Demographic Transitions: analyzing the effects of mortality on fertility

Luis Angeles*

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Abstract

The effect of mortality reductions on fertility is one of the main mechanisms stressed by the recent growth literature in order to explain demographic transitions. We analyze the empirical relevance of this mechanism based on the experience of all countries since 1960. We distinguish between the effects on gross and net fertility, take into account the dynamic nature of the relationship and control for alternative explanatory factors and for endogeneity. Our results show that mortality plays a large role in fertility reductions, that the change in fertility behavior comes with a lag of about 10 years and that both net and gross fertility are affected. We find comparatively little support for explanations of the demographic transition based on economic development or technological change.

Keywords: mortality, fertility, demographic transitions, unified growth models.

1 Introduction

The economic mechanisms explaining demographic transitions have attracted an increasing amount of attention from the profession over the last decade. In this paper we contribute to this ongoing literature by providing an extensive empirical analysis of one of the most important mechanisms used by researchers to explain these transitions: the effect of mortality reductions on fertility.

Probably the main reason behind the regain of interest in the demographic transition has been the development of what are usually called "unified growth

*Department of Economics, University of Glasgow. Adam Smith Building, Glasgow G12 8RT, UK. Email: l.angeles@lbss.gla.ac.uk , fax: +44 141 330 4940

theories". This body of theoretical work has extended the traditional post-war time horizon of previous growth models in order to understand the passage from a near-zero steady state growth regime in pre-industrial times to a positive steady state growth regime from the Industrial Revolution onwards. Most researchers in the area have stressed the role of the demographic transition in this context as both cause and effect of the transition in growth regimes. Unified growth theories build on a large body of literature on fertility decisions developed from the seminal works of Becker (1960) and Schultz (1969).

The theoretical literature on unified growth models is by now extensive and offers several alternative explanations for the demographic transition. The idea that mortality rates to a large extent determine fertility outcomes has been used in numerous unified growth models such as Kalemli-Ozcan (2002, 2003), Lagerlöf (2003), Weisdorf (2004), Soares (2005), Azarnert (2006), Tamura (2006) and Falcao and Soares (2007). The idea is by no means recent, as it has been stressed in varying degrees by demographers since the first formulations of what became known as "classical transition theory" (Notestein 1945, for a discussion see Kirk 1996).

Mortality rates are far from being the only determinant of fertility proposed by the unified growth literature. An equally large section of the literature points towards raising GDP per capita (Becker and Lewis 1973, de la Croix and Doepke 2003) or technological progress (Galor and Weil 2000, Jones 2001, Kogel and Prskawets 2001, Hansen and Prescott 2002, Cervellati and Sunde 2005) as the cause behind falling fertility. Many additional factors have been used with less frequency, among which we can mention the decline in the gender wage gap (Galor and Weil 1996), the reduction in the importance of child labour (Hazan and Berdugo 2002, Doepke 2004), Darwinian evolution (Galor and Moav 2002) and the effects of trade specialization (Galor and Mountford 2006).

In addition to the above, most of the models in this literature reserve an important role for human capital formation by incorporating Becker's well-known quantity-quality tradeoff for children in the modelling of fertility decisions. As a rule, changes in any of the above mentioned factors would tip parental choices towards more child quality and less child quantity; causing a simultaneous reduction in fertility and increase in human capital levels. This increase in human capital can then be used to accelerate technological innovation, providing a natural and attractive link between the demographic transition and the growth take-off.

It is noteworthy that education has also figured up on demographers' lists of variables associated with fertility outcomes. The mechanisms that demographers have put forward, however, differ significantly from those used by economists. Demographers have viewed education as an exogenous factor affecting fertility, instead of the endogenous and simultaneous determination of fertility and education that is embedded in the economists' models. Demographers have emphasized the role of schooling in spreading information about contraceptive methods and, perhaps as important, supporting the idea that the use of these methods is socially acceptable (Caldwell 1980).

Next to this rich theoretical literature economists' efforts on the empirical side look rather meager. Although our understanding of the potential mechanisms affecting fertility is quite advanced, few attempts have been made to distinguish quantitatively important factors from secondary ones. Galor (2005a, 2005b) compares alternative explanations for the demographic transition but limits himself to a graphical analysis and does not consider the evidence from developing countries. Most other papers only provide some "stylized facts" based on the experience of one or a few developed countries.

We believe that research effort in this area needs to be reallocated towards more empirical work and act in consequence. We focus on the role of mortality as a driver for fertility change, but will also discuss the effects of other factors that will be included as control variables in our empirical analysis. Our analysis distinguishes itself by exploring several dimensions of the mortality-fertility relationship that, to the best of our knowledge, have not been properly addressed in the empirical literature: (i) Is the magnitude of the effect large enough to account for a demographic transition? (ii) Is net fertility, as apposed to gross fertility, also affected by mortality rates?, (iii) What is the time pattern of the process, how long does it take for mortality changes to affect fertility?, (iv) How do the effects of mortality on fertility compare with those of other factors such as education, GDP per capita or urbanization? (v) Through what mechanisms does mortality affect fertility?

Very few papers in economics have provided careful econometric analyses of the determinants of fertility levels across countries. A notable exception is

Schultz (1994), who analyses the role of factors such as schooling and urbanization in this context. Schultz does not include mortality rates or GDP per capita in his analysis, however, which are among the most prominent factors driving fertility changes in the recent literature. Besides including these last two factors, our analysis improves on Schultz (1994) in terms of country and time coverage and econometric techniques. More recent empirical works that are related to the present one are Lorentzen et al. (2008), who focus on the effects of mortality on economic development, and Soares (2006), who deals with the case of Brazil.

Demographers have produced a very large body of empirical work on this subject over the last decades. Their analyses, however, have usually suffered from the failure to adopt econometric techniques that are now common in the economics literature and control for relevant empirical biases[1].

