"Keeping up with the Joneses" and fertility choice

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Abstract

This paper analyses how "keeping-up-with-the-Joneses" (KUJ) preferences affect fertility choice, and aims to explain patterns in fertility which are inconsistent with existing theories. In the developed model, KUJ preferences are defined over three contemporaneous factors: average consumption, fertility rate, and human capital in society. The extended model shows that implications of KUJ preferences on fertility choice well agree with the patterns in fertility data. This paper tests the fertility choice implications of KUJ preferences using fertility survey data from the United States. The empirical results support the predictions of the theoretical model.

1 Introduction

The evolution of fertility is an important factor that affects long-term economic growth. The fertility choice models developed by Becker and Barro (1988) and Barro and Becker (1989) introduce the concept of dynastic altruism: the utility of parents includes the utility of their children. Using those models, a line of literature has rationalised a fertility decline from various perspectives. For example, Galor and Weil (2000), Galor (2005), and Tamura (2002) argue that a fertility decline is caused by an increase in the return to human capital. Other researchers link the fertility decline to changes in child mortality (Kalemli-Ozcan, 2002), the demand for aged-care (Morand, 1999), and social norms related to the number of children (Bhattacharya and Chakraborty, 2012; Goto, 2008; Munshi and Myaux, 2006; Palivos, 2001).

Furthermore, another line of literature considers cross-country differences in a fertility decline. For example, Kalemli-Ozcan (2003) finds that the uncertainty of child

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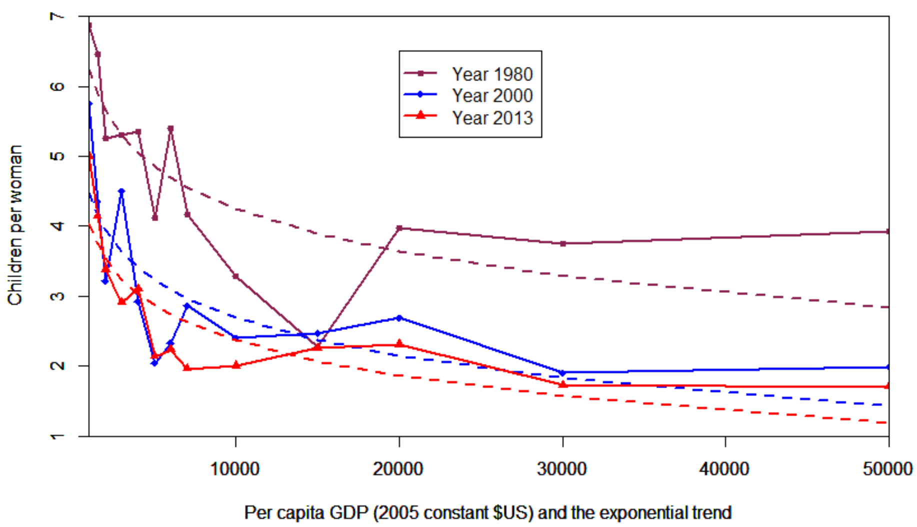
surival changes the trade-off between the quality and quantity of children, where higher uncertainty of child survival correlates with higher fertility rates. Doepke (2004) argues that government polices affecting the opportunity cost of education can explain the cross-country differences in the fertility decline. Fioroni (2010) shows that the effect of reduced child mortality on fertility is conditional on a country's educational system. Manuelli and Seshadri (2009) find that the observed cross-country variation in fertility can be explained by a country's productivity and taxes. Palivos (2001) and Munshi and Myaux (2006) demonstrate how social norms related to fertility can explain the differences in demographic development paths across countries.

Figure 1. *Fertility rate distribution and income levels*

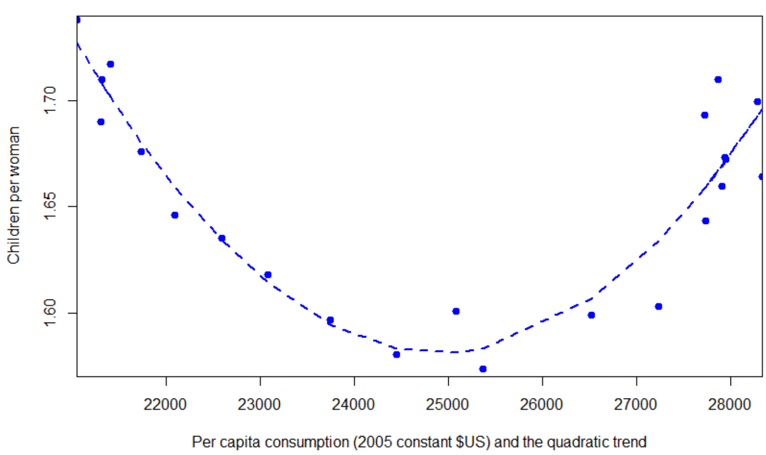


The fertility rates are the averages for each income bracket. Source of data: World Development Indicators.

Overall, the literature on the evolution of fertility presents valuable insights into the mechanisms influencing this process. Nevertheless, some empirical findings are still inconsistent with the theoretical models. First, let us consider the basic empirical evidence on the fertility decline (Figure 1). Figure 1 reflects two facts about the evolution of fertility rates: (1) fertility rates are falling in relation to the level of income; and (2) the income-fertility relationship is shifting downwards over time. Based on empirical facts, Doepke (2005) argues that the significant fall in net fertility rates (Fact 1) is caused not only by child survival and income effects, but also by other factors that are not taken into account in the existing models. Moreover, as Jones et al. (2010) point out, the existing fertility theories cannot fully explain the downward shift in the income-fertility relationship (Fact 2) observed in Figure 1.

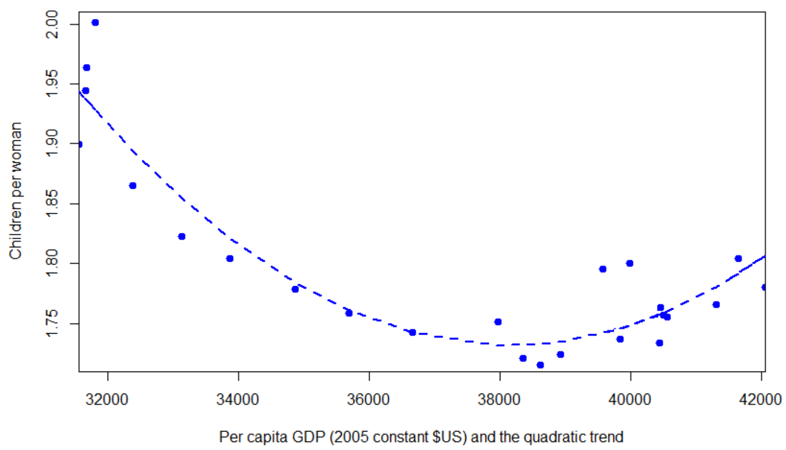
Another inconsistency between the theory and evidence is the following. Figure 2 and Figure 3 demonstrate a U-shaped relationship between fertility and consumption (income) levels for high-income economies (Fact 3). Both figures show that after achieving a high level of consumption (income), the fertility rate starts increasing. Several recent empirical studies provide corroborating evidence of the reversal of fertility decline (Bongaarts and Sobotka, 2012; Goldstein et al., 2009; Luci and Thévenon, 2011; Myrskylä et al., 2009). Notably, the existing theories do not encompass a positive relationship between the fertility rate and high levels of income and consumption. Instead, they are focused on explaining the fertility decline, and therefore, cannot explain Fact 3. To the best of our knowledge, the only exception in this area is the study by Day (2016). In that study, a positive relationship between fertility and per capita income has been associated with the condition that the workers become skilled and their wages grow more than proportionately to childcare costs. The latter condition holds only with public subsidies through increased returns on childcare production. Thus, Day (2016) does not provide a general solution to the problem we consider here.

Figure 2. *The relationship between consumption and fertility for rich economies*



The total fertility rates and consumption levels are the annual averages for each income group. Source of data: World Development Indicators. The period covered: 1990-2013.

Figure 3. *The relationship between income and fertility for rich economies*



The total fertility rates and income levels are the annual averages for each income group. Source of data: World Development Indicators. The period covered: 1990-2013.

Due to the existence of the above-mentioned inconsistencies between the theory and evidence, the purpose of this paper is to develop a model that can explain the following facts: (1) the fertility decline is steeper than can be explained by income level only; (2) the relationship between income and fertility is shifting downwards; and (3) at high levels of income, the fertility decline reverses. In particular, the aim is to ascertain whether the individual fertility choice is subject to the effect of externalities caused by the average levels of consumption, fertility and human capital in society. Thus, we believe that taking these social externalities into account will allow us to explain why fertility is declining and the relationship between income and the fertility rate is changing over time.

The role of consumption externalities in capital accumulation and long-term growth has been discussed extensively in the literature.[1] Those externalities are classified as "keeping up with the Joneses" (KUJ hereafter) and "catching up with the Joneses" (CUJ).[2] This study focuses only on KUJ preferences. Denoting the utility function by u and the levels of the agents' consumption and the average consumption in the economy in period t by c_t and $\bar{c}_t$, respectively, the positive KUJ effect stems from the contem-

[1]See Chen et al. (2015) for a literature review.

