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The Demographic Transition and the Sexual Division of Labor*

Abstract

This paper presents a theory where increases in female labor force participation and reductions in the gender wage-gap are generated as part of a single process of demographic transition, initially characterized by reductions in mortality and fertility. The paper suggests a relationship between gains in life expectancy and changes in the role of women in society that has not been identified before in the literature. Mortality reductions affect the incentives of individuals to invest in human capital and to have children. Particularly, gains in adult longevity reduce fertility, increase investments in market human capital, increase female labor force participation, and reduce the wage differential between men and women. Child mortality reductions, though reducing fertility, do not generate this same pattern of changes. The model generates changes in fertility, labor market attachment, and the gender wage-gap as part of a single process of social transformation, triggered by reductions in mortality. Predictions of the model are consistent with the timing of mortality reductions in some historical experiences of demographic transition, and also with the relationship between adult longevity, child mortality, and female labor force participation observed on micro and macro data.

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1 Introduction

This paper presents a theory where increases in female labor force participation and reductions in the gender wage-gap are generated as byproducts of the classical process of demographic transition, initially characterized by reductions in mortality and fertility. In the theory, gains in adult longevity raise the returns to human capital and reduce fertility, reducing the demand for household production. As women are initially specialized in the household sector, the fraction of the productive lifetime that women allocate to the market increases and, through changes in human capital accumulation, the wage differential between genders is reduced. Reductions in child mortality, although reducing fertility, do not generate this same pattern of changes. Since reductions in child mortality increase the return to investments in children, and therefore the return to time spent at home, their overall impact on female labor supply is less straightforward than that of reductions in adult mortality. Our theory highlights a link between mortality and the changing role of women in society that has never before been identified in the literature. At the same time, it generates a pattern of social transformation consistent with the timing of events during the historical experiences of demographic transition, and with the pattern of correlations observed on micro and macro data.

There have been profound changes in the labor supply of women during the last decades, both in developed and developing countries. In the United States, female participation in the paid labor force rose from 17% in 1880 to more than 60% in 2000. At the same time, life expectancy at birth increased by 30 years, from 47 to 77, while total fertility rate dropped from 4.6 to 2.1.[1] These changes in life expectancy and fertility reflect trends that were observed since the beginning of the 19^{th} century, when the total fertility rate was above 7 points and life expectancy at birth was below 40 years.

Figure 1 portrays the experience of the US, together with the cases of Great Britain and Brazil. Great Britain goes through an experience similar to that of the US, with substantial gains in life expectancy, reductions in fertility, and increases in female labor force participation. Similar trends were also observed in various other developed countries. These reductions in mortality and fertility were part of the classical process of demographic transition, which spread through most of the world in the post-war period.

The empirical pattern characterizing the transition has been widely documented and discussed in the demographic literature. It is usually understood as being marked by an initial reduction in child mortality, followed by reductions in adult mortality and fertility (see, e.g., Heer and Smith,

[1] The temporary increase in fertility in the post-war period corresponds to the "Baby-Boom" phenomenon. Our focus here is on the long term trend of fertility decline.

1968, Cassen, 1978, Kirk, 1996, and Mason, 1997).[2] Not so widely acknowledged is the fact that changes in female labor force participation also reached most of the "latecomers" of the demographic transition. Figure 1(c) illustrates the demographic changes experienced by Brazil in the period between 1960 and 2000. In this forty-year interval, life expectancy at birth rose from 55 to 68 years, while fertility declined from 6 to 2.2. Though data on female labor force participation is not available before the mid 1970's, the pattern suggests that its increases gained momentum starting in 1980. In the twenty five years between 1975 and 2000, women's labor market participation in Brazil increased from 39% to 58%.

Among developing countries, this pattern is not particular to Brazil. The fraction of the labor force composed of women increased in almost every country where significant reductions in fertility were observed, while, at the same time, the gender wage-gap was reduced (e.g., see Blau and Kahn, 2000 and World Bank, 2004). In the three cases presented in Figure 1, for example, the gap between female and male earnings was reduced by more than 12 percentage points in the period between 1980 and 2000 (Blau and Kahn, 2000 and Simão et al, 2001).

The implications of the increased attachment of women to the labor market encompass issues such as the bargaining power of husband and wife, the enhanced independence of women, and the availability of parents to invest in children. A long strand of literature relates this change to its immediate determinants, such as rising wages and returns to specific attributes, or falling fertility (Rosenzweig and Schultz, 1985, Hotz and Miller, 1988, Angrist and Evans, 1998, Jones et al, 2003, Olivetti, 2001, Mulligan and Rubinstein, 2005, and Leukhina and Bar, 2006). Other line of research links it to cultural and technological transformations, such as the advent of the contraceptive pill and the introduction of electricity in the household (Goldin and Katz, 2002, Lagerlöf, 2003, and Greenwood et al, 2004, among others).

This paper proposes a new mechanism, not considered in precious studies. We suggest that changes in the role of women in society can be partly understood as a consequence of the impact of reductions in mortality on household decisions. In this context, increased female labor force participation and narrowing wage-gap can be seen as later developments of the same process of demographic transition characterized by increases in life expectancy and reductions in the size of families. Our model incorporates all these dimensions into a unified theory of demographic change, with the goal of highlighting one potentially important force that has been overlooked in the literature. Therefore, we abstract entirely from changes in technologies, culture, and preferences. This modelling decision should not be taken as meaning that we do not consider these factors

[2] There is still some controversy regarding the early experience of the first Western European countries to go through the demographic transition. Nevertheless, this sequence of events is accepted as an accurate description of reality in the vast majority of cases.

important in explaining the social changes observed during the last century. Rather, we offer an alternative explanation that should be seen as complementary to them.

Galor and Weil (1996) have a goal similar to ours. They analyze the process of increased participation of women in the labor market as a consequence of the reduced demand for children induced by economic growth. But key aspects of our theory differ from theirs, and we also extend the analysis in new directions. First, we focus on reductions in mortality as the only triggering mechanism behind all other social changes, while they do not consider mortality in their theory. Second, the only difference between men and women in our model is that women are marginally more productive at raising children (childbearing, breast-feeding, etc.), while they rely on differential productivity of men and women in physical and intellectual labor. And third, we explore the consequences of these changes to the quality of children, while they do not incorporate investments in children.[3]

This paper follows a long strand of literature that stresses the interaction between fertility and investments in human capital as one of the distinguishing features of modern economies, and as the main determinant of the differential behavior of population before and after the demographic transition (as originally proposed in Becker et al, 1990). As O'Hara (1975), Meltzer (1992), Kalemli-Ozcan (2002), Soares (2005), and Cervellati and Sunde (2006), we explore the particular role played by health in this interaction in order to shed light on the determinants of the behavior of society in the long-run. To explore the implications of this mechanism to female labor force attachment and the gender wage-gap is the main original contribution of our work.

We argue that exogenous reductions in mortality – driven by technological progress in medical and biological sciences[4] – have two fundamental effects: they reduce the gain from large families and increase the return to investments in human capital. Still, the impact of mortality reductions may vary along the age distribution: (i) increases in adult longevity increase the return to investments in market human capital and reduce fertility, moving women out of the household and into the labor force; while (ii) reductions in child mortality also reduce fertility, but increase the return

[3] Experiences of demographic transition in the vast majority of cases have been characterized by initial reductions in mortality that, after some delay, are followed by reductions in fertility (see, e.g., Heer and Smith, 1968, Cassen, 1978, Kirk, 1996, and Mason, 1997). This has taken place in different areas of the world at very different development levels, so to connect the changes exclusively to economic growth leaves out the major role played by mortality during the demographic transition.

[4] Our theory has exogenous reductions in mortality as the main driving force behind all other demographic changes. Though there are several dimensions on which individuals can invest in their own health, our focus here is on changes in mortality brought about by technological advances or diffusion of previously existing technologies. An extensive literature has pointed to the fact that recent changes in mortality have been largely unrelated to income and living conditions, and are to a great extent exogenous to individuals and countries. This issue is discussed in Preston (1975, 1980), Becker et al (2005) and Soares (2005), and will not be explored in further detail here. Theoretical discussions on endogneous health and empirical evidence on the reverse effect of education on health can be found, among others, in Grossman (2000), Scott (2002), Arendt (2005), and Lleras-Muney (2005).

to time invested in each child, therefore increasing the return to time spent at home. We develop a model where households composed of two members (female and male) jointly decide on their allocation of time, number of offspring, and human capital investments in children and adults. Since women are marginally more productive in raising children, females are partially specialized in the household. In this situation, gains in adult longevity reduce fertility and increase women's labor supply in relation to men's. The differential change across genders translates – through changes in human capital accumulation – into increased labor force participation of women and narrowing of the gender wage-gap. Contrary to the superficial intuition, the model does not generate this same pattern of change as a result of reduced child mortality. Reductions in child mortality do not increase the return to market attachment directly, but they do increase the return to investments in children. In our setup, this effect is strong enough to guarantee that women's labor force participation and investments in market human capital do not rise as child mortality reductions take place.

The paper reconciles demographic theory with the timing of changes in fertility and female labor force participation after the transition. Fertility reductions are observed soon after the onset of sustained gains in life expectancy, when reductions in child mortality still play a prominent role. Increases in female labor force participation, on the other hand, appear only later on, as adult mortality gains relative importance. We offer some macro and micro evidence to support the differential role played by adult and child mortalities as determinants of female labor supply.

The remainder of the paper is organized as follows. Section 2 presents the basic framework of the model. Section 3 discusses the effect of adult longevity gains. Section 4 analyzes the impact of child mortality reductions. Section 5 discusses the pattern of historical changes generated by the model and presents some empirical evidence. Finally, section 6 concludes the paper.

2 The Model

Consider an economy inhabited by families who live for a deterministic amount of time. Each family is composed of a male and a female (denoted by subscripts m and f, respectively), who jointly decide on the allocation of time of each member towards investments in adult human capital, work, and raising children. As Galor and Weil (1996), we abstract from matching and issues related to the formation of families and assume that fertility is realized in terms of couples who grow up to be a household. Each member of the family is endowed with a level of basic human capital determined from the previous generation's decisions (both members receive the same level of basic human capital). This basic human capital determines the productivity of time allocated to acquiring market human capital and raising children. Market human capital, on its turn, determines the productivity of time allocated to labor supply, and goods produced in the market can be used for consumption or investment in children.

Once we incorporate mortality into the model, quality of children cannot be understood simply as human capital. Evolutionary considerations lead to the conclusion that, in such context, survival should also be seen as an additional dimension of quality. This comes immediately from the fact that survival into adulthood affected evolutionary fitness in earlier hunter-gatherer populations, due to the necessity of providing to offspring until early teenage years. Given that number of offspring – or fertility – represents an additional dimension of evolutionary fitness, scarcity of resources implies the existence of a biological trade-off between quantity and quality of offspring (in the economics literature, see Robson and Kaplan, 2003, Robson, 2004, or Galor and Moav, 2005; references in the anthropological and biological literature include Lack, 1968, Smith and Fretwell, 1974, Beauchamp, 1994, and Kaplan and Lancaster, 2003; a detailed discussion is contained in Soares, 2005).

In other words, natural selection imposes a trade-off between life expectancy and number of offspring that, if recognized by preferences, implies a dominant evolutionary strategy. This dominant evolutionary strategy would correspond to a set of preferences where parents derive utility not only from the number and human capital of children, but also from their life expectancy. In addition, these considerations imply that parents should regard life expectancy and fertility in similar ways. This is the logic underlying a recent model developed by Robson (2004), where preferences aiming at maximizing the product of life expectancy (quality) and fertility (quantity) arise as evolutionarily dominant in the long run. This same idea is implicit in traditional arguments relating child mortality to fertility, where parents are assumed to derive utility from the number of surviving children. Here we follow Soares (2005) and extend this idea to later ages, by assuming that parents also care about the adult longevity of their offspring. This is a natural extension once we consider that parents are concerned not only with the immediate survival of their children, but also with the continuing survival of their lineage. In this case, families should care about whether their children would live long enough to have and raise their own offspring, therefore guaranteeing the long term survival of descendents.

