The Large Fall in Global Fertility*: A Quantitative Model

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Abstract

Over the past four decades, fertility rates have fallen dramatically in most middle- and low-income countries around the world. To analyze these developments, we study a quantitative model of endogenous human capital and fertility choice, augmented to allow for social norms over the number of children. The model enables us to gauge the role of human capital accumulation on the decline in fertility and to simulate the implementation of population-control policies aimed at affecting social norms and fostering the use of contraceptive technologies. Using data on several socio-economic variables as well as information on funding of population-control policies to parametrize the model, we find that policies aimed at altering family-size norms have provided a significant impulse to accelerate and strengthen the decline in fertility that would have otherwise gradually taken place as economies move to higher levels of human capital.

Key words: fertility rates, birth rate, convergence, macro-development, Malthusian growth, population.

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1 Introduction

Most developing countries experienced remarkable declines in total fertility rates (TFR) over the past few decades. The world's average TFR declined steadily during this period, falling from 5 children per woman in 1960 to 2.4 in 2015. This decline in fertility is not skewed by the experience of a few countries. In 1960, more than half of the countries in the world experienced fertility rates greater than 6. By 2015, the median TFR was 2.2 children per woman. Interestingly, the rapid decline in fertility has taken place in countries at widely different levels of development.

De Silva and Tenreyro (2017) have argued that while socioeconomic factors play an important role in the worldwide fertility decline, the timing and speed of the decline over the past five decades suggests that the population control policies implemented in many developing countries over this period might have played a significant role in accelerating the process. The design of population-control programs consisted of two main parts. The first was the diffusion of contraceptive supply and information. The second was the implementation of public campaigns aimed at reversing pro-natalist attitudes and establishing a new small-family norm. The authors argue that the second strategy of employing public campaigns to reduce desired levels of fertility was critical in complementing contraceptive provision.

To analyze the rapid decline in fertility, we study a model of endogenous fertility and human capital accumulation, augmented to include a role for endogenously evolving social norms on family size. In the model, individuals derive utility from both the quantity and "quality" of children and dislike deviating from the social norm on the number of children, where the norm is a weighted average of the fertility of the previous generation and the replacement level of fertility, which is close to two.[1] Calibrating the model's structural parameters and initial conditions to match key moments in the data for developing countries in 1960, we use the model to simulate the transition to the steady-state levels of fertility and human capital. While the baseline model with no role for norms is able to endogenously generate a slight decline in fertility, we find that incorporating social norms into the model generates a much larger decline.

We then simulate the effect of population-control policies on family-size norms using information on funding for family-planning programs. In particular, we allow the weight placed on the fertility of the previous generation - family size is greatly

[1] We follow the literature's jargon, where "quality" relates to the level of human capital of the individual.

influenced by the family of origin - to decline with the intensity of these programs, given that the majority of these programs advocated having two children. We also consider several alternative mechanisms that might explain the fertility decline, including the fall in infant and child mortality and improvements in contraceptive technologies (the second component of the population-control policies). The model allows us to gauge quantitatively the role played by these different channels - human capital accumulation, declining infant mortality, improved control over fertility, and reductions in the social norm on family size - in generating the fertility decline.

We find that the baseline model without norms generates a small decline in fertility. The inclusion of endogenously evolving social norms on fertility can generate a decline in fertility which is twice as large as the decline generated by the baseline mode, but still not enough to replicate the large declines in the data. We find that policies aimed at altering family-size norms significantly accelerate and strengthen the decline in fertility that would have otherwise gradually taken place as economies move to higher levels of human capital, lower levels of infant mortality, and higher supplies of contraceptive technologies.

The rest of the paper is organized as follows. Section II describes the model and Section III explains the calibration strategy. Section IV presents the main results of the paper and Section V studies various extensions. Section VI presents concluding remarks.

2 The Model

This Section studies a simple quantitative model of endogenous human capital and fertility choice. The goal is to gauge the impact of human capital accumulation and population-control policies on the rapid fall in fertility experienced by most developing countries in recent decades. The model builds on the Barro-Becker framework of fertility choice, incorporating human capital investment (see Barro and Becker 1989; Galor and Weil, 2000; Galor and Moav, 2002; Moav, 2005). We sequentially extend the analysis along many dimensions. First and foremost, we augment the model by introducing social norms on family size, which were a key target of population-control policies in developing countries (de Silva and Tenreyro, 2017).

Our modelling of adherence to social norms borrows from the literature on social distance and conformity (Jones 1984, Akerlof 1997) in that individuals derive disutility from a function of the distance between their realized fertility and the social norm.[2] We define the social norm on fertility as a weighted average of the fertility rate of the previous generation and the replacement level of fertility. The first term draws from the sociology literature that discusses the importance of reference groups in forming fertility norms (e.g. Clay and Zuiches 1980). Norms on family size are highly influenced by the family of origin.[3] We choose the replacement level as the second term in the average based on the observation that most economies appear to be converging to a similar focal point for fertility, currently just about two children per woman. This endogenously evolving norm naturally leads to a decline in fertility that is larger than that generated in a model without social norms. In this baseline model, we assume households count with the technology to control fertility. We model the impact of the family planning programs and their mass communication strategies as an increase in the weight placed on the replacement level of fertility, causing the social norm on family size to shift downwards, accelerating the decline even more.

In further extensions of the model we also consider the role played by the overall fall in mortality rates. In a setting in which there is child mortality and uncertainty about how many children survive to adulthood, we find that the decline in mortality alone is not sufficient to explain the fall in fertility observed over the past few decades.[4] The decline in mortality rates did seem to have played an important role in triggering population-control policies, but it is unlikely to have fueled the fast fall in fertility through individual or decentralized responses, without the policy intervention. A second extension considers the case in which households cannot directly control fertility rates (contraception technologies are either not available or imperfect) and the role played by increased access to contraception (the second main component of population-control policies).

We do not explicitly model the possibility that children provide their parents with

[2] We deviate from the existing work on the impact of social norms on fertility in how we model social norms. Munshi and Myaux (2005), Palivos (2001) and Bhattacharya and Chakraborty (2012) model norms as the outcome of strategic decision-making and interaction, We take a simpler specification that is more amenable to quantification and in line with the literature on external habits or reference dependence.

[3] The impact of parental fertility on their children's fertility is also explored in the demography literature, focusing on developed countries. For example, Thornton 1980, Murphy 1999 and Kolk 2014.

[4] This point was previously made by Doepke (2005). Becker and Barro (1988)'s model predicts that when mortality rates decrease, the total fertility rate falls, but the number of surviving children remains the same. In survey data, we observe a decline not only in fertility rates, but also in the desired number of children. Kalemli-Ozcan (2002) introduces a precautionary motive to have children; in that context, a decline in mortality reduces both the fertility rate and the number of (desired) surviving children.

transfers in their old age, but our modelling choices can be recast in those terms, as parents care about their children's future earning capacity.[5]. In what follows, we describe the model in more detail, specifying technologies and preferences.