The rest of this paper is organized as follows. The next section discusses the theoretical mechanisms linking mortality changes to fertility rates. Section 3 is the core of the paper as it describes the data and empirical methodology we use and presents our results. Section 4 summarizes and offers some concluding remarks.

2 Theoretical mechanisms linking mortality to fertility

Since the early work by demographers in the area, mortality has been an oft-cited explanatory factor of the transition in fertility rates. The demographic literature has traditionally focused on three mechanisms to explain this link (see, inter alia, Palloni and Rafalimanana 1999): the physiological effect, the replacement effect and the hoarding effect.

The physiological and replacement effects are similar in that both of them point towards an increased likelihood of pregnancy following the death of a child. With the physiological effect this happens by necessity through the "sudden termination of breastfeeding, which, in turn, triggers resumption of menses

[1] A large body of work in demography argues against the importance of socioeconomic factors such as mortality or GDP per capita in demographic transitions (see Coale and Watkins 1986 for an overview). These analyses, however, do not use panel data techniques such as the inclusion of country fixed effects to control for unobserved country characteristics. Recent research has shown that controlling for these aspects restores the role of socioeconomic factors (Brown and Guinnane 2007).

and ovulation and thus increases the period of exposure to a new conception" (Palloni and Rafalimanana 1999). The replacement effect, on the other hand, refers to the deliberate actions taken by a couple to have an additional birth in order to "compensate" for the death of an offspring; maybe because of the existence of a target family size.

While the physiological effect has naturally not found its way into economic models, the replacement effect is to be found in all models of fertility choice in which parental utility is a function of the number of *surviving* offsprings instead of the number of births. Note, however, that this modelling choice implies full replacement by assumption whereas demographers allow for the possibility of partial replacement (i.e. an increased probability of giving birth in the period following the death of a child). These two mechanisms imply a positive effect of mortality on gross fertility, though the effect on net fertility is more ambiguous[2].

The hoarding effect, finally, has been the object of more rigorous economic modelling. We talk of a hoarding effect when a family decides to have more births than their optimal number of children in order to protect themselves against the possibility of future high mortality in the family. Hoarding is an ex-ante precautionary measure that arises once the randomness of mortality events is taken into account and induces families to "insure" themselves against high mortality scenarios by having more births. Sah (1991) and Kalemli-Ozcan (2002, 2003) present models of fertility choice in which this effect is at play and where mortality has a positive effect on both gross and net fertility.

Before relying too much on the hoarding effect as an explanation for the mortality-fertility link, we must note that its magnitude depends rather heavily on the particular modelling assumptions being made[3]. Several realistic generalizations would eliminate or at least attenuate this effect: parents would be less likely to hoard children if each birth is costly (as in Cigno 1998) or if they can take the decision of replacing a child *after* the occurrence of mortality (as in Doepke 2005).

It is thus the case that the majority of the economics literature has focused on another mechanism which did not originate in demography but within economics: Becker's quantity-quality tradeoff for children. As is well-known, this

[2] See below for a discussion of the difference between gross and net fertility.
[3] The point has been raised by Galor 2005a.

mechanism is based on the assumption that parental utility is a function both of the number of children and of their quality (defined as their level of human capital). As both rearing and educating children is costly, a tradeoff between these two activities arises[4]. A fall in mortality rates is relevant in this context because it makes investments in human capital more attractive by extending the time horizon over which such capital can be used. Lower mortality rates would thus induce a substitution of child quantity for child quality.

Kalemli-Ozcan (2002, 2003), Lagerlöf (2003), Weisdorf (2004), Soares (2005), Azarnert (2006), Tamura (2006) and Falcao and Soares (2007) all use some version of the above argument to generate a demographic transition and a passage to a high-growth regime[5]. It is noteworthy that, within this mechanism, the decision to invest in a child's human capital is not affected by mortality rates at early ages, before human capital investment starts[6]. Conversely, adult mortality rates could have an important effect in this area since much of the benefits of human capital accumulation can be reaped only in adulthood.

This last consideration suggest a strategy for identifying, at least partially, which of the above mentioned mechanisms is at play. The physiological effect depends exclusively on infant and early childhood mortality since breastfeeding does not extend beyond this period. The replacement and hoarding effects depend in principle on mortality rates at all ages; but since mortality is greatest during early childhood there would be not much of a loss if post-childhood rates are excluded. The effect on fertility through the quantity-quality tradeoff, on the other hand, would depend less on early childhood mortality than on late childhood and adult mortality following the argument given before. For this particular mechanism we would expect a sizeable difference when mortality rates at later ages are included. These differences offer some interesting possibilities that will be explored in the empirical part of the paper.

[4] Further developments made parental utility dependent not on the children's human capital but on the children's future utility. The results of the model remain similar, however, once we consider that the children's future utility is a function of their human capital (Becker and Barro 1988).

[5] The consideration of a quantity-quality tradeoff for children does not have to lead to the conclusion that lower mortality rates produce declines in fertility. Hazan and Zoabi (2006) constitute an interesting exception to this common result.

[6] We are aware that researchers in psychology would object to this claim by noting that much of a child's learning takes place in the early years. This objection does not invalidate our argument if this learning is not costly to parents. Human capital formation with explicit costs to parents (schooling, university studies) takes place only from age 6 onwards.

All of the above mentioned theoretical linkages abstract from the time dimension of the mortality-fertility relationship by assuming that parents know all current mortality rates when taking their fertility decisions. This is a natural assumption within theoretical models but needs to be revised for empirical work. Since the early days of the classical transition theory it has been common to assume a lag of several years between mortality declines and the corresponding changes in fertility. Falling mortality rates are not readily observable for households and it is only after one or two decades, when cumulated changes become obvious to everyone, that families might feel confident enough to take them into account in their fertility plans. Our empirical study allows for this dynamic pattern by using different lagged values of mortality rates as determinants of current fertility.

