	2.9701[a]
	0.4280	0.4074	0.6415	0.6204
Age fixed effects	Yes	Yes	Yes	Yes
State fixed effects	No	No	Yes	Yes
Observations (*N*)	11,770	11,374	11,374	11,374
R^2	0.19	0.27	0.28	0.31

Numbers below the coefficients are standard errors. All equations include age dummies. Dependent variable is mother's years of education. Longevity variable is mother's siblings adult survival rate. Other independent variables are: mother's siblings' child survival rate, urban residence dummy, religion dummies (Christian and weekly presence in religious service), race dummies (black, mixed, and Asian), electricity in the household dummy, piped water in the household dummy, flush toilet in the household dummy, number of cars in the household, total number of siblings of the mother, and state fixed effects. Regressions weighted by sampling weights. Standard errors adjusted for survey clustering

[a] Significant at 5%

[b] Significant at 10%

Nevertheless, longevity has a consistent relation with educational attainment. The numbers in Table 3 imply that a one-standard-deviation change in adult survival explains between 3.1 and 2.2% of the variation in educational attainment in the sample, once age is accounted for. Although the results may seem quantitatively small, the goal of the paper is not to argue that adult longevity is the main determinant of the variation in educational attainment in a cross-section of individuals. Our goal is simply to present evidence that changes in adult longevity are associated with changes in educational attainment. But, in a given country at a point in time, the exogenous component in the variation of adult longevity is likely to be small, so it is not surprising that the share of the overall variation in educational attainment that can be attributed to longevity is also small. However, the result does support the idea that, in other contexts, when there are large exogenous changes in adult longevity—as when technological breakthroughs in medical sciences take place—educational attainment is likely to respond positively to the gains in longevity.

Table 4 presents the results related to fertility. The two columns labeled 1 present results for the basic specification in Eq. (4) (without and with education, respectively). Adult survival (adult survival) is significant and has the expected negative effect.[4] The other independent variables also have the expected effects. Child survival (child survival), education, and urban residence reduce fertility. Fertility is also lower for women who were never married or who are currently infertile (due to menopause or sterility). It is interesting to note that, as mentioned before, child survival seems to be much more related to economic conditions than adult survival. While the coefficient on adult survival is reduced by 20% when the education variable is introduced, the coefficient on child survival is reduced by 50%.

The main concern in relation to this initial specification is the possibility of omitted variable bias. The question is what kind of omitted variable could be captured in the longevity indicator, therefore biasing the results. We control for three different possibilities of bias. In the following specifications, we present results with and without the education variable, but we concentrate the discussion on the estimations with education since they are the strongest test of the model.

First, if wealthier families have better survival prospects, and wealth drives everything[5]—educational attainment, fertility, etc.—the coefficient on adult survival would capture the effect of family wealth on fertility, and not truly the longevity effect. Note that the basic specification already includes family-specific child mortality, which is highly correlated with income. This partly controls for the absence of a variable measuring initial wealth since child mortality is much more sensitive to economic conditions than adult mortality. The inclusion of the mother's educational attainment variable also helps minimize this problem, precisely for the same reasons that one might expect the coefficient on adult survival to be biased (education may be a good indicator of initial conditions in a credit-constrained environment). Nevertheless, we account for the possibility of this kind of bias by

---

[4] It is very difficult to interpret coefficients in an ordered probit model. A significant positive sign means that some mass is being shifted from very low realizations to very high ones, but in relation to intermediary outcomes it is impossible to make any general statement. In our case, it is easier to think it terms of the expected value of the outcome. In this sense, we can always say that a positive sign means a shift in the whole distribution to the right and an increase in the expected value of the outcome. Later on, when discussing the quantitative implications of the estimated coefficients, we calculate marginal effects on the expected value of the outcome.

[5] For example, family wealth (grandparent's income) could determine parent's educational attainment and, as a result, reduce fertility, or determine access to contraceptive techniques.