We adopt a simplified version of the formulation proposed by Soares (2005). Households derive utility from consumption in each period of life (c^σ/σ, over τ years of life) and from children. We assume that parents derive utility from the quality, or basic human capital, of children (q_c^α/α), and that this utility is affected by the number of children (n), the child mortality rate (δ), and the lifetime that each child will enjoy as an adult (τ). The discount factor applied to basic human capital is assumed to be a concave and increasing function $\rho(.)$ of the total expected lifetime of children $(n(1-\delta)\tau)$, or the total of "child-years."[5] Abstracting from life-cycle considerations and setting the discount rate to zero, the household utility function is given by

$$\tau \frac{c^{\sigma}}{\sigma} + \rho\left(n(1-\delta)\tau\right)\frac{q_c^{\alpha}}{\alpha} \tag{1}$$

where c is consumption at a given instant and $0 < \alpha, \sigma < 1$.[6]

Production of basic human capital for children (q_c) can use either one of two inputs. The first (x_τ) is produced with time invested by adult members of the household, while the second (x_y) is a good purchased in the market (at a fixed price p). For simplicity, we assume that these two inputs are perfect substitutes in the production function for q_c:

$$q_c = Ax_\tau + (1-A)\,x_y, \tag{2}$$

where A is a constant between zero and one.[7] The household produced input (x_τ) makes use of the time of parents according to the following production function:

$$x_\tau = (Fb_f + Mb_m)q_p, \tag{3}$$

where b_i is the time invested in a child by parent i, q_p is the basic human capital of parents

[5] The function $\rho(.)$ is analogous to the discount term written as a function of n in traditional fertility models (typically, an expression such as $\alpha n^{1-\varepsilon}$, as in Becker et al, 1990). Soares (2005) shows that the main results generated by our functional form are also present under a more general setting. Specifically, if the discount term assumes the general form $\rho(n,\tau,\delta)$, and $\varepsilon(n,\tau,\delta) = \frac{\rho_n(n,\tau,\delta)n}{\rho(n,\tau,\delta)}$ denotes its elasticity in relation to n, the condition needed is $sign\{\varepsilon_n(n,\tau,\delta)\} = sign\{\varepsilon_\tau(n,\tau,\delta)\} = -sign\{\varepsilon_\delta(n,\tau,\delta)\}$, where the subscripts denote partial derivatives. We adopt the alternative formulation because it relates directly to the endogenous preferences results from the evolutionary literature (Robson, 2004). In addition, it is intuitively more appealing and simpler. Explicit consideration of uncertainty in this context would tend to reinforce some of the effects discussed here (see Kalemli-Ozcan, 2002 and 2008).

[6] We investigate the effect of technologically induced mortality changes, which are perceived as permanent by agents. So we do not distinguish between parents' and children's adult longevity. As long as changes are permanent, long-run effects are the ones discussed here. In this perspective, one could understand our exercise as comparing households two generations apart. Also, though we do not make this distinction formally in the model, the relevant dimension of changes in τ refers to the length of productive life. So extensions in life when individuals are not able to work should not bring together the effects stressed by our theory. Given that we abstract from lifecycle consideration and do not have utility derived from leisure, the model is unable to capture changes in retirement age, such as have been observed in some developed countries in recent years. This may be explained by increased demand for leisure induced by income effects from economic growth.

[7] In reality, when parents purchase investments in children through the market, a large part of these investments is composed of other people's time (baby-sitters, teachers, etc.). As long as the changes analyzed here are economy-wide, any impact on parents' productivity and wages should also be reflected on the wages of these service providers, and therefore should minimize the differential change on household production *vis-à-vis* market purchase of inputs. In order to simplify the framework and to focus on the wedge between household production and market purchase, we take the price of x_y as given. Generally, similar results would hold as long as the price of x_y increased less than proportionally with the productivity and the market wage of parents (or as long as there were other inputs in the production of x_y). Also, evidence suggests that parents do invest differently in boys and girls. This is a limitation of our model introduced in order to simplify the analysis. If parents could invest different amounts in boys and girls, and basic human capital were complementary to adult human capital, the effects discussed here would tend to be exacerbated.

(inherited from previous generations decisions), and F and M are constants.[8] In this context, the idea that women are more productive in raising children can be translated into $F > M$, such that each unit of time invested in a child by a woman generates more of the input x_τ than the same unit invested by a man. This hypothesis is maintained throughout the paper. It is the only intrinsic difference between men and women in our model.

Basic human capital of each parent is also used, together with time invested in adult education (e_i), to produce market human capital (h_i). We use a specification similar to that of Becker (1985) to analyze specialization within the household:

$$h_i = He_i q_p, \tag{4}$$

where $H > 0$ is a constant.

This is the human capital that is actually used to produce goods. The market human capital of each member determines the productivity of each unit of time used as labor. The lifetime value of the total amount of market goods produced (or wages earned) by the household is

$$y = l_m h_m + l_f h_f, \tag{5}$$

where $l_i = \tau - nb_i - e_i$ is the lifetime labor supply of agent i. The distinction between basic and market human capital highlights the different types of human capital acquired at different points in life. Basic human capital q, or child quality (assumed to be common to females and males), refers to basic skills (language, cognitive and motor ability, etc.) and general knowledge accumulated during early stages of life, while investments decisions are taken by parents. Market human capital h (allowed to be different between genders) refers to the accumulation of skills related to a specific occupation or profession, when investment decisions are already taken by the individuals themselves. Since the model is unable to capture all the subtleties of human capital investments, we understand market human capital very broadly as referring to any type of human capital investment specific to a particular task, including college and graduate education, professional training, and the investment dimension of on-the-job training and learning-by-doing. The distinction between these two types of human capital is key in identifying the different effects of changes in child mortality and adult longevity.

The total amount of goods produced by the household is allocated between consumption and raising children. We assume that households have access to perfect capital markets, but that

[8] In the presentation of the model, we use lowercase letters to indicate endogenous variables chosen by families (or by their previous generations), uppercase letters to indicate technological constants, and Greek lowercase letters to indicate exponents and exogenous variables of interest. To keep notation to a minimum, we are not indexing by generation, and are distinguishing parents' from children's basic human capital by the subscripts p and c. These are obviously related across generations. If we let t index generations, $q_{p,t+1} \equiv q_{c,t}$. So the change in basic human capital across consecutive generations is $q_{c,t}/q_{p,t} = q_{p,t+1}/q_{p,t} = q_{c,t}/q_{c,t-1}$.

borrowing from future generations and bequests are not allowed, so that the budget constraint is

$$y \geq \tau c + npx_y, \tag{6}$$

where x_y is the market investment in basic human capital per child, and p its price (with growth, any other fixed cost of children would be asymptotically irrelevant).[9]

Each adult member of the family also faces a time constraint. Adult lifetime has to be allocated between investing in market skills (adult human capital), working, and raising children. The time constraint of agent i is given by

$$\tau = l_i + e_i + nb_i. \tag{7}$$

Once we substitute for y and h_i in the budget constraint and for q_c in the utility function, the problem of the household can be written as

$$\begin{aligned} \max_{\{c,n,x_y,l_m,l_f,e_m,e_f,b_m,b_f\}} V &= \tau \frac{c^\sigma}{\sigma} + \rho\left(n\left(1-\delta\right)\tau\right) \frac{\left[Ax_\tau + \left(1-A\right)x_y\right]^\alpha}{\alpha} \\ \text{subject to } l_m H q_p e_m + l_f H q_p e_f &\geq \tau c + pnx_y, \\ \tau &= l_i + e_i + nb_i, \text{ for } i = f, m, \text{ and} \\ x_\tau &= (Fb_f + Mb_m)q_p. \end{aligned} \tag{8}$$

In this framework, there are two forces working toward specialization. First, since women's time is relatively more productive in household activities, simple comparative advantage considerations lead to women's partial specialization in household production. Second, the possibility of increasing market productivity through human capital investments generates increasing returns to the total amount of time allocated to the market (investments in adult education plus labor supply).[10] The presence of increasing returns to market related activities enhances the tendency toward specialization generated by any minor difference in comparative advantages and exacerbates *ex-post* differences.

[9] The assumption of perfect capital markets is certainly not realistic, but it allows us to abstract from lifecycle consideration and to focus on lifetime decisions, and how these are affected by changes in mortality. Our main interest lies on the comparison of these changes across generations, and therefore we maintain this assumption throughout the paper.

[10] If t_i denotes the total amount of time allocated to market related activities by agent i ($t_i = e_i + l_i$), the optimal allocation of time between human capital investments and labor supply is $e_i = l_i = t_i/2$. Substituting both back into the production functions, total production for agent i is given by $Aq_p t_i^2/4$. So there are increasing returns to the total amount of time t_i dedicated to market related activities. This is the type of return to specialization discussed in Becker (1985). In Lagerlöf (2003), it is also true that, though men and women are intrinsically identical in terms of potential market productivity, they end up with different levels of human capital. But in his case this is due to anticipated discrimination against women (as a Nash equilibrium), and not to returns to specialization and differences in household productivity, as we have here. In reality, men and women do share some of the time investment in children. Our model is not able to capture this outcome, which may be explained partly by the utility value attached to time spent with children.

Therefore, there can be no optimal solution where both agents share their time between market activities and household production. Comparative advantage and investments in education generate an incentive toward specialization, and at least one agent must always be completely specialized in some activity. When agents spend some amount of time investing in children, there can only be three possible solutions: (a) m specializes in the market and f works both in the market and in the household; (b) m works in the market and in the household and f specializes in the household; or (c) m specializes in the market and f specializes in the household. This has to be the case since, if both agents share their time between market and household activities, it is always possible to increase total production by increasing the market time of m and reducing that of f (since there are increasing returns to the total amount of time dedicated to the market and $F > M$). If only one agent works in the household, it must be f. It is also possible that both agents spend all of their time investing in market human capital and working, in which case investments in children are done through the market.

In what follows, we concentrate on the case where women spend at least part of their time on the market, and men are completely specialized in market activities.[11] Early stages of the process of economic development and of the movement of households out of subsistence agriculture may be better characterized as a movement of men from household activities to the market. This is a possibility that deserves further thought and discussion, but we do not deal with it here. Our main focus is on the increased female labor force participation that characterizes most industrial societies and also many less developed countries that have already experienced the demographic transition.

3 The Effect of Longevity Gains

The Solution with Time Investments in Children

When women share their time between market and household activities, first order conditions in relation to $c, n, e_m, l_m, b_m, e_f, l_f$, b_f, and x_y are given by, respectively:

[11] First order conditions for the general problem are presented in Appendix A.1. In the next section, we present first order conditions for the case of interest, when women share their time between the household and the market.

$$
\begin{aligned}
\tau c^{\sigma-1} &= \psi\tau, \\
\rho'\tau(1-\delta)\frac{q_c^{\alpha}}{\alpha} &= \lambda_f b_f, \\
Hq_p l_m \psi &= \lambda_m, \\
Hq_p e_m \psi &= \lambda_m, \\
\rho q_c^{\alpha-1} AMq_p &< \lambda_m n, \text{ with } b_m = 0 \\
Hq_p l_f \psi &= \lambda_f, \\
Hq_p e_f \psi &= \lambda_f, \\
\rho q_c^{\alpha-1} AFq_p &= \lambda_f n, \text{ and} \\
\rho q_c^{\alpha-1}(1-A) &< \psi pn, \text{ with } x_y = 0,
\end{aligned}
$$

where ψ, λ_f, and λ_m denote the multipliers on the budget constraint, the female time constraint, and the male time constraint. First order conditions for e_m and l_m, together with the time constraint, lead to (with $b_m = 0$)

$$e_m = l_m = \frac{\tau}{2}, \tag{9}$$

and, similarly, for agent f one can show that

$$e_f = l_f = \frac{\tau - nb_f}{2}. \tag{10}$$

First order conditions for n and b_f can be used to arrive at (with $x_y = 0$)

$$\frac{\rho' n\tau(1-\delta)}{\rho} = \alpha. \tag{11}$$

This expression determines the response of n to exogenous changes in longevity (τ) and child mortality (δ). Particularly,

$$\frac{dn}{d\tau} = -\frac{n}{\tau} < 0, \tag{12}$$

so that changes in τ lead to responses in n that keep the product τn constant. This is similar to the relationship found in Soares (2005), and it reflects the interaction between n and τ inside the function ρ.

The fraction of time that women dedicate to the market (human capital investments plus labor supply) increases in τ. The fraction of time spent in the household declines, but the net effect on the absolute value of b_f (investment per child) is ambiguous, since fertility is also reduced (see Appendices A.3.1 and A.3.2). The impact on consumption is positive. These effects are summarized by

$$\frac{d\left(e_f/\tau\right)}{d\tau} = \frac{d\left(l_f/\tau\right)}{d\tau} > 0, \ \frac{dc}{d\tau} > 0, \tag{13}$$
$$\text{and } \frac{d\left(nb_f/\tau\right)}{d\tau} < 0, \text{ but } \frac{db_f}{d\tau} \gtreqless 0.$$

When women spend part of their time in the household, an increase in τ increases overall incentives to invest in market human capital, because returns can be enjoyed over a longer period of time. Therefore, the opportunity cost of time increases. In addition, the gain in longevity itself reduces the benefits from larger families, and these two forces together determine a reduction in fertility. The result is that the total amount of time spent on market related activities increases more than proportionally with the gain in life-span, reducing the fraction of time allocated to the household. As a result, the fraction of f's productive lifetime allocated to labor supply (l_f/τ) – or female labor force participation – rises, and the time invested in each child may increase or decrease, depending on the relative responses of fertility and the total time allocated to the household.

Defining the market wage as the productivity of one unit of time allocated to labor supply, we can write $w_i = h_i = Hq_p e_i = Hq_p t_i/2$, where t_i is the total amount of agent i's time allocated to the market. Since gains in longevity lead to more than proportional increases in t_f, while increases in t_m are just proportional to τ, the gender wage-gap $(1 - w_f/w_m)$ is reduced as τ rises.