A final note is required to make clear the difference between gross and net fertility. Gross fertility is simply the total number of births per person, net fertility is the total number of surviving children per person where survival is typically understood as reaching sexual maturity. Mortality may have a clear effect on gross fertility through any of the mechanisms mentioned previously, but the effect on net fertility is often less staightforward. Assume mortality falls and this leads to a reduction in the number of births. It is not clear that the number of surviving children will also be lower since a smaller proportion of those births will die in infancy. Thus, the effect of mortality on net fertility should be expected to be smaller, and eventually even of opposite sign, to the effect on gross fertility[7].

3 Empirical analysis

3.1 Data and methodology

This section provides an empirical analysis of the effects of mortality rates on gross and net fertility using mortality and fertility data from the United Nations'

[7]A simple formalization of the argument would assume a two-period model in which gross fertility is a positive function of mortality rates, $GF(m)$ with $GF' > 0$, and mortality takes place only in the first period. Net fertility would be defined as the number of children surviving to the second period: $NF = (1-m)GF$.

It follows that the elasticity of net fertility with respect to the rate of mortality would be $\varepsilon_{NF} = \varepsilon_{GF} - \frac{m}{1-m}$, where $\varepsilon_{GF} > 0$ is the elasticity of gross fertility with respect to mortality. In other words, ε_{NF} is necessarily smaller than ε_{GF} and potentially of negative sign.

Common Database and several relevant econometric techniques to deal with the problems of unobserved country-specific characteristics and endogeneity bias.

It is a well-known fact that mortality and fertility rates are strongly correlated. Indeed, in the dataset we use in this paper and which covers most developing and developed countries over the period 1955 - 2005 the simple correlation between child mortality and total fertility rates is 0.82 while that between life expectancy (a negative function of mortality rates) and total fertility rates is -0.86.

Correlation does not imply causation, however, and we must remain prudent in face of these numbers. First, mortality is far from being the only variable strongly correlated with fertility so any hypothesis of a causal relationship must be analyzed in a multivariate context. Second, causality might very well run in the opposite direction - from fertility to mortality - as the presence of many children implies less resources per child and thus poorer health and nutrition. In other words, serious consideration should be given to endogeneity problems.

In addition to this, the time dimension should not be overlooked and our empirical model must allow for realistic time lags between mortality and fertility. Our baseline econometric specification will thus be as follows:

$$f_{i,t} = \alpha_i + \sum_{s \in S} \beta_s m_{i,t-s} + \sum_j \gamma_j x_{i,t,j} + \varepsilon_{i,t} \quad (1)$$

where $f_{i,t}$ is a measure of fertility for country i at time t, $m_{i,t-s}$ is a corresponding measure of mortality with a lag of s years, $x_{i,t,j}$ are a set of control variables that also affect fertility and α_i are country-specific fixed effects.

As stated, equation (1) will incorporate several lags of the mortality measure in order to account for the effect of this variable over time. We will use three versions of equation (1) throughout our empirical work: one in which mortality affects fertility only contemporaneously ($S = \{0\}$) and two in which the effect extends over 10 and 20 years respectively ($S = \{0, 10\}$ and $S = \{0, 10, 20\}$)[8]. In each case we will be interested not only in the individual coefficients β_s but

[8] Other lag structures give similar results. Including lags at five-year intervals results in multicollinearity.

also in the sum of coefficients $\sum_s \beta_s$, which can be interpreted as the overall long run effect of a change in mortality rates.

The presence of fixed effects in equation (1) is important as there might be several additional country-specific factors that affect fertility which we would like to control for (culture, religion, climate and so on). This specification is clearly superior to the inclusion of dummies for, say, Muslim countries or African countries since we allow for every Muslim and African country to be different. With this specification, only the within-country variability is used to determine the relationship between mortality and fertility.

Three alternative econometric procedures will be used to estimate equation (1). Two are standard panel regressions; the first one with fixed effects and the second one with fixed effects and time dummies. The inclusion of time dummies in this context can be subjected to criticism. While periods of unusually high or low fertility can be observed in some countries or groups of countries (think of the post-war "baby-boom"), it is doubtful that such a phenomenon occurred at the global level. Time dummies could simply pick up some of the effect of other variables, most of which have a clearly defined time trend. It is for these reasons that we estimate equation (1) both with and without time dummies and compare the results.

The third econometric procedure is the GMM methodology developed by Arellano and Bond (1991) in order to deal with endogeneity problems such as those discussed above. In this procedure we difference equation (1) and instrument the regressors in differences with the adequate lags of the regressors in levels. This estimation strategy relies on the assumption that lagged values of the regressors are uncorrelated with changes in the error term, which we will maintain throughout this work[9].

While this GMM estimation is the only one purposefully developed to deal with endogeneity, the other two approaches are not to be dismissed on this

[9] A second estimation strategy that has also gained popularity in the literature is the system-GMM methodology of Arellano and Bover (1995) and Blundell and Bond (1998). We do not apply this methodology here since the assumption that it requires in our context, namely that changes in the regressors $x_{i,t,j}$ are uncorrelated with the country-specific fixed-effects, is unrealistic. High fixed-effects correspond to the less-developed countries and it is to be expected that these countries will also present the largest changes in variables such as mortality or GDP per capita. As discussed by Roodman (2007), system-GMM requires that "throughout the study period, individuals sampled are in a kind of steady-state"; which is clearly not our case since we are analyzing transitions from high to low fertility.

account. While reverse causality may bias the estimated effect of contemporaneous mortality on fertility, this is much less of a concern with respect to lagged values of mortality. Indeed, we may assume safely that 10 and 20 year lags of mortality are not affected by current fertility and therefore that their estimated coefficients do not suffer from bias.

Turning on to the data, we use the following two popular measures of gross and net fertility:

- The Total Fertility Rate (TFR), which is defined as the number of *children* that would be born per woman if she faced the age-specific fertility rates prevailing in a given country at a given year during each of her child-bearing years[10].
- The Net Reproduction Rate (NRR), defined as the number of *daughters* that would be born per woman if she faced the age-specific fertility rates prevailing in a given country at a given year during each of their child-bearing years and the age-specific mortality rates from her birth until her child-bearing years[11].