[2]The *CUJ* effect stems from past average levels of consumption and it is defined as $\frac{\partial^2 u}{\partial c_t \partial \bar{c}_{t-1}} > 0$ (see Abel, 1990; Ljungqvist and Uhlig, 2000).

porary average level of consumption, which is defined as $\frac{\partial^2 u}{\partial c_t \partial \bar{c}_t} > 0$ (see Chen et al., 2015, for details).[3] However, given the significance of the effect of KUJ preferences on inter-temporal consumption allocation and capital accumulation as highlighted in the literature, it appears natural to analyse whether KUJ preferences can help to explain the relationship between income and fertility.

This study generalises the fertility choice models by incorporating KUJ preferences. Specifically, we assume that KUJ preferences depend on the social norms in society related to consumption, the number of children (fertility) and the amount spent on education (quality of children). Hence, it is argued that the fertility choice of an individual is influenced by the average consumption (first factor), the average fertility rate (second factor), and the average human capital (third factor) in society. Exploration into the social norms associated with fertility has been suggested in the literature which emphasises that social norms impact individual fertility choice (Bhattacharya and Chakraborty, 2012; Goto, 2008; Munshi and Myaux, 2006; Palivos, 2001). The link established by these studies has been used to explain the differences in patterns of fertility evolution across countries, the relationship between child mortality and fertility, and the implications of fertility choice on inequality. However, they do not consider the social norms as a factor behind the sharp decline in fertility and the structural changes in the income-fertility relationship. In addition, the fertility choice models with human capital (de la Croix and Doepke, 2003) assume that the average human capital (third factor) exerts positive externalities on educational spending; therefore, the average human capital of the adult generation in society affects the human capital accumulation of the young generation. Since the average human capital levels in society affect educational spending at the individual level, this effect can also be viewed as a type of KUJ preference. In light of this, the model considered in this paper incorporates KUJ preferences into the agents' utility optimisation problem and shows their implications on the individual's fertility choice.

This paper demonstrates that both the structural shift in the income-fertility relationship and the reversal of the fertility decline can be explained by a combined

[3] There is an alternative view, which argues that these consumption externalities can also be negative. The implications of the negative consumption externalities are presented in Ulph (2014).

effect of a quantity-quality trade-off and KUJ preferences. The analysis shows that accounting for KUJ preferences stemming from consumption adds a new channel that affects fertility by increasing the marginal value of consumption compared to that of descendants. Additionally, by including the fertility norms into KUJ preferences, this papers finds that the declining average fertility rate creates additional downward pressure on the fertility of individuals. As a consequence, the observed downward shift in the relationship between fertility rates and income levels (see Figure 1) is caused by changes in both consumption and fertility norms.

Next, this study demonstrates that the externalities generated by the average consumption can be described as a concave function, and the evolution of these externalities explains a reversal of the fertility decline. This reversal occurs due to a fall in the negative effect of consumption externalities on fertility combined with the effects of average human capital on survival and education. Specifically, when the survival of children reaches the maximum level at high levels of human capital, a further increase in the human capital does not directly affect fertility. At the same time, a further increase in the average human capital reduces the cost of education through the generated positive externalities. In addition, when consumption externalities start fading after reaching some threshold level, the marginal utility of consumption also starts decreasing. Optimising agents use the savings from reduced consumption and educational spending to increase the quantity of children. This result is consistent with the empirical facts reflected in Figure 2 and Figure 3.[4]

This study contributes to the existing literature by suggesting an additional set of factors that affect fertility choice. In particular, this paper introduces a new mechanism that explains an individual's fertility choice by incorporating the effect of externalities that stem from the consumption and human capital of others in society. In addition, we generalise the existing models with social norms related to fertility developed in Palivos (2001), Goto (2008), Munshi and Myaux (2006), and Bhattacharya and Chakraborty (2012) by additionally incorporating consumption and education norms

[4]It should be noted that the increase in fertility does not seem to be driven by the immigrant population's fertility, which may be higher than that of the local population. For example, Lanzieri (2013) indicates that in most of the high income European countries, the immigrant population exhibited lower fertility than the local population.

as part of KUJ preferences. The extended model shows that the effect of KUJ preferences explains not only the cross-country differences in fertility rates, but also the evolution of the relationship between fertility and consumption (income) over time. The theoretical propositions stemming from our model have been confronted with the US data. The estimation results indicate strong supporting evidence that the externalities incorporated into the fertility model do, indeed, play a significant role in the evolution of fertility.

The paper is organised as follows. The next section presents the outline of the basic model. Section 3 describes the basic model with KUJ preferences stemming from consumption and presents the analysis of its solution. Additionally, the section presents a further extension of the model by incorporating KUJ preferences in terms of fertility and educational spending, and the implications of these factors are discussed. Section 4 tests empirically the analytical propositions obtained in Section 3. Section 5 concludes the paper. The proofs of the propositions are provided in the appendix.

2 Outline of the model

To analyse the effect of KUJ preferences on fertility choice, we set up a basic model that incorporates the following factors: consumption, fertility and education, through which social externalities affect the individual's optimisation problem. First, we consider KUJ preferences that stem from consumption externalities and ascertain their impact on the fertility choice of agents. Then, we consider an extension of this basic model by allowing for KUJ preferences driven by the average rate of fertility, along with the average level of consumption. Since both consumption and fertility are entered into the utility function, the agents can be influenced by externalities stemming from both the consumption and fertility choices of others. Additional externalities are generated by human capital in society due to the spillover effect of knowledge accumulation.[5] Following this rationale, we consider an extended model where the average level of consumption, human capital,

[5]In addition, it does not seem too far-fetched to assume that the benchmark in terms of what to provide your children with can also be subject to some social pressure. However, the consumption of children is included in the consumption of parents; hence, this type of externality is another aspect of KUJ preferences captured in our model through the effect of the average level of consumption.

and the fertility rate are used as factors that induce externalities on fertility choice. To allow for deviations from the average in equilibrium, we assume an environment with heterogeneous agents in terms of their human capital.

Let us consider an overlapping-generation model where agents live in two periods: childhood and adulthood. Agents are endowed with one unit of time that is inelastically spent on labour and child-rearing. Adult agents care about their consumption, $c_{it} \geq 0$, and the number of children, n_{it}. Rearing each child requires time equal to ϕ; by the end of their childhood, each child obtains human capital equal to $h_{i,t+1}$. Thus, in general, the preferences of the adult agents are determined by:

$$U_{it} = u(c_{it}, \bar{c}_t, n_t h_{i,t+1}),\; u'_x > 0, u''_x < 0 : \; x \in \{c_t, \bar{c}_t, n_t, h_{t+1}\},$$

subject to their budget constraints and human capital evolution process. The rest of the time is spent working in the production sector and is given as:

$$l_{it} = 1 - \phi n_{it}. \tag{1}$$

It is assumed that the agents are heterogeneous in terms of their human capital levels. The probability distribution function (pdf) of human capital over the adult population is given by $f(h_{it})$. Under this setting, the effective labour of an agent is given as $h_{it} l_{it}$. The production function is specified as follows:

$$y_{it} = w h_{it} l_{it}. \tag{2}$$

Given that income is a linear function of labour, for simplicity, we normalise the wage rate, w, to 1. The budget constraint faced by an agent is then given as:

$$c_{it} = h_{it}[1 - \phi n_{it}] - e_{it} \pi_{it} n_{it}, \tag{3}$$

where e_{it} is the amount of income spent on education for each surviving child. The survival probability is defined similarly to Blackburn and Cipriani (2002), and is given as a function of the human capital of the parents:

$$\pi(h_{it}) = \underline{\pi} + \frac{h_{it}}{\tilde{\pi} + h_{it}}, \tag{4}$$

where $0 < \tilde{\pi}$, $0 < \underline{\pi} < 1$; hence, $\frac{\partial \pi}{\partial h} > 0$, $\frac{\partial^2 \pi}{\partial h^2} < 0$, if $\pi < 1$. However, this formulation of the probability of survival implies that for high human capital levels, it is possible that $\pi = 1$; hence, $\frac{\partial \pi}{\partial h} = 0 | h > argmax[\pi(h)]$. That is, a further increase in human capital does not have any effect on survival.