The response of investment per child (b_f) is not so straightforward. Three forces are at work here when longevity increases. First, the increase in longevity itself relaxes the resources constraint by increasing full lifetime income. Second, the reduction in fertility that accompanies the gain in longevity reduces the relative price of investment in children. And third, due to increased human capital accumulation, the rise in longevity increases the opportunity cost of time. The first two forces work toward increased investments in children, while the third works against it. For low levels of female labor force participation, the effect of increasing returns is relatively weak, so the first two forces tend to dominate. At the other extreme, for high levels of female labor force participation, consumption is relatively high and fertility low, so the income effect is strong and it takes relatively little time to improve the quality of children. Also in this case, the first two forces tend to dominate. The only situation where the third force tends to dominate is an intermediary one, where increasing returns kick in strongly and, to take advantage of them, women shift their allocation of time abruptly to the market.

Appendix A.3.3 shows that, in most situations, the increased opportunity cost of time does not overcome the first two forces and, when it does, it is only over a relatively narrow interval. For low initial levels of female labor force participation, increases in longevity bring both increases in female labor supply and improvements in the quality of children.[12] For intermediary values of b_f, and conditional on other parameters, investments in children may decrease as longevity and female labor force participation increase. But for sufficiently high levels of initial female labor force participation, increases in longevity are again accompanied by increased quality of children. Therefore, for a given set of parameters, the relationship between female labor supply and child quality may be either positive or non-monotonic.

The Solution with Market Investments in Children

When households use market goods to invest in children, we have $b_f = b_m = 0$. In this case, following the same steps outlined above, it is easy to show that $l_m = l_f = e_m = e_f = \tau/2$. First order conditions for n and x_y yield the familiar expression $\frac{\rho'(1-\delta)\tau n}{\rho} = \alpha$. Adult members of the household allocate their total lifetime to market related activities, sharing it equally between investments in human capital and labor supply. Again, fertility falls with increases in τ, since the marginal gain from having a large family is reduced as children live longer.

Contrary to before, the effect of longevity on investments in children is unambiguously positive, so that $dq_c/d\tau > 0$ (see Appendix A.4 for proof). Here again, increases in longevity reduce the shadow cost of investments in children, because of reduced fertility, and increase full lifetime income. But there is no countervailing effect of increased opportunity cost, since there is no time investment in children.

Extensive Margin Choice

Longevity also affects the choice of the technology to be used in investments in children (extensive margin). Since mother's time (b_f) and market goods (x_y) are perfect substitutes in the production function for children's basic human capital (q_c), only the one with the higher relative return will be used. There are two possible choices, discussed before: one where investment in basic human capital is done using the domestic technology ($b_f > 0$ and $x_y = 0$), and another where investment is done using market goods ($b_f = 0$ and $x_y > 0$).

Appendix A.2 proves that, for large enough τ, returns to market human capital are so high that both members of the household spend all their time in market related activities, and make their investments in children through the market. For lower levels of τ, this may not be the case,

[12] The relationship between female labor force participation and quality of children is a major topic of demographic research (see, for example, Preston, 1984, Bianchi, 2000, and McLanahan, 2004), and is still subject of debate (Sayer et al, 2004, Gauthier et al, 2004, and James-Burdumy, 2005).

and women may share their time between the market and the household. The intuition for this result is clear: for lower τ, returns to market human capital and the cost of time are lower, the family is poorer, and, therefore, it is cheaper to spend time investing in children than to buy this investment through the market; as longevity increases, returns to human capital rise, and so do market productivity and the opportunity cost of women's time. If this change is large enough, it eventually becomes cheaper for families to make their investments in children through the market, and to allocate all household time to market related activities.

Long-Run Growth

Differences in investments in children in this model translate into long-run differences in growth rates, since basic human capital determines the productivity of later investments in market specific human capital. In steady-state, the growth rate between generations is determined by the evolution of basic human capital between parents and children.[13] Changes in women's labor force participation may therefore be associated with growth in different ways, depending on what happens to child quality. When women share their time between the market and the household, growth rates are given by

$$
\begin{aligned}
1+g &= \frac{q_c}{q_p} = AFb_f, \text{ and so} \\
\frac{d\,(1+g)}{d\tau} &= AF\frac{db_f}{d\tau} \gtrless 0.
\end{aligned} \tag{14}
$$

When investments in children make use of market goods, increases in longevity reduce fertility, relax the budget constraint, and unambiguously increase investments in children:

$$
\begin{aligned}
1+g &= \frac{q_c}{q_p} = (1-A)\frac{x_y}{q_p}, \text{ and} \\
\frac{d\,(1+g)}{d\tau} &= \frac{(1-A)}{q_p}\frac{dx_y}{d\tau} > 0.
\end{aligned} \tag{15}
$$

As discussed before, longevity may have ambiguous effects on the quality of children only when women share their time between the market and the household. For sufficiently low or high initial levels of female labor supply, the impact of longevity on basic human capital is positive, while for intermediary levels it may be negative, depending on parameters of the model. It is therefore possible to observe an intermediary stage where growth rates are reduced as women increase their attachment to the market. This is due to the possibility of reduced investments in children during this transition period. Still, the quality of children and the growth rate eventually

[13] As shown in Soares (2005), a steady-state only exists in this type of economy when $\alpha = \sigma$. We implicitly make this assumption whenever talking about steady-states.

start rising again as women intensify their attachment to the market. This tendency is reinforced when investments in children use market goods.

4 The Effect of Child Mortality Reductions

The Solution with Time Investments in Children

The impact of child mortality changes is much simpler in nature than that of adult longevity. The effects of child mortality on fertility can be seen, as before, from expression 11. This relationship implies that reductions in child mortality are accompanied by reductions in fertility:

$$\frac{dn}{d\delta} = \frac{n}{(1-\delta)} > 0, \tag{16}$$

so that the product $(1-\delta)\,n$ is kept constant as δ changes.

This is the only direct impact of child mortality in the model, with all subsequent changes following from how fertility affects other margins of the household problem. When women share their time between market and household activities, the reductions in fertility and child mortality imply a reduction in the shadow price of investments in children (or an increase in the rate of return). In the presence of increasing returns to market activities, the marginal cost of market goods in terms of time is decreasing in total production (or, alternatively, the marginal productivity of goods is increasing in the total amount of time allocated to the market). This non-linear time cost tends to magnify responses to price changes. For this reason, the reduction in the shadow price of child quality represented by the fertility decline is strong enough to increase the total amount of time allocated to children. This happens here, among other things, because there are increasing returns to market activities. Otherwise, the reduction in fertility would generate the typical price response of a normal good, where consumption (b_f or q_c) necessarily increases, but total expenditures (nb_f) may not. Since there is a reduction in the total amount of time allocated to the market, female educational attainment and labor force participation are actually reduced by reductions in child mortality, and the wage differential between men and women rises (see Appendix A.3.2 for proof). These effects can be summarized by

$$\begin{aligned} \frac{de_f}{d\delta} &= \frac{dl_f}{d\delta} > 0, \text{ and} \\ \frac{db_f}{d\delta} &< 0, \text{ also with } \frac{d\left(nb_f/\tau\right)}{d\delta} < 0. \end{aligned} \tag{17}$$

The prediction that female labor force participation is unequivocally reduced by reductions in child mortality is not general, and depends partly on the specific functional forms adopted. Nevertheless, it does highlight a general economic principle that is particularly strong in our theory. Changes in child mortality are, in nature, similar to changes in the price of investments in children (due to reduced fertility, together with higher survival probability of each child). Changes in adult longevity, on the other hand, are similar to changes in the return to labor market attachment (due to longer productive life and reduced fertility). Both changes affect the returns to investment in human capital, but in one case it refers to investment by parents in children, while in the other it refers to investment by parents in themselves. Therefore, in the case of gains in adult longevity, mortality and fertility are two forces working together toward increased labor supply (increased productive life and fewer children). In the case of reductions in child mortality, mortality and fertility work in opposite directions, since reduced fertility tends to increase labor supply (fewer children), but reduced child mortality tends to increase household production (increased return to investment per child). This essential distinction should lead to a relationship of female labor supply with child mortality, if not opposite, at least weaker than that with adult longevity, irrespective of the particular functional forms adopted. Contrary to common belief, the general result suggested by our theory is that female labor force participation should be closely related to adult longevity, not to child mortality.

Market Investments in Children, the Extensive Margin, and Growth

When investments in children make use of goods purchased in the market, the reduction in child mortality and fertility is reflected on higher investments in children, as the simple response of a normal good to price changes. But the extensive margin choice is also affected by child mortality. In order for households to allocate part of women's time to the market, it must be the case that $p\frac{A}{(1-A)}\frac{F}{H} > e_f$ (see Appendix A.2). Since reductions in child mortality reduce female investments in market human capital, they move the household away from the solution where both individuals allocate all their time to the market.

In both cases, increased investments in children lead to higher growth rates and, in the long run, higher consumption (this may take place at the cost of reduced current consumption). But, most important, reductions in child mortality cannot lead to increased female labor force participation and narrowing gender wage-gap. In fact, the model generates exactly the opposite result when women allocate part of their time to domestic activities: reductions in child mortality reduce female labor supply and widen the wage differential between men and women. This result highlights the key role played by adult longevity in our theory. Reductions in fertility are not enough to generate the typical change in women's labor supply. Increased return to market specific human capital is essential in explaining the observed trends.

5 Empirical Evidence

The theory proposed in this paper generates a close link between adult longevity, female labor force participation, and the gender-wage gap. Child mortality, on its turn, does not appear as an important determinant of female labor force participation, even though its effect on fertility may be very relevant. These predictions are roughly in line with historical evidence, since increases in female labor force participation typically gain momentum only at later stages of the demographic transition, when changes in adult longevity become important. This could explain the lag between the initial increase in life expectancy during the onset of the demographic transition, and the later increase in female labor force participation, as Figure 1 from the introduction highlights. In the cases of the US and Great Britain, the timing of changes in female labor force participation seems to be much more closely related to increases in life expectancy at age 20 than to life expectancy at birth. Both countries experienced very expressive gains in life expectancy at age 20 during the second half of the 20^{th} century, of roughly 10 years or more.

This evidence illustrates the fact that changes in adult longevity have been an important part of recent gains in life expectancy throughout the world. For example, female mortality between ages 15 and 60 in Brazil was reduced by 39% from 1960 to 2000, while the analogous number for countries as diverse as Australia, Austria, Chile, China, Colombia, Germany, India, Indonesia, Ireland, South Korea, Mexico, and Spain was around or above 50% (World Bank, 2004). In absolute terms, these changes represented reductions in the probability of death between ages 15 and 60 of up to 30 or 50 percentage points in cases such as China, Indonesia and Korea.

In the remainder of this section, we explore in further detail some micro and macro evidence on the relationship between adult longevity and female labor force participation. It is difficult to unequivocally establish causality in this context, since mortality data are typically available only at the aggregate level and there are potential endogeneity issues between mortality and other socioeconomic characteristics. Though our exercises do not solve these problems entirely, they provide robust evidence on the close relationship between adult longevity and female labor force participation in very diverse empirical environments and with different types of data. We believe that, together, they provide compelling initial evidence on the potential role of adult longevity as one of the determinants of female labor force participation.

Micro Evidence

Data

Micro-level estimates of the effects of mortality or life expectancy on individual behavior are very rare. Mortality is only observed well after the behavior that typically interests economists occurs, and it is thought to be considerably affected by the previous behavior itself, as well as by the economic conditions prevalent during the agents' lifetimes. The most difficult challenge in this direction is to obtain measures of life expectancy or mortality that are at least partly exogenous at the individual level and have enough variation within the sample.

In this subsection, we use the 1996 Brazilian Demographic and Health Survey (DHS)[14] to construct a proxy for adult longevity based on the mortality history of the previous generation of an individual's family (siblings of the respondent). We then analyze how this variable is related to a woman's reported attachment to the labor market. 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 unknown to the woman herself. This approach finds support on a large array of empirical evidence suggesting that subjective assessments of individual life expectancy are considerably accurate, and react to exogenous events in consistent ways. In particular, the most important event determining updates in individuals' assessments of their own life expectancies is the death of a relative (see, for example, Hamermesh, 1985, Hurd and McGarry, 1997, Smith et al, 2001, Perozek, 2008).

Our main goal is to identify one independent source of variation in mortality, and show that this variation is systematically related to choices regarding labor market attachment. Brazil is an interesting case from this perspective because the demographic transition has been long underway, but the great diversity in population and geographic conditions may help generate enough variation in family specific mortality. The DHS sample is composed of 12,612 women between ages 15 and 49, from all Brazilian states, and both urban and rural areas. The survey contains information related to realized fertility, individual characteristics, household characteristics, and previous mortality history of the respondent's family. This last set of variables allows the construction of family specific measures of survival. 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 neighborhood unobservables and household characteristics related to socioeconomic status.