We use two alternative measures of mortality, the first one covering only child mortality and the second one encompassing all mortality rates:

[10] In mathematical terms the TFR is defined as:

$$TFR = \sum_{j=\tau_0}^{\tau_1} f_j$$

where f_j are fertility rates at age j and τ_0 and τ_1 are the first and last age at which women have children.

[11] In mathematical terms, the NRR is defined as:

$$NRR = \sum_{j=\tau_0}^{\tau_1} s_j f_j$$

where f_j are fertility rates at age j (redefined as female births per woman), τ_0 and τ_1 are the first and last age at which women have children and s_j is the survival rate to age j. The survival rate is defined as:

$$s_j = (1 - m_0)(1 - m_1)...(1 - m_{j-1})$$

with m_j being the mortality rate at age j. This can be used to rewrite the NRR as follows:

$$NRR = s_{\tau_0} \sum_{j=\tau_0}^{\tau_1} (1 - m_{\tau_0})...(1 - m_{j-1}) f_j$$

This last expression shows that the NRR is also the number of daughters that would survive until the beginning of their child-bearing years for each woman entering her child-bearing years.

- The child mortality rate, the number of deaths between ages 0 and 5 per 1000 live births.
- Life expectancy at birth, the average number of years that a person would live if faced with all age-specific mortality rates prevalent in a given country at a given year.

As we advanced before, the interest of considering these two measures of mortality is that different theoretical mechanisms emphasize the role of mortality rates at different ages. If we find that the effect of life expectancy on fertility is of similar magnitude to that of child mortality on fertility, we would conclude that mortality rates after age 5 can be pretty much ignored from the relationship. This, in turn, could be interpreted as evidence in favour of the physiological, replacement and hoarding effects and against a major role of the quantity-quality tradeoff effect. If, on the other hand, changes in life expectancy lead to a larger effect on fertility than changes in child mortality, we would have evidence in favour of a sizeable quantity-quality tradeoff effect.

Finally, the control variables that we include alongside mortality are chosen to take into account some of the most popular factors used in the economics and demographic literatures to explain fertility declines:

- The level of education, as measured by the average number of years of schooling for the population aged 15 or over.
- The level of economic development, as measured by the country's GDP per capita (measured in logs).
- The level of urbanization, as measured by the urban ratio.

Economic development, or the closely related concept of technological progress, has figured prominently in much of the recent unified growth literature as a driver of fertility levels. For example, as countries grow rich the relative price of goods with respect to children would fall since children use up a given amount of parental time whereas goods require less and less (work) time to be afforded. This, in turn, could induce parents to substitute goods for children. Alternatively, as technological progress makes human capital a more valuable asset than physical strength, parents would chose to reduce their quantity of children and improve their quality.

Education has also been a major component of unified growth models through the quantity-quality tradeoff, although its inclusion as an exogenous factor here corresponds more to the role assigned to it by the demographic literature. Finally, urbanization was one of the most popular socioeconomic variables (alongside education and economic development) that demographers used to characterize the process of "modernization" which would bring falling fertility rates with a certain lag. Urban life was thought to alter the perceptions towards fertility control and emancipate women from a traditional paternal society.

The source for our measures of gross and net fertility, child mortality, life expectancy and the urban ratio is the United Nations' Common Database. This source provides us with 11 quinquennial observations per country from 1955 to 2005[12]. The average number of years of schooling is taken from Barro and Lee (2000) and also consists of quinquennial observations but these cover the period 1960-2000. Quinquennial observations of GDP per capita from 1955 to 2005 are taken from Maddison (2006). Our regressions cover up to 118 countries over the period 1960-2000[13]. Most developing countries experienced a demographic transition, or the initial stages of one, during this period. Let us note, finally, that we restrained from using other potential explanatory factors of fertility mentioned in the literature such as female labor force participation or child labor because of their much more limited time and country coverage.

Table 1 presents descriptive statistics for all the variables and Table 2 is a matrix of correlations among variables. A fertility transition is usually understood as the passage from a Total Fertility Rate of around 6 children per woman to 2 or less children per woman. Net Reproduction Rates are typically at or below replacement level (one surviving daughter per woman) following a demographic transition; down from levels of 2 or more. All our regressors are clearly correlated with gross and net fertility, although mortality and education present stronger correlations than GDP per capita and the urban ratio, and the correlations are stronger with gross than with net fertility.

[12] For life expectancy there are no observations for 2005.

[13] Most variables are available for as many as 152 countries, but the data on education severely reduces this number. It is still the case, though, that all major developing and developed countries are included in our regressions.

3.2 Results

The effect of child mortality on Total Fertility Rates is analyzed in table 3, while table 4 considers Net Reproduction Rates. These and each of the following tables report the results of nine regressions since we estimate each relationship using three econometric procedures and, for each procedure, three alternative lag structures for mortality. According to the theoretical mechanisms reviewed in the preceding section, we would expect a positive relationship between mortality and gross fertility, though the effect may appear only with a lag. Net fertility, on the other hand, should present a contemporaneous *negative* relationship with mortality as higher mortality rates will decrease the number of surviving children immediately. With a lag, however, we would expect net fertility to be affected positively through the effect on the number of births; which of these two effects dominate is a question left for the empirical analysis to answer.

A first result that emerges from table 3 is that the time dimension is indeed important in the relationship between mortality and fertility. Columns (1), (4) and (7) would lead to think than there is a contemporaneous effect of child mortality on fertility, but this coefficient is statistically significant only when the lagged values of mortality are not present. Once we include the 10 year or 20 year lags of child mortality, we obtain an intuitive dynamic pattern with very mild effects contemporaneously and strong effects arriving with a 10 year lag. We also observe that the effect "dies out" after 10 years, with a small residual effect being reported for the 20 year lag.