Since, according to (3), the level of consumption is proportional to the agent's level of human capital, the average level of consumption, $\bar{c}_t$, is also proportional to the average human capital, $\bar{h}_t$, given as:

$$\bar{h}_t = \int_{h_{min}}^{h_{max}} h_{it} f(h_{it}) dh_{it}. \tag{5}$$

Similar to de la Croix and Doepke (2003), Fioroni (2010) and Omori (2009), human capital of an agent evolves according to:

$$h_{i,t+1} = \left(\bar{h}_t^{1-\beta} h_{it}^{\beta} \right)^{1-\tau} e_{it}^{\tau}, \tag{6}$$

where $0 < \tau < 1$ and $0 < \beta < 1$.[6]

Total population grows according to the function given as follows:

$$P_{t+1} = P_t \int_{h_{min}}^{h_{max}} n_{it} \pi_{it} f_t(h_{it}) dh_{it}. \tag{7}$$

The average fertility rate is determined by:

$$\bar{n}_t = \int_{h_{min}}^{h_{max}} n_{it} f_t(h_{it}) dh_{it}, \tag{8}$$

[6]Unlike the above studies, the focus of this study is not on determining the impact of educational spending on fertility; for simplicity, it is assumed that human capital accumulation is possible only with non-zero spending on education.

whereas, the average consumption is determined by:

$$\bar{c}_t = \int_{h_{min}}^{h_{max}} c_{it} f_t(h_{it}) dh_{it}. \tag{9}$$

The distribution of human capital evolves as follows:[7]

$$f_t(h_{it}) = \left[\frac{P_0}{P_t} \prod_{\tau=0}^{t} n_{i\tau} \right] f_0(h_{i0}). \tag{10}$$

Definition of Equilibrium

Given an initial distribution of human capital $f_0(h_0)$, and an initial population size P_0, an equilibrium consists of sequences of aggregate quantities $\{\bar{c}_t, \bar{h}_t, \bar{n}_t, P_{t+1}\}$, distributions $f_t(h_{it})$, and decision rules c_{it}, n_{it}, e_{it}, $h_{i,t+1}$ such that:

- the individual's decision rules c_{it}, n_{it}, e_{it}, $h_{i,t+1}$ maximize utility subject to the constraints (3) and (6);
- markets clear by labour being distributed between child-rearing and production (1), and in the goods market, the output is allocated between consumption and educational spending (3);
- the distribution of human capital evolves according to (10);
- aggregate variables $\bar{h}_t$, P_t, $\bar{n}_t$, $\bar{c}_t$ are given by (5), (7), (8) and (9).

3 KUJ preferences and fertility

3.1 KUJ preferences in consumption

To capture the fertility effects of the KUJ behaviour in consumption, we consider a simple environment. In this environment, adults care about their own consumption, the number of children they have and the level of human capital of their children, $h_{i,t+1}$. To

[7]To obtain this formula, consider a change in the human capital distribution from period 0 to period 1. In period 0, the number of agents with human capital h_{i0} is found as the product of the share of this type of agent and the total population, $f_0(h_{i0})P_0$. In period 1, each type i agent will have n_{i1} children with h_{i1} human capital. Given that the total adult population in period 1 is P_1, the share of these type-i agents is found as $f_1(h_{i1}) = \frac{[f_0(h_{i0})P_0]n_{i1}}{P_1}$. Using this recursive rule, one obtains the general rule given by equation (10).

focus only on consumption externalities, let us assume that the average human capital has no effect on human capital accumulation, which is assumed to evolve according to:

$$h_{i,t+1} = h_{it}^{1-\tau} e_{it}^{\tau}.$$

Following Fioroni (2010) and de la Croix and Doepke (2003), let us assume a paternalistic utility function in the constant elasticity of substitution (CES) form given as:[8]

$$U_{it} = \gamma \left[\alpha (\bar{c}_t^{\delta} c_{it})^{\rho} + (1-\alpha)(n_{it} h_{it}^{1-\tau} (e_{it})^{\tau})^{\rho} \right]^{\frac{1}{\rho}}, \tag{11}$$

where $\bar{c}_t$ stands for the average consumption, $0 < \rho < 1$, $\gamma > 0$, and $\delta > 0$. Using the first-order conditions of the optimisation problem, we solve e_{it} and n_t (see Appendix A1 for details):

$$e_{it}^{*} = \frac{h_{it} \tau \phi}{\pi_{it}(1-\tau)}. \tag{12}$$

By analysing the equilibrium value of educational spending, the following lemma is stated.

Lemma 3.1 *Spending on education increases with the level of the parents' human capital.*

Proof Taking the first-order derivative of (12) and accounting for (4) yields:

$$\frac{\partial e_{it}}{\partial h_{it}} = \frac{\tau \phi (h^2 (\underline{\pi} + 1) + \tilde{\pi} \underline{\pi} (\tilde{\pi} + 2h))}{[\underline{\pi} \tilde{\pi} + (1 + \underline{\pi}) h]^2 (1-\tau)} > 0. \blacksquare$$

Using the first-order conditions, the equilibrium fertility rate is determined by the following:

$$n_{it}^{*} = \frac{\left(\frac{\phi \alpha}{1-\tau}\right)^{\frac{1}{\rho-1}}}{\left[(1-\alpha)\left(\frac{\tau\phi}{\pi(1-\tau)}\right)^{\tau\rho} \bar{c}_t^{-\rho\delta}\right]^{\frac{1}{\rho-1}} + \left[\alpha\left(\frac{\phi}{1-\tau}\right)^{\rho}\right]^{\frac{1}{\rho-1}}}. \tag{13}$$

By analysing the expression for the equilibrium fertility rate, the following proposition is stated.

[8] The reason for this choice is that the CES function is less restrictive than the Cobb-Douglas function employed by the above authors, and in the current context, the CES form allows for better tractability.

Proposition 3.2 *For an agent with preferences defined by* (11) *and a budget constraint given by* (3)*, an increase in the level of average consumption and own human capital results in a reduction of fertility.*

Proof Using (13), it can be verified that $\frac{\partial n_{it}^*}{\partial \bar{c}_t} < 0$ and $\frac{\partial n_{it}^*}{\partial h_{it}} < 0$. See Appendix A2 for details.■

The intuition behind this result is simple. When the average consumption levels increase due to positive externalities, this change lifts the marginal utility of consumption. Given the budget constraint, the agents respond to this change by increasing consumption and decreasing fertility. An increase in the parents' human capital raises the probability of a child's survival; hence, as agents who care about the effective value (quality multiplied by their quantity), they increase spending on education and reduce fertility. In other words, the so-called quantity-quality trade-off occurs.

We can generalise the above result for the whole economy by considering whether the average fertility decreases with an increase in the average consumption and human capital. From the budget constraint of an agent given by (3), one can see that the average consumption depends on the average human capital and the average fertility rate. Thus, we can write:

$$\bar{c}_t = \bar{h}_t(1 - \phi\bar{n}_t) - \bar{\pi}\bar{n}_t\bar{e}, \tag{14}$$

where $\bar{h}_t$, $\bar{n}$, $\bar{\pi}$, and $\bar{e}_t$ are the average human capital, fertility rate, survival rate, and educational spending, correspondingly. Since, according to Proposition 3.2, an increase in the human capital of an individual reduces the fertility rate, one can also relate the effect of such changes to a rise in the average human capital and a decline in the average fertility rate. For that purpose, we can re-write (13) for an average agent as follows:

$$\bar{n}_t^* = \frac{\left[\frac{\phi\alpha}{1-\tau}\right]^{\frac{1}{\rho-1}}}{\left[(1-\alpha)\left(\frac{\tau\phi}{\bar{\pi}(1-\tau)}\right)^{\tau\rho}\bar{c}_t^{-\rho\delta}\right]^{\frac{1}{\rho-1}} + \left[\alpha(\frac{\phi}{1-\tau})^{\rho}\right]^{\frac{1}{\rho-1}}}. \tag{15}$$

Analysing (14), we see that the average consumption can increase only if the average human capital increases and the average fertility rate falls. This implies that the consumption externalities are possible only if the average human capital rises are accompanied with a fall in average fertility. This rationale does not contradict Proposition 3.2. Indeed, increasing human capital at the individual level decreases fertility and pushes the average human capital up, which, in turn, increases the average consumption that creates additional negative externalities for fertility. By analysing the comparative statics of (15), we state the following proposition:

Proposition 3.3 *A higher level of the average human capital reduces fertility both through the quality-quantity trade-off effect of an increase in the survival rate of children and through the consumption externalities.*

Proof It can be verified that $\frac{\partial \bar{n}_t}{\partial \bar{h}_t} < 0$ holds as both an increase in survival, $\frac{\partial \bar{\pi}_t}{\partial \bar{h}_t} > 0$, and consumption externalities, $\frac{\partial \bar{c}_t}{\partial \bar{h}_t} > 0$, lead to a lower fertility rate. The details of the proof are provided in Appendix A2.1

From the above analysis, we find that an increase in the average human capital reduces the average fertility rate. Therefore, Proposition 3.3 reinforces Proposition 3.2, as we see that both the number of offspring and the externalities created by consumption goods are driven by the average human capital level.

3.2 The effect of KUJ preferences on fertility through other channels

It appears natural to extend KUJ preference to non-consumption spending. For example, it is not just the utility of parents that depends on the social preference levels for consumption; the utility that stems from the number of offspring also depends on the externalities created by the the norms in society regarding the number of children. Another way, the social structure can affect the cost of having children, stems from the fact that education is, in fact, provided by the schools (de la Croix and Doepke, 2003). This implies that the human capital evolution process depends not only on educational spending and the parents' human capital, but also that the average human capital exerts positive externalities on human capital accumulation. In light of this, we examine how the KUJ preferences affect fertility and human capital accumulation through these channels.