Our dependent variable is a dummy assuming value 1 when the respondent has a professional occupation. The independent variable of interest is the family specific adult survival. The variable is the survival rate of the respondent's adult siblings, defined as the fraction of the respondent's siblings that reached 15 who were still alive at the moment of the interview or who lived at least

[14] 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 (U. S. Agency for International Development/Bureau for Global Programs, Field Support, and Research). The Brazilian survey was executed by BEMFAM.

until 60. This indicates the adult mortality history in the previous generation of the woman's family. The key identifying assumption is that individuals who lost adult siblings tend to have lower assessments of their own life expectancies, 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 main concern in this setting is that family specific adult survival may be related to other family specific mortality rates and to socioeconomic characteristics. This concern guides our choice of controls. We construct a measure of family specific child survival, defined as the fraction of respondent's siblings born who reached 15. This variable is constructed in a way analogous to the family specific adult survival rate, and indicates the child mortality history in the previous generation of a woman's family. This variable helps control for family specific health conditions during childhood, which may have long lasting effects on health. Also, it partly accounts for socioeconomic conditions, since child mortality is much more closely affected by economic resources in the household than adult mortality. In order to incorporate in more detail the economic background of the family, we also control for unobservable neighborhood characteristics, by using sample-cluster fixed-effects. The fixed-effects account for all neighborhood characteristics that are fixed across households, and therefore are strongly related to the overall socioeconomic status of a given area. Finally, since women in the sample are of different ages – and therefore at different moments in the life-cycle and with siblings of varying ages – we also control for age specific fixed-effects.

These four independent variables – family specific adult survival, family specific child survival, sample-cluster fixed-effects, and age fixed-effects – constitute our baseline specification. We then introduce, in sequence, variables that try to account for: (i) cultural determinants of individual behavior (religion and race); (ii) additional socioeconomic controls, related to household infrastructure (presence of treated water, toilet connected to the public sewer system, electricity, car, and washing machine in the household), and total number of siblings of the respondent (which may capture family background or preferences for number of children in the previous generation, since it represents the respondent's mother fertility); (iii) years of education; and (iv) total number of children ever born to the respondent. The durable goods chosen as household characteristics are more or less ordered in terms of income, so as to represent different socioeconomic status, as opposed to differences in tastes. So, for example, electricity, piped water, toilet, and a car, in this order, denote increasingly higher socioeconomic status. 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 think of them as representing different socioeconomic groups.

Given the discrete nature of the dependent variable, we estimate a probit model, weighted by sampling weights, and allowing for arbitrary within sample-cluster correlation in the error term (standard errors clustered at the sample-cluster level).

Results

Results are presented on Table 1, as probit marginal effects. In column 1, adult survival appears as significantly related to female labor force participation, while child survival appears with a very low and non-significant coefficient. The sample-cluster fixed effects (not shown in the table) also appear most of the times as statistically significant, suggesting that they do a good job in capturing overall socioeconomic conditions (they are also jointly significant). Columns 2 and 3 confirm this suspicion: when we include either cultural or racial variables (highly correlated with economic background) or additional measures of socioeconomic status (household infrastructure), the adult survival variable remains statistically significant with an almost identical coefficient, while child survival remains non-significant. Family specific adult survival seems to be systematically related to female labor force participation.

Given the coefficient presented in column 3, a one standard deviation increase in family specific adult survival (0.11) would lead to an increase of 1.3 percentage points in the probability of having a professional occupation. Though this result may seem quantitatively small, the goal of this subsection is not to argue that family specific variation in adult longevity is among the main determinants of female labor force participation in a cross-section of individuals. Our goal is simply to present evidence that changes in adult survival are associated with changes in female labor force participation. But in a given country at a point in time, the exogenous component of the variation in adult survival is likely to be small. So it is not surprising that the typical variation in family specific adult survival has a quantitatively small effect on female labor force participation. Nevertheless, 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 – labor force participation is likely to respond positively to gains in longevity.

Columns 4 and 5 introduce other individual level controls: education and number of children of the respondent, respectively. These variables should be endogenous to the theory being discussed here, and strictly should not belong in the right-hand-side of this equation. Still, their introduction as additional controls may be clarifying and help us understand the source of the correlation between adult mortality and female labor force participation. When education is introduced as an additional control, the coefficient on adult survival is reduced by roughly 15%, but remains statistically significant. When education and number of children are introduced together, there is some additional reduction on the coefficient, but it remains statistically significant at the 10% level (also notice that, as expected, education is positively related to labor force participation, and number of children negatively, both statistically significant). So the relationship between adult survival and female labor force participation seems to work partly through investments in human capital and fertility, as predicted by our theory.[15]

In this context, for the estimated effect of adult survival to be still capturing some omitted variable, it has to be a variable uncorrelated with the following characteristics of women: child survival rate of siblings, socioeconomic status, neighborhood of residence, total number of siblings (or fertility of the grandmother), education, number of children, religion, and race. Even more, adult survival itself does not seem to be particularly correlated with socioeconomic status.[16] In other words, omitted variable bias does not seem to be a problem.

Macro Evidence

Data

We now present results on the relationship between adult mortality and female labor force participation based on cross-country panel regressions of the fraction of the labor force composed of women on different sets of variables. Despite the limitations intrinsic to this type of data, we believe they provides useful and sometimes surprising insights, and help unmake some commonly held misconceptions about the typical correlation between these variables.

The various specifications presented include as independent variables combinations of adult mortality (between ages 15 and 60), infant mortality (before age 1), income per capita adjusted for terms of trade, average educational attainment in the population aged 15 and above, total fertility rate, and country and time fixed-effects. Country fixed-effects are included to account for country specific characteristics that do not change with time, and time fixed-effects are included to account for common trends in female labor force participation across countries. Reported standard errors are clustered at the country level, to allow for serial correlation and heteroskedasticity, and

[15] This analogy with the theory has some limitations, since the education variable presented here refers only to formal education, while investments in adult human capital in the model refer to any type of investment in market related skills.

[16] Adult survival is significantly related to only one of our six socioeconomic variables (car in the household), and even in this case the coefficient of correlation is only 0.03. Nevertheless, the household infrastructure variables intended to capture socioeconomic status seem to do a good job, since they are highly correlated to each other, and also to education, race, religion, and urban status.

to avoid overestimation of the significance of coefficients (as suggested by Bertrand, Duflo, and Mullainathan, 2004). Income per capita is from the Penn World Tables version 6.1, educational attainment is from the Barro and Lee Dataset, and all remaining variables are from the World Bank's World Development Indicators. Observations are in five-year intervals between 1960 and 2000 (five-year averages centered in the reference year).[17]

Our first set of regressions explores the simple correlation between these variables in an OLS context. These regressions are not intended to imply a causal relationship. They should be seen simply as a descriptive tool, used to reveal the pattern of conditional correlations observed across countries. Our initial goal is to show that this pattern of simple correlations is quite different from what is commonly believed and, maybe surprisingly, is remarkably consistent with our theory. Following, we use the same specifications from the OLS exercise in an IV setting. Our instrumental variables exploit the mortality shocks represented by AIDS and by the collapse of communism. This exercise tries to reveal some of the causal impact of mortality on female labor force participation.

Results

Columns 1 to 4 in Table 2 present the results from OLS regressions of the fraction of the labor force composed of women on different combinations of independent variables. The results show that higher adult mortality is significantly correlated with lower female labor force participation in all specifications. Countries with high adult mortality have typically lower female labor supply. At the same time, columns 2 to 4 show that this correlation does not seem to be driven by the simple correlations between, on one side, mortality and development and, on the other side, development and female labor force participation. Even after controlling for infant mortality, income per capita, and socioeconomic characteristics such as education and fertility, adult mortality remains significantly related to female labor supply.[18] Interestingly, and maybe surprisingly to most, infant mortality appears as positively and significantly related to female labor force participation in all columns in the table, as suggested by our theory. Across countries, reductions in child mortality are associated with reductions in female labor supply. Finally, column 5 shows that, once we break down adult mortality into male and female adult mortality, the negative effect

[17] The regressions presented make use of all the data available, and therefore the panel is unbalanced. Qualitative results are the same when a balanced panel is used. Qualitative results also remain unchanged when child mortality (before age 5) is used instead of infant mortality (before age 1).

[18] Though fertility and education should be endogenous to our problem, the specifications in columns 4 and 5 highlight the fact that the correlation between adult mortality and female labor supply is not an artifact of the correlation between general socioeconomic conditions and these two variables. Also notice that formal education, as measured by the Barro & Lee statistic used as our education variable, does not map exactly with the idea of adult human capital that we have in the paper, since the latter would incorporate all other dimensions of investments in market specific human capital.

comes entirely from changes in female adult mortality. The effect of male adult mortality on female labor force participation is positive, as one would expect from a pure income effect.

The main problem with the results from Table 2 is that the sources of variation in mortality are unknown, and one might suspect that some omitted variable could be driving the results, or that the shocks responsible for changes in mortality could also have direct effects on female labor supply. One alternative in this case is to look for specific mortality shocks that can be clearly identified, and analyze their impact on female labor force participation. In the cross-country context, during the period in question, there seem to be two natural candidates: the spread of AIDS in Sub-Saharan Africa and the collapse of communism in Eastern Europe and the former USSR. Both events had significant impacts on adult mortality, but also on other dimensions of economic life and social organization. Nevertheless, the impacts on mortality were more immediate and clearly identifiable. Therefore, analyzing the timing of these events in the relevant regions, and controlling for other dimensions that may have been affected by them, one could in principle try to identify their effects on mortality and, through mortality, on female labor force participation.

In order to implement this idea, we create two variables indicating, respectively, the arrival of AIDS in Sub-Saharan Africa and the collapse of communism in Eastern Europe and the former USSR. The AIDS variable is defined for each Sub-Saharan country as a dummy assuming value 1 after the date when the first HIV case was diagnosed in a given country (other countries have value zero).[19] The communism collapse variable is defined for each former communist country in Eastern Europe and the former USSR as a dummy assuming value 1 after the date when the country declared independence or the communist regime was overthrown (other countries have value zero).[20] Since we have country and year fixed-effects, these dummy variables provide the equiva-

[19] Since the actual dynammic behavior of the HIV-AIDS epidemic within a country may be endogenous to its characteristics, we choose to use the official "arrival" of the disease as the exogenous shock.

[20] In our five-year interval dataset, most Subsaharan African countries have the AIDS dummy assuming value 1 starting in 1990 (36% in 1985, 59% in 1990, and 5% in 1995). Most former communist countries in Eastern Europe and the former USSR have the collapse of communism dummy assuming value 1 in 1995 (22% in 1990 and 78% in 1995). Qualitative results are similar to those obtained when we use a dummy variable assuming value 1 for Subsaharan Africa starting in 1990, and another dummy variable assuming value 1 for former communist countries starting in 1995. Countries and respective dates (in parenthesis) of first registered HIV-AIDS are: Angola (1985), Benin (1985), Botswana (1986), Burkina Faso (1986), Burundi (1984), Cameroon (1986), Central African Republic (1984), Chad (1986), Congo, Dem. Rep. (1983), Congo, Rep. (1983), Cote d'Ivoire (1987), Djibouti (1988), Eritrea (1988), Ethiopia (1986), Gabon (1987), Ghana (1986), Guinea (1987), Guinea-Bissau (1987), Kenya (1983), Lesotho (1986), Liberia (1991), Malawi (1986), Mali (1985), Mauritania (1988), Mozambique (1986), Namibia (1992), Niger (1987), Nigeria (1987), Rwanda (1983), Senegal (1986), Sierra Leone (1987), Somalia (1987), South Africa (1982), Swaziland (1987), Tanzania (1984), Togo (1987), Uganda (1982), Zambia (1984), Zimbabwe (1985). Countries and respective dates (in parenthesis) of regime change are: Albania (1992), Armenia (1991), Azerbaijan (1991), Belarus (1991), Bosnia and Herzegovina (1991), Bulgaria (1990), Croatia (1991), Czech Republic (1990), Estonia (1991), Georgia (1991), Hungary (1989), Kazakhstan (1991), Kyrgyz Republic (1991), Latvia (1991), Lithuania (1991), Macedonia, FYR (1991), Moldova (1991), Poland (1989), Romania (1989), Russian Federation (1991), Slovak Republic (1990), Slovenia (1991), Tajikistan (1991), Turkmenistan (1991), Ukraine (1991), Uzbekistan (1991), and Yugoslavia, Fed. Rep. (1991). Data on HIV-AIDS from the World Health Organization (http://www.who.int/hiv/countries/en/), AVERT (http://www.avert.org/aidsinafrica.htm), and Velayati et

lent of difference-in-difference estimates of the effects of AIDS and the collapse of communism on the variables of interest.

Table 3 summarizes the correlation between these two variables and mortality in different age groups: columns 1 to 3 have infant mortality as the dependent variable, while columns 4 to 6 have adult mortality. It is clear from the table that the arrival of AIDS is not related to significant changes in infant mortality, even though it is strongly related to adult mortality. Also, most of the effect of AIDS on adult mortality does not seem to work through other socioeconomic channels. In reality, once we control for income and other socioeconomic characteristics, the coefficient on the AIDS variable becomes larger, consistent with the notion that the HIV-AIDS epidemic is more prevalent among relatively urbanized and well-off areas of Africa. In relation to the collapse of communism, the table suggests that regime change was associated with increased child mortality, but that this relationship was driven by deterioration in socioeconomic conditions: once income per capita is introduced as an additional control, the effect of collapse of communism on child mortality is reduced by roughly 65%, while it becomes non-significant once fertility and education are included. In the case of adult mortality, on the other hand, the effect of the collapse of communism is robust to the inclusion of income per capita and other socioeconomic variables.