The inclusion of time dummies alters results only marginally, as a comparison of columns (1)-(3) with columns (4)-(6) shows. In both cases the total effect of child mortality on gross fertility after 20 years, the sum of coefficients $\sum_s \beta_s$, is close to 0.0125. This number implies that a fall in child mortality of one standard deviation would produce a decline in TFRs of 1.13 children per woman, a large and meaningful effect. The size of the effect is reduced in the GMM estimates, though it remains clearly statistically significant. Note, additionally, that studying the effect of mortality on fertility using only contemporaneous mortality rates would give us a much reduced effect; further supporting the case for the approach used in this paper.

Turning to our control variables, education and the urban ratio appear to have a sizeable effect on fertility while GDP per capita turns out to be a much weaker predictor of fertility. Our measure of education is statistically significant in all regressions and its value is maintained when we include time dummies or when we use the GMM methodology. With a coefficient of around -0.300, a one standard deviation increase in education is associated with a decline in TFRs of 0.87. The urban ratio is also significant in the first six columns but loses significance in some GMM regressions. The size of its coefficient, however, implies an effect on fertility of roughly similar size to that of education.

GDP per capita, finally, becomes statistically not significant (and, against standard theory, even of positive sign) as soon as we include any lag of mortality. In the GMM regressions GDP per capita is never significant and its coefficient is always positive. These results are strong indication of a weak role of GDP per capita when compared with mortality or education.

In table 4 we turn our attention to the effects of child mortality on net fertility. The results are consistent with those presented in table 3. Table 3 revealed that, once we include lagged values of child mortality, the contemporaneous effect of this variable is not statistically significant; in accordance with the hypothesis that families need some time to "internalize" changes in the socioeconomic environment. As discussed before, however, net fertility should still be affected immediately through the change in survival probabilities for children. This is indeed the case, the non-lagged level of child mortality has a negative and strongly significant effect on NRRs.

Columns (3) and (6) indicate that this initial effect is roughly countered after 10 years; by which time the net effect on NRRs is about zero. The overall effect does not manage to become clearly positive even after 20 years, however, since 20 year lags have a relatively small additional effect. As table 4 shows, the sum of coefficients on child mortality never reaches statistical significance with a positive sign. GMM estimates conserve this same pattern but once again reduce the effect of mortality in most regressions.

Regarding the rest of the variables, results are once again consistent with education being always significant and large, the urban ratio usually significant and with a somewhat smaller effect and GDP per capita being not significant once mortality lags are included.

To summarize the results of tables 3 and 4, child mortality has important effects on both gross and net fertility but the overall effect on net fertility after 20 years is still subject to doubt since it is not statistically significant (and even negative in the GMM regression). We proceed by considering life expectancy at birth as our measure of mortality, incorporating in this way all mortality rates that have been left out until now.

Table 5 reports the results for gross fertility and table 6 for net fertility. In these two tables we have pre-multiplied life expectancy by the factor (-1) in order to have a positive function of mortality rates. In this way the expected signs of the coefficients are the same as those for tables 3 and 4.

The results in table 5 have many similarities with those reviewed in table 3 but also some interesting differences. Changes in life expectancy do not affect TFRs contemporaneously once lagged values are taken into account, as was the case with child mortality rates. On the other hand, the effects of life expectancy do not "die out" after 10 years but have a similar or even larger effect at 20 year lags than at 10 year lags. This result would be consistent with changes in post-childhood mortality rates being more difficult to identify and evaluate than changes in childhood mortality, maybe because of their lower overall levels.

Correspondingly, the overall effect of longer life expectancy on gross fertility after 20 years appears to be larger than that obtained with child mortality. Columns (3), (6) and (9) predict an overall decline of TFRs of between 1.61 and 2.01 children per woman following a one standard deviation increase in life expectancy. It is also noteworthy that this time the results from the GMM equations are very similar to those of the traditional panel techniques.

With respect to all other variables, their effects remain very similar: education has always a negative and statistically significant effect, GDP per capita is not robust to the inclusion of all lags of mortality or to the GMM estimation and the urban ratio is somewhere between these two. In addition, we remark that the use of life expectancy instead of child mortality has tended to produce smaller coefficients for most control variables: the size of the effect of education is up to a third smaller than what it was in table 3 and for the urban ratio the reduction can be even larger. We hypothesize that the effect of the omitted post-childhood mortality rates in table 3 was partially taken up by our control variables.

When we turn our attention to net fertility (table 6), the results are affected in consequence. We find again the intuitive result that net fertility is negatively related to contemporaneous changes in mortality rates, as denoted by the negative and statistically significant coefficient on the non-lagged level of life expectancy. The changes in parental behavior that follow over the next 20 years, however, are now found to more than compensate this initial effect. In our three estimation procedures, the sum of coefficients becomes positive and statistically significant once we extend the lag length to 20 years. This sum of coefficients takes values between 0.026 and 0.037, implying a reduction of NRRs of between 0.32 and 0.46 for a one standard deviation increase in life expectancy. Thus, besides being statistically significant, this result is economically important. And once again, the GMM results are very similar to those obtained in the other regressions.

The results of tables 5 and 6 reinforce the role of mortality reductions and highlight the fact that mortality rates after the age of 5 are also an important factor in fertility decisions. As discussed before, this can be interpreted as evidence that mortality affects fertility through the quantity-quality tradeoff for children. The physiological, replacement and hoarding effects cannot be ruled out, however, as child mortality by itself has also a sizeable effect on fertility. This could denote the importance of the three aforementioned effects or simply the fact that child mortality is highly correlated with mortality rates at other ages.

If we compare mortality with our other control variables we conclude that only education is able to match the magnitude of the effect of mortality on fertility. The urban ratio and GDP per capita have considerably smaller effects which are often not statistically significant. In table 6, for instance, the effect of education on net fertility is between 0.26 and 0.43 while those of GDP per capita and the urban ratio are between 0.07 and 0.09 and between 0.05 and 0.07 respectively[14]. This is to compare with the overall effect of life expectancy on NRRs, which is between 0.32 and 0.46. For gross fertility, the results in table 5 show an even larger difference between the effect of life expectancy and those of all other control variables, including education.

