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# Delay in Childbearing and the Evolution of Fertility Rates

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# Delay in Childbearing and the Evolution of Fertility Rates*

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**Abstract**
We present a growth model whose novelty is to explicitly account for the direct, preference-related factors that reinforce the delay in the timing of childbearing. Given the strength of these factors, the model generates the empirically observed dynamics in completed cohort fertility. Furthermore, the quantitative analysis of our results verifies that our model provides a good fit for actual data of the rebound of the completed cohort fertility rates in Nordic countries. The fact that these countries are widely considered as the most progressive ones, in terms of their cultural norms and in terms of their family-oriented policies, offers credence to the hypothesis that our model advances. More generally, our framework provides a platform for research that can uncover empirically relevant, but yet unexplored, mechanisms in the joint analysis of demographic change and economic growth.

*Keywords:* Economic Growth; Human Capital; Fertility; Timing of Childbearing; Culture; Behavioural Change.

*JEL Classification:* J13; O41

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# 1 Introduction

During the last four decades, researchers have observed an increase of the mean age at birth in developed economies (e.g., Frejka and Sardon, 2006; see also Figure 1).[1] Despite the plethora of studies that incorporate endogenous fertility in models of economic growth (e.g., Galor and Weil, 2000; Blackburn and Cipriani, 2002; de la Croix and Doepke, 2009; Vogl, 2016; Strulik, 2017; Futagami and Konishi, 2019 ), only a limited number have explicitly considered issues pertaining to the timing of childbearing (Iyigun, 2000; Momota and Horii, 2013; d'Albis *et al.,* 2018). In this study, we also take explicit account of the timing of childbearing in order to enrich our understanding of the factors that cause its delay. We show that, by accounting for factors that have so far eluded the attention of the aforementioned literature, we can uncover empirically observed patterns in the dynamics of cohort fertility rates, both analytically and quantitatively. In this respect, our framework can facilitate a more accurate design of policies aimed at the economic impact of demographic change (e.g., population ageing).

Since the latter parts of the 20th century, some developed countries witnessed a moderate, but also persistent, increase in their Total Fertility Rate (TFR) – known as the 'fertility rebound' (Luci-Greulich and Thévenon, 2014).[2] For some researchers, this marked the end of low fertility rates (e.g., Goldstein *et al.,* 2009) – an outcome with significant socio-economic implications, since it occurred in countries with below-replacement fertility rates. Although the TFR increase has been modest, the cumulative impact could have significant repercussions, by alleviating the strain that population ageing imposes, and will continue to impose, in social security systems and in national healthcare services. Nevertheless, in light of the delay in childbearing, and given the methodology used to measure the TFR, one could argue that the observed reversal in fertility trends may, on the outset, reflect a mere *tempo* adjustment: The initial stages of childbearing postponement cause a notable drop in the TFR measurement, but as higher birth rates eventually materialise at older reproductive ages, the TFR adjusts upwards.

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[1] Data are extracted from the Human Fertility Database (www.humanfertility.org).

[2] The TFR is defined as "*the mean number of children a woman would have by age 50 if she survived to age 50 and was subject, throughout her life, to the age-specific fertility rates observed in a given year.*" This definition reveals the TFR is, by construction, a hypothetical measure: It assumes that current age-specific fertility rates will prevail in the future.

**Figure 1.** *Increasing mean age at birth in recent decades*

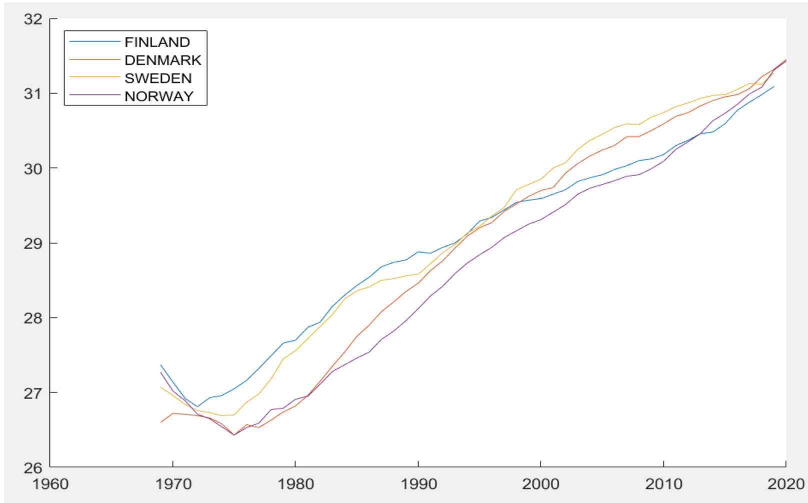


**Figure 1(a)**

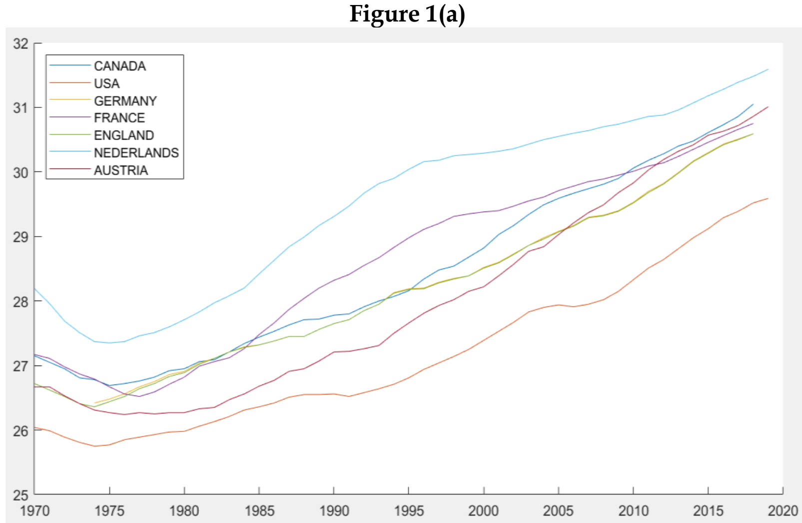


**Figure 1(b)**

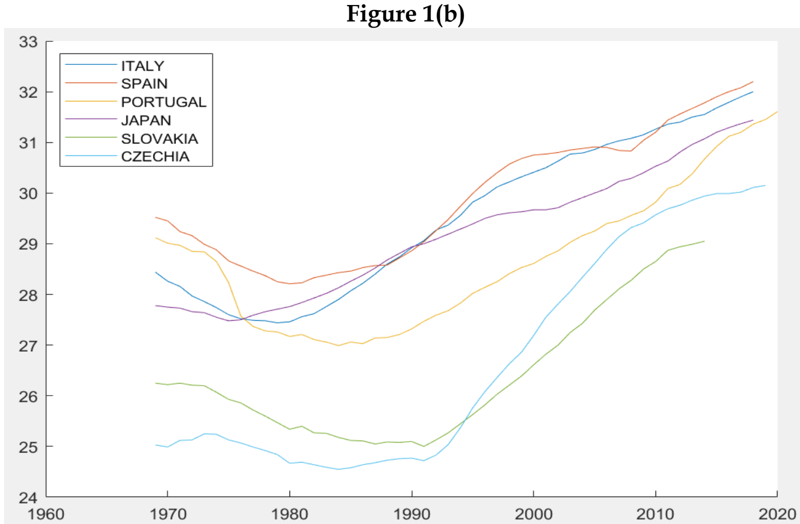


**Figure 1(c)**

Obviously, if the fertility rebound is just a figment of the TFR measurement in an environment of childbearing postponement, then any attempt to delve deeper into its underlying characteristics and its potential implications seems of rather limited interest – if any. Is it a mere statistical correction though? A look at Figure 2, which depicts data on Completed Cohort Fertility (CCF)[3] – a measure which, compared to TFR, reflects the intertemporal elements of fertility choice more accurately – reveals that this is not always the case. While Japan and South European countries have seen successive generations of birth cohorts bearing fewer children on average, other developed nations, e.g., United States, Canada, Nordic countries, and Northwestern European countries, have either already experienced increased fertility from several successive generations of birth cohorts, or seem to be entering a similar phase of demographic change. For these countries, the *tempo* effect of delayed childbearing seems to have coincided with an actual *quantum* effect of increased overall childbearing. Put differently, for some countries, and for a significant number of successive cohorts, the increase in the number of births at older reproductive ages was more pronounced than the decrease in the number of births at younger reproductive ages, thus leading to an actual increase in cohort fertility. This outcome has also been pointed out by Andersson *et al.* (2009) whose empirical analysis led them to the conclusion that "*fertility postponement does not always imply fewer children.*" (Andersson *et al.,* 2009; p.325).

Motivated by these facts, our study aims at presenting a model that is consistent with the aforementioned trends in the timing of childbearing and the dynamics of cohort fertility. It emphasises and formalises the idea that, for a reversal towards higher cohort fertility to emerge, factors that have a direct impact on childbearing preferences (e.g., cultural change, medical advances, family-related policies etc.) must complement economic factors (e.g., the return to education) – and be sufficiently strong as well – in contributing to the postponement of parenthood as the economy grows. When these

[3] The CCF is defined as "*the average number of children born alive to women born in the same year (i.e., a birth cohort) during their reproductive lives.*". In an OLG context, it is the average number of children born by agents (of the same age) over their lifetime, whereas the TFR equivalent is the sum of fertility rates of all generations alive in a given time period. Thus, CCF is a more accurate measure of intertemporal fertility choice, fertility dynamics and, therefore, it can facilitate the design of policies targeting at demographic change.

conditions do apply, then a rebound of cohort fertility is a genuine change in demographic trends, rather than a mere statistical correction.