Table 4 Effect of adult longevity on fertility; ordered probits; Brazilian Demographic and Health Survey (1996)

	(1)		(2)	
Adult survival	−0.3547[a]	−0.2804[a]	−0.3119[a]	−0.2583[a]
	0.1031	0.1074	0.1073	0.1109
Child survival	−0.4356[a]	−0.2214[a]	−0.3517[a]	−0.1950[a]
	0.0566	0.0567	0.0583	0.0582
Educ		−0.0987[a]		−0.0916[a]
		0.0037		0.0038
Urban	−0.4296[a]	−0.2063[a]	−0.1876[a]	−0.0765
	0.0430	0.0426	0.0532	0.0529
Christian	0.1012[b]	−0.0269	0.0688	−0.0313
	0.0526	0.0504	0.0538	0.0514
Church	−0.0898[a]	−0.0498[b]	−0.0643[a]	−0.0371
	0.0261	0.0260	0.0256	0.0257
Black	0.3240[a]	0.1523[a]	0.2127[a]	0.1224[b]
	0.0635	0.0607	0.0654	0.0630
Mixed	0.3431[a]	0.2271[a]	0.2517[a]	0.1867[a]
	0.0265	0.0262	0.0271	0.0267
Asian	−0.2569	−0.0309	−0.2157	−0.0399
	0.2623	0.2651	0.2882	0.2767
Nevermar	−2.1393[a]	−2.0652[a]	−2.1462[a]	−2.0686[a]
	0.0478	0.0492	0.0496	0.0506
Infecund	−0.3726[a]	−0.4361[a]	−0.4030[a]	−0.4496[a]
	0.0509	0.0520	0.0523	0.0527
Electric			−0.3808[a]	−0.3086[a]
			0.0650	0.0678
Water			−0.0738	0.0124
			0.0452	0.0454
Toilet			−0.1529[a]	−0.1265[a]
			0.0298	0.0284
Cars			−0.2358[a]	−0.0824[a]
			0.0219	0.0213
Observations (*N*)	11,773	11,770	11,377	11,374
Pseudo R^2	0.27	0.29	0.28	0.29

Numbers below the coefficients are standard errors. All equations include age dummies. Dependent variable is number of children born. Longevity variable is mother's siblings adult survival rate. Other independent variables are: mother's siblings' child survival rate, mother's years of education, urban residence dummy, religion dummies (Christian and weekly presence in religious service), race dummies (black, mixed, and Asian), never married dummy, infertile woman dummy, electricity in the household dummy, piped water in the household dummy, flush toilet in the household dummy, and number of cars in the household. Regressions weighted by sampling weights. Standard errors adjusted for survey clustering

[a] Significant at 5%

[b] Significant at 10%

adding the socioeconomic variables related to household characteristics to the basic specification.

Specification 2 from Table 4 presents the results with the socioeconomic variables included, without and with education. The table shows that, while there is some reduction in the coefficient from specification 1 to specification 2 when we are not controlling for education (0.043), the reduction is rather small once education is controlled for (0.022). In any case, all coefficients remain significant.

Another bias possibility is that regional development is affecting the results. This would be the case if more developed states had better provision of public health and education. Better provision of health might reduce mortality and increase access to contraceptive techniques, and better public schools might improve human capital production technologies, increasing educational attainment. In this situation, we would observe correlations between adult mortality, educational attainment, and fertility that would be driven by access to public services (or, in terms of the model, by technological aspects of the production technologies).

To check for this possibility, we include state fixed effects (27 Brazilian states) in the estimation. Specification 1 from Table 5 presents the results including the state dummies, without and with the education variable. For the case with education, results regarding adult survival are very similar—and even slightly stronger—when compared to specification 2 of Table 4 (the coefficient changes from −0.26 to −0.27). Results regarding education are also virtually the same. Interestingly, the coefficients on child survival (child survival), urban residence (urban), and household characteristics (electric, water, toilet, and cars)—all of which are known to be strongly correlated with income—are reduced. Once more, the evidence points to the independence of our measure of adult survival in relation to income (or development).

Finally, the adult survival variable (adult survival) could capture tastes for family size. This could be the case if women born in larger families had stronger preferences for children, and larger families—for economic or biological reasons—had naturally higher mortality levels. This could be an economic outcome if the same amount of resources had to be distributed among a larger number of children and a biological one if, for example, shorter intervals between gestation periods were associated with the birth of weaker individuals.