2.1 Model setup

We consider an overlapping generation economy in which individuals live for two periods: childhood and adulthood. In each period, the economy produces a single consumption good using the productive capacity of the working adults and a fixed factor as inputs, where the supply of the fixed factor is exogenous. The human capital stock is determined by the fertility and educational choices of individuals.

2.2 Technology

Production occurs according to a constant returns to scale production technology. Using the specification in Galor and Weil (2000), output at time t, Y_t is:

$$Y_t = \left[(\bar{H} + H_t)L_t)\right]^{\rho} (A_t X)^{1-\rho}, \qquad 0 < \rho < 1 \tag{1}$$

where $\bar{H} + H_t$ is the productive capacity of a worker, L_t is the working age population, X is the fixed factor and A_t is the technology at time t, with $A_t X$ referring to "effective resources". The term $\bar{H}$ is a physical labour endowment all individuals are born with and H_t is human capital produced with investments in schooling.

Output per worker at time t, y_t, is

$$y_t = ((\bar{H} + H_t))^{\rho} x_t^{1-\rho}, \tag{2}$$

where $x_t = A_t X / L_t$ is the effective resources per worker at time t.

As in Galor and Weil (2000), we assume that the return to the fixed factor is zero.This assumption helps to keep the model simple so that the only source of earnings for households is labour income, which is a reasonable description of households' funding in developing countries. The factor X can then be interpreted as some productive public good which does not yield private returns to the citizens. (Galor and Weil (2000)'s interpretation is that there are no property rights over this

[5]There is a growing literature which addresses these inter-generational transfers explicitly (see for example Boldrin and Jones 2002, Coeurdacier, Guibaud and Jin 2014, Choukhmane, Coeurdacier and Jin 2014)

resource in the country.) Alternatively, as in Cespedes and Velasco (2012), one can think of X as being owned by a small group of "elite" individuals, who spend all the returns from X abroad (and whose behaviour we do not consider in our model).

The return to productive labour, w_t, is then given by its average product:

$$w_t = \left(\frac{x_t}{(\bar{H} + H_t)} \right)^{1-\rho} \tag{3}$$

2.3 Households

Each household has a single decision maker, the working adult. Individuals within a generation are identical. Children consume a fraction of their parents' time. Working adults supply labour inelastically, decide on their consumption, the number of children, and their education in period t.

Parents are motivated by altruism towards their children but are conscious of the social norm on the number of children that a family should have. As such, while parents derive utility from their children (both the quantity and the quality), they derive disutility from deviating from the social norm. The utility function for a working age individual of generation t can be expressed as:

$$U_t = u(C_t;\ n_t;\ q_{t+1}) - \varphi g(n_t, \hat{n}_t), \tag{4}$$

where u is a standard utility function over three goods: C_t, denoting consumption at time t, n_t, which denotes the number of children, and q_{t+1}, which indicates the quality of children as measured by their future earning potential. Following Galor and Weil (2000) and Moav (2005), we assume $q_{t+1} = w_{t+1}(\bar{H} + H_{t+1})$, where w_{t+1} is the future wage per unit of productive labour of a child, and $\bar{H} + H_{t+1}$ is the productive capacity of a child. The factor $\varphi > 0$ governs the disutility from deviating from the social norm and $g(n_t, \hat{n}_t)$ is a function of the deviation of the chosen number of children, n_t, from the social norm on family size, $\hat{n}_t$, where $g_{11}(n_t, \hat{n}_t) > 0$ and $g_{12}(n_t, \hat{n}_t) < 0$. The first condition implies that movements further away from the norm involves heavier penalties, while the second implies that the marginal cost of the additional child is decreasing in the social norm. We model the social norm on family size as a weighted average between the previous generation's fertility, n_{t-1}, and the replacement level of fertility, n^*, so that $\hat{n}_t$ can be expressed as:

$$\hat{n}_t = \phi n^* + (1-\phi)n_{t-1}, \qquad 0 \le \phi \le 1 \tag{5}$$

The individual's choice of desired number of children and optimal education investment for each child is subject to a standard budget constraint. While parental income is given by $w_t(\bar{H} + H_t)$, we assume that a fixed fraction of income, τ_0, is spent on each child regardless of education and a discretionary education cost for each child, $\tau_1 h_t$, which is increasing in the level of education, h_t, is chosen by the parents. The remaining income is spent on consumption.[6] The budget constraint at time t is therefore,

$$C_t = [1 - (\tau_0 + \tau_1 h_t)n_t]w_t(\bar{H} + H_t) \tag{6}$$

Following Becker, Barro, and Tamura (1990) and Ehrlich and Kim (2005), we specify the human capital production function as:

$$H_{t+1} = z_t(\bar{H} + H_t)h_t, \tag{7}$$

where $\bar{H} + H_t$ is the productive capacity of the parent, h_t is the educational investment (or schooling) in each child and z_t is the human capital production technology. This specification of productive capacity prevents perfect intergenerational transmission of human capital, allowing for positive levels of human capital even for children whose parents have no schooling ($H_t = 0$).

2.4 Equilibrium

In a competitive equilibrium, agents and firms optimally solve their problems and all markets clear.Let $v = (\bar{H} + H_t, n_{t-1})$. A competitive equilibrium for this economy consists of a collection of policy functions for households $\{C_t(v), n_t(v), h_t(v)\}$, and prices w_t such that:

1. Policy functions $C_t(v)$, $n_t(v)$, and $h_t(v)$ maximize

$$u(C_t; n_t; q_{t+1}) - \varphi g(n_t, \hat{n}_t)$$

[6]It is also possible to interpret the constraint as a restriction on the total amount of time available to work and have and raise children. In that case, τ_0 would be the fraction of time that has to be spent on raising a child regardless of the education level.

subject to the budget constraint (6), human capital production function (7) and $(C_t, n_t, h_t) \geq 0$;

2. w_t satisfies (3); and

3. Markets clear such that:

$$C_t = [1 - (\tau_0 + \tau_1 h_t)n_t]y_t$$

3 Calibration

In the policy experiments that we carry out, we examine the transition of the economy from a given initial condition to a steady state level of fertility and human capital investment. Our calibration strategy, therefore, involves choosing structural parameters and initial conditions so that the outcomes of the model in the first period match the appropriate moments for consumption, income, fertility, education and population in developing countries in 1960.[7] Since the economic agent in this model is an individual, the fertility rate in the model is one half of the total fertility rates in the data. Similarly, we interpret the units of investment in human capital per child, h_t, as years of education.[8] In addition, one period in the model corresponds to the length of a generation, around 25 years.

The data on household consumption, per capita GDP, population and fertility are obtained from the World Bank's World Development Indicators (WDI) dataset while the data on average years of education are taken from the Barro-Lee educational attainment datasets (Barro and Lee 2015, Barro and Lee 2013).

3.1 Technology

We set the productive labour share of income, ρ, to 0.66. Estimates of total factor productivity in East Asian countries over the 1966-1990 period by Young (1995)

[7] We refer to all countries which were not classified as OECD countries prior to 1970 as developing countries in the starting period. 1960 is the first year for which cross-country data on fertility, income, education and consumption are available.