**Figure 2.** *The evolution of Completed Cohort Fertility (CCF)*

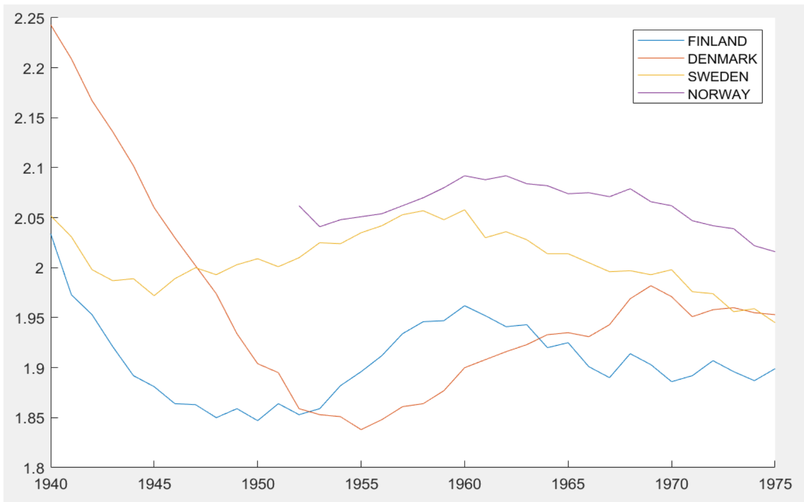


**Figure 2(a)**

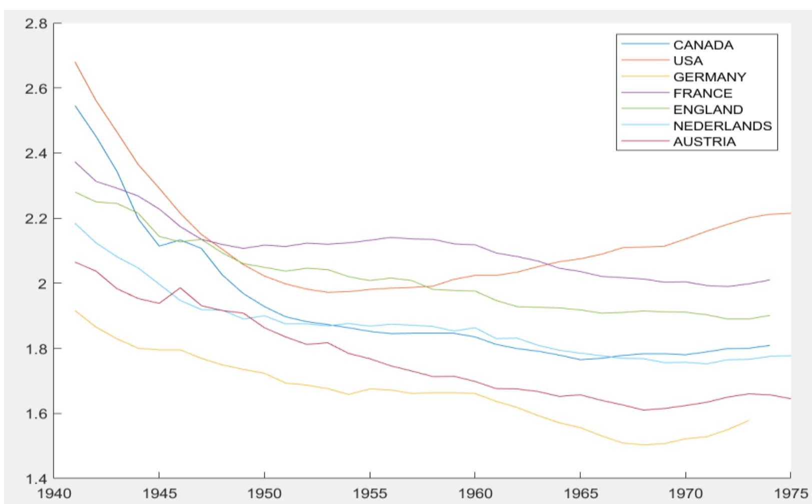


**Figure 2(b)**

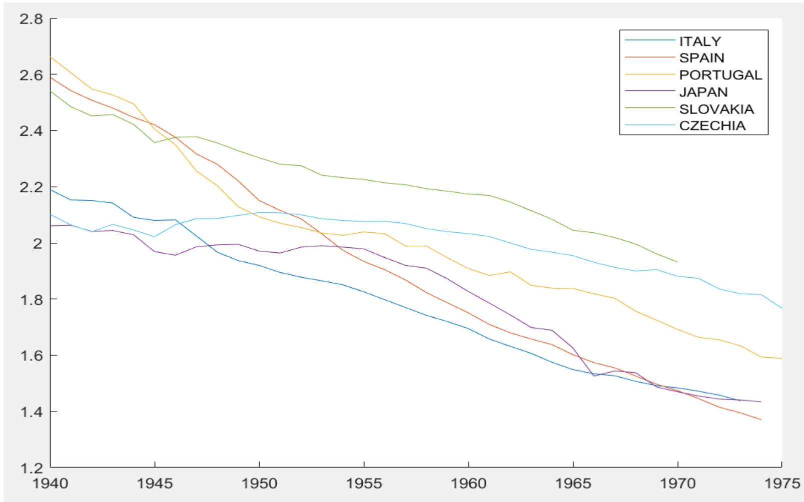


**Figure 2(c)**

| Country | Cultural Openness | Country | Cultural Openness | Country | Cultural Openness |
|---|---|---|---|---|---|
| Sweden | 3.10785912 | Canada | 2.03200793 | Italy | 0.815307 |
| Norway | 3.031380901 | USA | 1.508656324 | Spain | 1.437109 |
| Finland | 2.448326828 | Germany | 2.163378967 | Portugal | 0.357042 |
| Denmark | 2.876767368 | France | 1.906922128 | Japan | 1.292139 |
| | | England | 2.345753706 | Slovakia | 0.561574 |
| | | Netherlands | 2.498869582 | Czech Rep. | 0.974991 |
| | | Austria | 1.952027655 | | |
| **Average** | **2.866083554** | | **2.058230899** | | **0.90636** |

**Table 1** *Secular-rational vs traditional values (WVS)*

To motivate our approach even further, let us consider the 2020 Inglehart-Welzel World Cultural Map, which distinguishes groups of countries whose populations' cultural profiles are open to more progressive changes, from groups of countries whose populations' cultural profiles are more rigidly attached to traditional values.[4] Based on this, the 2020 Inglehart-Welzel index of secular-rational *vs* traditional values gives a numerical score, with higher values being indicative of a greater degree of cultural openness (as opposed to cultural rigidity). In Table 1 we report these scores for the groups of countries whose data we use in Figures 2(a)-2(c). Computing the average across each group, we observe that Nordic countries display a greater degree of cultural openness relative to the groups of countries whose demographic data are displayed in Figures 2(b) and 2(c). What is particularly interesting from the combined reading of

[4] See https://www.worldvaluessurvey.org/WVSEventsShow.jsp?ID=428

Figures 2(a)-2(c) and Table 1 is that the CCF rebound is more pronounced in countries with a high degree of cultural openness, whereas countries that are culturally rigid are the ones that see motononically declining CCFs rates.

So far, existing models have focused solely on the return to human capital investment as the factor that generates a postponement of childbearing (e.g., Iyigun, 2000; d'Albis *et al.,* 2018). This is an outcome that emerges in this study as well: We construct an overlapping generations model in which parents have two reproductive periods. In the first one, they face a trade-off between childrearing and human capital investment; in the second one, the trade-off is between childrearing and labour supply. We verify that the rise of the return to education motivates individuals to postpone parenthood for the latter stage of their reproductive age – an outcome that finds strong empirical support in the existing literature (e.g., Bloemen and Kalwij, 2001; McCrary and Royer, 2011).

Nonetheless, the existing evidence suggests that the return to education is not the only factor promoting the postponement of childbearing. On the contrary, there are several other factors that can have a more direct impact on the timing of childbearing. For example, cultural changes towards gender equality, female emancipation, the gradual decline of the importance of traditional family values and the corresponding gradual increase of the desire for individual autonomy, have also been shown to be major determinants of the postponement of parenthood (e.g., van de Kaa, 1987; Liefbroer, 2005; Bernhardt and Goldscheider, 2006; Mills *et al.,* 2011). This is aptly reflected in Beaujouan's (2020) argument that the *"rise in late childbearing across the low-fertility countries […] certainly reflects the diversity of childbearing norms and constraints across different countries."* (Beaujouan, 2020; p. 225). These changes in cultural values and social norms, which have raised the desirability and the acceptability of late childbearing, have been supported by medical advances that gave individuals more freedom and ability to choose this aspect of family planning – advances such as improved contraception methods (e.g., Goldin and Katz, 2002) and *in vitro* fertilisation (e.g., Tan *et al.,* 1992). It is also worth emphasising the example of Nordic countries, where the institutional and policy environments are considered models on how to sustain relatively high fertility rates in developed nations (Bernhardt, 1992). Some researchers have argued that these policies merely reflect and, at the same time, accommodate the progressive cultural environment of Nordic countries. Andersson (2008) could not be more explicit when he argues that *"family policy has never specifically targeted childbearing but has rather aimed at strengthening women's participation in the labour market and promoting gender and social equality […] Policies are explicitly focusing on individuals […] the goal is to enable women and men to raise the number of children they want to have."* (Andersson, 2008; p. 90).

Our model's novelty is to capture the aforementioned ideas by incorporating a direct, preference-related factor that reinforces agents' desire to delay some of their childbearing in the process of economic growth. We show that an intermediate stage of demographic change in a developed economy, where cohort fertility actually recuperates, emerges if and only if this preference-related factor contributes to the postponement of parenthood. This outcome is consistent with existing views and evidence that link the recuperation of fertility rates to culturally-induced changes that directly affect people's preferences (e.g., Arpino *et al.,* 2015; Esping-Andersen and Billari, 2015; Feichtinger *et al.,* 2017; Beaujouan, 2020). Nonetheless, the model also shows that the trend reversal from declining to increasing cohort fertility is followed by yet another reversal towards once more decreasing fertility rates. This latest phase of demographic change will eventually lead to a cohort fertility that is even lower compared to the one that marked the onset of the fertility rate's recuperation. This outcome has major policy implications: It implies that, even when the rebound the fertility is a true change in demographic trends, it is still a temporary one. The likelihood that cohort fertility will eventually drop below the one that marks the onset of the CCF rebound, means that governments should be less reluctant and more proactive in the design and implementation of policies that will address the adverse future socioeconomic implications of population ageing.