To account for this factor, we estimate the model including a variable measuring the size of the family in which the mother grew up. The variable is the total number of mother's siblings (number siblings). Note that this variable is simply the fertility rate of the grandmother (minus one). Therefore, it should also incidentally address the issue of family wealth. If the main concern is still the fact that fertility, mortality, and education are all affected by initial conditions (wealth), grandparent's fertility —being, for the same reasons, highly correlated with initial family wealth—should help tackle this problem. The results are presented in specification 2 of Table 4. The number of siblings variable (number siblings) is significant and has the expected effect when education is excluded from the regression, but is virtually zero and not significant once education is controlled for. In the specification with education, results with and without number siblings are virtually identical for all the independent variables. Tastes for children are not introducing any bias. And yet once again, wealth does not seem to be driving the results.

There is one additional possibility of bias that we do not test for, but that, in any case, would bias our results towards zero and make it harder for us to support our point. It is possible that the effect assigned to adult survival partly reflects changes in economic conditions brought about by the death of a sibling. This event could be associated with increased expenses on the part of the household if additional care had to be provided to elderly grandparents or if the children of the deceased sibling had to be taken in and looked after. However, note that these changes would be pure negative wealth shocks, and no substitution effect would be at work. Therefore, assuming that children are normal goods, the negative income effect would tend to reduce the ideal lifetime fertility, introducing a negative relation

Table 5 Robustness of the effect of adult longevity on fertility, ordered probits; Brazilian Demographic and Health Survey (1996)

	(1)		(2)		(3)	
Adult survival	−0.3195[a]	−0.2708[a]	−0.3226[a]	−0.2705[a]	−0.3056[a]	−0.2662[a]
	0.1070	0.1110	0.1074	0.1111	0.1077	0.1112
Child survival	−0.3407[a]	−0.1774[a]	−0.2558[a]	−0.1806[a]	−0.2267[a]	−0.1592[a]
	0.0597	0.0602	0.0623	0.0628	0.0620	0.0623
Educ		−0.0934[a]		−0.0935[a]		
		0.0038		0.0039		
Urban	−0.2031[a]	−0.1115[a]	−0.1955[a]	−0.1116[a]	−0.1561[a]	−0.0948[b]
	0.0537	0.0524	0.0532	0.0524	0.0537	0.0536
Christian	0.0349	−0.0657	0.0264	−0.0655	−0.0094	−0.0664
	0.0543	0.0522	0.0546	0.0522	0.0538	0.0524
Church	−0.0836[a]	−0.0531[a]	−0.0851[a]	−0.0530[a]	−0.0835[a]	−0.0491[b]
	0.0259	0.0262	0.0259	0.0262	0.0260	0.0260
Nevermar	−2.1655[a]	−2.0923[a]	−2.1653[a]	−2.0922[a]	−0.2518[a]	−0.1596[a]
	0.0503	0.0519	0.0504	0.0519	0.0657	0.0672
Infecund	−0.4124[a]	−0.4600[a]	−0.4106[a]	−0.4601[a]	−0.0479	0.0221
	0.0523	0.0530	0.0524	0.0530	0.0461	0.0459
Electric	−0.3113[a]	−0.2170[a]	−0.3060[a]	−0.2171[a]	−0.1054[a]	−0.0639[b]
	0.0636	0.0657	0.0641	0.0657	0.0334	0.0330
Water	−0.0890[b]	0.0110	−0.0880[b]	0.0111	−0.1852[a]	−0.0775[a]
	0.0459	0.0455	0.0458	0.0455	0.0225	0.0220
Toilet	−0.1163[a]	−0.0651[a]	−0.1135[a]	−0.0651[a]	−2.1191[a]	−2.0751[a]
	0.0335	0.0328	0.0337	0.0329	0.0508	0.0523
Cars	−0.2263[a]	−0.0623[a]	−0.2175[a]	−0.0624[a]	−0.4269[a]	−0.4646[a]
	0.0224	0.0217	0.0226	0.0218	0.0518	0.0523
Number siblings			0.0170[a]	−0.0007	0.0130[a]	0.0005
			0.0037	0.0038	0.0037	0.0038
Work					−0.0731	−0.0460
					0.0464	0.0462
Self					0.1154[a]	0.0958[a]
					0.0388	0.0392
Unpaid					−0.3165[a]	−0.3681[a]
					0.1547	0.1657