[8] The data available is the average years of education of the adult population (aged 25 and above). As such, the investment in education for children born in a given period is observed in the data as the average years of education of the adult population in the next period. I.e., if the length of a generation is 25 years, h_{1960} is given by the average years of education of the adult population in 1985.

indicate that on average, annual TFP growth over the period ranged from -0.003 in Singapore to 0.024 in Taiwan. As such, we will assume a constant annual TFP growth rate of 0.018 which is compounded to obtain the TFP growth rate between generations, g_A.[9] In addition, we assume that there is no growth in the technology used in human capital production, z_t.

3.2 Cost of childrearing

Household expenditure surveys report the fraction of household expenditure allocated to education. In our model, this fraction is represented by $\tau_1 n_t h_t$. This ranges from 2.6 percent in India in the period 2007-2008 to 5.5 percent in Singapore in 2012-2013. However, the value for τ_1, calculated using corresponding values for n_t and h_t from the data, is much more uniform, around 0.3 percent.[10] We therefore set τ_1 to 0.003. We then use the household budget constraint to back out the value for τ_0, given the initial levels of income, consumption, fertility and education.

3.3 Preferences

Following the literature, we assume utility is additively log linear in consumption, the number of children, the quality of children and social norms:

$$U_t = \ln C_t + \alpha \ln n_t + \theta \ln[w_{t+1}(\bar{H} + H_{t+1})] - \varphi g(n_t, \hat{n}_t), \tag{8}$$

$\alpha > 0$ reflects preferences for children, $\theta > 0$ for child quality. As noted in Akerlof (1997), the use of the absolute value of the difference between individual fertility and the social norm gives rise to multiple equilibria. We use a more tractable functional form given by:

$$g(n_t, \hat{n}_t) = (n_t - \hat{n}_t)^2,$$

where individuals derive disutility from deviating above as well as below the social norm and deviations in either direction are penalized symmetrically. In Section 5, we consider a different functional form which treats upward and downward deviations asymmetrically and find that the results are very similar.

[9] Our specification of utility implies that the value of g_A affects the simulations only through the initial value for the human capital stock as wages do not have an effect on fertility or human capital investment decisions. Assuming $g_A = 0$ barely changes the results of the quantitative exercise.

[10] See the appendix for the full set of countries and expenditure statistics.

Given these preferences, the first order condition for n_t is given by:

$$\frac{\alpha}{n_t} = \frac{(\tau_0 + \tau_1 h_t)}{1 - (\tau_0 + \tau_1 h_t)n_t} + 2\varphi(n_t - \hat{n}_t) \tag{9}$$

The first-order condition equates the marginal benefit of having children with the marginal cost. The first term on the right hand side is the marginal cost in terms of foregone consumption while the second term will be a cost if the additional child pushes the total number of children over the social norm.

The first-order condition for h_t is:

$$\frac{\theta z_t(\bar{H} + H_t)}{(\bar{H} + H_{t+1})} = \frac{\tau_1 n_t}{(1 - (\tau_0 + \tau_1 h_t)n_t)}, \tag{10}$$

where the right hand side is the marginal utility to the parent from giving her child an additional unit of education and the left hand side is the marginal cost in terms of foregone consumption.

Our specification of utility leaves us with three preference parameters (α, θ, and φ) to be calibrated. We also require initial values for H_t and z_t. We start by calibrating a baseline model in which individuals do not care about norms ($\varphi = 0$) and pin down α from the first-order condition for n_t, using the cross-country macro data for developing countries for 1960. We use the per capita output growth in the economy to pin down $\frac{\bar{H}+H_{t+1}}{\bar{H}+H_t}$ (which we will refer to as g_H, hereafter). Then, for given values of z_t (which we choose to match the empirical estimates of the returns to schooling) and $\bar{H}$, we use the first order condition for h_t and the human capital production function to obtain values for θ and H_1, the level of human capital of parents in the initial period.[11]

[11] Rearranging the human capital production function gives:

$$H_t = (\frac{1}{g_H - z_t h_t} - 1)\bar{H}$$

where $g_H = \frac{\bar{H}+H_{t+1}}{\bar{H}+H_t}$. In order to obtain $H_t > 0$, it is required that $\frac{g_H - 1}{h_t} < z_t \leq \frac{g_H}{h_t}$. Using values for g_H and h_t from the data, we can obtain an upper and lower bound for z_t.

The Mincerian return to schooling is given by $\frac{\rho z_t}{g_H}$ in our model. Setting z_t close to the lower bound implies a return to an additional year of education of around 0.1, which is in line with the empirical estimates of the returns to schooling.

3.4 Norms

We use the first order condition for fertility from the full model (equation 9) to obtain a value for ϕ, for given values of φ and n_{t-1}. We do not have enough moments in the data to back out φ and, to the best of our knowledge, there are no empirical estimates of this parameter. Therefore, we set $\varphi = 0.1$ (the estimates of φ for later periods indicate that this value is reasonable). While data on fertility rates in developing countries prior to 1960 is scarce, we set n_0 to 3.5 (meaning seven children per woman - recall that in the model n_t is fertility per household) based on estimates of fertility for several non-European countries in the early twentieth century provided by Therborn (2004). Finally, the replacement level of fertility, n^*, is set to 1, reflecting a replacement level fertility rate of 2.

Table 1 summarizes the results of the calibration exercise.

3.5 Estimating the change in ϕ

We model the role of population-control policies in changing the social norms on family size by an increase in ϕ. In order to estimate the value of ϕ in subsequent periods, we estimate by ordinary least squares, the first-order condition for fertility using data for 2010, holding all parameters other than ϕ and φ constant. In other words, only preferences on how much individuals care about conforming to social norms and the weight placed on the replacement rate of fertility are allowed to change. In addition, we model ϕ as a function of the intensity of family-planning programs. Specifically, we set $\phi = \phi_0 + \phi_1 P$, where P is family planning program intensity, measured by the logarithm of per capita funds for family planning, with the data on family planning funds compiled from Nortman and Hofstatter (1978), Nortman (1982), and Ross, Mauldin, and Miller (1993). This gives rise to the following estimable equation:

$$\frac{\alpha}{n_t} - \frac{(\tau_0 + \tau_1 h_t)}{1 - (\tau_0 + \tau_1 h_t) n_t} = 2\varphi(n_t - n_{t-1}) + 2\varphi\phi_0(n_{t-1} - n^*) + 2\varphi\phi_1 P(n_{t-1} - n^*) \quad (11)$$

We estimate the equation using data on fertility, consumption and GDP per capita for 2010, and the average value of per capita funds for family planning over the 1970-2000 period.[12] Ideally, P would be the total spending per capita on family

[12]The budget constraint gives $\frac{(\tau_0+\tau_1 h_t)}{1-(\tau_0+\tau_1 h_t)n_t} = \frac{w_t(\bar{H}+H_t)}{C_t} - 1 = \frac{y_t}{C_t} - 1$.