In short, both AIDS and the collapse of communism had clear effects on adult mortality and no noticeable effect on infant mortality. Though these events also had impacts on other dimensions of economic life, as long as we control for income per capita and other socioeconomic characteristics, we may be able to use them as exogenous shocks to adult mortality. But before doing that, we present on Table 4 reduced form estimates of the direct effect of AIDS and the collapse of communism on the fraction of the labor force composed of women. Specifications are identical to those presented on Table 3, but for the fact that the dependent variable is replaced by the fraction of the labor force composed of women, and infant mortality is introduced as an additional control in some specifications. In all cases, both the collapse of communism and the arrival of AIDS are associated with reductions in the fraction of the labor force composed of women.

The most likely biases in this case are associated with other channels through which these two events might affect female labor supply. In the collapse of communism, deterioration in the provision of public goods and overall economic stagnation immediately after the transition may have led to increases in the labor supply of women through pure income effects, biasing the estimated coefficients against the main hypothesis raised here. In relation to the arrival of AIDS, incapacitation associated with final stages of the disease may reduce labor supply. If HIV prevalence among women is higher than among men, this may lead to a spurious negative

al (2007). Data on regime change and the collapse of communism from the CIA World Factbook.

correlation between AIDS and the fraction of the labor force composed of women. Though HIV-AIDS in Sub-Saharan Africa was initially more common among males, the trend has been reversed over the last decade and women have become the main victims of the epidemic (UNAIDS and WHO, 2006). In any case, in the results from Table 4, the coefficient on the arrival of AIDS does not seem to be affected by issues related to incapacitation, since it remains virtually unchanged when other variables that should be related to the mechanism described above – such as income per capita and fertility, for example – are included as additional controls. In short, women in Sub-Saharan African countries seem to have reduced their labor supply in relation to men's after the arrival of AIDS, similarly to women in former communist countries after the collapse of the regime.

On Table 5, we present the results of our last exercise with the aggregate cross-country panel. We use the AIDS and collapse of communism variables as instruments for adult mortality, and then analyze the impact of instrumented adult mortality on the fraction of the labor force composed of women. First stage specifications are similar to those presented on Table 3, but for the fact that, depending on the specification, infant mortality also enters the equation for adult mortality. Second stage specifications are identical to the first four columns on Table 2. In line with the previous results, instrumented adult mortality appears as significantly negatively related to female labor force participation in all specifications. The coefficient increases substantially when infant mortality and income per capita are introduced as additional controls, and then drops again after fertility and education are introduced. This pattern suggests that shocks to mortality associated with AIDS and the collapse of communism were not determined by short-term economic performance, and that changes in education and fertility may have captured part of the impact of mortality increases. Curiously, the coefficients on adult mortality on Table 4 are substantially larger than those obtained in an OLS setting (Table 2). This could be expected if, for example, short-run increases in economic activity associated with increases in female labor force participation led to deterioration of health conditions. Quantitatively, the coefficient from column 4 implies that a one standard deviation increase in adult mortality (145) would lead to a 12 percentage point increase in the fraction of the labor force composed of women (the mean of this variable in the sample is 37).

Discussion

One of the main issues that made it difficult for researchers to relate female labor force participation to the demographic transition was the delayed increased in the labor supply of women, when compared to the timing of reductions in mortality and fertility. Our theory overcomes this problem by showing that reductions in fertility are not enough to generate the movement of women out of the household. The latter is only guaranteed when reduced fertility is accompanied by increased return to labor market attachment, which does not happen until reductions in adult mortality are observed, during the later stages of the demographic transition.

This close association between female labor force participation and adult longevity, as opposed to child mortality, is somewhat at odds with the accepted common knowledge in the profession. Typically, female labor force participation is seen as closely linked to fertility, which in turn is affected by child mortality. Therefore, child mortality should exhibit a negative correlation with female labor force participation. In addition, the idea that development brings together modernization and health improvements should reinforce this correlation, even in the absence of a strictly causal relationship between the two variables.

The evidence discussed here shows that this belief is not supported by the pattern of correlations observed in the data. Be it through time, across countries, or within countries, female labor supply tends to be positively associated with adult survival, and, at best, not closely related to child mortality. These patterns are different from what is commonly believed, and yet entirely consistent with our theory. Further research is needed in order to precisely establish the quantitative relevance of adult longevity as a determinant of female labor force participation.

6 Concluding Remarks

This paper presents a model where, ultimately, longevity gains are solely responsible for the increased participation of women in the labor market and the narrowing of the gender wage-gap. Though the direct link between these two phenomena may seem obscure, the intuition becomes clear once other dimensions of the demographic transition are brought into the analysis. Increased longevity increases the returns to investments in market oriented human capital. Higher returns to investment in human capital increase the cost of time and shift the quantity-quality trade-off toward fewer and better educated children. In addition, lower mortality reduces the return to large families, representing an additional force toward reduced fertility. With higher returns to human capital and fewer children, women increase their investments in human capital and their attachment to the market. Since women are initially specialized in the household sector, their gain in productivity is more than proportional to the initial gain in longevity, leading to a reduction in the gender wage-gap.

At the same time, the theory does not generate increases in female labor force participation or reductions in the gender wage-gap as results of reductions in child mortality. Though reductions in child mortality reduce fertility, they also increase the return to investment in children, therefore increasing the demand for household production. In this situation, increased return to investment in children represents an opposing force that tends to minimize the positive effect of fertility reduction on labor supply. Our model shows that, under reasonable assumptions, this force may be strong enough to generate a positive relationship between child mortality and labor supply of women. Generally, our theory shows that increases in female labor supply and reductions in the gender wage-gap should be closely related to gains in adult longevity, not to reductions in child mortality.

The predictions generated by our model suggest a single process of demographic transition, consistent with several social changes observed in the course of the last century. Though other technological and cultural factors are certainly important in explaining the transformation in the role of women in society, we highlight one important economic force that has been entirely ignored in the previous literature.

A Appendix

A.1 The Problem of the Household and First Order Conditions

The problem of the household is given by

$$\begin{aligned} \max_{\{c,n,x_y,l_m,l_f,e_m,e_f,b_m,b_f\}} V &= \tau\frac{c^\sigma}{\sigma} + \rho\left(n\left(1-\delta\right)\tau\right)\frac{\left[Ax_\tau + \left(1-A\right)x_y\right]^\alpha}{\alpha} \qquad \text{(A.18)} \\ \text{subject to } l_m H q_p e_m + l_f H q_p e_f &\geq \tau c + pnx_y, \\ \tau &= l_i + e_i + nb_i, \text{ for } i = f, m, \text{ and} \\ x_\tau &= (Fb_f + Mb_m)q_p. \end{aligned}$$

Let ψ, λ_f, and λ_m denote the multipliers on the three constraints above. Substituting for x_τ in the objective function, Kuhn-Tucker first order conditions can be obtained for c, n, e_m, l_m, b_m, e_f, l_f, b_f and x_y. In their most general form, these first order conditions are given by, respectively:

$$
\begin{aligned}
\tau c^{\sigma-1} &= \psi\tau, \\
\rho'\tau(1-\delta)\frac{q_c^{\alpha}}{\alpha} &= \psi p x_y + \lambda_f b_f + \lambda_m b_m, \\
H q_p l_m \psi &\leq \lambda_m, \text{ with } = \text{ if } e_m > 0 \\
H q_p e_m \psi &\leq \lambda_m, \text{ with } = \text{ if } l_m > 0 \\
\rho q_c^{\alpha-1} A M q_p &\leq \lambda_m n \text{ , with } = \text{ if } b_m > 0 \\
H q_p l_f \psi &\leq \lambda_f, \text{ with } = \text{ if } e_f > 0 \\
H q_p e_f \psi &\leq \lambda_f, \text{ with } = \text{ if } l_f > 0 \\
\rho q_c^{\alpha-1} A F q_p &\leq \lambda_f n \text{ , with } = \text{ if } b_f > 0 \text{ and} \\
\rho q_c^{\alpha-1}(1-A) &\leq \psi p n, \text{ with } = \text{ if } x_y > 0.
\end{aligned}
$$

A.2 The Choice of the Technology for Investments in Children

When investments make use of the mother's time, $b_f > 0$, $b_m = x_y = 0$, and we have $\rho'\tau(1-\delta)\frac{q_c^{\alpha}}{\alpha} = \frac{\rho q_c^{\alpha-1} A F q_p}{n} b_f$. When investments make use of income, $x_y > 0$, $b_f = b_m = 0$, so we have $\rho'\tau(1-\delta)\frac{q_c^{\alpha}}{\alpha} = \frac{\rho q_c^{\alpha-1}(1-A)}{n} x_y$.

Proposition 1 *There is a τ^* such that, for every $\tau < \tau^*$, investments in children use the domestic technology (mother's time), and, for every $\tau \geqslant \tau^*$, investments use goods purchased in the market.*

Proof. The rate of return to investments using the domestic technology (marginal productivity divided by opportunity cost) is given by $RRb_f = \frac{\rho q_c^{\alpha-1} A F q_p}{\lambda_f n}$. The rate of return to investments using income is $RRx_y = \frac{\rho q_c^{\alpha-1}(1-A)}{\psi p n}$. The household will choose to use time whenever $RRb_f \geqslant RRx_y$, or $\frac{A F q_p}{\lambda_f} > \frac{(1-A)}{\psi p}$. Substituting for λ_f, this inequality can be rewritten as $e_f < p\frac{A}{(1-A)}\frac{F}{H}$. For τ sufficiently low (in particular, for $\tau < p\frac{A}{(1-A)}\frac{F}{H}$) $RRb_f > RRx_y$ and investments in children are done domestically. In addition, since e_f increases at least proportionately with τ, there is a τ large enough so that $e_f \geqslant p\frac{A}{(1-A)}\frac{F}{H}$. In this case, $RRb_f \leqslant RRx_y$ and investments in children are done through the market. ■

A.3 The Solution with Time Investments in Children

When women share their time between the market and the household, first order conditions for n and b_f yield

$$
\frac{n(1-\delta)\tau\rho'}{\rho} = \alpha,
$$

which gives $dn/d\tau = -n/\tau < 0$ and $dn/d\delta = n/(1-\delta) > 0$. These expressions mean that n responds to changes in τ and δ so as to keep $n(1-\delta)\tau$ constant.

The first order conditions for e_m, l_m, e_f and l_f, together with the time and budget constraints, give $\tau c = Hq_p\left(\tau^2 + e_f^2\right)$, a result that will be used later on.

A.3.1 Expressing the Problem in Terms of Time Shares

When investments in children make use of the domestic technology, it is convenient to rewrite the problem in terms of the shares of total lifetime (τ) dedicated to each different activity. Define the new variables $e_i^* = e_i/\tau$, $l_i^* = l_i/\tau$ and $b_i^* = nb_i/\tau$ as the shares of total lifetime allocated to, respectively, investments in adult human capital, labor supply, and domestic activities (raising children). Incorporating $x_y = 0$, the original problem can be rewritten as

$$\max_{e_i^*, l_i^*, b_i^*, n, c} \tau\frac{c^\sigma}{\sigma} + \rho[(1-\delta)\tau n]\frac{q_c^\alpha}{\alpha}$$

subject to

$$\begin{aligned}
\left(Hq_pe_m^*l_m^* + Hq_pe_f^*l_f^*\right)\tau^2 &\geq \tau c, \\
1 &\geq e_i^* + l_i^* + b_i^* \text{ , with } i = m,\ f,\ \text{and} \\
q_c &= \frac{\tau}{n}A(Fb_f^* + Mb_m^*)q_p.
\end{aligned}$$

Let ζ be the multiplier on the first constraint, and λ_i the multiplier on the second constraint for agent i. In the equilibrium where men specialize in market activities and women share their time between market and domestic activities, first order conditions can be written in terms of the new variables as

$$\begin{aligned}
c^{\sigma-1} &= \zeta, \\
\rho'(1-\delta)\tau\frac{q_c^\alpha}{\alpha} &= \rho q_c^{\alpha-1}\frac{\tau}{n^2}AFb_f^*q_p, \\
\zeta\tau^2Hq_pl_m^* &= \lambda_m, \\
\zeta\tau^2Hq_pe_m^* &= \lambda_m, \\
\rho q_c^{\alpha-1}\frac{\tau}{n}AMq_p &< \lambda_m,\ \text{with } b_m^* = 0 \\
\zeta\tau^2Hq_pl_f^* &= \lambda_f, \\
\zeta\tau^2Hq_pe_f^* &= \lambda_f,\ \text{and} \\
\rho q_c^{\alpha-1}\frac{\tau}{n}AFq_p &= \lambda_f.
\end{aligned}$$

Therefore, $e_m^* = l_m^* = 1/2$, $b_m^* = 0$, and $l_f^* = e_f^*$. For each individual, the time spent on investments in adult human capital and labor supply is always the same. Therefore, to save on notation, we write t_i^* as the proportion of total lifetime allocated to market related activities (investments in human capital plus labor supply), so that $l_i^* = e_i^* = t_i^*/2$ ($t_i^* = t_i/\tau$, where t_i was defined before as the total amount of agent i's time allocated to the market).