Table 5 (continued)

	(1)		(2)		(3)	
Occup fixed effects	No	No	No	No	Yes	Yes
Educ fixed effects	No	No	No	No	No	Yes
Observations (*N*)	11,377	11,374	11,377	11,374	11,362	11,360
R^2	0.28	0.30	0.28	0.30	0.29	0.30

Numbers below the coefficients are standard errors. All equations include state, age, and race dummies. Dependent variable is number of children born. Longevity variable is mother's siblings adult survival rate. Other independent variables are: mother's siblings' child survival rate; mother's years of education; urban residence dummy; religion dummies (Christian and weekly presence in religious service); race dummies (black, mixed, and Asian); never married dummy; infertile woman dummy; electricity in the household dummy; piped water in the household dummy; flush toilet in the household dummy; number of cars in the household; total number of siblings of the mother; work dummy; self-employment dummy; unpaid work dummy; and state, occupation, and education fixed effects. Regressions weighted by sampling weights. Standard errors adjusted for survey clustering

[a] Significant at 5%

[b] Significant at 10%

between mortality and fertility. This would work against the hypothesis suggested here, biasing the estimated coefficients towards zero.

As a final test of the hypothesis that wealth may be affecting the results—via its simultaneous impacts on mortality, educational attainment, and fertility—we introduce several variables related to the working status of the mother and allow for a completely flexible functional form for the effects of education. We introduce dummies related to whether the mother works (work), whether she is self-employed (self), and whether she works in an unpaid job (unpaid). Furthermore, we introduce occupation fixed effects, using the occupational categories contained in the data set.[6] All these variables may be correlated with initial wealth, and, from the perspective of the traditional analysis of fertility, they may also determine the current opportunity cost of having children. Additionally, we introduce fixed effects for each additional year of mother's education (17 dummies), allowing for a completely flexible relation between education and fertility. If family background is still biasing the results related to adult longevity, we should expect the introduction of these variables to have some effect on the estimated coefficient.

Specification 3 from Table 5 presents the results for the regressions including all variables discussed before, plus the working status variables defined in the previous paragraph. The first column does not contain any educational variable, while the second column introduces the education fixed effects. In the regression with the education variables, the coefficient on adult longevity (adult survival) is virtually identical to the other ones from Table 5. The work-related variables and the flexible form in education have no impact on the effect of adult survival.

---

[6] The classifications of occupations available in the data set are the following: not working; professional, technical, or managerial; clerical; sales; agriculture self-employed; agriculture employee; household and domestic; services; skilled manual; and unskilled manual.

For the estimated effect of longevity to still be capturing some omitted variable, it has to be a variable uncorrelated with the following mother's characteristics: education, child survival rate of siblings, socioeconomic status, state of residence, total number of siblings (or fertility of the grandmother), occupation, working status, and job characteristics. Even more, our adult longevity proxy (adult survival) itself does not seem to be significantly correlated with socioeconomic status (job and household characteristics) and regional development (evidence discussed in Section 3.3). In addition, the adult longevity (adult survival) coefficient is very stable across the different specifications. In the fertility equations including education, the coefficient goes from −0.28 in the simplest specification to −0.27 in the most complete one, i.e., a change of only 0.01 after several different variables—all of which are supposedly correlated with income—are introduced. Omitted variable bias does not seem to be the case.

For the interested reader, Table 6 summarizes the most important features of these results when the model is estimated using standard OLS techniques. Qualitative results are identical to the ones discussed above.

5.2 Quantitative implications of the fertility model

To explore the quantitative implications of the fertility model, we calculate the marginal effects of the adult survival on the expected number of children. These are obtained by calculating the marginal effects of these variables on the probability of different outcomes, multiplying these effects by the values of the outcomes, and summing over all different outcomes. The expected number of births, given a certain set of characteristics X_o, can be written as $E(n|X = X_o) = \sum_{i=0}^{m+1} iP(i|X = X_o)$, where, as before, m+1 is the maximum number of births possible and $P(i\,|\,X{=}X_o)$ is the probability of observing i births given a set of characteristics X_o. Therefore, the marginal effect of a change in characteristic x_s on the expected number of births, evaluated at X_o, is given by:

$$\frac{\partial E(n|X = X_o)}{\partial x_s} = \sum_{i=0}^{m+1} i\frac{\partial P(i|X = X_o)}{\partial x_s}. \tag{6}$$