Table 1: Calibration of structural parameters

	Value	Description/Source
Parameters		
ρ	0.66	Productive labour share of output
g_A	1.56	TFP growth (Young 1995)
τ_0	0.04	Targeted to match household consumption in 1960
τ_1	0.003	Targeted to match share of household expenditure on education
g_H	2.61	Targeted to match per capita output and population growth
α	0.18	Targeted to match fertility rate of 5.96 in 1960 in baseline model
θ	0.06	Targeted to match years of education of 3.67 in 1960
φ	0.1	Disutility from deviating from social norm on fertility
ϕ	0.21	Targeted to match fertility rate of 5.96 in extended model
n^*	1	Corresponds to a replacement rate of fertility of 2
Initial conditions		
$\bar{H}$	1	Labour endowment
n_0	3.5	Targeted to match fertility rates in developing countries in early 20th century
z	0.44	Targeted to match returns to schooling of 0.1
H_0	0.004	Obtained from human capital production function, given g_H

Notes: The table reports the calibrated parameter values and initial conditions and the sources from which they are obtained.

Table 2: Estimation of φ and ϕ

Parameter	Value
φ	0.36
	(0.001)
ϕ_0	0.07
	(0.410)
ϕ_1	0.1
	(0.057)
ϕ $(= \phi_0 + \phi_1 \bar{P})$	0.44
Observations	52
R^2	0.27

Notes: The table reports the results from estimating Equation 11. The estimation is carried out using data on fertility, consumption and GDP per capita for 2010, and the average annual per capita spending on family planning over the 1970-2000 period. ϕ is calculated as $\phi = \phi_0 + \phi_1 \bar{P}$, where $\bar{P}$ is the sample average of per capita spending on family planning. Values in parentheses are p-values of the regression coefficients from which the values for φ, ϕ_0, and ϕ_1 are backed out and are based on robust standard errors.

planning programs over this period. However, given that for many countries we have data only for one or two years, we use the average per capita funding over the period 1970-2000. Note that this exercise is an attempt to recover a numerical estimate for ϕ which can be used in the quantitative analysis, rather than to establish a causal link between the family planning programs and fertility.

The estimation of Equation 11 provides us with values for φ, ϕ_0, and ϕ_1. We find that the coefficients of the first and third terms in the equation (corresponding to 2φ and $2\varphi\phi_1$) are significantly different from zero and that the obtained values for φ, ϕ_0, and ϕ_1 have the expected signs and magnitudes (see Table 2). The value of φ is 0.36, indicating that our initial calibration of 0.1 is reasonable, allowing an increase in the importance placed on adhering to norms over time. We calculate ϕ at the sample average of P to obtain a value of 0.44, which shows that the weight on n^* has doubled over the past fifty years.

4 Results

The dynamics of fertility and human capital accumulation in the economy are governed by equations 5, 7, 9, and 10.[13] We now use the calibrated model to investigate how the two channels in our model, human capital accumulation and the presence of social norms on fertility, contribute to fertility decline. We begin from an initial level of human capital stock and fertility and examine the transition to a steady state.

We start by considering a baseline model in which individuals do not care about social norms ($\varphi = 0$) and the only mechanism by which fertility falls is the faster accumulation of human capital. We compare this model with our extended model of fertility and social norms. We consider two cases: the first in which ϕ and φ remain unchanged over time and the second in which ϕ and φ rise to the values estimated in the previous section (referred to as the model with policy changes). Since the estimated values are for 2010, we set ϕ and φ in 1985 to be in between the values of the initial calibration for 1960 and the estimated values for 2010. We do not impose any changes to the parameters after the third period.

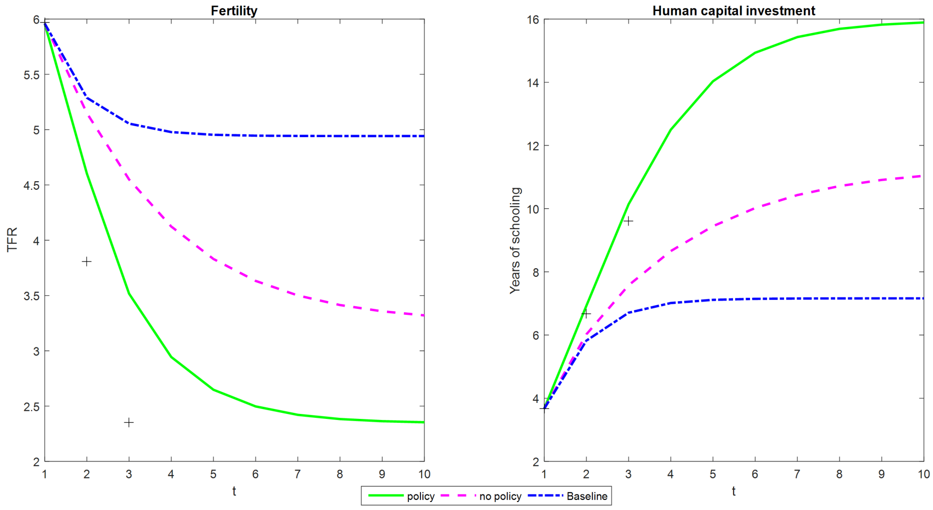
Figure 1 shows the model's predicted path of TFR and investment in education (measured in years of education) under the different versions outlined above. The corresponding values in the data (only available for the first three periods for fertility and education) are marked by crosses.

The baseline model (given by the blue dash and dot line) in which individuals do not care about norms generates a very small decline in fertility. TFR falls to 5.3 in $t = 2$ and reaches a steady state of around 4.9 children per woman while investment in education rises to 5.8 years of schooling in $t = 2$ and reaches a steady state of roughly 7.2. The inclusion of social norms on fertility generates a larger decline in fertility, even when ϕ and φ remain unchanged. In this case, TFR falls from 6 children per woman to 3.6 within six generations and a steady state of 3.2 is reached after approximately ten periods. At the same time, human capital investment reaches a steady state of around 11 years of schooling. The existence of endogenously evolving social norms on fertility is enough to generate a decline in fertility which is twice as large as the decline generated by the baseline model.

We next consider the effect of the population control policies (given by the green solid line), which we interpret as an increase in ϕ. As can be expected, the increase

[13] Note that since neither first order condition depends on w_t, the production side of the economy doesn't affect the dynamics of fertility and human capital.