Rewriting the problem after substituting for the budget constraint into the utility function, and incorporating the fact that $t_m^* = 1$, and $b_f^*, t_f^* \in [0,1]$:

$$\max_{t_f^*, b_f^*, n} \tau^{1+\sigma} \left(\frac{Hq_p}{4}\right)^{\sigma} \frac{\left[1+t_f^{*2}\right]^{\sigma}}{\sigma} + \rho[(1-\delta)\,\tau n] \frac{q_c^{\alpha}}{\alpha}$$

subject to

$$\begin{aligned} 1 &\geq t_f^* + b_f^*, \text{ and} \\ q_c &= \frac{\tau}{n} AFq_p b_f^*. \end{aligned}$$

In this form, first order conditions become

$$\begin{aligned} (1-\delta)\tau\rho' \frac{q_c^{\alpha}}{\alpha} &= \rho q_c^{\alpha-1} \frac{\tau}{n^2} AFq_p b_f^*, \\ \tau^{1+\sigma} \left(\frac{Hq_p}{4}\right)^{\sigma} \left[1+t_f^{*2}\right]^{\sigma-1} 2t_f^* &= \lambda_f, \text{ and} \\ \rho q_c^{\alpha-1} \frac{\tau}{n} AFq_p &= \lambda_f. \end{aligned}$$

A.3.2 Characterizing the Optimal Choice and Effects on Allocation of Time

The objective function is concave on b_f^* and convex on t_f^*, so we cannot, in principle, guarantee unicity of the internal solution nor trust on the Hessian to verify that a point of maximum is reached. The issue in question and the optimal solution can be better understood with the help of a figure. Define

$$\begin{aligned} f(t_f^*) &= \frac{\tau^{1+\sigma} \left(\frac{Hq_p}{4}\right)^{\sigma} \left[1+t_f^{*2}\right]^{\sigma}}{\sigma}, \text{ and} \\ g(b_f^*) &= \rho((1-\delta)\tau n) \frac{\left(\frac{\tau}{n} AFq_p b_f^*\right)^{\alpha}}{\alpha}. \end{aligned}$$

Conditional on being on this equilibrium, and given the choice on the number of children (n),the optimal allocation of a woman's time is the solution to the following problem.

$$\max_{t_f^*, b_f^*} f(t_f^*) + g(b_f^*)$$

subject to $t_f^* + b_f^* = 1$ and with $t_f^*, b_f^* > 0$.

The optimum is characterized by $f'(t_f^*) = g'(b_f^*)$, where these derivatives are given by the left hand side of the last two first order conditions. One can show that

$$
\begin{aligned}
f''(t_f^*) &= 2\tau^{1+\sigma}\left(\frac{Hq_p}{4}\right)^{\sigma}\left[1+t_f^{*2}\right]^{\sigma-2}\left[1+t_f^{*2}+2(\sigma-1)t_f^{*2}\right] > 0,\\
g''(b_f^*) &= (\alpha-1)\,\rho[(1-\delta)\tau n]\left(\frac{\tau}{n}AFq_p\right)b_f^{*\alpha-2} < 0, \text{ and}\\
f'''(t_f^*) &= 2\tau^{1+\sigma}\left(\frac{Hq_p}{4}\right)^{\sigma}\left[1+t_f^{*2}\right]^{\sigma-3}\left[\begin{array}{c} 6(\sigma-1)t_f^* + 2(\sigma-1)^2 t_f^{*3} + \\ +2\sigma t_f^{*3}(\sigma-1) \end{array}\right] < 0,
\end{aligned}
$$

where the last inequality comes from the fact that $t_f^* > t_f^{*3}$. In addition, these functions are characterized by the following properties: $g'''(b_f^*) > 0$, $\lim_{x\longrightarrow 0} g'(b_f^*) = \infty$, $\lim_{x\longrightarrow 1} g'(b_f^*) =$ constant > 0, $\lim_{t\longrightarrow 0} f'(t_f^*) = 0$, and $\lim_{t\longrightarrow 1} f'(t_f^*) =$ constant > 0. So we can plot the functions f' and g' against the fraction of time allocated to the market, as in Figure A.1 (remember that $b_f^* = 1 - t_f^*$).

In the figure, we assume that the two curves intersect. If they did not, the origin would be the optimal choice. Points II and III are the ones that satisfy the first order conditions.

Proposition 2 *Point III is preferrable to point II and, therefore, is the solution to the household problem.*

Proof. Starting from point II and moving to the right, t_f^* increases while b_f^* is reduced. The gains in terms of utility are given by f', while the losses are given by g'. Since $f' > g'$ in (II, III), III is preferrable to II. ■

Points I and III are not comparable on a strictly graphical basis. More rigorously, their ordering would depend on the value of the integral $\int (f' - g')\,dt^*$. Point I corresponds to the equilibrium where there is total specialization within the household (man on the market and woman in the household). For lower values of τ, the integral above is negative, and the optimal choice is point I. For a higher τ, the value of the integral increases and eventually becomes positive. This is what characterizes the first movement of women into the labor market.

Generally, the comparative statics of the problem can be analyzed from the impact of changes in the exogenous variables on the curves f' and g'. As τ increases, f' moves vertically at a rate $(1+\sigma)$, and g' moves vertically at a rate 2α. In order for a steady state to exist in this economy, we must have $\alpha = \sigma$ (see Soares, 2005). In this case, f' shifts at a faster rate and, therefore, point III moves to the right, corresponding to a higher t_f^* and a lower b_f^*. A reduction in δ reduces n, affecting the function g but leaving f unchanged. The reduction in n shifts the curve g' upwards, moving the optimal point III to the left, corresponding to lower t_f^* and higher b_f^*.[21]

[21] The discussion in this paragraph uses the fact that $(1-\beta)n\tau$ is constant as τ and δ change.

A.3.3 The Quality of Children in the Solution with Time Investments

First order conditions for l_f^* and b_f^* above lead to:

$$\zeta\tau^2 H q_p e_f^* = \rho q_c^{\alpha-1}\frac{\tau AF}{n} q_p.$$

Given that $\frac{dn}{d\tau} = -\frac{n}{\tau}$, terms on $n\tau$ remain constant as τ changes. Using this fact, together with $\zeta = c^{\sigma-1}$ and the expression $\tau c = Hq_p\left(\tau^2 + e_f^2\right)$ obtained in A.3:

$$\Omega\left(\frac{\tau^2 + e_f^2}{\tau}\right)^{\sigma-1} e_f^* = b_f^{\alpha-1},$$

where $\Omega = \frac{n\tau}{\rho}\frac{(Hq_p)^\sigma}{(AFq_p)^\alpha}$. Rearranging terms and substituting for $e_f = \tau - nb$:

$$\Omega\left(\tau^2 + (\tau - nb_f)^2\right)^{\sigma-1}(\tau - nb_f) = \tau^\sigma b_f^{\alpha-1}.$$

Define $\Phi = \left(\tau^2 + (\tau - nb_f)^2\right)^{\sigma-1}(\tau - nb_f)$. The effect of τ on b_f is obtained from the total differential

$$\Omega\Phi\left[-\frac{(1-\sigma)\left[2\tau + 2(\tau - nb_f) - 2(\tau - nb_f)\left(\frac{dn}{d\tau}\right)b_f\right]}{\tau^2 + (\tau - nb_f)^2} + \frac{1 - \left(\frac{dn}{d\tau}\right)b_f}{\tau - nb_f} - \frac{\sigma}{\tau}\right]d\tau =$$

$$= \Omega\Phi\left[-\frac{(1-\alpha)}{b_f} + \frac{n}{\tau - nb_f} - \frac{2(1-\sigma)(\tau - nb_f)n}{\tau^2 + (\tau - nb_f)^2}\right]db_f.$$

Cancelling terms and substituting for $\frac{dn}{d\tau} = -\frac{n}{\tau}$:

$$\left[-\frac{(1-\sigma)\left[2\tau + 2(\tau - nb_f) + 2(\tau - nb_f)\frac{nb_f}{\tau}\right]}{\tau^2 + (\tau - nb_f)^2} + \frac{1 + \frac{nb_f}{\tau}}{\tau - nb_f} - \frac{\sigma}{\tau}\right]d\tau =$$

$$= \left[-\frac{(1-\alpha)}{b_f} + \frac{n}{\tau - nb_f} - \frac{2(1-\sigma)(\tau - nb_f)n}{\tau^2 + (\tau - nb_f)^2}\right]db_f.$$

Rearranging:

$$\left[\frac{\begin{array}{c}-2(1-\sigma)\tau^2(\tau - nb_f) - 2(1-\sigma)\tau(\tau - nb_f)^2 - \\ -2(1-\sigma)(\tau - nb_f)^2 nb_f + \tau^3 + \tau(\tau - nb_f)^2 + \tau^2 nb_f + \\ +(\tau - nb_f)^2 nb_f - \sigma\tau^2(\tau - nb_f) - \sigma(\tau - nb_f)^3\end{array}}{\left(\tau^2 + (\tau - nb_f)^2\right)(\tau - nb_f)\tau}\right]d\tau =$$

$$= \left[\frac{\begin{array}{c} -(1-\alpha)\tau^2(\tau - nb_f) - (1-\alpha)(\tau - nb_f)^3 + nb_f\tau^2 + \\ +nb_f(\tau - nb_f)^2 - 2(1-\sigma)(\tau - nb_f)^2 nb_f \end{array}}{b_f(\tau - nb_f)\left(\tau^2 + (\tau - nb_f)^2\right)} \right] db_f.$$

Dividing both sides by τ^3, and remembering that $b_f^* = \frac{nb_f}{\tau}$, we have $(\tau - nb_f) = \tau(1 - b_f^*)$, so that we can write:

$$\left[\begin{array}{c} -2(1-\sigma)\left(1-b_f^*\right) - 2(1-\sigma)\left(1-b_f^*\right)^2 - \\ -2(1-\sigma)\left(1-b_f^*\right)^2 b_f^* + 1 + \left(1-b_f^*\right)^2 + b_f^* + \\ +\left(1-b_f^*\right)^2 b_f^* - \sigma\left(1-b_f^*\right) - \sigma\left(1-b_f^*\right)^3 \end{array} \right] \frac{d\tau}{\tau} =$$

$$= \left[\begin{array}{c} -(1-\alpha)\left(1-b_f^*\right) - (1-\alpha)\left(1-b_f^*\right)^3 + b_f^* + \\ +b_f^*\left(1-b_f^*\right)^2 - 2(1-\sigma)\left(1-b_f^*\right)^2 b_f^* \end{array} \right] \frac{db_f}{b_f}.$$

Define $\Theta = -2(1-\sigma)\left(1-b_f^*\right) - 2(1-\sigma)\left(1-b_f^*\right)^2 - 2(1-\sigma)\left(1-b_f^*\right)^2 b_f^* + 1 + \left(1-b_f^*\right)^2 + b_f^* + \left(1-b_f^*\right)^2 b_f^* - \left(1-b_f^*\right) - \left(1-b_f^*\right)^3$, and Λ as the coefficient on $\frac{db_f}{b_f}$ above. We have

$$\left(\Theta + (1-\sigma)\left[\left(1-b_f^*\right) + \left(1-b_f^*\right)^3\right]\right)\frac{d\tau}{\tau} = \Lambda\frac{db_f}{b_f}.$$

It is possible to show that $\Theta = 2\Lambda$:

$$2\Lambda - \Theta =$$

$$\begin{aligned}
&= -2(1-\alpha)\left(1-b_f^*\right) - 2(1-\alpha)\left(1-b_f^*\right)^3 + 2b_f^* + 2b_f^*\left(1-b_f^*\right)^2 - \\
&\quad -4(1-\sigma)\left(1-b_f^*\right)^2 b_f^* + 2(1-\sigma)\left(1-b_f^*\right) + 2(1-\sigma)\left(1-b_f^*\right)^2 + \\
&\quad +2(1-\sigma)\left(1-b_f^*\right)^2 b_f^* - 1 - \left(1-b_f^*\right)^2 - b_f^* - \left(1-b_f^*\right)^2 b_f^* + \left(1-b_f^*\right) + \left(1-b_f^*\right)^3 \\
&= 2(1-\alpha)\left[\begin{array}{c} -\left(1-b_f^*\right) - \left(1-b_f^*\right)^3 - 2\left(1-b_f^*\right)^2 b_f^* + (1-b_f^*) + \\ +(1-b_f^*)^2 + \left(1-b_f^*\right)^2 b_f^* \end{array} \right] + \\
&\quad +2b_f^* + 2b_f^*\left(1-b_f^*\right)^2 - 1 - \left(1-b_f^*\right)^2 - b_f^* - \left(1-b_f^*\right)^2 b_f^* + \left(1-b_f^*\right) + \left(1-b_f^*\right)^3 \\
&= 2(1-\alpha)[0] + 0.
\end{aligned}$$