3.3 KUJ preferences in fertility

Here, we introduce one of the above-mentioned factors of KUJ preferences, by assuming that the utility of the parents obtained from the number of offspring depends on the externalities created by the norms in society pertaining to the number of children. That is, similar to consumption, the average number of children in a household, $\bar{n}$, exerts an additional effect on the utility of an agent from the number of his/her own children.[9]

Under such consideration, the agent's preferences are given as:

$$U_{it} = \gamma \left[\alpha(\bar{c}_t^{\delta} c_{it})^{\rho} + (1-\alpha)(n_{it}\bar{n}_t^{\varepsilon} h_{it}^{1-\tau} e_{it}^{\tau})^{\rho}\right]^{\frac{1}{\rho}}. \tag{16}$$

Solving the optimisation problem for e_{it}, we obtain the following:

$$e_{it}^* = \frac{\tau h_{it}\phi}{\pi_{it}(1-\tau)}. \tag{17}$$

Now, solving the first-order conditions for n_{it} yields the equilibrium value of the fertility rate:

$$n_{it}^* = \frac{\left[\frac{\phi\alpha}{1-\tau}\right]^{\frac{1}{\rho-1}}}{\left[(1-\alpha)\bar{n}_t^{\varepsilon\rho}\left(\frac{\tau\phi}{\pi_{it}(1-\tau)}\right)^{\tau\rho}\bar{c}_t^{-\rho\delta}\right]^{\frac{1}{\rho-1}} + \left[\alpha(\frac{\phi}{1-\tau})^{\rho}\right]^{\frac{1}{\rho-1}}}. \tag{18}$$

By analysing the equilibrium fertility rate, one can state the following proposition:

Proposition 3.4 *In the presence of KUJ preferences ($\varepsilon > 0$), an increase in the average level of fertility, $\bar{n}$, raises the fertility rate of an agent.*

Proof Using (18), it can be verified that $\frac{\partial n_{it}^*}{\partial \bar{n}_t} > 0$. See Appendix A3 for details. ■

The above result indicates that the existence of externalities stemming from the average (socially desirable) level of fertility makes the effect of consumption externalities even stronger. This is because an increase in the average consumption reduces the average fertility, which, in turn, exerts greater downward pressure on fertility through the externalities it creates. The complementarity of these externalities might be why in many countries the fertility rates have been spiralling down rapidly.

[9] We follow Palivos (2001) and Goto (2008) who employ the average fertility rate as the measure of the social norm on fertility preferences.

3.4 The effect of average human capital on fertility

Following de la Croix and Doepke (2003), we assume that the human capital of the next generation increases with the level of average human capital, $\bar{h}_t$, along with the human capital of their parents. Thus, the effect of education spending for children increases with the average level of human capital. In this case, the evolution of human capital is given by:

$$h_{i,t+1} = \left(\bar{h}_t^{1-\beta} h_{it}^{\beta}\right)^{1-\tau} e_{it}^{\tau}. \tag{19}$$

In addition, the probability of survival of children can be a function of the average human capital as well as the parents' human capital. That is, we can assume that:

$$\pi_{it} \equiv \pi(h_{it}, \bar{h}_t),\ \frac{\partial \pi}{\partial \bar{h}} > 0. \tag{20}$$

The Lagrangian of this problem is given by:

$$L = \gamma \left[\alpha(\bar{c}_t^{\delta} c_{it})^{\rho} + (1-\alpha)(\bar{n}_t^{\varepsilon} \left(\bar{h}_t^{1-\beta} h_{it}^{\beta}\right)^{1-\tau} e_{it}^{\tau} n_{it})^{\rho}\right]^{\frac{1}{\rho}} + \lambda[h_{it}(1-\phi n_{it}) - \pi_{it} e_{it} n_{it} - c_{it}].$$

Solving the first-order conditions, we obtain the following:

$$e_{it}^{*} = \frac{\tau \phi h_{it}}{\pi_{it}(1-\tau)}, \tag{21}$$

$$n_{it}^{*} = \frac{\left[\frac{\phi\alpha}{(1-\tau)}\right]^{\frac{1}{\rho-1}}}{\left[(1-\alpha)\bar{n}_t^{\rho\varepsilon}\left(\frac{\bar{h}_t}{h_{it}}\right)^{\rho(1-\beta)(1-\tau)}\left(\frac{\tau\phi}{\pi_{it}(1-\tau)}\right)^{\tau\rho}\bar{c}_t^{-\rho\delta}\right]^{\frac{1}{\rho-1}} + \left[\alpha(\frac{\phi}{(1-\tau)})^{\rho}\right]^{\frac{1}{\rho-1}}}. \tag{22}$$

The expression for educational spending in equilibrium appears to be formally not different from the one found earlier (17). However, accounting for the effect of the average human capital on the survival rate indicated by (20), leads us to consider the implcations of this new channel. This consideration leads to the following lemma:

Lemma 3.5 *A higher level of average human capital increases the probability of survival of children, and as result, reduces educational spending.*

Proof According to (20), $\frac{\partial \pi}{\partial h} > 0$, hence, from (21) $\frac{\partial e^*}{\partial h} < 0$.■

By analysing the expression for the fertility rate (22), the following proposition is stated:

Proposition 3.6 *Given the presence of KUJ preferences in consumption and fertility, an increase in the parents' human capital results in a lower fertility rate.*

Proof It can be verified by considering the comparative statics of (22) that $\frac{\partial n_{it}^*}{\partial h_{it}} < 0$. See Appendix A4 for details. ■

The above results provide an explanation for the steep decline in fertility (as highlighted in Doepke, 2005), as well as why the negative relationship between income and fertility has been shfting downwards over time. The shift appears to have been caused by the feedback effect from the falling average fertility rate to the individual fertility rates. Moreover, KUJ preferences also drive cross-country differences in fertility, as two economies with different $\bar{h}_t$, $\bar{c}_t$, and parameters, δ, ε, β, and τ, according to (22), would have different fertility rates. The above proposition can be generalised to the whole economy. If for any agent, an increase in their human capital reduces fertility, then the same must hold for all agents. Therefore, the same relationship is expected to hold for the average agent. Based on this rationale, we state the following corollary:

Corollary 3.7 *An increase in the average level of human capital reduces the average fertility rate.*

3.5 A reversal of the fertility decline

Overall, the model specified above can explain why the fertility rate is falling and why this decline has accelerated across countries. However, based on the above model, we still cannot explain how the observed reversal of the fertility decline occurred in high-income countries after they reached some threshold levels of their per capita income. One possible explanation for such a pattern may be that the consumption externalities are a concave function of the average consumption. That is, after reaching some threshold value, the positive effect of average consumption on the individual marginal utility might start to fall. One way to model this type of non-linear relationship is to formulate it as a concave function of the average consumption:

$$v = v(\bar{c}_t) \in R^+, \ \frac{\partial v}{\partial \bar{c}} \gtrless 0, \ \frac{\partial^2 v}{\partial \bar{c}^2} < 0. \tag{23}$$

This implies that the marginal effect of consumption externalities initially rises with the average consumption, but after reaching $\bar{c}_m = argmax\{v\}$, it falls.

In light of this generalisation, the utility function is re-stated as follows:

$$U_{it} = \gamma \left[\alpha (v_t^{\delta} c_{it})^{\rho} + (1-\alpha)(n_{it} \bar{n_t}^{\varepsilon} h_{it}^{1-\tau} e_{it}^{\tau})^{\rho} \right]^{\frac{1}{\rho}}. \tag{24}$$

Under this setting, we can analyse the comparative statics of $\bar{n}$ with regards to $\bar{h}$, and state the following proposition:

Proposition 3.8 *Given that the average consumption* $\bar{c} > \bar{c}_m = argmax[v(\bar{c})] \Rightarrow \frac{\partial v}{\partial \bar{c}} < 0$ *and the level of average human capital is above the threshold value, such that* $\bar{h}_t \geq arg[\pi(\bar{h}) = 1]$*, the average fertility rises with an increase in the average human capital.*

Proof Using (22) and taking into account (23), it can be verified that $\frac{\partial \bar{n}_t}{\partial \bar{h}_t} \gtrless 0$. Given that $\frac{\partial \pi}{\partial \bar{h}} = 0$ and $\frac{\partial v}{\partial \bar{c}} < 0$, it can be verified that $\frac{\partial \bar{n}_t}{\partial \bar{h}_t} > 0$ holds. See Appendix A5 for details of the proof.■

The above result indicates that when income is above a certain threshold, fertility rises with income growth.[10]

[10]The model we consider here is quite simple and, hence, does not take into account other factors that may affect fertility, along with income and the externalities discussed above. Therefore, one cannot tell how the upper bound on fertility will be determined based on this model. In general, it is reasonable to expect that the upper bound can be determined by natural fertility limits if there is no other factor that would constrain it; it can also be affected by other factors such as environmental degradation and congestion that stem from overpopulation and production. To answer this question, one needs to consider a model that incorporates the environment and its impact on fertility; as such, this question is beyond the scope of this study.