We also undertake a series of numerical examples to test our analytical results quantitatively, using data from countries whose cohort fertility dynamics display the different phases of demographic change that emerge in our model. This quantitative analysis shows that our model is a reasonably good fit for the actual data of completed cohort fertility in these countries.

In light of the fact that there are countries which, despite experiencing a shift in the timing of childbearing, have not undergone a rebound in cohort fertility rates, we should emphasise that our model is consistent with such outcomes. As we indicated previously, the preference-related factors that reinforce the delay in childbearing must be sufficiently strong to generate a rebound of cohort fertility; if the impact of these factors is not strong enough, cohort fertility declines monotonically. If anything, the fact that the rebound in completed cohort fertility is observed in countries that are widely considered as the most progressive ones, in terms of their cultural norms and in terms of their family-oriented policies, offers even more credence to the ideas and mechanisms that we advance through our model. This is perhaps a testament to the fact that the explicit consideration of the direct, preference-related factors relevant to the timing of childbearing, opens an avenue for further research. This research can uncover several relevant, but yet unexplored mechanisms, in the joint dynamics of demographic change and economic growth. Indeed, the reduced-form manner through which we incorporate the preference characteristics that underlie the timing of childbearing, opens up a wide array of possibilities for future research and policy implications.

Given that the results of our model are inexorably linked to the so-called fertility rebound in developed economies, this study is also related to research work that has uncovered this phase of demographic change in models of economic growth. In Futagami and Konishi (2019), a fertility rebound emerges because of the rising longevity induced by R&D-driven technological progress, whereas Ohinata and Varvarigos (2020) attribute the fertility rebound to differences in the human capital elasticities of childrearing costs and output. However, none of these studies consider issues pertaining to the timing of childbearing, which is actually the key underlying mechanism of this study.[5] Furthermore, the fertility rebound in these models is the final phase of a three-stage process of demographic change, i.e., they do not uncover a reversal back to declining fertility rates. However, a look at the completed cohort fertility of Nordic countries (see Figure 2a) is indicative of yet another reversal towards declining fertility rates – a reversal that it is likely to occur gradually in other developed nations.

[5] It is worth mentioning that another phase of increasing fertility in the developed world occurred with the post-World War II "baby boom". The underlying reasons behind the baby boom (e.g., Greenwood *et al.*, 2005; Doepke *et al.*, 2015) are not linked to a shift in the timing of childbearing and, therefore, not related to the recent fertility rebound.

The remaining analysis is organised as follows. In Section 2, we present the model's set-up and derive the optimal choices regarding fertility and human capital investment. Section 3 is devoted to the dynamics of cohort fertility. Section 4 presents the quantitative investigation and implications of our analytical results. In Section 5, we conclude.

# 2 The Economy

Time is discrete and indexed by $t$. The economy is populated by a mass of overlapping generations of agents who have a lifespan of four periods. The first period of an agent's lifetime is childhood – a period during which each agent is largely inactive. The remaining three periods represent collectively an agent's adulthood and are divided into early youth (indexed by $EY$), late youth (indexed by $LY$) and maturity (indexed by $M$). The biological disposition of the population renders early youth and late youth as the only reproductive periods. The cost structure of childrearing is simple. In particular, we assume that each child requires a rearing cost that accounts for a fraction $\theta \in (0,1)$ of her parent's available time.

Although there is heterogeneity across the total population of agents who are alive in any given period – emanating from the overlapping generations structure – the agents who belong in a specific age group, and in a given period, are identical. Consequently, we can focus on an agent as being the representative one. With this in mind, consider an agent who is born in period $t-1$. Next period, she is endowed with a unit of time and decides how to allocate it between childrearing and a learning activity that supports the accumulation of human capital – an activity for which she dedicates $i_t$ units of time.[6] Therefore, an agent who decides to raise $n_{t,EY}$ children in her early youth, must abide by

[6] We choose the approach of considering childrearing costs that are measured in terms of parental time, rather than being pecuniary. The reason is twofold. First, we want our framework to be methodologically closer to the majority of studies on demographic change and economic growth (e.g., Galor and Weil, 1996, 2000; de la Croix and Doepke, 2009) and, especially, those studies that explicitly consider the timing of childrearing (e.g., Iyigun, 2000; d'Albis *et al.*, 2018), most of which focus on the time cost of rearing children. Second, another justification (also pointed out by the aforementioned literature) is that childrearing time is not pecuniary neutral; it implies a monetary, opportunity cost in terms of foregone labour income – either

$$1 = \theta n_{t,EY} + i_t \,. \tag{1}$$

Let us use $\bar{h}_t$ to denote the average stock of human capital. Learning activities can contribute to further improvements in knowledge and skills, i.e., the elements that constitute the human capital that will be available during an agent's late youth. Specifically, we assume that each agent's human capital evolves according to

$$h_{t+1} = \eta\left[X\left(\bar{h}_t\right) + i_t \bar{h}_t\right], \quad \eta > 0\,, \tag{2}$$

where $X\left(\bar{h}_t\right) \in [0,1)$ is a continuous function that satisfies $X' > 0$ and $X'' < 0$. Defining

$$x\left(\bar{h}_t\right) = \frac{X\left(\bar{h}_t\right)}{\bar{h}_t}\,, \tag{3}$$

it is also assumed that $x' < 0$. According to the second term in (2), the existing average stock of human capital complements an agent's effort towards improvements in her knowledge and skills (e.g., through formal education; see Glomm and Ravikumar, 1992). At the same time, however, the first term in (2) points out an externality that also allows individuals to pick up some of the existing knowledge effortlessly (e.g., through direct observation or interactions with others).[7]

During their late youth, agents are also endowed with a unit of time. They decide how much to consume and how to allocate their available time between childrearing and labour. The latter is supplied to perfectly competitive firms which produce units of the economy's consumption good by utilising effective labour under a linear production technology. By 'effective' labour, it is meant that, in order to determine labour services, each worker's time is augmented by her stock of human capital. The linear production technology implies that the wage per unit of effective labour is constant over time. Therefore, we save on notation by normalising the constant wage rate to 1.

Upon reaching their maturity, agents will not receive any time endowment. Nevertheless, they will still have consumption needs to satisfy. For this reason, they have access to a storage technology through which units of output stored during an

directly or because of the lower parental human capital. It should also be noted that there is empirical evidence showing that, nowadays, parents spend more time with their children, than they did in previous decades (see Gauthier *et al.*, 2006 for a review) and that childrearing time involves significant opportunity costs as it affects a host of other activities (e.g., Apps and Rees, 2002).

[7] For empirical support on this learning-by-doing mechanism, and the importance of human capital for the diffusion of learning externalities, see Jarosch *et al.* (2021) and Makris and Pavan (2021).

agent's late youth will deliver, on a one-to-one basis, units of output during an agent's maturity. Given the above, the budget constraints faced by each agent during late youth and maturity are given by

$$c_{t+1,LY} = (1-\theta n_{t+1,LY})h_{t+1} - s_{t+1}, \tag{4}$$

and

$$c_{t+2,M} = s_{t+1}, \tag{5}$$

where $c_{t+1,LY}$ denotes consumption during late youth, $c_{t+2,M}$ denotes consumption during maturity, $s_{t+1}$ is the amount of income stored during late youth, and $n_{t+1,LY}$ is the total number of children reared by an agent in late youth.

It should be noted that, given the age and demographic structures of the model, the completed cohort fertility of agents who are born in $t-1$ and, therefore, enter adulthood in $t$, is

$$N_t = n_{t,EY} + n_{t+1,LY}. \tag{6}$$

Indeed, the expression in (6) captures closely the definition of cohort fertility as it measures the number of all children reared by agents, who were born in the same period, during their reproductive lives. This is somehow different to the total fertility rate, for which the corresponding formula would be $n_{t,EY} + n_{t,LY}$, thus measuring fertility as if the period-$t$ age-specific fertility rates apply to those who begin their reproductive lives in period $t$. As we shall see shortly, this is not the case in an environment of childbearing postponement; that is why the focus of our analysis is the cohort fertility rate that is presented in (6).

The lifetime utility of an agent who begins adulthood in period $t$ is given by

$$V_t = \ln(c_{t+1,LY}) + \beta\ln(c_{t+2,M}) + \delta\ln(\nu_t), \tag{7}$$

where $\beta \in (0,1)$ and $\delta > 0$. The term $\ln(\nu_t)$ captures the utility that agents enjoy by the children they rear over their lifetime. In this context however, the felicity that agents enjoy from parenthood depends on other factors as well, in addition to the number of children they bear. Formally, we assume that $\nu_t$ is determined by

$$\nu_t = A_t n_{t,EY} + A_{t+1} n_{t+1,LY}, \tag{8}$$

where $A_\tau$ ($\tau = t, t+1, ...$) is the variable that measures other factors that affect the utility that parents enjoy from bearing and rearing children, thus measuring it in effective terms. In the absence of these factors (i.e., when $A_{t+1} = A_t = 1$) the utility enjoyed from childrearing would be captured by the term $\ln(n_{t,EY} + n_{t+1,LY})$ which is exactly the formulation most commonly used in the literature (see Iyigun, 2000). In this respect, our study enriches existing studies through the adoption of the additional preference-related factors that weigh the utility enjoyed from childbearing in different periods of an agent's reproductive age. Later, when we present the agents' optimal choices, we will delve into a more detailed discussion on the interpretation of the variables $A_t$ and $A_{t+1}$, the ideas that justify their presence, as well as their role in agents' decision making.