Noting that $-\left(1-b_f^*\right)^2 b_f^* + (1-b_f^*)^2 = (1-b_f^*)^3$, one can write:

$$\left(2\Lambda + (1-\sigma)\left[\left(1-b_f^*\right) + \left(1-b_f^*\right)^3\right]\right)\frac{d\tau}{\tau} = \Lambda\frac{db_f}{b_f}, \text{ so that}$$

$$\frac{db_f}{d\tau} = \frac{\Lambda}{\left(2\Lambda + (1-\sigma)\left[\left(1-b_f^*\right) + \left(1-b_f^*\right)^3\right]\right)} \frac{b_f}{\tau}.$$

Since $(1-\sigma)\left[\left(1-b_f^*\right) + \left(1-b_f^*\right)^3\right] > 0$, $\frac{db_f}{d\tau} < 0 \Longleftrightarrow \Lambda < 0$ and $2\Lambda + (1-\sigma)\left[\left(1-b_f^*\right) + \left(1-b_f^*\right)^3\right] > 0$, otherwise $\frac{db_f}{d\tau} \geq 0$. Therefore, $\frac{db_f}{d\tau} < 0$ if and only if

$$-(1-\sigma)\frac{[(1-b_f^*) + (1-b_f^*)^3]}{2} < \Lambda < 0, \text{ or}$$

$$\begin{aligned} -(1-\sigma)\frac{[\left(1-b_f^*\right) + \left(1-b_f^*\right)^3]}{2} &< -(1-\alpha)\left(1-b_f^*\right) - \\ -(1-\alpha)\left(1-b_f^*\right)^3 + b_f^* + b_f^*\left(1-b_f^*\right)^2 - 2(1-\sigma)\, b_f^*\left(1-b_f^*\right)^2 &< 0. \end{aligned}$$

Incorporating the condition for existence of steady-state ($\alpha = \sigma$), this inequality can be further simplified to

$$\begin{aligned} -(1-\sigma)\frac{[\left(1-b_f^*\right) + \left(1-b_f^*\right)^3]}{2} &< -(1-\sigma)\,2 + (2-\sigma)\,2b_f^* - \\ -(1+\sigma)b_f^{*2} + \sigma b_f^{*3} &< 0. \end{aligned}$$

The effect of the change in longevity on the quality of children depends, therefore, on the equilibrium fraction of time allocated to the household (b_f^*), which is a function of the other parameters of the model, and on σ. In principle, any value of b_f^* between 0 and 1 will be the solution to the household problem, for a given set of parameters.[22] From the expression above, it is immediately clear that for sufficiently small or sufficiently large b_f^* the inequality cannot hold. So, if female labor supply is sufficiently low or sufficiently high, we have $\frac{db_f}{d\tau} \geq 0$. Child quality can only be reduced if the initial female labor supply is at intermediary levels.

We illustrate this pattern by calculating $db_f/d\tau$ for various combinations of σ and initial values of b_f^*. Results are presented in Figure A.2 (truncated at -2 and $+2$, to keep the scale in

[22] From the extensive margin choice between household and market technologies, women will spend time investing in children as long as

$$e_f = \frac{\tau(1-b_f^*)}{2} < p\frac{a}{1-a}\frac{B}{A}.$$

Since p does not affect the intensive margin choice of b_f^*, and b_f^* falls with τ, there are always values of p and τ high enough to make the solution where women share their time between market and household activities compatible with arbitrarily low levels of b_f^*. Similarly, everything else constant, reductions in τ increase b_f^* monotonically, until eventually women become entirely specialized on household production. So, in principle, there are parameter values such that any b_f^* between 0 and 1 can be made compatible with the solution where women share their time between market and household activities.

perspective). The lighter area denotes positive values of $db_f/d\tau$, while the darker area denotes negative values. From the figure, it is clear that $db_f/d\tau$ is positive for the vast majority of combinations of b_f^* and σ.

In particular, when female labor force participation rises from low levels, child quality increases together with the increased attachment of women to the labor force. In an intermediary interval, it is possible that further increases in female labor force participation are accompanied by reductions in the quality of children. But for sufficiently high initial levels of b_f^*, child quality again increases with increases in female labor supply (driven by increases in τ). Therefore, the model generates either a positive or a non-monotonic relationship between female labor force participation and quality of children. Section 3 discusses the intuition for these results.

A.4 The Solution with Market Investments in Children

When investments in children are done through the market, $x_y > 0$ and $b_m = b_f = 0$. In this case, the problem can be written in a simple form as

$$\max_{\{c,n,x_y,e_m,e_f\}} V = \tau\frac{c^\sigma}{\sigma} + \rho\left(n\left(1-\delta\right)\tau\right)\frac{\left[\left(1-A\right)x_y\right]^\alpha}{\alpha}$$

$$\text{subject to } Hq_p[e_m(\tau - e_m) + e_f(\tau - e_f)] \geq \tau c + pnx_y. \qquad (\lambda)$$

First order conditions give $e_m = e_f = \tau/2$, plus:

$$\begin{aligned} c^{\sigma-1} &= \lambda, \\ \rho'(1-\delta)\tau\frac{q_c^\alpha}{\alpha} &= \lambda p x_y, \text{ and} \\ \rho q_c^{\alpha-1}(1-A) &= \lambda pn. \end{aligned}$$

Using the first order conditions for n and x_y, one can obtain again the familiar expression $\frac{\rho'(1-\delta)\tau n}{\rho} = \alpha$.

Substituting for the multiplier in the first order condition for x_y, one can obtain write

$$c = \left[\frac{\rho[(1-A)x_y]^{\alpha-1}(1-A)}{pn}\right]^{1/(\sigma-1)}.$$

The expression for consumption can be plugged into the budget constraint, together with $e_m = e_f = \tau/2$, in order to obtain another expression where the only endogenous variables are n and x_y. Using $dn/d\tau = -n/\tau$ (which also implies constant $n\tau$), the effect of τ on x_y can be obtained from the total differential of this new expression in relation to x_y and τ:

$$\frac{dx_y}{d\tau} = \frac{\Delta \tau n^{1/(1-\sigma)} + pn}{Hq_p\tau + \frac{\sigma}{1-\sigma}\Delta x_y n^{1/(1-\sigma)} + px_y\frac{n}{\tau}} > 0,$$

where $\Delta = (1-A)\left[\frac{\rho(1-A)}{p}\right]^{1/(\sigma-1)}$.

The result means that investments in children, and therefore the quality of children, increase as longevity increases in the equilibrium where investments are purchased in the market. Intuitively, this happens here since increases in longevity reduce the shadow cost of investments in children, because of a lowered fertility rate, and expand the budget constraint (higher lifetime income of both members of the family). When τ increases, n falls and y increases more then proportionately ($y = l_m h_m + l_f h_f = Hq_p\tau^2/2$).

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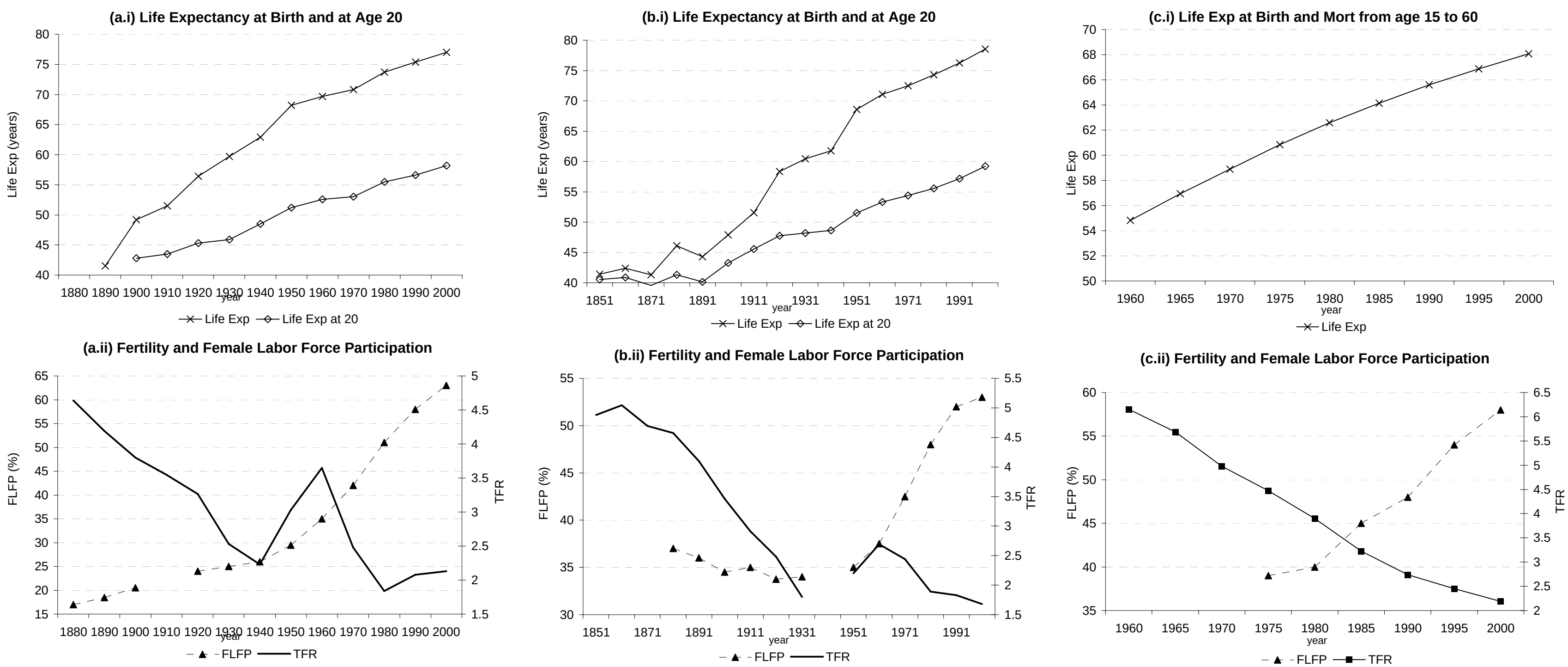
Figure 1: Life Expectancy, Fertility and Female Labor Force Participation - United States, Great Britain, and Brazil

Figure 1(a): United States | **Figure 1(b): Great Britain** | **Figure 1(c): Brazil**



Source: Costa (2000), National Center for Health Statistics (2003), and US Census Bureau (1975)

Source: Wrigley et al (1997), Keyfitz and Fieger (1968), Costa (2000), World Bank (2004) and Human Mortality Database (2006).

Source: Soares and Izaki (2002) and World Bank (2004)