4 Empirical evidence

Our theoretical analysis yields propositions regarding the effects of average consumption, fertility and human capital levels on individual fertility choice. In particular, our model indicates that KUJ preferences stemming from the average consumption, fertility and human capital levels can drive the individual's fertility choice. Moreover, if KUJ preferences stemming from consumption are of a concave shape, this may explain the observed reversal of fertility decline. Since our theory implies that consumption and fertility externalities affect individual choices, the best way to test the predictions of the theory is to estimate the fertility rate by using micro-level data. We address this task by using the survey data from the 'General Social Survey' conducted throughout the United States (US) by the National Opinion Research Center.

4.1 Empirical model

To formulate the empirical model that is used to estimate the relationships between the fertility rate and social externalities, we state the fertility rate in a more general form. Specifically, we re-write the solution for the fertility rate (22) as follows:

$$n_{it}^{*} = \frac{\left[\frac{\phi\alpha}{(1-\tau)}\right]^{\frac{1}{\rho-1}}}{\left[(1-\alpha)\bar{n}_t^{\rho\varepsilon}\left(\frac{\bar{h}_t}{h_{it}}\right)^{\rho(1-\beta)(1-\tau)}\left(\frac{\tau\phi}{\pi_{it}(1-\tau)}\right)^{\tau\rho}v_t^{-\rho\delta}\right]^{\frac{1}{\rho-1}}+\left[\alpha(\frac{\phi}{(1-\tau)})^{\rho}\right]^{\frac{1}{\rho-1}}}. \tag{25}$$

where we generalise the consumption externalities as a concave function given by: $v = v(\bar{c}) \in R^{+}$, $\frac{\partial v}{\partial \bar{c}} \gtrless 0$, $\frac{\partial^2 v}{\partial \bar{c}^2} < 0$

Based on the relationship between fertility choice and other variables given by (25), we formulate the following empirical model:[11]

$$n_{it} = \alpha + \beta \mathbf{X} + \gamma_0 \left(\frac{h_{it}}{\bar{h}_t} \right) + \gamma_1 \bar{c}_t + \gamma_2 \bar{c}_t^2 + \gamma_3 \bar{n}_t + u_t. \tag{26}$$

Here we take into account that $v = v(\bar{c})$ is a non-linear function and we express this by adding the squared average consumption. In fact, our empirical model can be viewed as an extended version of the model employed in Sander (1992). Specifically, we extend Sander's model by replacing the level of individual human capital with its ratio to the average human capital, and adding the average consumption and the average number of children as additional explanatory variables. In light of the analytical findings presented above, we expect the followings signs of the coefficients given in (26): $\gamma_0 < 0$, $\gamma_1 < 0$, $\gamma_2 > 0$, and $\gamma_3 > 0$. In other words, we expect that the level of human capital of an agent relative to the average has a negative impact on fertility. The level of the avergage consumption reduces fertility, whereas its squared value is expected to have a positive effect on fertility. The social fertility norms captured by the average fertility rate are expected to have a positive impact on individual fertility choice.

4.2 Data and estimation

The dataset is obtained from the website of the National Opinion Research Center.[12] The data were collected in the survey titled 'General Social Survey' throughout the US. The survey has been conducted annually most years from 1972 to 1994, then biannually since 1996. It consists of a random sample of approximately 2,000 English-speaking persons 18 years of age or older living in non-institutional arrangements in the US. The survey data are not longitudinal. In this study, data from all of the available surveys are used (1972 to 2014). Sander (1992) argued that younger women should not be

[11] It is possible to linearise equation (25) approximately as follows:

$$\ln n_{it} \approx a_0 + a_1 \ln \frac{h_{it}}{\bar{h}_t} + a_2 \ln \bar{n}_t + a_3 \ln v_t.$$

The estimations of such an equation leads to results similar to the case of a simple linear regression; however, we lose some information, as the observations with zero children or education have to be excluded due to the log form of the specification. Therefore, we only use the linear specification suggested by Sander (1992).

[12] Accessed on 17 March 2016, http://www.norc.org/

selected because a relatively high proportion may not have completed their schooling and fertility. The vast majority of women in the US aged 35 to 50 have completed their fertility (Monte and Ellis, 2012); therefore, women of those ages are included in our dataset. The fertility rates are estimated using both ordinary least squares (OLS) and two-stage least squares (TSLS) methods.

The rest of the variables are found as follows: the average number of children is computed as the average of all children born for each year across all regions of the US covered in the survey; the average schooling is computed as the average for each year; the per capita real consumption in the US is obtained from the website of the Federal Reserve Economic Data.[13] We also include other control variables such as age, black, region at age sixteen (relative to the South), type of residence at age 16 (relative to big cities of over 250,000 and their suburbs). A summary of statistics is provided in Table 1. An additional statistical analysis of the dataset yields supportive evidence that the individual fertility rates might be affected by the average levels of consumption, fertility rate, and schooling. The box-plots (Figure 4) between the number of children and those tree variables capturing the social externalities clearly indicate the existence of structural relationships implied by the empirical model. Moreover, one can find a U-shaped relationship between average fertility rates and per capita consumption in the US (see Figure 4, bottom right diagram), which is similar to what we presented for a cross-country case in Figure 2.

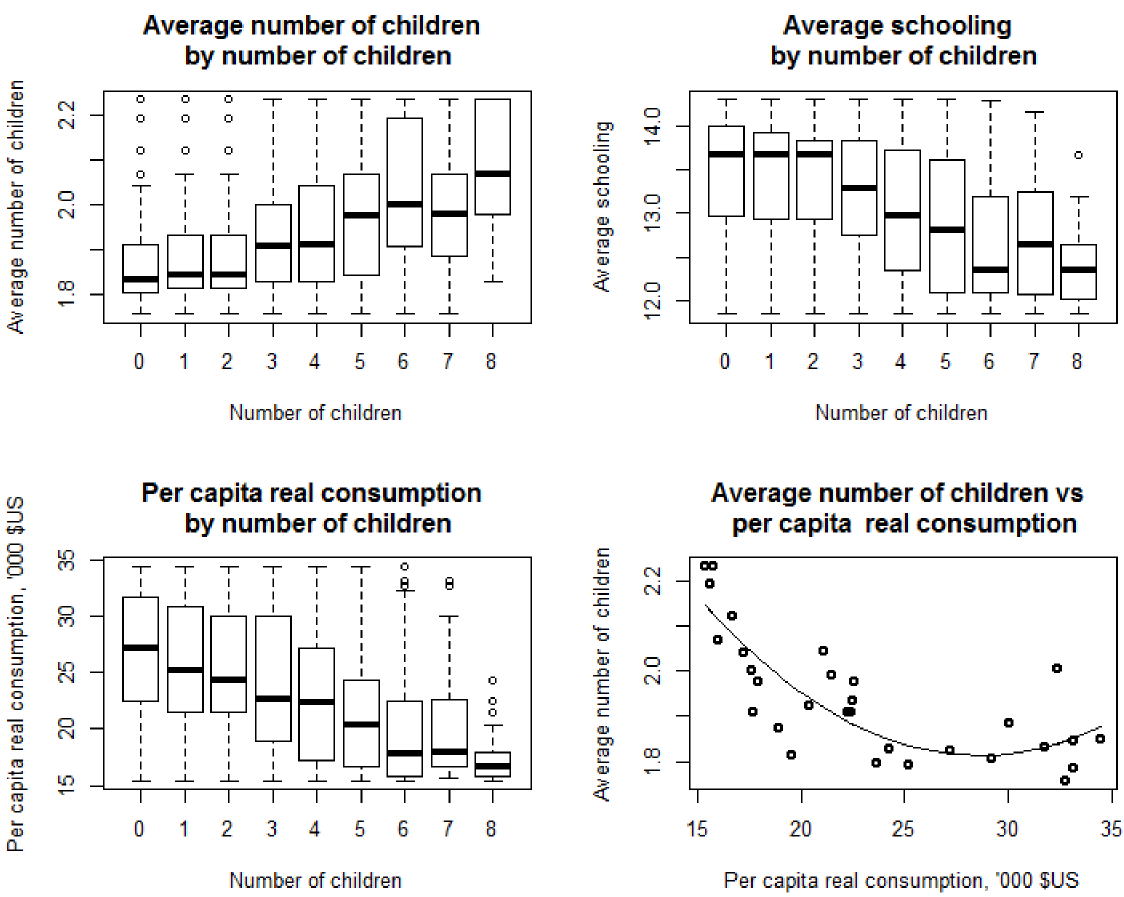
In TSLS estimates, the possible endogeneity of a woman's educational level is addressed by instrumenting it with her father's and mother's educational levels. A Durbin-Wu-Hausman test on the regressor endogeneity fails to reject the hypothesis that women's education is endogenous. A Hansen's test shows that the overidentification restrictions are valid. A test for weak instruments rejects the null hypothesis of weak instruments.