## 2.1 Equilibrium Analysis

Individuals make their choices so as to maximise their lifetime utility in (7), subject to the constraints in Eq. (1), (2), (4), (5) and (8). We follow several other studies of growth and demographic change (e.g., Galor and Weil, 2000; de la Croix and Doepke, 2009; Strulik, 2017; Iyigun, 2000; d'Albis *et al.*, 2018) in treating fertility as continuous variable. Put differently, agents in these types of models choose their fertility rates. In order to solve this problem, we can substitute these constraints in (7) and maximise with respect to $n_{t,EY}$, $n_{t+1,LY}$ and $s_{t+1}$. When maximising their lifetime utility, agents take $\bar{h}_t$, $A_t$ and $A_{t+1}$ as given. The respective first order conditions are given by

$$\frac{(1-\theta n_{t+1,LY})\theta\eta\bar{h}_t}{(1-\theta n_{t+1,LY})\eta\left[X\left(\bar{h}_t\right)+(1-\theta n_{t,EY})\bar{h}_t\right]-s_{t+1}} \geq \frac{\delta A_t}{A_t n_{t,EY} + A_{t+1}n_{t+1,LY}}, \quad n_{t,EY} \geq 0, \tag{9}$$

$$\frac{\theta\eta\left[X\left(\bar{h}_t\right)+(1-\theta n_{t,EY})\bar{h}_t\right]}{(1-\theta n_{t+1,LY})\eta\left[X\left(\bar{h}_t\right)+(1-\theta n_{t,EY})\bar{h}_t\right]-s_{t+1}} \geq \frac{\delta A_{t+1}}{A_t n_{t,EY} + A_{t+1}n_{t+1,LY}}, \quad n_{t+1,LY} \geq 0, \tag{10}$$

and

$$\frac{1}{(1-\theta n_{t+1,LY})\eta\left[X\left(\bar{h}_t\right)+(1-\theta n_{t,EY})\bar{h}_t\right]-s_{t+1}} \geq \frac{\beta}{s_{t+1}}, \quad s_{t+1} \geq 0. \tag{11}$$

The expressions in (9)-(11) offer familiar conditions, according to which the marginal benefit from each activity must be equal to the corresponding marginal cost – both expressed in terms of utility. Given that agents within an age cohort are identical, the condition $\bar{h}_t = h_t$ holds in equilibrium. Henceforth, this condition is going to be applied to all the subsequent derivations and results.

We can express (11) as an equality in order to derive the optimal amount of storage that ultimately determines consumption in the final period of an agent's lifetime. That is,

$$s_{t+1} = \frac{\beta}{1+\beta}(1-\theta n_{t+1,LY})\eta\left[X(h_t)+(1-\theta n_{t,EY})h_t\right] = \frac{\beta}{1+\beta}(1-\theta n_{t+1,LY})h_{t+1}. \tag{12}$$

According to Eq. (12), agents will store a fixed fraction of disposable labour income in order to finance consumption in the final period of their lifetime. Intuitively, this fraction is increasing in the utility weight of consumption during maturity. We can substitute this result in (9) and solve for $n_{t,EY}$. Eventually, we get

$$\theta n_{t,EY} \geq \frac{\delta[1+x(h_t)]}{1+\beta+\delta} - \frac{1+\beta}{1+\beta+\delta}\frac{A_{t+1}}{A_t}\theta n_{t+1,LY}. \tag{13}$$

The next step is to substitute (12) in (10) and solve for $n_{t+1,LY}$ to derive

$$\theta n_{t+1,LY} \geq \frac{\delta}{1+\beta+\delta} - \frac{1+\beta}{1+\beta+\delta}\frac{A_t}{A_{t+1}}\theta n_{t,EY}. \tag{14}$$

As we can see, the agent's fertility choices depend, among other factors, on the ratio $\frac{A_{t+1}}{A_t}$, which is the relative utility weighting of childrearing in the two reproductive periods. Specifically, the results in (13)-(14) reveal that an increase of this ratio shifts childrearing from early to late youth. This is an intuitive outcome of course: When preferences shift in this manner, the agent find optimal to rebalance her choices in favour of the reproductive period in which childrearing becomes more desirable, in relative terms. Naturally, an important issue involves the underlying reasons for the shift in $\frac{A_{t+1}}{A_t}$. Our study considers a scenario whereby the shift of the agents' preferences, in a manner that increases the appeal of childbearing during the latter stages of their reproductive age, occurs as a consequence of changes that follow the process of economic development.

There is a broad set of empirically-relevant arguments to interpret and justify this scenario. Some of them are cultural in nature: They involve a shift away from traditional values and norms, which prioritise family and children as key aspirations, and towards an environment that fosters gender equality and attitudes of individual autonomy, personal development and self-fulfilment among younger generations, together with the understanding that parenthood requires a certain level of emotional maturity (Liefbroer, 2005; Mills *et al.,* 2011). The impact of these cultural factors in shifting the desired age of childbearing, is reinforced by medical advances such as improved means of contraception and fertility treatments that have gradually improved the likelihood of successful conception by women who are at a later stage of their reproductive age (Tan *et al.,* 1992); also by a shift in the policy agenda that is meant to accommodate the change in the prevailing cultural environment (Andersson, 2008). Since all these factors gradually materialise as economies reach higher stages of economic development, henceforth we will assume that the relative utility weighting of childrearing in late *vs* early youth is increasing in $h_t$. Formally,

$$\frac{A_{t+1}}{A_t} = \gamma(h_t)\,, \tag{15}$$

such that $\gamma' > 0$.

For presentation purposes, in what follows we define the composite parameter term

$$\psi \equiv 1 + \frac{\delta}{1+\beta}\,, \tag{16}$$

In Appendix A.1, we provide a detailed analysis show that, when expressed as equalities, the solution of the system in (13)-(14) leads to

$$n_{t,EY} = \begin{cases} \dfrac{(\psi-1)[1+x(h_t)]}{\theta\psi} & \text{if} \quad n_{t,EY} > 0, n_{t+1,LY} = 0 \\ \dfrac{\psi[1+x(h_t)] - \gamma(h_t)}{\theta(\psi+1)} & \text{if} \quad n_{t,EY} > 0, n_{t+1,LY} > 0 \end{cases}, \tag{17}$$

and

$$n_{t+1,LY} = \begin{cases} \dfrac{\psi-1}{\theta\psi} & \text{if} \quad n_{t,EY} = 0, n_{t+1,LY} > 0 \\ \dfrac{\psi - \dfrac{1+x(h_t)}{\gamma(h_t)}}{\theta(\psi+1)} & \text{if} \quad n_{t,EY} > 0, n_{t+1,LY} > 0 \end{cases}. \tag{18}$$

To facilitate the model's tractability and analytical solutions, as well as the calibration and numerical analysis at a later part of, henceforth we will adopt specific functional forms for $X(h_t)$ and $\gamma(h_t)$. These are

$$X(h_t) = \frac{\xi h_t}{1+h_t}, \quad 0 < \xi < 1, \tag{19}$$

and

$$\gamma(h_t) = \frac{\underline{g} + \overline{g} h_t}{1+h_t}, \quad \overline{g} > \underline{g} \geq 0. \tag{20}$$

Notice that the case where $\underline{g} = \overline{g} = 1$ reduces the model to a baseline scenario where $\frac{A_{t+1}}{A_t}$ does not change with the stock of human capital, i.e., $\gamma' = 0$. Instead, the formulation in (20) is one whereby, in relative terms, childbearing preferences shift towards agents' latter reproductive periods, i.e., $\gamma' > 0$.

Given the above, we also define the composite terms

$$h^* \equiv \frac{1+\xi - \underline{g}\psi}{\overline{g}\psi - 1}, \tag{21}$$

$$h^{**} \equiv \frac{(1+\xi)\psi - \underline{g}}{\overline{g} - \psi}, \tag{22}$$

and impose the following parametric restrictions:

**Assumption 1.** $\xi < \min\{(\psi-1)^{-1}, \psi - 1\}$.

**Assumption 2.** $\underline{g}\psi < 1+\xi$.

**Assumption 3.** $\overline{g} > \psi$.

**Assumption 4.** $\eta > \frac{\psi(\overline{g} - \underline{g}) + \xi}{\overline{g}(1+\xi) - \underline{g}}$.

The role of Assumption 1 is twofold: First, it is necessary to ensure that the optimal choice for $n_{t,EY}$ is always below the upper bound $\frac{1}{\theta}$ – a case in which agents would devote their whole time in early youth purely for childrearing purposes. In addition to its rather limited interest, such a case would be at odds with reality. Second, when combined with Assumption 4, it is sufficient to ensure that the economy always grows at positive rate, thus transitioning through distinct stages of economic development. Assumptions 2 and 3 jointly ensure that (21) and (22) define these stages of economic development at which distinct shifts in fertility choices, and their timing, occur. As we shall see shortly, the transition through these demographic regimes is consistent with demographic changes for which we presented supporting data and evidence in the Introduction.