We calculate the marginal effects for a woman at age 49, and at the mean of the other independent variables, so that we obtain a picture closer to the average effect of longevity on complete fertility. This is our X_o. The x_s is the family-specific adult survival rate (adult survival). Results are presented in Table 7 for four specifications: the simplest case (1 from Table 4) with and without education, and the most complete case (3 from Table 5) with and without education. As a side note, marginal effects for the ordered probit are similar to the ones obtained in the simple OLS regressions, although a little smaller.

Based on the numbers in Table 7, we can calculate the quantitative implications of the estimated model. For this task, we use standard deviations of the variables restricting the sample to women at age 49 to try to mimic the predictions in terms of complete fertility. A one-standard-deviation increase in the family adult survival rate (0.18) implies a reduction ranging from 0.11 to 0.08 in lifetime fertility, depending on the specification adopted. This represents between 3.7 and 2.5% of the variation of complete fertility in the sample. Again, although the results may seem quantitatively small, the goal of the paper is only to show that changes in adult longevity are associated with changes in fertility. We do not intend to claim that exogenous changes in adult longevity are one of the main determinants of the cross-sectional variation of complete fertility among Brazilian women. The exogenous variation in adult mortality in a given place and point in time is likely to be small, and so should be the share of the variation in fertility explained by this factor. Nevertheless, the evidence opens the possibility that, when large exogenous

Table 6 Effect of adult longevity on fertility; OLS regressions; Brazilian Demographic and Health Survey (1996)

	(1)	(2)	(3)	(4)
Adult survival	−0.6525[a]	−0.5182[a]	−0.4997[a]	−0.5028[a]
	0.1917	0.1896	0.1899	0.1893
Child survival	−0.5829[a]	−0.2859[a]	−0.2032[a]	−0.2138[a]
	0.0785	0.0756	0.0756	0.0771
Educ		−0.1246[a]	−0.1155[a]	
		0.0048	0.0048	
Urban	−0.6999[a]	−0.3898[a]	−0.2212[a]	−0.1877[a]
	0.0693	0.0651	0.0757	0.0751
Christian	0.1625[a]	0.0252	−0.0108	0.0090
	0.0585	0.0529	0.0537	0.0536
Church	−0.1141[a]	−0.0643[a]	−0.0636[a]	−0.0448
	0.0329	0.0310	0.0305	0.0302
Nevermar	−1.5725[a]	−1.3312[a]	−1.3359[a]	−1.3596[a]
	0.0351	0.0366	0.0373	0.0377
Infecund	−0.4713[a]	−0.5317[a]	−0.5533[a]	−0.5567[a]
	0.0856	0.0824	0.0816	0.0795
Electric			−0.3714[a]	−0.1939[b]
			0.1084	0.1107
Water			−0.0069	0.0291
			0.0611	0.0617
Toilet			−0.0840[a]	−0.0854[a]
			0.0379	0.0384
Cars			−0.0422[b]	−0.0727[a]
			0.0224	0.0223
Number siblings				−0.0075
				0.0049
Work				−0.0263
				0.0444
Self				0.0877[b]
				0.0454
Unpaid				−0.4201[a]
				0.1682
Cons	2.7753[a]	2.8696[a]	3.3908[a]	3.8992[a]
	0.2198	0.2117	0.2530	0.2880

Table 6 (continued)

	(1)	(2)	(3)	(4)
State fixed effects	no	no	yes	yes
Occup fixed effects	no	no	no	yes
Educ fixed effects	no	no	no	yes
Observations (*N*)	11,773	11,770	11,374	11,342
R^2	0.48	0.52	0.53	0.54

Numbers below the coefficients are standard errors. All equations include age and race dummies. Dependent variable is number of children born. Longevity variable is mother's siblings adult survival rate. Other independent variables are: mother's siblings' child survival rate; mother's years of education; urban residence dummy; religion dummies (Christian and weekly presence in religious service); race dummies (black, mixed, and Asian); never married dummy; infertile woman dummy; electricity in the household dummy; piped water in the household dummy; flush toilet in the household dummy; number of cars in the household; total number of siblings of the mother; work dummy; self-employment dummy; unpaid work dummy; and state, occupation, and education-fixed effects. Regressions weighted by sampling weights. Standard errors adjusted for survey clustering

[a] Significant at 5%

[b] Significant at 10%

changes in adult longevity take place, we might also observe significant changes in the number of children women choose to have.