[13] Accessed 17 March 2016, https://research.stlouisfed.org/fred2/

Table 1: Descriptive statistics

Variable	Mean (1)	Standard deviation (2)
All children born	2.20	1.58
Schooling (years)	13.75	2.66
Age	42.28	4.50
Black	11.12	31.44
Farm	12.45	33.01
Other rural	11.47	31.87
Town	31.37	46.40
Small city	17.00	37.56
West	18.39	38.74
Northeast	28.61	45.19
Midwest	22.01	41.44
Catholic	25.12	43.37
Protestant	61.35	48.70
Per capita real consumption (thousand $US)	24.72	5.89
Average number of children	1.91	0.12
Average schooling	13.31	0.71
Schooling/Average schooling	1.03	0.19
Sample size	4900	

Figure 4. *Fertility and externalities*



4.3 Results

Table 2 shows the estimation results. The highly significant negative coefficient for real per capita consumption indicates that fertility declines with growth in real per capita consumption. The negative relationship between fertility rate and real per capita consumption reveals that fertility decline in the US can be partially attributed to the effect of KUJ preferences. Moreover, the positive sign on the squared consumption indicates that the effect of KUJ preferences is convex, suggesting an explanation for the fertility reversal observed in the data. The effect of an increase in real per capita consumption on the fertility rate changes as we move from lower to higher levels of real per capita consumption: $\frac{\partial KIDS}{\partial PCRC} = -.355 + 2 \times 0.006 \times PCRC$. One can verify that when per capita real consumption exceeds \$29,000, the effect of consumption externalities on fertility becomes positive. The coefficient on the average number of children has the expected positive sign and is statistically significant, which implies that the norms about fertility in society exert an external effect on individual fertility choices, and hence, amplifies both its decline and rise. The relative schooling coefficient suggests that the inequality in terms of human capital accumulation contributes to the fertility rate dispersion. This finding confirms the proposition of de la Croix and Doepke (2003) about the positive effect of inequality on the average fertility, as the effect of schooling on fertility is weaker if its level is below the average schooling level.

5 Conclusion

When KUJ preferences are taken into account, the marginal value of consumption increases with the average level of consumption. The optimising agents respond to an increase in the average level of consumption by reducing their fertility rate and increasing consumption. Therefore, accounting for KUJ preferences adds another channel through which rising average income and the associated higher per capita consumption can additionally depress fertility. This suggests an insight as to why the observed fertility decline has been greater than the fertility decline that would have been caused solely by the fall of child mortality and an increase of income (Doepke, 2005). Incorpo-

Table 2: Estimates of all children born to women aged 35 to 50

Variable	Estimated coefficients		Standard errors	
	(OLS)	(TSLS)	(OLS)	(TSLS)
Schooling/Average schooling	-1.726***	-1.848***	0.109	0.235
Age	0.028***	0.028***	0.005	0.005
Black	0.554***	0.549	0.067	0.067
Farm	0.012	0.004	0.073	0.074
Other rural	0.115	0.108	0.073	0.074
Town	0.091*	0.087	0.054	0.055
Small city	0.092	0.091	0.064	0.064
West	0.180***	0.181***	0.061	0.061
Northeast	0.081	0.054	0.081	0.054
Midwest	0.122**	0.125**	0.058	0.058
Catholic	0.464***	0.457***	0.070	0.071
Protestant	0.302***	0.296***	0.064	0.065
Per capita real consumption	-0.355***	-0.353***	0.047	0.048
Per capita real consumption^2	0.006***	0.006***	0.001	0.001
Average number of children	1.157***	1.162***	0.300	0.301
Intercept	4.926***	5.032***	1.116	1.131
R^2	17.47			
F statistic	68.91			

* Significant at 10% level
** Significant at 5% level
*** Significant at 1% level

rating the fertility choice of others into KUJ preferences demonstrates that the average fertility rate contributes to the observed structural shifts in the relationship between fertility rates and income levels (see Figure 1). Finally, assuming that the externalities exerted by the average consumption is a concave function of the average human capital, it follows that the fertility decline can be reversed at high levels of human capital, due to the diminishing marginal utility of consumption externalities. In addition, this process is exacerbated by average human capital externalities. This is because at high levels of human capital, the survival of children reaches the maximum level; thus, a further increase in human capital does not directly affect fertility, but it reduces the cost of education. The income saved on educational spending and consumption at the margin is used to increase the quantity of children the agents have. This result explains the observed reversal of the fertility decline that occurred in some high-income countries in recent years (see Figure 2).

By estimating the number of children born to women aged 35 to 50 in the US, we obtained strong evidence that the fertility rate has been affected by both the per capita real consumption and the average number of children. Moreover, the estimations show that the effect of consumption on fertility changes as we move from lower to higher levels of average per capita real consumption. When the per capita real consumption increased above $29,000, this effect becomes positive. Our results also indicate that the effect of human capital on fertility is not uniform and it depends on the relative position of the individual's educational level to the average level of education. That is, if an individual's educational level is above the average, its effect on reducing fertility is relatively stronger, and it becomes weaker when an individual's educational level is below the average.

Overall, by simultaneously accounting for KUJ preferences in consumption, fertility, and average human capital, this paper suggests new insights into the differences in fertility rates across countries and time.

Appendix

A1. Solution of the model in Subsection 3.1

From here on, for the clarity of exposition, we drop i and t indexes. The agent's optimisation problem can be solved by maximising the following Lagrangian:

$$L = \gamma \left[\alpha(\bar{c}^{\delta}c)^{\rho} + (1-\alpha)(nh^{1-\tau}e^{\tau})^{\rho}\right]^{\frac{1}{\rho}} + \lambda\left[h(1-\phi n) - c - e\pi n\right]. \tag{27}$$

The first-order conditions are written as follows:

$$\frac{\partial L}{\partial c} = \frac{\gamma}{\rho}\left[\alpha(\bar{c}^{\delta}c)^{\rho} + (1-\alpha)(nh^{1-\tau}e^{\tau})^{\rho}\right]^{\frac{1-\rho}{\rho}}\left(\alpha\rho\bar{c}^{\delta\rho}c^{\rho-1}\right) - \lambda = 0. \tag{28}$$

$$\frac{\partial L}{\partial n} = \frac{\gamma}{\rho}\left[\alpha(\bar{c}^{\delta}c)^{\rho} + (1-\alpha)(nh^{1-\tau}e^{\tau})^{\rho}\right]^{\frac{1-\rho}{\rho}}\left((1-\alpha)\rho n^{\rho-1}(h^{1-\tau}e^{\tau})^{\rho}\right) - \lambda(h\phi + \pi e) = 0. \tag{29}$$

$$\frac{\partial L}{\partial e} = \frac{\gamma}{\rho}\left[\alpha(\bar{c}^{\delta}c)^{\rho} + (1-\alpha)(nh^{1-\tau}e^{\tau})^{\rho}\right]^{\frac{1-\rho}{\rho}}\left((1-\alpha)\rho\tau e^{\tau\rho-1}(nh^{1-\tau})^{\rho}\right) - \lambda\pi n = 0. \tag{30}$$

Using (28) and (29), we write

$$(1-\alpha)n^{\rho-1}(h^{1-\tau}e^{\tau})^{\rho} = (h\phi+\pi e)(\alpha\bar{c}^{\delta\rho}c^{\rho-1}).$$

Solving for n, we obtain:

$$n = \left(\frac{(h\phi+\pi e)(\alpha\bar{c}^{\delta\rho})}{(1-\alpha)[h^{(1-\tau)}e^{\tau}]^{\rho}}\right)^{\frac{1}{\rho-1}} c. \tag{31}$$

Using (29) and (30) we write the following:

$$\frac{(nh^{1-\tau}e^{\tau})^{\rho}}{n(h\phi+\pi e)} = \frac{\tau(nh^{1-\tau}e^{\tau})^{\rho}}{n\pi e}.$$

Solving the latter equation for e, we obtain:

$$e^{*} = \frac{\tau h\phi}{(1-\tau)\pi}. \tag{32}$$

Given that labour supply is inelastic and the utility function is concave, the budget constraint is binding:

$$c = h(1-\phi n) - \pi e^{*}n. \tag{33}$$

Now solving (33) together with (31) yields the equilibrium value of the fertility rate:

$$n^{*} = \frac{h\left(h\phi+\pi e)\alpha\bar{c}_t^{\rho\delta}\right)^{\frac{1}{\rho-1}}}{\left[(1-\alpha)\left(h^{1-\tau}e^{\tau}\right)^{\rho}\right]^{\frac{1}{\rho-1}} + \left[(h\phi+\pi e)^{\rho}\alpha\bar{c}_t^{\rho\delta}\right]^{\frac{1}{\rho-1}}}. \tag{34}$$

By accounting for (32), (34) can be simplified as follows:

$$n^{*} = \frac{\left(\frac{\phi\alpha}{1-\tau}\right)^{\frac{1}{\rho-1}}}{\left[(1-\alpha)\left(\frac{\tau\phi}{\pi(1-\tau)}\right)^{\tau\rho}\bar{c}^{-\rho\delta}\right]^{\frac{1}{\rho-1}} + \left[\alpha\left(\frac{\phi}{1-\tau}\right)^{\rho}\right]^{\frac{1}{\rho-1}}}. \tag{35}$$

A2. Proposition 3.2 in Subsection 3.1

Proposition 3.2 can be verified by the following:

$$\frac{\partial n^*}{\partial \bar{c}} = \frac{\delta\rho}{\rho - 1} \frac{\left(\frac{\phi\alpha}{1-\tau}\right)^{\frac{1}{\rho-1}} \left[(1-\alpha)\left(\frac{\tau\phi}{\pi(1-\tau)}\right)^{\tau\rho}\right]^{\frac{1}{\rho-1}} \bar{c}_t^{-\frac{\rho\delta}{\rho-1}-1}}{\left(\left[(1-\alpha)\left(\frac{\tau\phi}{\pi(1-\tau)}\right)^{\tau\rho} \bar{c}^{-\rho\delta}\right]^{\frac{1}{\rho-1}} + \left[\alpha(\frac{\phi}{(1-\tau)})^{\rho}\right]^{\frac{1}{\rho-1}}\right)^2} < 0,$$

as $\frac{\delta\rho}{\rho-1} < 0$ due to $\rho < 1$, while the other terms are positive.