Figure 1: Transition to steady state



Notes: The figure plots the path of fertility and investment in education for the different versions of the model. The dash and dot line corresponds to the baseline model where $\varphi = 0$. The dashed line represents the case where ϕ and φ remain unchanged over time, while the solid line represents changes in ϕ to 0.35 and 0.44 at $t = 2$ and $t = 3$, respectively and changes in φ to 0.25 and 0.36 at $t = 2$ and $t = 3$ respectively. The points marked by "+" refer to the values observed in the data where $t = 2$ is 1985 and $t = 3$ is 2010.

in ϕ (a larger weight placed on the replacement level of fertility) generates a much larger decline in fertility, increase in education and a quicker convergence to the steady state. We allow ϕ to rise from 0.21 in $t = 1$ to 0.35 and then 0.44 in the two subsequent periods, which corresponds to a change in the norm on number of children from around 6 children in the initial period to around 3.4 by $t = 3$. Accordingly, the model predicts a decline in TFR to 3.4 at $t = 3$ and fertility reaches a steady state of around 2.4 after 6 periods. At the same time, years of schooling rises from 4 to around 10 in just three generations. The increase in φ is slightly less important, quantitatively, than the increase in ϕ. If we set the starting level of φ to 0.35 (which cannot be ruled out given that the initial value was calibrated), the resulting transition path is hardly different from that illustrated in Figure 1.

Comparing the results of the model with the data indicates that the inclusion of social norms with an increase in ϕ over time improves the predictions of fertility and years of schooling considerably. The model predicts years of schooling well while predicting levels of fertility that are slightly higher than what is observed in the data. However, the predicted steady state level of fertility is close to two children per woman. Note that we do not allow ϕ and φ to change after $t = 3$. If we allowed ϕ to increase continuously over time, convergence to a steady state low fertility rate would be even faster. The changes in ϕ which would be required to exactly match the data would be an increase to 0.6 in $t = 2$ and then to 0.9 by $t = 3$. While we estimate the change in ϕ captured by spending on family planning programs, it is likely that when taking into account other factors such as increased access to mass media and modernization, the actual increase in ϕ is larger than that estimated in this paper.

To summarize, this quantitative exercise points to the importance of changing social norms on family size for the decline in fertility observed in developing countries over the past few decades. We use data on family planning program funds to capture the change in social norms brought about by these programs which were widely adopted in developing countries during this period. The results suggest that the change in social norms brought about by these programs considerably accelerated the fertility decline. This is consistent with empirical studies that find evidence of the effectiveness of public persuasion measures in reducing fertility (La Ferrara, Chong and Duryea 2012 and Bandiera et al. 2014).

5 Extensions and robustness checks

In this section we discuss a number of extensions of the model. First, we extend the model to allow a role for declining infant and child mortality in the fertility fall. Next, we incorporate imperfect control over fertility, allowing for a role for improvements in contraceptive technologies. Finally, we consider the effect of changing the specification of disutility from deviating from the norm, allowing upward and downward deviations to be treated asymmetrically.

5.1 Including mortality

The model presented in the previous section did not take into account the mortality decline observed in developing countries during this period. In this section, we extend our model to include uncertainty regarding the number of children that survive to adulthood. We then investigate the impact of an increase in survival rates on fertility and human capital investment. We follow Kalemli-Ozcan (2003) in how we incorporate mortality into the model.[14]

[14]In the original Barro-Becker (1989) framework, child mortality is modeled as an explicit cost of childrearing. Doepke (2005) studies three variations of this model: a baseline model where fertility choice is continuous and there is no uncertainty over the number of surviving children, which is contrasted with an extension involving discrete fertility choice and stochastic mortality and another with sequential fertility choice. He finds that while the total fertility rate falls as child mortality declines in each model, the number of surviving children increases, and concludes that

Parents choose a number of children, n_t, but only N_t of the infants survive to childhood and all children survive to adulthood. Parents spend on rearing and educating their surviving children and derive utility from the quantity and quality of these children.[15] In addition, parents care about how the number of their surviving children compares with the social norm on family size. The utility function for an adult of generation t can then be written as:

$$E_tU_t = E_t \ln C_t + \alpha \ln N_t + \theta \ln[w_{t+1}(\bar{H} + H_{t+1})] - \varphi(N_t - \hat{N}_t)^2 \tag{12}$$

where $\hat{N}_t = \phi n^* + (1-\phi)N_{t-1}$ is the norm on family size.

Expected utility is maximized subject to,

$$C_t = [1 - (\tau_0 + \tau_1 h_t)N_t]w_t(\bar{H} + H_t), \tag{13}$$

and the human capital production function (7).

As in Kalemli-Ozcan (2003), N_t is a random variable drawn from a binomial distribution, with $s_t \in [0,1]$ the survival probability of each infant. We use a second-order approximation of the expected utility function around the mean value of N_t, i.e. $n_t s_t$. The approximated expected utility function is given by:

$$E_tU_t = E_t \left\{ \begin{array}{c} \ln[(1 - (\tau_0 + \tau_1 h_t)n_t s_t)w_t(\bar{H} + H_t)] + \\ \alpha \ln(n_t s_t) + \theta \ln[w_{t+1}(\bar{H} + H_{t+1})] \\ -\varphi(n_t s_t - \hat{N}_t)^2 - \frac{n_t s_t(1-s_t)}{2}[\left(\frac{(\tau_0+\tau_1 h_t)}{(\tau_0+\tau_1 h_t)n_t s_t)}\right)^2 + \frac{\alpha}{(n_t s_t)^2} + 2\varphi] \end{array} \right\} \tag{14}$$

which incorporates the budget constraint (13). The last three terms represent the disutility arising from uncertainty in the number of infants that survive to adulthood.

The first-order conditions for fertility and human capital investment become:

$$\frac{\alpha}{n_t}(1 + \frac{(1-s_t)}{2n_t s_t}) = \begin{array}{c} 2\varphi s_t(n_t s_t + \hat{N}_t) + \varphi s_t(1-s_t) + \\ \frac{(\tau_0+\tau_1 h_t)s_t}{1-(\tau_0+\tau_1 h_t)n_t s_t}\left[1 + \frac{1+(\tau_0+\tau_1 h_t)n_t s_t}{2(1-(\tau_0+\tau_1 h_t)n_t s_t)}\frac{(\tau_0+\tau_1 h_t)(1-s_t)}{(1-(\tau_0+\tau_1 h_t)n_t s_{t)}}\right] \end{array} \tag{15}$$

factors other than declining infant and child mortality were responsible for the fertility transition observed in industrialized countries.

[15]This is a slight deviation from Kalemli-Ozcan (2003) where education is provided before the uncertainty is realized.

$$\frac{\theta z_t(\bar{H}+H_t)}{(\bar{H}+H_{t+1})} = \frac{\tau_1 n_t s_t}{(1-(\tau_0+\tau_1 h_t)n_t s_t)}\left[1+\frac{(\tau_0+\tau_1 h_t)(1-s_t)}{(1-(\tau_0+\tau_1 h_t)n_t s_t)^2}\right] \tag{16}$$

The key difference between this setup and that in Section 2 is that there is now an additional term in the marginal cost of both fertility and schooling which reflects the cost of uncertainty.

5.1.1 Calibration and results

The calibration exercise is carried out in the same way as before - we start from a model with mortality and no norms to back out all the parameters except ϕ and then use the extended model with norms and mortality to get an initial value for ϕ. We use the mortality rate for children below 5 years of age (measured as the number of deaths of children below 5 years of age per 1000 live births) for developing countries in 1960 (from the WDI database) as a measure of $1 - s_t$. The re-calibration causes τ_0, α, θ, and ϕ to change. τ_0, α and θ change by very little (to 0.05, 0.17 and 0.05, respectively) whereas ϕ changes significantly (to 0.02, much lower than 0.21 in the model without mortality).