Figure A.1: Characterization of First Order Conditions

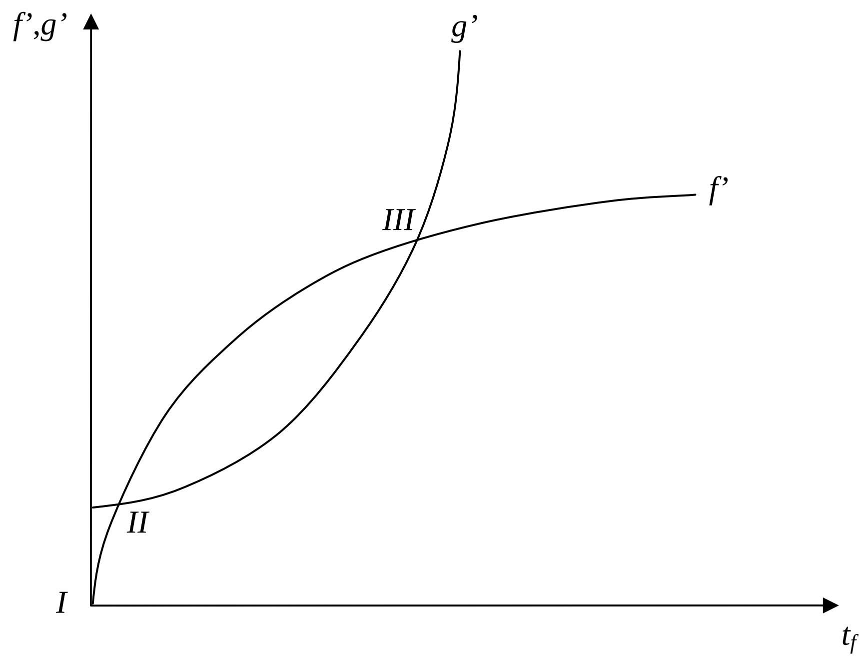


Figure A.2: Effect of *T* on b_f - Different Combinations of b_f^* and *sigma*

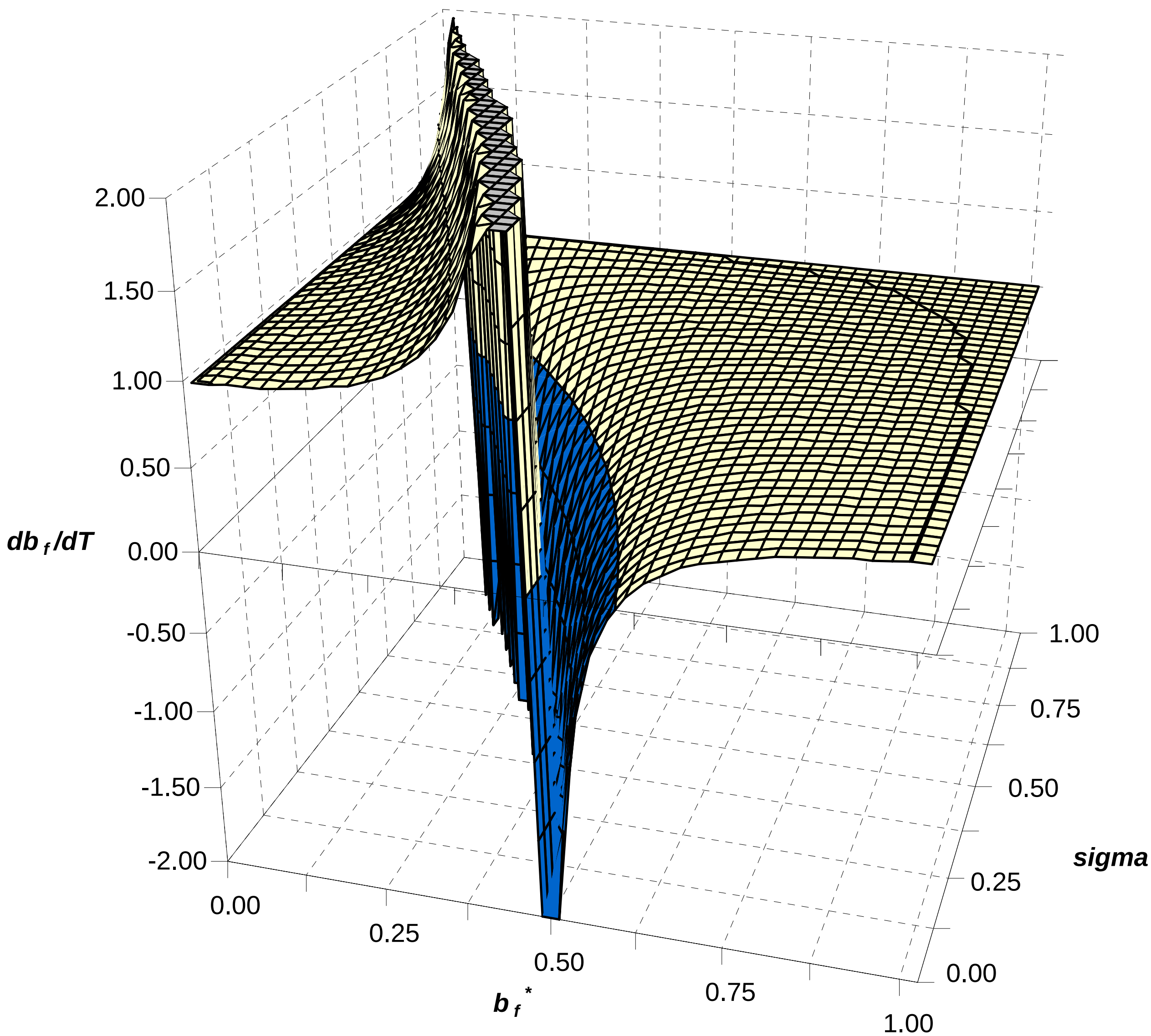


Table 1: Probit Estimation of the Effect of Family Specific Adult Survival on the Probability of Having a Professional Occupation, Brazil, Demographic and Health Survey, 1996

	1	2	3	4	5
Adult Survival	0.120**	0.124**	0.119**	0.103**	0.099*
	[0.053]	[0.053]	[0.053]	[0.052]	[0.053]
Child Survival	-0.003	0.003	-0.014	-0.018	-0.021
	[0.038]	[0.038]	[0.040]	[0.040]	[0.040]
Education				0.029***	0.027***
				[0.002]	[0.002]
N Children					-0.019***
					[0.004]
Religion Variables:					
Catholic		-0.005	-0.008	0.007	0.006
		[0.020]	[0.020]	[0.021]	[0.021]
Evangelical		-0.036	-0.042*	-0.021	-0.021
		[0.024]	[0.025]	[0.025]	[0.025]
Race Variables:					
Black		0.094***	0.095***	0.116***	0.116***
		[0.027]	[0.027]	[0.026]	[0.027]
Mixed		0.045***	0.042***	0.062***	0.065***
		[0.013]	[0.013]	[0.013]	[0.013]
Socioeconomic Status Variables:					
Water			0.026	0.011	0.009
			[0.028]	[0.027]	[0.027]
Toilet			0.005	-0.01	-0.013
			[0.020]	[0.020]	[0.021]
Electricity			0.009	-0.025	-0.032
			[0.041]	[0.039]	[0.039]
Car			-0.062***	-0.097***	-0.098***
			[0.015]	[0.016]	[0.016]
Wash Mach			0.063***	0.037**	0.036**
			[0.017]	[0.018]	[0.018]
N Siblings			-0.002	0.004*	0.003*
			[0.002]	[0.002]	[0.002]
N Obs	11337	11337	11227	11225	11225

Obs.: Probit marginal effects reported. Standard errors in brackets. * significant at 10%; ** significant at 5%; *** significant at 1%. Dependent variable is a dummy with value 1 if respondent has a professional occupation. All regressions include a constant, and age and sampling-cluster dummies. Adult Survival is respondent's siblings survival rate between 15 and 60; Child Survival is respondent's siblings survival rate between 0 and 15; Education indicates years of schooling of the respondent; N Children indicates the number of children of the respondent; Catholic and Evangelical are religion dummies; Black and Mixed are race dummies; Water is a dummy for piped water in the household; Toilet is a dummy for toilet connected to the sewer system in the household; Electricity is a dummy for electricity in the household; Car is a dummy for at least one car in the household; Wash Mach is a dummy for washing machine in the household; and N Siblings is the number of siblings of the respondent. Regressions weighted by sampling weights. Standard errors robust to within sampling-cluster correlation in the error term (clustering at the sampling-cluster level).

Table 2: Regressions for the Fraction of the Labor Force Composed of Women, Cross-country, 1960-2000

	1	2	3	4	5
Adult Mort	-0.011***	-0.014***	-0.011**	-0.014**	
	[0.003]	[0.003]	[0.005]	[0.006]	
Female Mort					-0.027**
					[0.014]
Male Mort					0.014
					[0.012]
Inf Mort		0.037**	0.057***	0.074***	0.079***
		[0.015]	[0.019]	[0.022]	[0.023]
Income PC			2.941***	1.419	1.049
			[1.018]	[1.353]	[1.398]
Fertility				-0.855*	-0.800*
				[0.483]	[0.466]
Education				0.613	0.597
				[0.506]	[0.521]
N Obs	983	970	762	558	501
R-Sq	0.93	0.93	0.92	0.92	0.92

Obs.: Standard errors in brackets. * significant at 10%; ** significant at 5%; *** significant at 1%. Dependent variable is the fraction of the labor force composed by women (WDI). All regressions include a constant, year and country fixed-effects. Inf Mort is mortality under age 1 (per 1,000 live births, WDI); Adult Mort is mortality between ages 15 and 60 (per 1,000, WDI); Female Mort is female mortality between ages 15 and 60 (per 1,000, WDI); Male Mort is male mortality between ages 15 and 60 (per 1,000, WDI); Income PC is income per capita adjusted for terms of trade (PWT 6.1, rgdptt), Fertility is the total fertility rate (WDI); Education is average educational attainment in the population aged 15 and above (Barro & Lee). Data in five-year intervals between 1960 and 2000. Standard errors robust to within country correlation in the error term (clustering at the country level).

Table 3: Effect of AIDS and Collapse of Communism on Mortality by Age-Group, Cross-country, 1960-2000

	Dep Var: Inf Mortality			Dep Var: Adult Mortality		
	1	2	3	4	5	6
AIDS Arrival in Subsaharan Africa	2.152	3.823	2.218	70.977***	65.621***	85.585***
	[3.241]	[3.788]	[4.234]	[17.579]	[23.726]	[27.878]
Regime Collapse in Eastern Europe and USSR	14.390***	5.432**	3.089	75.428***	40.956**	58.527***
	[2.760]	[2.240]	[2.065]	[9.238]	[15.940]	[13.503]
Income PC		3.362	6.839*		-7.163	5.515
		[3.570]	[3.823]		[16.783]	[17.468]
Fertlity			8.377***			12.744***
			[1.758]			[4.447]
Education			0.432			-0.04
			[1.813]			[6.509]
N Obs	1617	1151	833	1052	790	564
R-Sq	0.94	0.95	0.96	0.91	0.91	0.92

Obs.: Standard errors in brackets. * significant at 10%; ** significant at 5%; *** significant at 1%. Dependent variables are mortality under age 1 (per 1,000 live births, WDI) and mortality between ages 15 and 60 (per 1,000, WDI). All regressions include a constant, year and country fixed-effects. AIDS Arrival in Subsaharan Africa is a dummy variable assuming value 1 for Subsaharan African Countries after the first recorded case of HIV-AIDS in each country; Regime Collapse in Eastern Europe and USSR is a dummy variable assuming value 1 for former communist countries in Eastern Europe and the former USSR after independence was declared or a new constitution was approved; Income PC is income per capita adjusted for terms of trade (PWT 6.1, rgdpttt), Fertility is the total fertility rate (WDI); Education is average educational attainment in the population aged 15 and above (Barro & Lee). Data in five-year intervals between 1960 and 2000. Standard errors robust to within country correlation in the error term (clustering at the country level).

Table 4: Reduced Form Effect of AIDS and Collapse of Communism on Fraction of Labor Force Composed of Women, Cross-country, 1960-2000

	1	2	3	4
AIDS Arrival in Subsaharan Africa	-5.436***	-5.591***	-5.451***	-5.896***
	[0.503]	[0.513]	[0.798]	[1.005]
Regime Collapse in Eastern Europe and USSR	-3.855***	-4.047***	-2.610***	-3.270***
	[0.638]	[0.620]	[0.957]	[0.974]
Inf Mortality		0.029**	0.050***	0.069***
		[0.011]	[0.015]	[0.018]
Income PC			1.512	0.16
			[0.932]	[1.106]
Fertility				-0.931**
				[0.365]
Education				0.32
				[0.390]
N Obs	1530	1475	1103	824
R-Sq	0.95	0.95	0.95	0.94

Obs.: Standard errors in brackets. * significant at 10%; ** significant at 5%; *** significant at 1%. Dependent variable is the fraction of the labor force composed by women (WDI). All regressions include a constant, year and country fixed-effects. AIDS Arrival in Subsaharan Africa is a dummy variable assuming value 1 for Subsaharan African Countries after the first recorded case of HIV-AIDS in each country; Regime Collapse in Eastern Europe and USSR is a dummy variable assuming value 1 for former communist countries in Eastern Europe and the former USSR after independence was declared or a new constitution was approved; Inf Mortality is mortality under age 1 (per 1,000 live births, WDI), Income PC is income per capita adjusted for terms of trade (PWT 6.1, rgdptt), Fertility is the total fertility rate (WDI); Education is average educational attainment in the population aged 15 and above (Barro & Lee). Data in five-year intervals between 1960 and 2000. Standard errors robust to within country correlation in the error term (clustering at the country level).

Table 5: IV Regressions for Fraction of the Labor Force Composed of Women, Instruments: AIDS and Collapse of Communism, Cross-country, 1960-2000

	Only Adult Mortality Instrumented			
	1	2	3	4
Adult Mortality	-0.077***	-0.092***	-0.105***	-0.086***
	[0.014]	[0.019]	[0.032]	[0.023]
Inf Mortality		0.147***	0.193***	0.170***
		[0.034]	[0.057]	[0.047]
Income PC			-0.103	-0.589
			[1.540]	[1.523]
Fertility				-0.719
				[0.598]
Education				0.36
				[0.608]
N Obs	983	970	762	558

Obs.: Standard errors in brackets. * significant at 10%; ** significant at 5%; *** significant at 1%. Dependent variable is the fraction of the labor force composed by women (WDI). All regressions include a constant, year and country fixed-effects. Adult Mort is mortality between ages 15 and 60 (per 1,000, WDI); Inf Mortality is mortality under age 1 (per 1,000 live births, WDI), Income PC is income per capita adjusted for terms of trade (PWT 6.1, rgdptt), Fertility is the total fertility rate (WDI); Education is average educational attainment in the population aged 15 and above (Barro & Lee). Instruments are a dummy variable assuming value 1 for Subsaharan African Countries after the first recorded case of HIV-AIDS, and a dummy variable assuming value 1 for former communist countries in Eastern Europe and the former USSR after independence was declared or a new constitution was approved. Data in five-year intervals between 1960 and 2000. Standard errors robust to within country correlation in the error term (clustering at the country level).