The marginal effects calculated from the complete specification indicate that the inclusion of education as a control reduces the adult survival coefficient by roughly 20% of its initial value. This suggests that 80% of the estimated longevity effect is due to the direct effect on fertility (via preferences), while the remaining 20% is due to the indirect effect through increased educational attainment. Nevertheless, note that the latter also partly captures the effect of initial family wealth on fertility.

There is still another interesting aspect of the results. In addition to information on the number of children ever born to the respondent, the data set used also contains information on the number of children born to the respondent who are still alive (children alive). In theory, these two variables are interrelated since parents decide on fertility (number of children born) based on a certain expectation over the number of children who will survive. From an empirical perspective, if the model is well specified and consistently estimated, we should be able to recover the effect of longevity on the number of children alive from the effect of longevity on the

Table 7 Marginal effect of adult survival rate on expected number of children born; Brazilian Demographic and Health Survey (1996)

	Without educ	With educ
Specification 1 from Table 3 (basic specification)	−0.6285	−0.4435
Specification 3 from Table 4 (complete specification)	−0.5192	−0.4103

Calculated from coefficients in Tables 3 and 4, based on the change in probability of different outcomes. Dependent variable is number of children born. Adult longevity variable is the adult survival rate of the mother's siblings number of children born. If we truly control for child mortality, this has to be the case almost mechanically since:

$$\frac{\partial \text{childalive}}{\partial \text{longevity}} = \frac{\partial[(1-\text{child mort})\text{childborn}]}{\partial \text{longevity}} = (1-\text{child mort})\frac{\partial \text{childborn}}{\partial \text{longevity}}. \tag{7}$$

However, note that if there is some specification problem in the estimation, this will not necessarily be true. For example, if we are not adequately controlling for child mortality, and there is an omitted variable—such as family income—that affects both child mortality and longevity, we would obtain

$$\begin{aligned}\frac{\partial[(1-\text{child mort})\text{childborn}]}{\partial \text{longevity}} = {} & (1-\text{child mort})\frac{\partial \text{childborn}}{\partial \text{longevity}} \\ & -\text{childborn}\frac{\partial \text{child mort}}{\partial \text{longevity}}\end{aligned} \tag{8}$$

In this case, one would get the wrong answer when trying to calculate the effect of longevity on the number of surviving children from the estimated effect of longevity on the number of children born.

But again, if the model is well specified and the right parameters are estimated, the marginal effects estimated with number of children born and number of children alive should be linearly related to each other, with the relation being determined by the child survival rate.

To check whether our estimated model passes this consistency test, we re-estimate specifications 1 from Table 4 and 3 from Table 5, using the number of children born who are still alive (children alive) as the dependent variable. We then calculate marginal effects analogous to the ones in Table 7. These give the estimated effects of longevity on number of children alive. Finally, using the marginal effects from Table 6 and the sample average of child mortality (child survival), we calculate —based on the right-hand side of Eq. 7—what the effects of longevity on number of children alive should be, given the results obtained with number of children born. We call these the "calculated" effects of longevity on number of children alive. The results comparing the "calculated" and "estimated" effects are presented in Table 8. The table shows that the marginal effects on number of children alive obtained via the two different methods are very close to each other. The differences are of the

Table 8 Calculated and estimated effect of adult survival rate on expected number of children alive; Brazilian Demographic and Health Survey (1996)

		Without educ	With educ
Specification 1 from Table 3	Calculated	−0.5037	−0.3555
(basic specification)	Estimated	−0.5132	−0.3655
Specification 3 from Table 4	Calculated	−0.4161	−0.3288
(complete specification)	Estimated	−0.4223	−0.3394

Calculated coefficient: from coefficients in Table 6, using the sample average of family-specific child mortality (0.8015) in the calculation. Estimated coefficient: marginal effects (analogous to Table 6) for ordered probit regressions, with number of children alive as dependent variable. Adult longevity variable is the adult survival rate of the mother's siblings order of 0.01, or less than 3% of the magnitude of the estimated coefficients. Once more, the consistency of the results gives credibility to the specification adopted.