We can now use (3), (19) and (20) to rewrite the expressions in (17) and (18) as follows:

$$n_{t,EY} = n_{EY}(h_t) = \begin{cases} \dfrac{\psi-1}{\theta\psi}\left(1+\dfrac{\xi}{1+h_t}\right) & \text{if} \quad n_{t,EY}>0, n_{t+1,LY}=0 \\ \dfrac{1}{\theta(\psi+1)}\left[\psi\left(1+\dfrac{\xi}{1+h_t}\right)-\dfrac{\underline{g}+\overline{g}h_t}{1+h_t}\right] & \text{if} \quad n_{t,EY}>0, n_{t+1,LY}>0 \end{cases}, \tag{23}$$

$$n_{t+1,LY} = n_{LY}(h_t) = \begin{cases} \dfrac{\psi-1}{\theta\psi} & \text{if} \quad n_{t,EY}=0, n_{t+1,LY}>0 \\ \dfrac{1}{\theta(\psi+1)}\left(\psi-\dfrac{1+\xi+h_t}{\underline{g}+\overline{g}h_t}\right) & \text{if} \quad n_{t,EY}>0, n_{t+1,LY}>0 \end{cases}, \tag{24}$$

The expressions in (23) and (24) allow us to derive

**Lemma 1.** *Under Assumptions 2 and 3, it is* $h^{**} > h^{*}$. *Furthermore*

$$if \ \ h_t \begin{cases} \le h^{*} & then \quad n_{t,EY}>0, n_{t+1,LY}=0 \\ \in (h^{*}, h^{**}) & then \quad n_{t,EY}>0, n_{t+1,LY}>0 \\ \ge h^{**} & then \quad n_{t,EY}=0, n_{t+1,LY}>0 \end{cases}.$$

*Proof.* See Appendix A.2. □

This result reveals that, for some levels of human capital, the solutions for age-specific fertility may be at a corner. The intuition will be discussed at a later point. For now, we shall combine (1), (23) and Lemma 1 to derive the optimal amount of time that young agents devote towards human capital investment. This is equal to

$$i_t = i(h_t) = \begin{cases} \dfrac{1}{\psi}\left[1 - \dfrac{\xi(\psi-1)}{1+h_t}\right] & \text{if} \quad h_t \le h^* \\ \dfrac{1}{\psi+1}\left(1 + \dfrac{\underline{g} + \overline{g}h_t - \psi\xi}{1+h_t}\right) & \text{if} \quad h^* < h_t < h^{**} \\ 1 & \text{if} \quad h_t \ge h^{**} \end{cases} . \tag{25}$$

We illustrate (25) diagrammatically in Figure 3(a). In terms of human capital accumulation (which dictates the process of output growth in this model), we can substitute (3), (19) and (25) in (2) to derive

$$h_{t+1} = f(h_t) = \begin{cases} \dfrac{\eta h_t}{\psi}\left(1 + \dfrac{\xi}{1+h_t}\right) & \text{if} \quad h_t \le h^* \\ \dfrac{\eta h_t}{\psi+1}\left(1 + \dfrac{\xi + \underline{g} + \overline{g}h_t}{1+h_t}\right) & \text{if} \quad h^* < h_t < h^{**} \\ \eta h_t\left(1 + \dfrac{\xi}{1+h_t}\right) & \text{if} \quad h_t \ge h^{**} \end{cases} . \tag{26}$$

Given the expression in (26), human capital and, therefore, the economy's output evolve according to the result in

**Lemma 2.** *Under Assumption 4, the economy sustains positive growth along all the stages of the transition and in the long-run. That is,* $h_{t+1} > h_t \ \forall t$.

*Proof.* See Appendix A.3. □

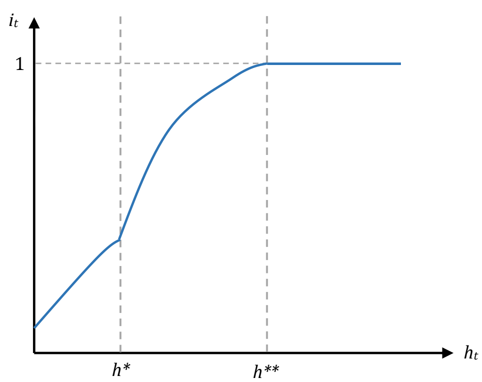


**Figure 3(a)**

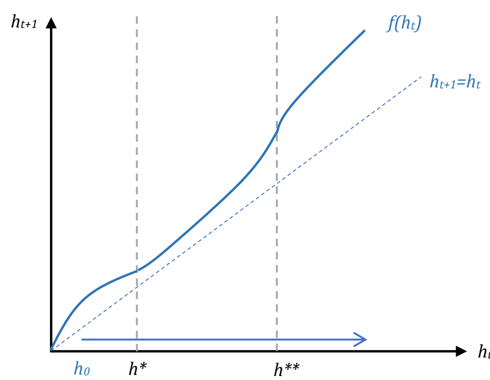


**Figure 2(b)**

The expression in (26) also reveals that $\lim_{h_t \to +\infty} f(h_t) = +\infty$ applies to each distinct branch of human capital formation. Together with Lemma 2, these imply that, as long as $h_0 < h^*$ – a condition that is assumed to hold thereafter – the economy will experience a transition through all the phases that are associated with the threshold levels in (21) and (22) – see Figure 3(b). One objective of this study is to examine the agent's education and fertility decisions during these different stages of the growth process. This is an analysis that we will undertake in the following section. Before we do this however, we should briefly mention the outcomes that transpire when Assumption 4 is violated.

If $\eta$ is not as high as Assumption 4 requires, then the complementarity between the stock of human capital and education investment can generate path-dependent outcomes. Specifically, whether the economy will achieve a high income/long-run growth equilibrium, or it will converge to a poverty trap of permanently low income, will depend on whether the initial condition $h_0$ is above or below an unstable steady state, acting as an endogenous threshold.[8] Under such circumstances, the results and implications of this study will apply only to economies for which $h_0$ is above the threshold, as long as they can sustain positive growth in the long-run. The reason we rule out this scenario in our model is mainly because our focus and objective are quite different. We do not aim at presenting a framework of 'club' convergence through which one can investigate persistent differences in per capita income among countries, and how these may explain observed cross-country differences in demographic characteristics. Although these issues are indubitably important, they go beyond our objective. Instead, our focus is to analyse and get a better understanding of the gradual transition between different phases of demographic change, experienced by currently

[8] In fact, there are subcases of possible equilibrium outcomes when Assumption 4 is violated. When $\eta > 1$, an unstable steady state $h^{threshold}$ separates an equilibrium of positive, sustained growth from an equilibrium in which human capital converges to a stable stationary point, which is either equal to zero if $1 < \eta < \frac{\psi}{1+\xi}$ or positive if $\eta > \frac{\psi}{1+\xi}$. When $\eta < 1$, then the economy will be unable to sustain positive growth: In this case, the unstable steady state $h^{threshold}$ separates two stationary, stable steady state solutions – one which is equal to zero and one which is positive.

developed countries. These are countries whose growth rates have been, on average, positive over a quite protracted period of time; therefore, frameworks of multiple, path-dependent equilibria are not necessarily be the most relevant ones for our analysis.

### 2.2 Human Capital, Investment in Education, and the Timing of Childbearing

Consider the solutions in (23)-(25). From these solutions, we can derive the result in

**Lemma 3.** *The agent's optimal decisions satisfy* $n'_{EY}(h_t) \leq 0$, $n'_{LY}(h_t) \geq 0$ *and* $i'(h_t) \geq 0$.

*Proof.* See Appendix A.4. □

Based on this, we can now uncover a mechanism that is important for the model's results. It comes in the form of

**Proposition 1.** *As the economy grows, individuals increase their investments in education and shift some of their childbearing towards the latter phase of their reproductive age.*

*Proof.* It follows from Lemmas 1-3. □

Consider an economy where human capital is below $h^*$. At this point, the non-economic factors that directly affect the utility from parenthood have not evolved sufficiently enough to motivate agents to postpone parenthood. This is because the marginal gain in utility from doing so falls short of the marginal utility loss of foregone labour income and, therefore, reduced consumption expenditures. Under such circumstances, agents in their early youth effectively face a trade-off between childrearing and investing in education. In order to understand how economic growth affects this trade-off, recall that the stock of human capital has two conflicting effects on the incentive to invest in education. On the one hand, it is a substitute for such investment through the impact of the direct externality (i.e., the term $X(h_t)$ in Eq. 2); on the other hand, it increases the marginal return of this investment. The latter effect is in fact dominant, therefore agents increase their education investment at the expense of fertility (a key mechanism behind the so-called demographic transition).

The increased investment in human capital fosters economic growth and, therefore, the economy will at some point exceed the threshold level $h^{*}$. In this phase, the factors that are captured by the evolution of $A_t$, become relevant in the sense that the effective benefit of postponing childbearing is high enough to induce agents to have children in their late youth. This supresses the utility gain of having children in the earlier reproductive period, hence agents smooth their overall childbearing profile by reducing even further the number of children they rear in their early youth. Consequently, they have more time available to invest in their education – an outcome that supports human capital accumulation and growth. As the economy grows even further, the process whereby agents postpone parenthood continues.

The process of economic growth will eventually allow the economy to exceed the threshold level $h^{**}$. When this happens, the combined effects of the return to education investment and of the preference factors determining the desirability of childrearing at different phases of the reproductive age, motivate agents to commit fully to education during their early youth and to rear children during their late youth. Since there is no trade-off involved in this choice, the fertility rate settles down and remains constant as the economy continues to grow.