Then, by accounting for $\frac{\partial\pi}{\partial h} > 0$, we find:

$$\frac{\partial n^*}{\partial h} = -\frac{\tau\rho}{1-\rho} \frac{\left(\frac{\phi\alpha}{1-\tau}\right)^{\frac{1}{\rho-1}} \left[(1-\alpha)\left(\frac{\tau\phi}{(1-\tau)}\right)^{\tau\rho} \bar{c}^{-\delta\rho}\right]^{\frac{1}{\rho-1}} \pi^{\frac{\tau\rho}{1-\rho}-1} \frac{\partial\pi}{\partial h}}{\left(\left[(1-\alpha)\left(\frac{\tau\phi}{\pi(1-\tau)}\right)^{\tau\rho} \bar{c}^{-\rho\delta}\right]^{\frac{1}{\rho-1}} + \left[\alpha(\frac{\phi}{1-\tau})^{\rho}\right]^{\frac{1}{\rho-1}}\right)^2} < 0.$$

A2.1 Proposition 3.3 in Subsection 3.1

Proposition 3.3 can be verified by the following. The average fertility rate can be written based on (35) as:

$$\bar{n}^* = \frac{\left(\frac{\phi\alpha}{1-\tau}\right)^{\frac{1}{\rho-1}}}{\left[(1-\alpha)\left(\frac{\tau\phi}{\bar{\pi}(1-\tau)}\right)^{\tau\rho} \bar{c}^{-\rho\delta}\right]^{\frac{1}{\rho-1}} + \left[\alpha\left(\frac{\phi}{1-\tau}\right)^{\rho}\right]^{\frac{1}{\rho-1}}}. \tag{36}$$

By taking the first-order derivative of the latter equation, we obtain:

$$\frac{\partial \bar{n}^*}{\partial \bar{h}} = -\frac{1}{1-\rho} \frac{\left(\frac{\phi\alpha}{1-\tau}\right)^{\frac{1}{\rho-1}} \left[(1-\alpha)\left(\frac{\tau\phi}{1-\tau}\right)^{\tau\rho} \bar{c}^{-\delta\rho}\bar{\pi}^{-\tau\rho}\right]^{\frac{1}{\rho-1}} \left(\frac{\tau\rho}{\bar{\pi}}\frac{\partial\bar{\pi}}{\partial \bar{h}} + \frac{\delta\rho}{\bar{c}}\frac{\partial\bar{c}}{\partial \bar{h}}\right)}{\left(\left[(1-\alpha)\left(\frac{\tau\phi}{\bar{\pi}(1-\tau)}\right)^{\tau\rho} \bar{c}^{-\rho\delta}\right]^{\frac{1}{\rho-1}} + \left[\alpha\left(\frac{\phi}{1-\tau}\right)^{\rho}\right]^{\frac{1}{\rho-1}}\right)^2}.$$

The sign of the effect of the average human capital on the average fertility rate depends on the sign of $\left(\frac{\tau\rho}{\bar{\pi}}\frac{\partial\bar{\pi}}{\partial h} + \frac{\delta\rho}{\bar{c}}\frac{\partial\bar{c}}{\partial h}\right)$. The first term of this expression is positive as by definition, $\frac{\partial\bar{\pi}}{\partial \bar{h}} > 0$. This implies that an increase in the survival rate of children reduces fertility. Combining this outcome with Lemma 3.1, one can identify this effect as "the quality-quantity trade-off". Moreover, if the consumption basket consists of normal goods, it follows that with an increase in the average income level (which is determined by the average human capital in our context), $\frac{\partial\bar{c}}{\partial \bar{h}} > 0$ holds. Thus, $\frac{\partial\bar{n}^*}{\partial \bar{h}} < 0$.

That is, with higher average human capital the average fertility rate falls.

A3. Proposition 3.4 in Subsection 3.3

Proposition 3.4 can be verified by the following. Recall the equilibrium value of the fertility rate:

$$n^* = \frac{\left[\frac{\phi\alpha}{1-\tau}\right]^{\frac{1}{\rho-1}}}{\left[(1-\alpha)\bar{n}^{\varepsilon\rho}\left(\frac{\tau\phi}{\pi(1-\tau)}\right)^{\tau\rho}\bar{c}^{-\rho\delta}\right]^{\frac{1}{\rho-1}} + \left[\alpha(\frac{\phi}{1-\tau})^{\rho}\right]^{\frac{1}{\rho-1}}}. \tag{37}$$

Since (37) is similar to (35), it is straightforward to show that: $\frac{\partial n^*}{\partial \bar{c}} =< 0$, and $\frac{\partial n^*}{\partial h} > 0$.

We can also consider the effect of average fertility of the fertility of an agent and show the following:

$$\frac{\partial n^*}{\partial \bar{n}} = -\frac{\rho\varepsilon}{\rho-1}\frac{\left[\frac{\phi\alpha}{\pi(1-\tau)}\right]^{\frac{1}{\rho-1}}\left[(1-\alpha)\left(\frac{\tau\phi}{\pi(1-\tau)}\right)^{\tau\rho}\bar{c}^{-\rho\delta}\right]^{\frac{1}{\rho-1}}\bar{n}^{\frac{\varepsilon\rho}{\rho-1}-1}}{\left(\left[(1-\alpha)\bar{n}^{\varepsilon\rho}\left(\frac{\tau\phi}{\pi(1-\tau)}\right)^{\tau\rho}\bar{c}^{-\rho\delta}\right]^{\frac{1}{\rho-1}} + \left[\alpha(\frac{\phi}{\pi(1-\tau)})^{\rho}\right]^{\frac{1}{\rho-1}}\right)^2} > 0.$$

A4. Proposition 3.6 in Subsection 3.4

The equilibrium fertility rate is given by:

$$n^* = \frac{\left[\frac{\phi\alpha}{1-\tau}\right]^{\frac{1}{\rho-1}}}{\left[(1-\alpha)\bar{n}^{\rho\varepsilon}\left(\frac{\bar{h}}{h}\right)^{\rho(1-\beta)(1-\tau)}\left(\frac{\tau\phi}{\pi(1-\tau)}\right)^{\tau\rho}\bar{c}^{-\rho\delta}\right]^{\frac{1}{\rho-1}} + \left[\alpha\left(\frac{\phi}{1-\tau}\right)^{\rho}\right]^{\frac{1}{\rho-1}}}. \tag{38}$$

To show that $\frac{\partial n^*}{\partial h} < 0$, divide the right-hand side of (38) by $\left[\frac{\phi\alpha}{1-\tau}\right]^{\frac{1}{\rho-1}}$:

$$n^* = \frac{1}{\left[\frac{(1-\alpha)}{\alpha}\bar{n}^{\varepsilon\rho}\left(\frac{\bar{h}}{h}\right)^{\rho(1-\beta)(1-\tau)}\left(\frac{\tau}{\pi}\right)^{\rho\tau}\left(\frac{\phi}{1-\tau}\right)^{\tau\rho-1}\bar{c}^{-\rho(\delta+1)}\right]^{\frac{1}{\rho-1}} + \left(\frac{\phi}{1-\tau}\right)}. \tag{39}$$

By taking the first-order derivative , we obtain:

$$\frac{\partial n^*}{\partial h} = -\frac{\left[\frac{(1-\alpha)}{\alpha}\bar{n}^{\varepsilon\rho}\bar{h}^{\rho(1-\beta)(1-\tau)}\tau^{\rho\tau}\left(\frac{\phi}{1-\tau}\right)^{\tau\rho-1}\bar{c}^{-\rho(\delta+1)}\right]^{\frac{1}{\rho-1}}\left(h^{(1-\tau)(1-\beta)}\pi^{\tau}\right)^{\frac{\rho}{1-\rho}}}{\left[\left[\frac{(1-\alpha)}{\alpha}\bar{n}^{\varepsilon\rho}\left(\frac{\bar{h}}{h}\right)^{\rho(1-\beta)(1-\tau)}\left(\frac{\tau}{\pi}\right)^{\rho\tau}\left(\frac{\phi}{1-\tau}\right)^{\tau\rho-1}\bar{c}^{-\rho(\delta+1)}\right]^{\frac{1}{\rho-1}}+\left(\frac{\phi}{1-\tau}\right)\right]^2}\times$$

$$\times\left(\frac{\rho(1-\tau)(1-\beta)}{1-\rho}\frac{1}{h}+\frac{\tau\rho}{1-\rho}\frac{1}{\pi}\frac{\partial\pi}{\partial h}\right). \quad (40)$$

Clearly, given that $\frac{\partial\pi}{\partial h} \geq 0$ and $\rho < 1$, $\frac{\partial n^*}{\partial h} < 0$.