To identify the change in ϕ and φ over the past two periods, we carry out the same estimation exercise as before, again setting $\phi = \phi_0 + \phi_1 P$ but now using Equation 15. We see an increase in ϕ and φ, with a much larger relative increase in the value of ϕ than in the model without mortality. Table 3 shows the values of the parameters obtained from the estimation.

We then plot the transition paths of fertility and human capital to their steady states for three cases: the baseline model with no norms or mortality (given by the blue dashed line), the model with falling mortality rates and no norms (given by the pink dotted line), and the extended model of mortality and social norms (given by the green solid line). We allow s_t to rise over time from 0.78 in $t = 1$ to 0.91 and 0.96 in $t = 2$ and $t = 3$ as seen in the data. As before, since the estimation of ϕ and φ was for 2010, values of ϕ and φ for 1985 are set to be in between the values of the initial calibration for 1960 and the estimates for 2010 and do not change after the third period.

As Figure 2 shows, the incorporation of mortality into the baseline model generates a larger decline in fertility than the baseline model which only includes human capital accumulation with TFR converging to around 3.9 children per woman rather than 4.9. However, the two models are not very different in their predictions of human capital investment. This is because the decline in the number of surviving

Table 3: Estimation of φ and ϕ with mortality

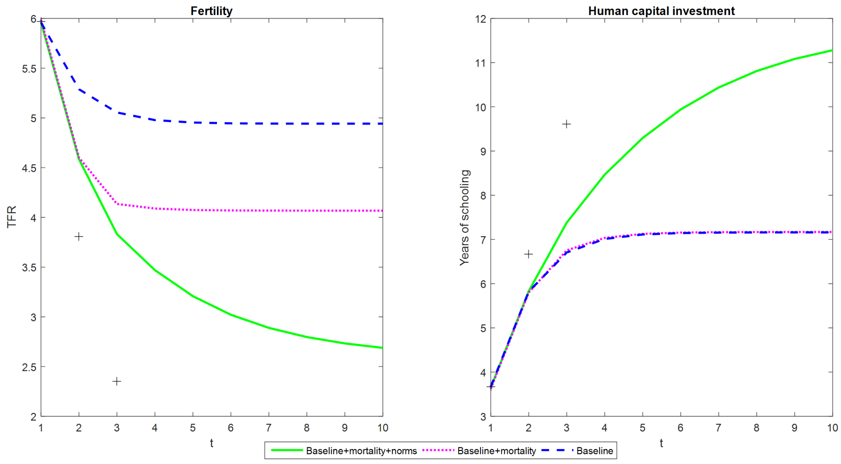
Parameter	Value
φ	0.29
	(0.006)
ϕ_0	-0.32
	(0.118)
ϕ_1	0.15
	(0.096)
ϕ $(= \phi_0 + \phi_1 \bar{P})$	0.21
Observations	50
R^2	0.37

Notes: The table reports the results from estimating Equation 15. The estimation is carried out using data on fertility, child mortality rates, consumption and GDP per capita for 2010, and the average annual per capita spending on family planning over the 1970-2000 period. ϕ is calculated as $\phi = \phi_0 + \phi_1 \bar{P}$, where $\bar{P}$ is the sample average of per capita spending on family planning. Values in parentheses are p-values of the regression coefficients from which the values for φ, ϕ_0, and ϕ_1 are backed out and are based on robust standard errors.

children is very similar in these two models (see Figure 3). In the baseline model that incorporates the mortality decline, the number of surviving children drops from 4.7 to just 3.9 (compared to the decline from 5.9 to 4.9 in the baseline model without mortality). By contrast, including a social norm that falls over time generates a large decline in the number of surviving children - a drop from 4.6 to 2.6. Given that the investment in schooling is made for surviving children, a smaller decline in surviving children leads to a smaller increase in the years of schooling.

Our modelling of mortality, which is based on Kalemli-Ozcan (2003), allows the mortality decline to generate a decline in fertility through a hoarding effect, where the risk of child mortality results in a precautionary demand for children. The decline in fertility generated by the decline in social norms is slightly smaller than that in the model described in the previous section because uncertainty about the number of surviving children leads to higher fertility as an insurance against infant mortality. However, the presence of social norms that decline over time still leads to a significant acceleration in the fertility decline, indicating that the mortality transition cannot rule out the role of the population control policies in the fertility fall. Taken as a whole, we would argue that while the decline in mortality rates did play an important role in triggering the introduction of population-control policies,

Figure 2: Incorporating mortality



Notes: The figure plots the path of fertility and investment in education in the three versions of the model. The dashed line represents the baseline model with no mortality or social norms while the dotted line represents the baseline model augmented to include mortality where s_t rises to 0.91 at t=2, and to 0.96 at t=3, where it remains in all successive periods. The solid line represents the model with mortality and social norms. Here, s_t rises as described earlier while ϕ rises to 0.15 and 0.21 in the second and third periods, while φ rises to 0.2 and 0.28. The points marked "+" refer to the values observed in the data.

its role in precipitating the fast fall in fertility through individual responses, without the policy intervention, is less clear.

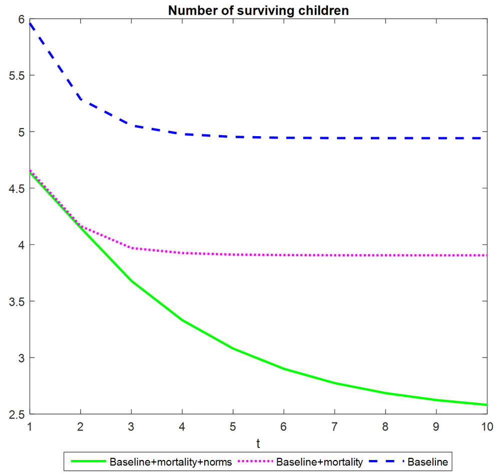
5.2 Incorporating unwanted fertility

So far we have simulated the effect of population control policies on the fertility decline by focusing on their role in changing the norm on family size. We now extend the model such that individuals do not perfect control fertility. In other words, we allow the lack of contraceptive technologies to cause a discrepancy between the desired and actual number of children.[16] This allows us to examine the impact of a reduction in unwanted fertility caused by the introduction of widespread modern contraceptives, which was the second main component of the population control policies.

We do not explicitly model the choice of contraceptive usage (see, for example, Cavalcanti, Kocharkov and Santos (2017)) but consider individuals' ability to control fertility to be exogenously determined. So while the production side of the model is the same as before, we now assume that parents' inability to perfectly control their fertility leads to a distinction between the desired or chosen number of children, n_t^d,

[16]The key difference between this and the mortality extension is that now individuals face the risk of overshooting their desired number of children whereas in the case of uncertainty about mortality, individuals faced the risk of ending up with less children than they wanted.