Before we proceed to the next section, we should clarify the issue of causality in our model's outcomes. From the previous results and discussion, it should be clear that, in terms of what causes demographic change, it is the stock of human capital $h_t$ that induces changes in fertility choice. The variable $h_t$ is, after all, predetermined at the time the young agent in period-$t$ makes her choices. That is not to say that demographic parameters do not have an impact on economic outcomes. Fertility and education investment are jointly determined; therefore, demographic characteristics will have an impact on next period's human capital stock and the economy's growth performance. Indeed, the expression in (26) reveals that human capital formation is affected by $\delta$ (through the composite term $\psi$), i.e., the parameter that quantifies an agent's utility from childrearing: Clearly, a higher $\delta$ (implying a higher $\psi$) impedes the rate of human capital formation as it induces agents to allocate more time to childrearing and less time to education. As we argued previously, our model focuses on parametric values which ensure that human capital formation sustains positive growth throughout.

# 3 The Dynamics of Cohort Fertility

The previous section analysed the factors that explain the shift of the timing of childbearing in a growing economy. In this part, we will examine the dynamics of the cohort's fertility rate, i.e., of the total number of children that an agent gives birth to during her lifetime, as expressed in (6).

Combining (6), (23), (24) and the result in Lemma 1, it follows that the cohort fertility, for those who begin their reproductive age in $t$, is

$$N_t = N(h_t) = \begin{cases} \dfrac{\psi-1}{\theta\psi}\left(1+\dfrac{\xi}{1+h_t}\right) & \text{if} \quad h_t \le h^* \\ \dfrac{1}{\theta(1+\psi)}\left(2\psi+\dfrac{\psi\xi-\underline{g}-\overline{g}h_t}{1+h_t}-\dfrac{1+\xi+h_t}{\underline{g}+\overline{g}h_t}\right) & \text{if} \quad h^* < h_t < h^{**} \\ \dfrac{\psi-1}{\theta\psi} & \text{if} \quad h_t \ge h^{**} \end{cases}. \tag{27}$$

Now, let us define the composite term

$$\hat{h} \equiv \frac{\sqrt{\overline{g}\xi+\overline{g}-\underline{g}}-\underline{g}\sqrt{\psi\xi+\overline{g}-\underline{g}}}{\overline{g}\sqrt{\psi\xi+\overline{g}-\underline{g}}-\sqrt{\overline{g}\xi+\overline{g}-\underline{g}}}. \tag{28}$$

It follows that the impact of human capital on the cohort fertility $N(h_t)$ can be summarised in

**Lemma 4.** *It is $h^* < \hat{h} < h^{**}$ and, therefore,*

$$N'(h_t)\begin{cases} <0 & \text{if} \quad h_t < h^* \\ >0 & \text{if} \quad h^* < h_t < \hat{h} \\ <0 & \text{if} \quad \hat{h} < h_t < h^{**} \\ =0 & \text{if} \quad h_t > h^{**} \end{cases}$$

*Proof.* See Appendix A.5. □

Recall that the initial condition satisfies $h_0 < h^*$. With this in mind, we can now characterise the dynamics of cohort fertility. This is done through

**Proposition 2.** *As the economy grows, cohort fertility initially declines. Then, the economy enters a phase of fertility rebound in which cohort fertility increases. Subsequently, cohort fertility declines again until it eventually settles down in the long-run.*

*Proof.* It follows from Lemma 1 and Lemma 4. □

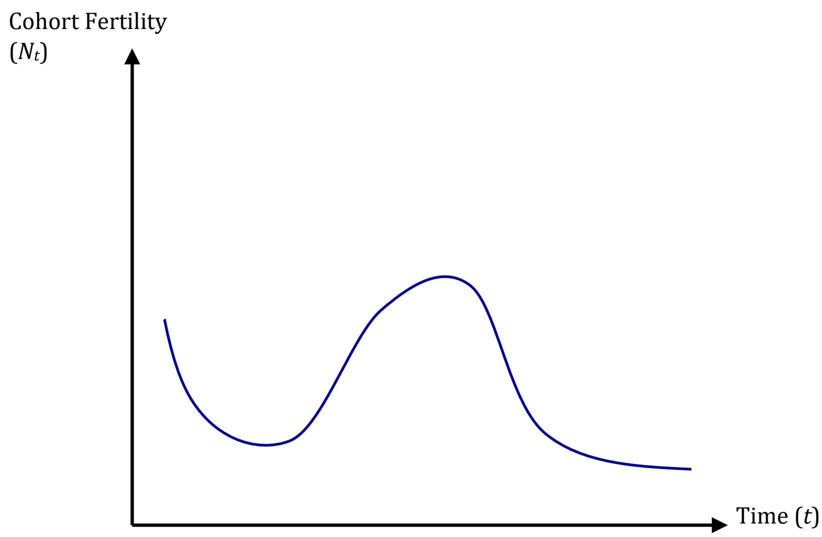


**Figure 4.** *The dynamics of cohort fertility*

As we can see from Proposition 2, the dynamics of cohort fertility are traced along four distinct phases (see also Figure 4).[9] During the first phase, agents rear

[9] Notice that the set of Assumptions 1-4 that we presented earlier, are consistent with $\xi = 0$. This does not mean that the presence of the parameter $\xi$ is inessential. On the contrary, this parameter ensures that, at the earlier stages of the economy's growth process, there is a phase of cohort fertility decline (see Eq. 27 and Lemma 4 for $h_t < h^*$). In its absence, substitution and income effects would be of equal magnitude, thus rendering the early youth's optimal time allocation between childrearing and education investment independent of the stock of human capital. The presence of $\xi$ allows the substitution effect of a higher human capital stock, emanating from an increase in the return to education, to dominate and induce a shift from childrearing to education as the economy grows in the 1st phase of our model's dynamics. This phase

children only during their early youth. Consequently, the only mechanisms at work are the change in the return to human capital investment and its impact on the trade-off between education and fertility – a trade-off which, as we have already established, works in favour of the former. As the economy enters the second phase, however, economic growth leads to a postponement of parenthood. When this happens, childbearing in late youth is initially more responsive to those preference factors that foster the postponement of childbearing. As a result, there is a recuperation stage during which cohort fertility increases. Nevertheless, the economy eventually enters a later stage where the decline in early youth's childbearing becomes more pronounced, as agents reap the benefits of accumulating human capital by deciding to postpone parenthood even further. Consequently, cohort fertility declines until the fourth phase in which the shift in the timing of childbearing is complete. During this phase, cohort fertility settles down to a stationary level as the economy grows even further.

Taking account of the above, another implication for the dynamics of fertility comes in the form of

**Corollary 1.** *The fertility rebound is a temporary phenomenon. It is followed by another change in trend where cohort fertility will once again decline as the economy grows.*

*Proof.* It follows from Lemma 4 and the preceding analysis. □

### 3.1 What Contributes to the Recuperation of Cohort Fertility?

The previous analysis and discussion have revealed that, broadly speaking, the phase of fertility rebound is attributed to the shift in the timing of childbearing from the early to the late reproductive age. However, the same shift can occur purely as a result of the impact of human capital on the return to education. In other words, the presence of other factors that directly affect the utility from rearing children – such as the ones captured by the evolution of the variable $A_t$ in this model – seem redundant. We will use this section to show that this conjecture is actually a false one.

Let us reconsider the problem after eliminating the impact of the factors associated with the evolution of the variable $A_t$. We can do this by simply setting

of cohort fertility decline is consistent with real world data, and it is the phase from which fertility may actually rebound.

$\underline{g} = \overline{g} = 1$ in (20), meaning that $A_{t+1} = A_t \; \forall t$ throughout. Given this, we can combine (13) and (14) to obtain the solutions for fertility as follows:

$$n_{t,EY} = n_{EY}(h_t) = \frac{1}{\theta(1+\psi)}\left[\psi\left(1+\frac{\xi}{1+h_t}\right)-1\right], \tag{29}$$

$$n_{t+1,LY} = n_{LY}(h_t) = \frac{1}{\theta(1+\psi)}\left(\psi-1-\frac{\xi}{1+h_t}\right). \tag{30}$$

From these expressions, it is straightforward to verify that $n'_{EY}(h_t) < 0$ and $n'_{LY}(h_t) > 0$. In other words, a shift in the timing of childbearing still occurs as the economy grows, even in the absence of the preference factors that affect an agent's utility from bearing children during the different phases of her reproductive age. In terms of intuition, the increase in the return to education motivates agents to postpone parenthood, thus devoting more resources in the accumulation of human capital during their early youth.

Now, let us consider the evolution of cohort fertility. Combining (6), (29) and (30), it follows that

$$N_t = N(h_t) = \frac{(\psi-1)}{\theta(1+\psi)}\left(2+\frac{\xi}{1+h_t}\right), \tag{31}$$

from which it can be easily verified that $N'(h_t) < 0$: Despite the change in the age-pattern of childbearing, a fertility rebound never occurs.

Note that 'shutting down' the direct, preference-related factors for the delay in childbearing is not necessary for the rebound in cohort fertility to disappear as a distinct demographic change. This is possible, even in the presence of these factors, as long as their impact is not sufficiently strong. To see this, suppose that we relax Assumption 3. In this case, Lemma 4 does not apply because $\hat{h} < h^*$, meaning that $N'(h_t) \le 0 \;\; \forall h_t$. In other words, even though the shift in childbearing preferences contributes to the delay in the timing of childbirth, this impact is not pronounced enough to reverse the decline in cohort fertility rates.