It is thus the case that mortality appears as a major determinant of fertility

[14] Effects of a one standard deviation change in each explanatory factor. Calculated using the regressions with all lags of life expectancy, columns (3), (6) and (9) of Table 6.

changes; one whose effects can account for a large share of the change in fertility rates that we observe through demographic transitions. GDP per capita, on the other hand, has a much smaller effect and is statistically rejected in our most complete specifications.

4 Conclusions

This paper contributes to the ongoing research effort improving our understanding of demographic transitions. The unified growth literature has produced many valuable theoretical contributions in this area, but we are lacking empirical studies to help us differentiate between first and second order mechanisms. We advance in that direction by analyzing in detail the role of mortality as a cause of fertility reductions while controlling for other prominent factors used in the literature, namely GDP per capita, education and urbanization.

Our main results can be summarized as follows:

(i) Mortality changes have a large impact on fertility reductions and can account for a major part of the fertility change characterizing demographic transitions. The effect is robust to different specifications, including GMM estimations accounting for endogeneity.

(ii) Both gross and net fertility are affected. The overall effect on net fertility becomes statistically significant once we take into account post-childhood mortality rates.

(iii) Gross fertility reacts to mortality changes with a lag of about 10 years; the effects continue to be felt after 20 years. Net fertility has an initial negative relationship with mortality; the direction of the effect being reversed after 10 years.

(iv) Compared with other factors, the effect of mortality is larger than those of GDP per capita and the urban ratio. Only education has an effect of similar magnitude in some regressions.

(v) The importance of post-childhood mortality rates points towards the existence of a quantity-quality tradeoff effect of mortality. Other mechanism such as the physiological, replacement and hoarding effect can also be present.

Turning back to the theoretical literature, our results bring support to the large part of the literature emphasizing the role of mortality changes but at the same time sides against the equally large part of the literature whose mechanisms are based on changes in GDP per capita or, more often, technological change. While the link between technological change and GDP per capita might be tenuous in the short run, over a time horizon of several decades like the one considered here a strong link can be reasonably expected. We must be cautious, however, before ruling out economic development in this context. While we have found a small or even inexistent direct effect of GDP per capita on fertility, many indirect channels might be in place. In particular, economic development might be a major cause of mortality reductions and would therefore affect fertility through this last variable.

References

Arellano, M. and Bond, S. R. 1991, Some tests of specification for Panel Data: Monte Carlo Evidence and an Application to Employment Equations, Review of Economic Studies 58, 277-297.

Arellano, M. and Bover, O. 1995, Another look at the instrumental-variable estimation of error-components models, Journal of Econometrics 68, 29-52.

Azarnet, L. V. 2006, Child mortality, fertility and human capital accumulation, Journal of Population Economics 19, 285-297.

Barro, R. J. and Lee, J-W 2000, International Data on Educational Attainment: Updates and Implications, CID Working Paper No. 42, April 2000.

Becker, G. S. 1960, An economic analysis of fertility, in: Demographic and Economic Change in Developed countries, National Bureau Conference series N.10, Princeton University Press.

Becker, G. S. and Lewis, H. G. 1973, On the interaction between the quantity and quality of children, Journal of Political Economy 81, S279-S288.

Becker, G. S. and Barro, R. J. 1988, A reformulation of the economic theory of fertility, Quarterly Journal of Economics 103 (1), 1-25.

Blundell, R. W. and Bond, S. R. 1998, Initial Conditions and Moment Restrictions in Dynamic Panel Data Models, Journal of Econometrics 87, 115-143.

Brown, J. C. and Guinnane, T. W. 2007, Regions and time in the European fertility transition: problems in the Princeton Project's statistical methodology, Economic History Review 60 (3), 574-595.

Caldwell, J. C. 1980, Mass education as a determinant of the timing of fertility decline, Population and Development Review 6, 225-255.

Cervellati, M. and Sunde, U. 2005, Human Capital Formation, Life Expectancy and the Process of Development, American Economic Review 95 (5), 1653-1672.

Cigno, A. 1998, Fertility decisions when infant survival is endogenous, Journal of Population Economics 11, 21-28.

Cleland, J. and Wilson, C. 1987, Demand theories of the fertility transition: an iconoclastic view, Population Studies 41, 5-30.

Coale, A. J. and Watkins, S. C. (eds.) 1986, The Decline of Fertility in Europe. Princeton University Press, Princeton, New Jersey.

de la Croix, D. and Doepke, M. 2004, Inequality and growth: why differential fertility matters, American Economic Review 93 (4), 1091-1113.

Doepke, M. 2004, Accounting for fertility decline during the transition to growth, Journal of Economic Growth 9, 347-383.

Falcao, B. L. S. and Soares R. R. 2007, The demographic transition and the sexual division of labor, NBER working paper 12838.

Galor, O. 2005a, From stagnation to growth: unified growth theory, in Aghion, P. and Durlauf (eds.), Handbook of Economic Growth. Elsevier. Amsterdam, The Netherlands.

Galor, O. 2005b, The demographic transition and the emergence of sustained economic growth, Journal of the European Economic Association 3, 494-504.

Galor, O. and Moav, O. 2002, Natural selection and the origin of economic growth, Quarterly Journal of Economics 117, 1133-1191.

Galor, O. and Mountford, A. 2006, Trade and the great divergence: the family connection, American Economic Review 96, 299-303.

Galor, O and Weil, D. N. 1996, The Gender Gap, Fertility, and Growth, American Economic Review 86, 374-387.

Galor, O and Weil, D. N. 2000, Population, Technology and Growth: From Malthusian Stagnation to the Demographic Transition and Beyond, American Economic Review 90, 806-828.