6 Concluding remarks

This paper presents individual-level evidence on the effect of adult longevity on educational attainment and fertility. The potential importance of this relation has been stressed in the theoretical literature as a factor determining both the demographic transition and the behavior of fertility after the transition. The correlation implied by these models has been shown to be present at the macro level—in cross-country analysis—but it is difficult to infer causality from this type of evidence, and endogeneity problems abound.

This paper presents microevidence indicating that adult longevity does affect schooling and fertility. The variable used to capture adult longevity is a family-specific measure of adult mortality, constructed from the mortality history of the respondent's family. This variable captures family-specific characteristics—maybe related to genetics—that reveal information about the individual's life expectancy that is otherwise unobservable to the researcher. Furthermore, death of a relative has been found to be the most important factor determining updates of individuals' assessments of their own life expectancies (see Hamermesh 1985; Hurd and Mcgarry 1997; Smith et al. 2001). The paper shows that family-specific adult mortality in previous generations is systematically related to fertility and educational attainment, even after a large array of factors is accounted for (demographic characteristics, family-specific child mortality, education, socio-economic status, regional development, tastes for children, etc.).

The main conclusion is that adult longevity has a significant negative effect on fertility and a significant positive effect on educational attainment. Changes in adult mortality can explain between 2.5 and 3.7% of the variation in complete fertility in the sample and between 2.2 and 3.1% of the variation in educational attainment. The estimation also indicates that 80% of the effect on fertility comes from a direct channel between mortality and fertility, while 20% comes from the indirect quantity–quality trade-off induced by increased educational attainment.

Curiously, alternative longevity proxies have also been found to have significant but quantitatively small effects in other economic contexts. For example, Hamermesh (1984) finds that his adult life expectancy measure has the expected significant effects on consumption, labor supply, and retirement decisions, but that these effects are quantitatively modest. It is difficult to tell whether these results reflect a truly quantitatively small effect of longevity, measurement error, or just a small fraction of exogenous variation in the proxies used. Indicators of individuals' subjective perception of their own life expectancies are very difficult to obtain. All the proxies used are nothing but imperfect measures of it. The one used here, in particular, trusts in a correlation well established in the literature, namely, the correlation between family mortality history and subjective assessments of life expectancy. Nevertheless, the presence of measurement error is still certain. In any case, we find it likely that the longevity effects estimated here and in other contexts are biased towards zero and should be interpreted as lower bounds for the impact of truly exogenous changes in adult mortality. However, to prove this claim, further research is still needed.

Our results are in line with the evidence from cross-country panel studies, which found adult longevity to reduce fertility and increase educational attainment. In addition, it further supports the idea that changes in adult mortality may be one of the important factors in understanding the behavior of fertility after the demographic transition.

Appendix

Definition of variables

Variable	Name	Source	Description
Number of children born	Children born	DHS	Number of children ever born to the respondent
Number of children alive	Children alive	DHS	Number of children born to the respondent who are still alive
Survival rate of adult siblings	Adult survival	DHS	Fraction of respondent's siblings that reached 10 who are still alive. Constructed from the mother's siblings' mortality history
Survival rate of infant siblings	Child survival	DHS	Fraction of respondent's siblings born alive who reached 10. Constructed from the mother's siblings' mortality history
Age	Age	DHS	Respondent's age in years
Education	Educ	DHS	Respondent's education in single years of final educational attainment
Religion	Christian	DHS	Respondent self-reported being from a Christian religion
Religious attendance	Church	DHS	Respondent reported going once a week to a religious service
Race	Black, mixed, Asian	DHS	Respondent's self-reported race (white and native South American are the missing categories)
Urban residence	Urban	DHS	Whether place of residence where respondent was interviewed is urban
Work	Work, self, unpaid	DHS	Whether respondent works, whether she is self-employed, and whether it is an unpaid job
Occupation	Occup	DHS	Respondent's occupation, according to the following categories: not working; professional, technical, or managerial; clerical; sales; agriculture self-employed; agriculture employee; household and domestic; services; skilled manual; and unskilled manual
Marriage history	Nevermar	DHS	Whether the respondent was never married
Fecundity status	Infecund	DHS	Whether respondent is menopausal or sterile
Number of siblings	Number siblings	DHS	Total number of respondent's siblings
Electricity in house	Electric	DHS	Whether the household has electricity
Water in house	Water	DHS	Whether major source of water for the household is piped water
Toilet in house	Toilet	DHS	Whether the household has flush toilet
Cars in house	Cars	DHS	Number of cars in the household
State per capita GDP	GDP	IPEA Ministry of Planning, Brazil	State-specific per capita GDP in *reais* (1996)