A5. Proposition 3.8 in Subsection 3.5

Now, we consider the comparative statics of the average fertility rate with regards to the average human capital. In this case, we take into account that the utility function of an agent is given by:

$$U = \gamma\left[\alpha(v^{\delta}c)^{\rho} + (1-\alpha)(n\bar{n}^{\varepsilon}\left(\bar{h}_t^{1-\beta}h_{it}^{\beta}\right)^{1-\tau}e^{\tau})^{\rho}\right]^{\frac{1}{\rho}},$$

where $v = v(\bar{c}) \in R^+$, $\frac{\partial v}{\partial \bar{c}} \gtrless 0$, $\frac{\partial^2 v}{\partial \bar{c}^2} < 0$. One can obtain the following solution for the fertility rate:

$$n^* = \frac{1}{\left[\frac{(1-\alpha)}{\alpha}\bar{n}^{\varepsilon\rho}\left(\frac{\bar{h}}{h}\right)^{\rho(1-\beta)(1-\tau)}\left(\frac{\tau}{\pi}\right)^{\rho\tau}\left(\frac{\phi}{1-\tau}\right)^{\tau\rho-1}v_t^{-\rho(\delta+1)}\right]^{\frac{1}{\rho-1}}+\left(\frac{\phi}{1-\tau}\right)}. \quad (41)$$

For the average agent (41) is modified as:

$$\bar{n}^* = \frac{1}{\left[\frac{(1-\alpha)}{\alpha}\bar{n}^{\varepsilon\rho}\left(\frac{\tau}{\pi}\right)^{\rho\tau}\left(\frac{\phi}{1-\tau}\right)^{\tau\rho-1}v_t^{-\rho(\delta+1)}\right]^{\frac{1}{\rho-1}}+\left(\frac{\phi}{1-\tau}\right)}.$$

$$\frac{\partial\bar{n}}{\partial\bar{h}} = -\frac{\left[\frac{(1-\alpha)}{\alpha}\bar{n}^{\varepsilon\rho}\left(\frac{\tau}{\pi}\right)^{\rho\tau}\left(\frac{\phi}{1-\tau}\right)^{\tau\rho-1}v^{-\rho(\delta+1)}\right]^{\frac{1}{\rho-1}}}{\left[\left[\frac{(1-\alpha)}{\alpha}\bar{n}^{\varepsilon\rho}\left(\frac{\tau}{\pi}\right)^{\rho\tau}\left(\frac{\phi}{1-\tau}\right)^{\tau\rho-1}v^{-\rho(\delta+1)}\right]^{\frac{1}{\rho-1}}+\left(\frac{\phi}{1-\tau}\right)\right]^2}\times$$

$$\times\frac{1}{\rho-1}\left[\frac{\varepsilon\rho}{\bar{n}}\frac{\partial\bar{n}}{\partial\bar{h}}-\frac{\rho\tau}{\pi}\frac{\partial\pi}{\partial\bar{h}}-\rho v^{-\rho(\delta+1)}\frac{\partial v}{\partial\bar{h}}\right]. \quad (42)$$

Let us denote by $\left[\frac{(1-\alpha)}{\alpha}\bar{n}^{\varepsilon\rho}\left(\frac{\tau}{\pi}\right)^{\rho\tau}\left(\frac{\phi}{1-\tau}\right)^{\tau\rho-1}\upsilon^{-\rho(\delta+1)}\right]^{\frac{1}{\rho-1}}$ by Γ and solve (42) for $\frac{\partial\bar{n}}{\partial\bar{h}}$:

$$\frac{\partial\bar{n}}{\partial\bar{h}} = -\frac{\frac{\Gamma\rho}{(1-\rho)}\left[\upsilon^{-\rho(\delta+1)}\frac{\partial\upsilon}{\partial\bar{h}} + \frac{\rho\tau}{\pi}\frac{\partial\pi}{\partial\bar{h}}\right]}{\left(\Gamma + \left(\frac{\phi}{1-\tau}\right)\right)^2 - \frac{\Gamma\varepsilon\rho}{\bar{n}(1-\rho)}}. \tag{43}$$

Since, for $\bar{c} > \bar{c}_m = argmax[v(\bar{c})]$, $\frac{\partial v}{\partial\bar{c}} < 0$, it implies that $\frac{\partial v}{\partial\bar{h}} = \frac{\partial v}{\partial\bar{c}}\frac{\partial\bar{c}}{\partial\bar{h}} < 0|_{\bar{c}>\bar{c}_m}$. Moreover, recall that for high levels of $\bar{h} \geq arg[\pi(\bar{h}) = 1]$, a further increase in the average level of human capital will not have any effect on child survival. That is, $\frac{\partial\pi}{\partial\bar{h}} = 0$ in this case. Therefore, when $\bar{h}_t$ is high enough, so that $\frac{\partial\pi}{\partial\bar{h}} = 0$ and $\frac{\partial v}{\partial\bar{c}} < 0$, the expression in the brackets in the numerator of (43) is negative, and hence, $\frac{\partial\bar{n}}{\partial\bar{h}} > 0$.

A6. Data used in the graphs

Figure 1, Figure 2, and Figure 3 are constructed using the data from the World Development Indicators database from the World bank:

http://data.worldbank.org/data-catalog/world-development-indicators

To construct, the graph in Figure 1, annual per capita income averages and raw fertility rates for years 1980, 2000, and 2013 were used for the following countries: Burundi, Liberia, Central African Republic, Malawi, Congo, Dem. Rep., Madagascar, Niger, Ethiopia, Guinea, Nepal, Togo, Guinea-Bissau, Mozambique, Rwanda, Uganda, Mali, The Gambia, Zimbabwe, Tajikistan, Sierra Leone, Burkina Faso, Tanzania, Benin, Comoros, Kyrgyz Republic, Kenya, Yemen, Bangladesh, Chad, Ghana, Lao PDR, Pakistan, Senegal, Mauritania, Uzbekistan, Sudan, Lesotho, Cameroon, Zambia, Cote d'Ivoire, Vietnam, Nigeria, Kiribati, Papua New Guinea, Solomon Islands, Moldova, India, Djibouti, Bolivia, Guyana, Nicaragua, Arab Rep. Egypt, Honduras, Philippines, Mongolia, Indonesia, Bhutan, Rep. Congo, Sri Lanka, Paraguay, Vanuatu, Ukraine, Georgia, Armenia, Guatemala, Fed. Sts. Micronesia, Swaziland, Morocco, Tonga, Angola, Iraq, Samoa, Cabo Verde, Jordan, Islamic Rep. Iran, El Salvador, Azerbaijan, Algeria, Thailand, Turkmenistan, China, Ecuador, Fiji, Macedonia, Albania, Belize, Tunisia, Peru, Namibia, Colombia, Suriname, Bulgaria, Dominican Republic, Belarus, Cuba, Kazakhstan, St. Vincent and the Grenadines, St. Lucia, Brazil, Costa Rica, Romania, South Africa, Grenada, Venezuela, Mauritius, Russian Federation, Botswana, Malaysia, Gabon, Lebanon, Uruguay, Argentina, Panama, Mexico, Turkey, Chile, Poland, Antigua and Barbuda, Oman, Equatorial Guinea, Barbados, Trinidad and Tobago, Czech Republic, Saudi Arabia, Malta, Bahrain, Portugal, Greece, Puerto Rico, The Bahamas, Cyprus, Rep.Korea, Israel, Brunei Darussalam, Spain, United Arab Emirates, Italy, New Zealand, Hong Kong SAR, France, Australia, Japan, Belgium, Canada, Finland, Germany, United Kingdom, Austria, Netherlands, Sweden, United States, Denmark, Ireland, Macao SAR, Switzerland, Iceland, Norway.

To construct the graph in Figure 2, the raw fertility rates and annual averages of real consumption per capita (constant 2005 US$) over 1990-2013 were used for the following countries: Hong Kong SAR China, Greece, The Bahamas, Ireland, Australia Italy, Canada, Germany, Belgium, Japan, France, Austria, Finland, Denmark, Iceland.

To construct the graph in Figure 3, the raw fertility rates and annual averages of GDP per capita (in constant 2005 US$) over 1990-2013 for the following countries were used: The Bahamas, Ireland, Australia, Italy, Brunei Darussalam, Canada, France, Belgium, Germany, United Kingdom, Finland, Austria, Netherlands, Japan, Sweden, United States, Denmark, Iceland, Norway, United Arab Emirates, Switzerland.

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