Hansen, G. and Prescott, E. 2002, Malthus to Solow, American Economic Review 92, 1205-1217.

Hazan, G. and Berdugo, B. 2002, Child labor, fertility and economic growth, Economic Journal 112, 810-828.

Hazan, M. and Zoabi, H. 2006, Does Longevity Cause Growth? A Theoretical Critique, Journal of Economic Growth 11 (4), 363-376.

Jones, C. I. 2001, Was an Industrial Revolution inevitable? Economic Growth over the very long run, Advances in Macroeconomics 1 (2).

Kalemli-Ozcan, S. 2002, Does the mortality decline promote economic growth?, Journal of Economic Growth 7, 411-439.

Kalemli-Ozcan, S. 2003, A stochastic model of mortality, fertility and human capital investment, Journal of Development Economics 70, 103-118.

Kirk, D. 1996, Demographic Transition Theory, Population Studies 50, 361-387.

Kogel, T and Prskawetz, A. 2001, Agricultural Productivity Growth and Escape from the Malthusian Trap, Journal of Economic Growth 6 (4), 263-357.

Lagerlöf, N. P. 2003, From Malthus to modern growth: can epidemics explain the three regimes?, International Economic Review 44, 755-777.

Lorentzen, P., McMillan, J. and Wacziarg, R. 2008, Death and Development, forthcoming in Journal of Economic Growth.

Notestein, F. 1945, Population: The long view, in Schultz, T. (ed.), Food for the World, Chicago.

Palloni, A. and Rafalimanana, H. 1999, The effects of infant mortality on fertility revisited: new evidence from Latin America, Demography 36 (1), 41-58.

Sah, R. K. 1991, The effects of child mortality changes on fertility choice and parental welfare, Journal of Political Economy 99 (3), 582-606.

Schultz, T. P. 1969, An economic model of family planning and fertility, Journal of Political Economy 77, 153-180.

Schultz, T. P. 1994, Human Capital, Family Planning and their effects on Population Growth, American Economic Review 84 (2), 255-260.

Soares, R. R. 2005, Mortality reductions, educational attainment and fertility choice, American Economic Review 95 (3), 580-601.

Soares, R. R. 2006, The effect of longevity on schooling and fertility: evidence from the Brazilian demographic and health survey, Journal of Population Economics 19, 71-97.

Tamura, R. 2006, Human capital and economic development, Journal of Development Economics 79, 26-72.

Weisdorf, J. 2004, From stagnation to growth: revisiting three historical regimes, Journal of Population Economics 17, 455-472.

Table 1
Descriptive statistics

Variable	Mean	Standard deviation	Min.	Max.	Number of obs.
Total Fertility Rate	4.59	2.08	0.94	8.70	1672
Net Reproduction Rate	1.74	0.64	0.45	3.31	1672
Child Mortality	105.50	90.76	3.0	500.0	1447
Life Expectancy	58.32	12.50	23.60	80.53	1520
Average years of schooling	4.87	2.91	0.09	12.05	932
GDP per capita (in logs)	7.90	1.10	5.35	10.38	1485
Urban ratio	44.08	24.36	1.40	100.0	1672

Table 2
Correlation matrix

	Total Fertility Rate	Net Reproduction Rate	Child Mortality	Life Expectancy	Average years of schooling	GDP per capita (in logs)	Urban ratio
Total Fertility Rate	1						
Net Reproduction Rate	0.9385	1					
Child Mortality	0.8194	0.5957	1				
Life Expectancy	-0.8644	-0.6642	-0.9557	1			
Average years of schooling	-0.8485	-0.7391	-0.8228	0.8583	1		
GDP per capita (in logs)	-0.7723	-0.6385	-0.8100	0.8651	0.8157	1	
Urban ratio	-0.6940	-0.5444	-0.7592	0.7970	0.7619	0.8443	1

Table 3
The effects of child mortality on gross fertility.

	Dependent variable: Total Fertility Rates								
	Panel with fixed effects			Panel with fixed effects and time dummies			Difference-GMM		
Child mortality	**0.0049**	**-0.0002**	**-0.0020**	**0.0053**	**0.0012**	**-0.0014**	**0.001**	**-0.0161**	**-0.0079**
	0	0.887	0.255	0	0.475	0.387	0.801	0.011	0.107
Child mortality, lagged 10 years		**0.0086**	**0.0126**		**0.0075**	**0.0136**		**0.0149**	**0.0145**
		0	0		0	0		0.001	0
Child mortality, lagged 20 years			**0.0017**			**0.0005**			**0.0008**
			0.454			0.818			0.822
Sum of coefficients on child mortality	**0.0049**	**0.0084**	**0.0123**	**0.0053**	**0.0087**	**0.0127**	**0.0007**	**-0.0012**	**0.0074**
	0	0	0	0	0	0	0.801	0.762	0.051
Average years of education	**-0.395**	**-0.301**	**-0.231**	**-0.323**	**-0.308**	**-0.249**	**-0.637**	**-0.38**	**-0.364**
	0	0	0	0	0	0	0	0.036	0.029
GDP per capita (in logs)	**-0.304**	**-0.212**	**0.027**	**-0.392**	**-0.196**	**0.063**	**0.153**	**0.436**	**0.371**
	0.003	0.042	0.781	0	0.072	0.544	0.591	0.163	0.124
Urban ratio	**-0.019**	**-0.027**	**-0.026**	**-0.017**	**-0.027**	**-0.027**	**-0.024**	**-0.031**	**-0.048**
	0.005	0	0.001	0.011	0	0	0.336	0.157	0.016
Observations	898	711	514	898	711	514	779	593	399
Countries	117	117	115	117	117	115	105	105	103
Instruments							122	113	88

Note: estimated coefficients are in bold and p-values are given below them. P-values are calculated using robust standard errors.

Table 4
The effects of child mortality on net fertility.