References

Barro RJ, Sala-i-Martin X (1995) Economic growth. McGraw-Hill, New York

Bergstrom TC (1996) Economics in a family way. J Econ Lit 34(4):1903–1934

Bils M, Klenow PJ (2000) Explaining differences in schooling across countries. Unpublished manuscript, University of Chicago

Blau DM, Robbins PK (1989) Fertility, employment, and child-care costs. Demography 26(2):287–299

Bleakley H, Lange F (2003) Chronic disease burden and the interaction of education, fertility and growth. Unpublished manuscript, University of Chicago

Cigno A (1998) Fertility decisions when infant survival is endogenous. J Popul Econ 11(1):21–28

Deaton A (1997) The analysis of household surveys—a microeconometric approach to development policy. World Bank and Oxford University Press, Washington, DC

Ehrlich I, Lui FT (1991) Intergenerational trade, longevity, and economic growth. J Polit Econ 99(5):1029–1059

Galor O, Weil DN (1999) From Malthusian stagnation to modern growth. Am Econ Rev 89 (2):150–154

Hamermesh DS (1984) Life cycle effects on consumption and retirement. J Labor Econ 2(3): 353–370

Hamermesh DS (1985) Expectations, life expectancy, and economic behavior. Q J Econ 100 (2):389–408

Heckman JJ, Walker JR (1990) The relationship between wages and income and the timing and spacing of births: evidence from Swedish longitudinal data. Econometrica 58(6):1411–1441

Hurd MD, Mcgarry K (1997) The predictive validity of subjective probabilities of survival. NBER Working Paper 6193, Cambridge

Kalemli-Ozcan S (2001) Mortality decline and the quality–quantity trade-off: evidence from Africa. Unpublished manuscript, University of Houston

Kalemli-Ozcan S, Ryder HE, Weil DN (2000) Mortality decline, human capital investment, and economic growth. J Dev Econ 62(1):1–23

Lorentzen P, McMillan J, Wacziarg R (2004) Death and development. Unpublished manuscript, Stanford University

Meltzer D (1992) Mortality decline, the demographic transition, and economic growth. Ph.D. thesis, University of Chicago, Department of Economics

Newman JL, Mcculloch CE (1984) A hazard rate approach to the timing of births. Econometrica 52(4):939–962

Ram R, Schultz TW (1979) Life span, health, savings, and productivity. Econ Dev Cult Change 27(3):399–421

Robson AJ (2001) The biological basis of economic behavior. J Econ Lit 39(1):11–33

Robson AJ (2003) A ‘bioeconomic’ view of the neolithic and recent demographic transitions. Unpublished manuscript, University of Western Ontario

Robson AJ, Kaplan HS (2003) The evolution of human life expectancy and intelligence in hunter–gatherer economies. Am Econ Rev 93(1):150–169

Rodriguez G, Cleland J (1988) Modelling marital fertility by age and duration: an empirical appraisal the page model. Popul Stud 42(2):241–257

Smith VK, Taylor DH Jr, Sloan FA (2001) Longevity expectations and death: can people predict their own demise? Am Econ Rev 91(4):1126–1134

Soares RR (2003) Fertility and schooling after the demographic transition. Unpublished manuscript, University of Maryland

Soares RR (2005) Mortality reductions, educational attainment, and fertility choice. Am Econ Rev 95:580–601

Tamura R (2001) Human capital and economic development. Unpublished manuscript, Clemson University

Zhang J, Zhang J, Lee R (2001) Mortality decline and long-run economic growth. J Public Econ 80(2):485–507