Figure 3: Number of surviving children



Notes: The figure plots the number of surviving children predicted by the three versions of the model. The dashed line represents the baseline model with no mortality or social norms while the dotted line represents the baseline model augmented to include mortality where s_t rises to 0.91 at t=2, and to 0.96 at t=3, where it remains in all successive periods. The solid line represents the model with mortality and social norms.

and the actual number of children, n_t^a. Specifically,

$$n_t^a = n_t^d + \varepsilon_t,$$

where ε_t is a stochastic error term causing the desired number of children, n_t^d, to differ from the actual number of children, n_t^a.

Individuals now have to maximize expected utility which, for an adult of generation t is given by:

$$E_t U_t = E_t[\ln C_t + \alpha \ln n_t^a + \theta \ln[w_{t+1}(\bar{H} + H_{t+1})] - \varphi(n_t^a - \hat{n}_t)^2], \tag{17}$$

where E_t denotes expectations as of time t.

Individuals maximize expected utility with respect to the human capital production function (same as before) and the budget constraint, which is now changed slightly to:

$$C_t = [1 - (\tau_0 + \tau_1 h_t) n_t^a] w_t(\bar{H} + H_t) \tag{18}$$

The formulation of the expected utility function requires some distributional assumptions about unwanted fertility, ε_t. The data on wanted fertility rates in developing countries (obtained from Demographic and Health Surveys) indicates that

ε_t is usually positive and has a positively skewed distribution. We assume that ε_t follows a Poisson distribution with mean λ. Thus, a reduction in λ translates to a reduction in uncertainty as well as average unwanted fertility. We then carry out a second-order approximation of the expected utility around the mean of unwanted fertility. Substituting in the budget constraint and human capital production function, the household problem can be rewritten as:

$$\{n_t^d, h_t\} = \arg\max \left\{ \begin{array}{c} \ln[(1-(\tau_0+\tau_1 h_t)(n_t^d+\lambda))w_t(\bar{H}+H_t)] \\ +\theta\ln[W_{t+1}(\bar{H}+z_t(\bar{H}+H_t)h_t)] \\ +\alpha\ln[n_t^d+\lambda]-\varphi(n_t^d+\lambda-\hat{n}_t)^2 \\ -\frac{\lambda}{2}[\frac{(\tau_0+\tau_1 h_t)^2}{(1-(\tau_0+\tau_1 h_t)(n_t^d+\lambda))^2}+2\varphi+\frac{\alpha}{(n_t^d+\lambda)^2}] \end{array} \right\} \tag{19}$$

subject to: $(n_t^d, h_t) \geq 0$.

The first-order conditions for n_t^d and h_t are given by:

$$\frac{\alpha}{n_t^d+\lambda} = \begin{array}{c} \frac{(\tau_0+\tau_1 h_t)}{(1-(\tau_0+\tau_1 h_t)(n_t^d+\lambda))}+2\varphi(n_t^d+\lambda-\hat{n}_t)+ \\ \lambda[\frac{(\tau_0+\tau_1 h_t)^3}{(1-(\tau_0+\tau_1 h_t)(n_t^d+\lambda))^3}-\frac{\alpha}{(n_t^d+\lambda)^3}] \end{array} \tag{20}$$

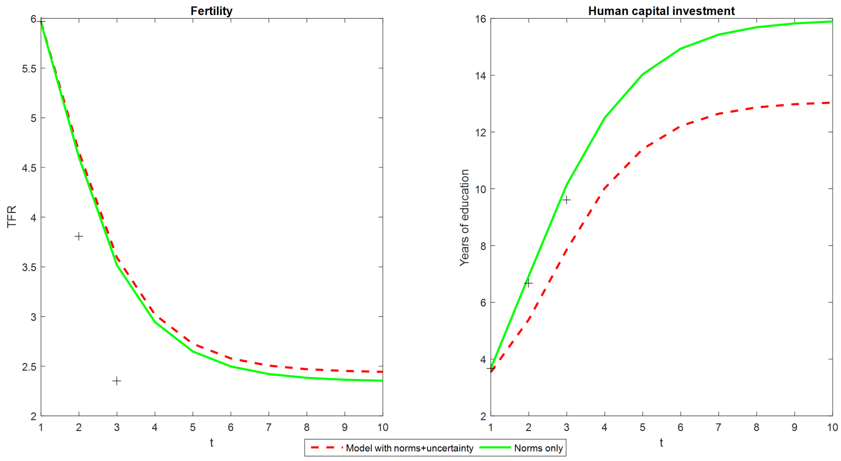
$$\frac{\theta z_t(\bar{H}+H_t)}{(\bar{H}+H_{t+1})} = \frac{\tau_1(n_t^d+\lambda)}{(1-(\tau_0+\tau_1 h_t)(n_t^d+\lambda))}+\lambda[\frac{\tau_1(\tau_0+\tau_1 h_t)}{(1-(\tau_0+\tau_1 h_t)(n_t^d+\lambda))^3}] \tag{21}$$

where the last term on the right hand side in Equation 21 reflects the cost of uncertainty. Since parents derive utility from all children (unwanted or not), the second line in Equation 20 reflects the cost of uncertainty adjusted for the gain in utility caused by having an extra child.

5.2.1 Calibration and results

The calibration strategy follows the same procedure as the main model, leaving parameters α, θ, τ_0, τ_1, g_H, ρ, and n^* and the initial conditions unchanged. However, ϕ needs to be re-calibrated using Equation 20 for given values of φ and λ. The parameter λ is chosen using data on wanted fertility rates obtained from Demographic and Health Surveys which start in the late 1980s. Unwanted fertility (calculated as the difference between TFR and wanted fertility rate) is around 1 birth, on average, in the 1980s. Since this is well after the introduction of the oral contraceptive pill and the implementation of many family planning programs worldwide, we set initial λ to 1 (reflecting an average of 2 unwanted births). We then use Equation 20, to

Figure 4: Incorporating unwanted fertility



Notes: The figure plots the path of fertility and investment in education in the two models. The dashed line represents the model with social norms and imperfect control over fertility while the solid line represents the model with only social norms. In both models ϕ rises to 0.35 and then 0.44 in the second and third periods. Similarly, φ rises to 0.25 and then 0.36. In the model with uncertainty, λ falls from 1 in the first period to 0.53 in the second, 0.28 in the third and then to 0.1, where it remains in all successive periods. The points marked by "+" refer to the values observed in the data.

obtain the value of ϕ, with φ set to 0.1 as before. This gives us $\phi = 0.21$ which is the same as in the main model. As such, we allow ϕ andφ to rise to the same levels estimated in Section 3.

We then compare the transition paths of fertility and human capital for this extended model and the norms-only model using the same policy experiment of rising ϕ and φ, but also allowing λ to fall over time in the extended model. The fall in λ reflects the increased contraceptive prevalence over the past few decades. Using the data on wanted fertility we allow λ to fall from 1 in the first period to 0.53 in the second, 0.35 in the third and then remain at 0.1 in all successive periods. Figure 4 plots the two transition paths.