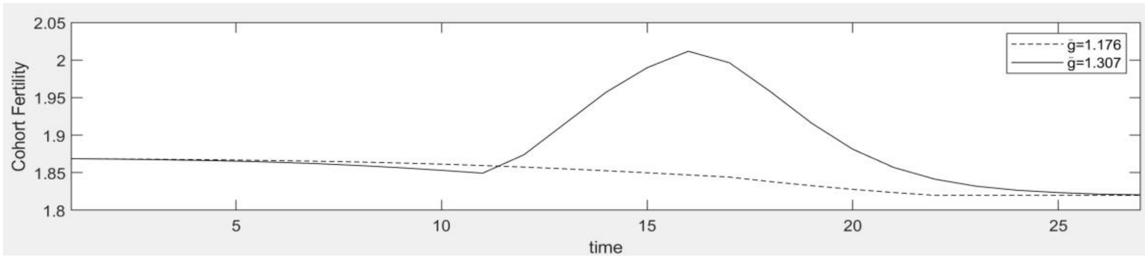


**Figure 5.** *Cultural openness and cohort fertility dynamics*

To visualise these differences, Figure 5 presents the dynamics of cohort fertility under two different scenarios regarding the preference parameter $\overline{g}$, higher values of which capture a greater responsiveness to the factors – among them, several cultural ones – that promote the postponement of childbearing. Given the values of all other parameters, these two scenarios differ in that $\overline{g} = 1.176$ violates Assumption 3 whereas $\overline{g} = 1.307$ is consistent with it.[10] In other words, the former scenario captures a culturally rigid environment, whereas the latter scenario captures a culturally open one. The dynamics in Figure 5 clearly indicate that the rebound of cohort fertility emerges in the economy where agents' preferences are more responsive to changes that induce a delay in childbearing, in contrast to the economy where agents' preferences are not as responsive and in which cohort fertility declines monotonically. These outcomes are consistent with the descriptive data presented in the Introduction: We observed that a rebound of cohort fertility is evident in the group of countries where cultural openness scores are, on average, higher (see Figures 2a-2b, and the left and middle columns of Table 1), whereas a monotonic decline of fertility rates is present in countries whose cultural openness scores are, on average, lower (see Figure 2c and the right column of Table 2). These implications are formalised in[11]

[10] For the remaining parameters, we use values that we adopt later in the numerical examples of Section 4.

[11] The reason why we associate the parameter $\overline{g}$ with cultural openness is because, given (20), $\frac{\partial(A_{t+1} / A_t)}{\partial h_t \partial \overline{g}} > 0$. Put differently, agents with a higher $\overline{g}$ are more receptive to development-induced cultural changes that affect fertility choice; hence, they are more responsive, behaviourally, in favouring a delay in childbearing as a result of these changes. This approach to cultural openness is, in fact, consistent with the 2020 Inglehart-Welzel distinction of countries according to the cultural values of their populations – secular (progressive) *vs*. traditional (rigid) – as we argued in the Introduction.

**Corollary 2.** *A rebound of cohort fertility does not emerge when the shift in the timing of childbearing is solely attributed to economic factors, such as the return to education. A fertility rebound can only occur if the process of economic growth prompts a pronounced change in preferences which, in turn, intensifies the postponement of parenthood.*

*Proof.* It follows from Lemma 4, Proposition 2 and the preceding analysis. □

The shift in the timing of childbearing that stems solely from the change in the return to education, does not generate a sufficiently strong response to alter the dynamics of cohort fertility, even after accounting for the postponement of parenthood. However, the evolution of $A_t$ along the process of economic growth, intensifies the shift in the age profile of childbearing; therefore, it may generate dynamic patterns consistent with a (temporary) recuperation of cohort fertility. This outcome may explain why the recuperation of cohort fertility is an outcome that has, so far, been observed in a subset of developed countries, and at different levels of intensity and duration among them.

### 3.2 Fertility Rebound and the 'Lowest-Low' Fertility

Among the various points of discussion that surround the recent demographic trends in several developed economies, some researchers have pointed out the possibility that the fertility rebound has marked the end of what is termed as the 'lowest-low' fertility (Kohler *et al.,* 2002). This is the view according to which, prior to the fertility rebound, some developed economies witnessed what are most likely to be their lowest observed rates of fertility (Goldstein *et al.,* 2009).

What is the current model's implication and prediction on the issue? We formalise this through

**Proposition 3.** *The lowest cohort fertility of the economy is not the one that materialises prior to the fertility rebound. It is the one to which the economy will converge in the long-run, i.e., after the phase of fertility rebound.*

*Proof.* Consider the expression in (27) and Lemma 4. Given these, the lowest total fertility rate prior to the fertility rebound is $\frac{\psi-1}{\theta\psi}\left(1+\frac{\xi}{1+h^{*}}\right)$. This is in fact higher compared to $\frac{\psi-1}{\theta\psi}$ which is the total fertility rate to which the economy will converge after $h_t$ exceeds $h^{**}$. □

Evidently, the model's results do not concur with the idea that developed economies have already witnessed what will prove to be their lowest rates of fertility. To understand why this happens, recall that, prior to the phase of fertility rebound, agent's decisions entail a trade-off between education investment and childrearing during the same period, i.e., in early youth. The direct externality in the human capital technology (quantified by the parameter $\xi$) fosters fertility in that period because it acts as a substitute to investment in education – an effect that does not appear after the fertility rebound and the shift in the timing of childbearing, simply because there is no trade-off between education investment in early youth and childbearing in late youth. It is exactly for this reason that cohort fertility will eventually fall below the one that marked the onset of the fertility rebound in this model.

# 4 Calibration and Numerical Examples

In this section we undertake a quantitative analysis of our model's results. Specifically, we replicate data from countries whose cohort fertility dynamics are consistent the patterns generated by our model, i.e., the Nordic countries in Figure 2(a).[12]

It should be noted that this section mainly serves as the platform to offer a visualisation of our analytical results, in light of the empirically-observed, non-monotone evolution of cohort fertility rates. Still, however, the parametric version of our theoretical model has the ability to generate series with a reasonable fit to the actual data. Naturally, the set-up of our model is flexible enough to admit more structure and

[12] As we have already shown in Figure 5, appropriate parametric values can allow our model to also capture the monotonically declining CCF of other countries (i.e., the countries in Figures 2b-2c).

more general functional forms, thus potentially allowing a more comprehensive quantitative analysis.

We investigate the quantitative performance of our model aiming at (i) helping the reader visualise our analytical results, and (ii) showing that a parametric version of our theoretical model can reasonably replicate the empirical data. To this end, we provide numerical examples by calibrating our model to Finland and Sweden where the non-monotone dynamics are more pronounced as we can see in Figure 2(a). For our calibration strategy, we set parameter values to produce an initial level of Completed Cohort Fertility (CCF) which is close to the average CCF of the first phase of fertility decline in the empirical datasets for each country. We also produce a steady state level of CCF close to what we observe in the data. Finally, we try to generate a speed of converge – from the initial to the steady state cohort fertility – such that the time series we produce from our model is comparable to what we observe in the data. All parameter values satisfy our model's assumptions and conditions.

### 4.1 Example 1: The Evolution of CCF in Finland

Our first numerical example is provided by calibrating our model to Finland. Following what is now standard in the literature, we set $\beta = 0.5$ (e.g., de la Croix and Doepke, 2003). Given the methodological approach we described above, we set $\xi = 0.0273$, $\delta = 0.46$ and the initial stock of human capital equal to $h_0 = 0.1$ for our model to match the average CCF of Finland's 1945-1950 birth cohorts, i.e., 1.86. We also set $\eta = 1.813$, $\underline{g} = 0.007$ and $\overline{g} = 1.3068$ so that the model's speed of convergence towards the steady state closely follows the fertility dynamics we observe in the data. Finally, we set $\theta = 0.129$ to calibrate the model's steady state as close as possible to Finland's CCF for the 1975 birth cohort.

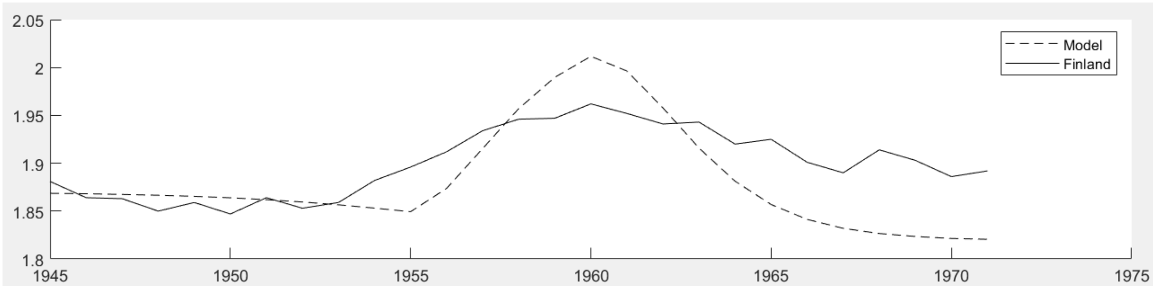


**Figure 6.** *Cohort fertility dynamics in Finland and in the model*

Figure 6 illustrates the cohort fertility dynamics of our model relative to the real data from Finland. As we can see, our model's analytical results (see Proposition 2) can qualitatively replicate the empirical data. In the initial phase, there is a drop of CCF. Subsequently, we observe a phase of fertility rebound as the CCF increases. In the next phase, we observe yet another trend reversal towards declining CCF – again, consistent with our analytical results. Quantitively, it works well in the first phase and slightly overestimates the maximum cohort fertility rate in the second phase (by roughly 0.1 units). It converges to a steady state value which is slightly lower compared to Finland's CCF of the 1975 birth cohort. It should be noted, however, that this outcome could imply that Finland has not yet converged to its CCF steady state. This is a reasonable assumption to make, given the latest phase of CCF decline we observe in Nordic countries (see Figure 2a).