	Dependent variable: Net Reproduction Rates								
	Panel with fixed effects			Panel with fixed effects and time dummies			Difference-GMM		
Child mortality	**-0.0017**	**-0.0036**	**-0.0041**	**-0.0017**	**-0.0029**	**-0.0038**	**-0.0053**	**-0.0114**	**-0.0074**
	0	0	0	0	0	0	0	0	0.002
Child mortality, lagged 10 years		**0.0033**	**0.0040**		**0.0024**	**0.0044**		**0.0060**	**0.0048**
		0	0		0.007	0		0.005	0.004
Child mortality, lagged 20 years			**0.0015**			**0.0005**			**0.0007**
			0.167			0.64			0.667
Sum of coefficients on child mortality	**-0.0017**	**-0.0003**	**0.0014**	**-0.0017**	**-0.0005**	**0.0011**	**-0.0053**	**-0.0054**	**-0.0019**
	0.0000	0.558	0.1405	0.0000	0.4329	0.3036	0.0000	0.0016	0.3118
Average years of education	**-0.184**	**-0.153**	**-0.124**	**-0.141**	**-0.141**	**-0.117**	**-0.267**	**-0.167**	**-0.169**
	0	0	0	0	0	0	0.001	0.064	0.038
GDP per capita (in logs)	**-0.161**	**-0.106**	**0.012**	**-0.201**	**-0.092**	**0.036**	**-0.068**	**-0.198**	**0.2**
	0	0.03	0.804	0	0.069	0.48	0.625	0.205	0.116
Urban ratio	**-0.006**	**-0.010**	**-0.012**	**-0.004**	**-0.009**	**-0.011**	**-0.006**	**-0.012**	**-0.023**
	0.37	0.001	0	0.108	0.003	0.001	0.569	0.264	0.02
Observations	898	711	514	898	711	514	779	593	399
Countries	117	117	115	117	117	115	105	105	103
Instruments							122	113	88

Note: estimated coefficients are in bold and p-values are given below them. P-values are calculated using robust standard errors.

Table 5
The effects of life expectancy on gross fertility.

	Dependent variable: Total Fertility Rates								
	Panel with fixed effects			Panel with fixed effects and time dummies			Difference-GMM		
Life expectancy	**0.053**	**- 0.016**	**- 0.009**	**0.058**	**- 0.011**	**- 0.002**	**0.056**	**- 0.059**	**- 0.016**
	0	0.092	0.366	0	0.268	0.838	0.03	0.008	0.332
Life expectancy lagged 10 years		**0.132**	**0.069**		**0.146**	**0.073**		**0.172**	**0.050**
		0	0		0	0		0	0.030
Life expectancy lagged 20 years			**0.069**			**0.090**			**0.110**
			0			0			0.000
Sum of coefficients on life expectancy	**0.053**	**0.116**	**0.129**	**0.058**	**0.135**	**0.161**	**0.056**	**0.113**	**0.144**
	0.000	0	0	0.0000	0	0	0.0300	0	0
Average years of education	**-0.365**	**-0.194**	**-0.139**	**-0.286**	**-0.243**	**-0.216**	**-0.413**	**-0.303**	**-0.231**
	0	0	0	0	0	0	0.01	0.03	0.080
GDP per capita (in logs)	**-0.227**	**-0.281**	**0.004**	**-0.305**	**-0.319**	**0.025**	**-0.323**	**-0.279**	**0.180**
	0.018	0.002	0.966	0.001	0.001	0.794	0.206	0.274	0.403
Urban ratio	**-0.017**	**0.002**	**-0.013**	**-0.015**	**-0.002**	**-0.017**	**-0.026**	**0.027**	**-0.010**
	0.011	0.708	0.045	0.024	0.807	0.006	0.188	0.153	0.547
Observations	911	818	629	911	818	629	791	698	510
Countries	118	118	118	118	118	118	106	106	106
Instruments							136	133	115

Note: estimated coefficients are in bold and p-values are given below them. P-values are calculated using robust standard errors.

Table 6
The effects of life expectancy on net fertility.

	Dependent variable: Net Reproduction Rates								
	Panel with fixed effects			Panel with fixed effects and time dummies			Difference-GMM		
Life expectancy	**- 0.012**	**- 0.035**	**- 0.029**	**- 0.010**	**- 0.032**	**- 0.025**	**- 0.010**	**- 0.052**	**- 0.031**
	0.007	0	0	0.038	0	0	0.393	0	0.001
Life expectancy lagged 10 years		**0.048**	**0.020**		**0.050**	**0.019**		**0.065**	**0.012**
		0	0.021		0	0.035		0	0.274
Life expectancy lagged 20 years			**0.035**			**0.043**			**0.050**
			0			0			0
Sum of coefficients on life expectancy	**- 0.012**	**0.013**	**0.026**	**- 0.010**	**0.018**	**0.037**	**- 0.010**	**0.013**	**0.031**
	0.007	0.0028	0	0.0380	0.0003	0	0.3930	0.2195	0.0191
Average years of education	**-0.193**	**-0.128**	**-0.090**	**-0.153**	**-0.139**	**-0.120**	**-0.244**	**-0.195**	**-0.147**
	0	0	0	0	0	0	0.002	0.005	0.018
GDP per capita (in logs)	**-0.196**	**-0.209**	**-0.081**	**-0.236**	**-0.225**	**-0.068**	**-0.305**	**-0.275**	**-0.077**
	0	0	0.057	0	0	0.122	0.024	0.043	0.433
Urban ratio	**-0.003**	**-0.004**	**-0.002**	**-0.001**	**0.003**	**-0.003**	**0.003**	**0.022**	**0.005**
	0.272	0.149	0.466	0.486	0.326	0.18	0.73	0.014	0.484
Observations	911	818	629	911	818	629	791	698	510
Countries	118	118	118	118	118	118	106	106	106
Instruments							136	133	115

Note: estimated coefficients are in bold and p-values are given below them. P-values are calculated using robust standard errors.