As seen in Figure 4, predicted fertility in the two models is very similar, with the presence of unwanted fertility raising TFR slightly above the norms-only model. The main difference between the two models is in the predicted years of education. Uncertainty slows down the accumulation of human capital and keeps investment in education at a lower level than the norms-only model.

The comparison between the two models indicate that changing the norms on fertility has a much larger effect on fertility decisions than merely increasing access to contraception. This is consistent with the fact that many of the family planning programs supplemented their supply-side strategies of increasing access to contraception with large scale mass media campaigns to promote smaller family sizes. This point was made by demographers Enke (1960) and Davis (1967) at early stages of the global population control movement, and later by Becker (1992), who argued that family planning programs focused on increasing contraceptive usage are effective only when the value of having children is lowered.

5.3 Functional form of disutility from deviation from the norm

We now consider the robustness of our results to an alternative specification for the disutility from deviating from the norm. In particular, we now use a functional form that treats upward and downward deviations from the norm asymmetrically with deviations below the norm being penalized more heavily than deviations above. This would be consistent with societal norms in developing countries where not having children is considered taboo. For this purpose, we set:

$$ng(n_t, \hat{n}) = [\ln(n_t/\hat{n}_t)]^2$$

The first order condition for fertility changes to the following:

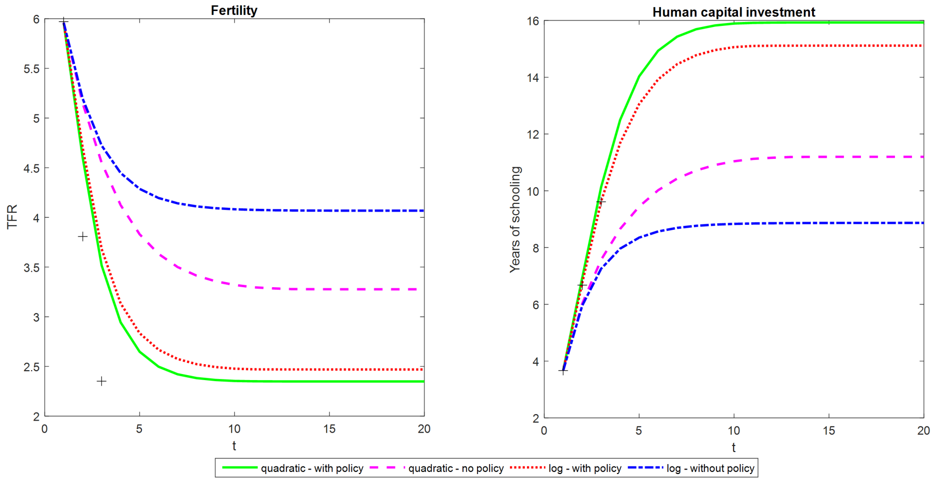
$$\frac{\alpha}{n_t} = \frac{(\tau_0 + \tau_1 h_t)}{(1 - (\tau_0 + \tau_1 h_t)n_t)} + 2\varphi \frac{1}{n_t} \ln(n_t/\hat{n}_t) \tag{22}$$

while the first order condition for human capital investment remains unchanged.

Under the same parameter and initial condition values as in the previous section, we plot the transition paths of fertility and investment in human capital to their steady state values. We consider two experiments: one in which ϕ and φ increase and the other in which both parameters remain unchanged over time. We compare the results of this model with the results of the main model with quadratic disutility from deviating from the norm.

The results show that the two functional forms yield results that are qualitatively very similar. The decline in fertility is slightly smaller in the log disutility version (corresponding to the red dotted line), reflecting the increasing penalties for deviating below the norm. The results under the two functional forms show greater divergence when ϕ and φ remain unchanged. As described before, the model with quadratic disutility converges to a TFR close to 3.2 and approximately 11 years of schooling after around ten periods. However, the model with log disutility converges to a TFR of approximately 4.1 and just 8.8 years of schooling.

Figure 5: Comparing functional forms



Notes: The figure plots the path of fertility and investment in education in the full model under two functional forms: quadratic disutility from norm deviation (main analysis) and log disutility from norm deviation. For each functional form we consider two experiments: one where ϕ and φ rise (to the levels estimated in Section 3.5 and the other where they remain unchanged. The solid and dashed lines correspond to quadratic disutility with and without policy changes, respectively. The dotted and dash-dot lines correspond to log disutility with and without policy changes. The points marked by "+" refer to the values observed in the data.

6 Conclusion

In this paper, we present a tractable model that allows us to quantitatively assess the role of different mechanisms driving the large declines in fertility experienced by developing countries over the past few decades. In particular, we examine the role of population-control policies aimed at affecting social norms and fostering contraceptive technologies. The model builds on the Barro-Becker framework of endogenous fertility choice, incorporating human capital accumulation and social norms over the number of children. Using data on several socio-economic variables as well as information on funding for family planning programs to parametrize the model, we simulate the implementation of population-control policies. We also consider several extensions such as adding a role for the mortality decline and improvements in contraceptive technologies. The model suggests that, while a decline in fertility would have gradually taken place as economies move to higher levels of human capital and lower levels of infant and child mortality, policies aimed at altering the norms on family size significantly accelerate and strengthen the decline.

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Appendix

Household spending on education

Country	$\tau_1 n_t h_t$	n_t	h_t	τ_1	Year	Source
India	0.026	1.4	5.94	0.003	2007/08	Tilak 2009
Singapore	0.055	0.6	11	0.008	2012/13	Singapore Dept. of Statistics 2014
Sub Saharan Africa	0.042	2.75	5.22	0.003	2001-08	Foko, Tiyab and Husson 2012
Sri Lanka	0.039	1.71	7.22	0.003	1980/81	Department of Census and Statistics
Sri Lanka	0.056	1.22	10.67	0.004	2012/13	of Sri Lanka 2015
Latin America and the Caribbean	0.019	1.1	8.71	0.002	2010	Regional Bureau of Education for Latin America and the Caribbean 2013
South Korea[a]	0.039	0.61	12.96	0.005	2012	OECD 2016a, OECD 2016c
Chile[a]	0.037	0.929	10.35	0.004	2012	OECD 2016a, OECD 2016c
Indonesia[a]	0.007	1.22	8.02	0.001	2012	OECD 2016a, OECD 2016c

Notes: The table reports the fraction of household expenditure spent on education and the backed out value for τ_1, which is the fraction of household expenditure spent per children per year of education using data for different countries and years. The sources for data on household expenditure on education in given in the last column while data for the corresponding years on fertility and years of schooling are obtained from the World Development Indicators and Barro-Lee datasets. Given that years of education are published at 5 yearly intervals, we choose the closest year for backing out τ_1.

[a] $\tau_1 n_t h_t$ calculated using private spending as a % of GDP and household expenditure as a % of GDP. Private spending on education excludes expenditure outside educational institutions such as textbooks purchased by families, private tutoring for students and student living costs so possibly underestimates household spending on education.