### 4.2 Example 2: The Evolution of CCF in Sweden

The second example calibrates our model to Sweden. We retain the value for $\beta$ and set $\xi = 0.014$, $\delta = 0.305$ and the initial stock of human capital $h_0 = 0.07$ for our model to match Sweden's average CCF in the first phase of fertility decline (i.e., for the 1941-1948 birth cohorts; that is, 1.998). We also set $\theta = 0.0856$, $\eta = 1.5316$, $\underline{g} = 0.007$, and $\overline{g} = 1.2035$, for the same reasons as explained above.

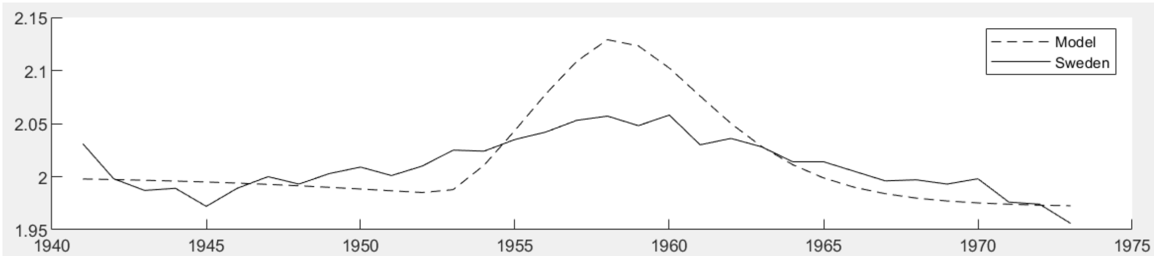


**Figure 7.** *Cohort fertility dynamics in Sweden and in the model*

Figure 7 reveals that our model's analytical results can account qualitatively for the three phases in the evolution of CCF in Sweden. The cohort fertility rate initially falls, then it rebounds for some periods and, subsequently, it falls again towards its steady state level. In the case of Sweden, the quantitative performance of the model is, on average, close to the data during the first phase, while it once more slightly overestimates the CCF peak during the fertility rebound – by roughly 0.1 units. The model performs quite well in the third phase, in the sense that it replicates Sweden's decline of the CCF below the level that marked the onset of the fertility rebound.

# 5 Conclusions

The purpose of this study was to offer a theoretical backdrop behind the changes in demographic trends that several developed countries have witnessed in recent years. We constructed a growth model where both economic-related and preference-related factors contribute to the postponement of parenthood. The model was able to reproduce, both analytically and quantitatively, the cohort fertility dynamics of these countries. A phase of fertility rebound emerges because the preference-related factors cause a significant boost to a cohort's 'late' fertility, increasing it at a rate which is higher compared to the decrease of the same cohort's 'early' fertility. This situation is only temporary though. Eventually, the decrease of 'early' fertility will dominate, hence cohort fertility will once more decline over time, gradually settling to a fertility rate which is even lower compared to the one that marked the onset of the fertility rebound.

This study's prediction concerning the prospects of fertility rates, for countries that have gone through the process of fertility rebound, has major policy implications.

After all, the fertility rebound was seen as a process with the potential to converge towards replacement levels, thus facilitating countries in alleviating the adverse socioeconomic consequences of population ageing. Given the likelihood that this is not going to happen solely through the working of forces such as economic, cultural and medical ones, and the equally likely outcome that cohort fertility will fall at levels below the ones observed at the beginning of the fertility rebound, there is major scope for governments to design and adopt policies that will aim at addressing the future socioeconomic repercussions of ever lower rates of fertility.

In addition to the previously mentioned results, our study offers wider implications of a methodological nature. It showed that a model can account for empirically relevant, yet previously unexplored, patterns in the evolution of fertility rates, once we consider explicitly the preference related factors behind the delay in childbearing. In this respect, our model opens up a wide avenue for future research that will attempt a more explicit structure of these factors, thus uncovering further unexplored issues on the relation between growth and demographic change.

We constructed our model with the objective of delivering analytically tractable results, thus being able to precisely identify the conditions that are important for generating the empirically observed rebound of cohort fertility. As always, analytical tractability necessitates the adoption of some simplifying assumptions. For example, our model focused on human capital-based arguments, thus missing the potential role of physical capital and of the interest rate on parental saving. In the context of endogenous timing of childbirth, these issues have been addressed by Momota and Horri (2013) who found the possibility of endogenous cycles in the economy’s dynamics. What their explicit consideration of physical capital, and its impact on saving rates, did not generate was the rebound in fertility rates. This is perhaps an indication that, although indubitably important in general, the roles of physical capital and of interest rates on saving are not critical for the demographic aspects that our study sought to explain. Another example of a simplifying assumption is the presence of scale effects in the time cost of childrearing, i.e., the idea that the time cost per child is decreasing in the number of children raised. Although this assumption will have most likely caused a higher equilibrium fertility rate throughout an agent’s reproductive age (i.e., in both early and late youth), there is nothing inherent in this assumption to suggest that it would have altered the main message of our study, which is the rebound of cohort fertility in an environment of delay in the timing of childbearing. If it did, then it would have led to results that are at odds with the actual data; after all, the delay in childbearing and the fertility rebound are outcomes that we observe empirically. In any case, our model provides a flexible enough platform for future research to investigate and uncover the implications of these extensions.

# Appendix

### A.1 Derivation of (17) and (18)

Substitute (15) in (13)-(14) to get

$$\theta n_{t,EY} \geq \frac{\delta[1+x(h_t)]}{1+\beta+\delta} - \frac{(1+\beta)\gamma(h_t)}{1+\beta+\delta}\theta n_{t+1,LY}, \tag{A1}$$

$$\theta n_{t+1,LY} \geq \frac{\delta}{1+\beta+\delta} - \frac{1+\beta}{(1+\beta+\delta)\gamma(h_t)}\theta n_{t,EY}. \tag{A2}$$

By virtue of (16), we have $\frac{\delta}{1+\beta+\delta} = \frac{\psi-1}{\psi}$ and $\frac{1+\beta}{1+\beta+\delta} = \frac{1}{\psi}$. Substituting these in (A1) and (A2) yields

$$\theta n_{t,EY} \geq \frac{(\psi-1)[1+x(h_t)]}{\psi} - \frac{\gamma(h_t)}{\psi}\theta n_{t+1,LY}, \tag{A3}$$

$$\theta n_{t+1,LY} \geq \frac{\psi-1}{\psi} - \frac{1}{\gamma(h_t)\psi}\theta n_{t,EY}. \tag{A4}$$

Now, consider the expressions in (A3) and (A4) as equalities. From these, we can see the corresponding solutions in (17) and (18), by setting $n_{t+1,LY}=0$ in (A3) and $n_{t,EY}=0$ in (A4) respectively. To see the solutions under $n_{t,EY}, n_{t+1,LY}>0$, once more consider these expressions as equalities, substitute (A4) in (A3) and solve for $n_{t,EY}$. That is

$$\theta n_{t,EY} = \frac{(\psi-1)[1+x(h_t)]}{\psi} - \frac{\gamma(h_t)}{\psi}\left[\frac{\psi-1}{\psi} - \frac{1}{\gamma(h_t)\psi}\theta n_{t,EY}\right] \Rightarrow$$

$$\theta n_{t,EY} = \frac{(\psi-1)[1+x(h_t)]}{\psi} - \frac{(\psi-1)\gamma(h_t)}{\psi^2} + \frac{\theta n_{t,EY}}{\psi^2}\theta n_{t,EY} \Rightarrow$$

$$\theta n_{t,EY}\left(\frac{\psi^2-1}{\psi^2}\right)=\frac{(\psi-1)\{\psi[1+x(h_t)]-\gamma(h_t)\}}{\psi^2}\Rightarrow$$

$$n_{t,EY}=\frac{\psi[1+x(h_t)]-\gamma(h_t)}{\theta(\psi+1)},$$

which is the corresponding solution in (17). Finally, substitute this solution in (A4) and solve for $n_{t+1,LY}$. It follows that

$$\theta n_{t+1,LY}=\frac{\psi-1}{\psi}-\frac{\psi[1+x(h_t)]-\gamma(h_t)}{\gamma(h_t)\psi(\psi+1)}\Rightarrow$$

$$\theta n_{t+1,LY}=\frac{\gamma(h_t)(\psi+1)(\psi-1)-\psi[1+x(h_t)]+\gamma(h_t)}{\gamma(h_t)\psi(\psi+1)}\Rightarrow$$

$$\theta n_{t+1,LY}=\frac{\gamma(h_t)\left[\psi^2-1-\psi\dfrac{1+x(h_t)}{\gamma(h_t)}+1\right]}{\gamma(h_t)\psi(\psi+1)}\Rightarrow$$

$$n_{t+1,LY}=\frac{\psi-\dfrac{1+x(h_t)}{\gamma(h_t)}}{\theta(\psi+1)},$$

which is the corresponding solution in (18). □

### A.2 Proof of Lemma 1

From (21)-(22), $h^{**}>h^{*}$ requires that the following holds:

$$\frac{(1+\xi)\psi-\underline{g}}{\overline{g}-\psi}>\frac{1+\xi-\underline{g}\psi}{\overline{g}\psi-1}$$

Given Assumptions 2-3, this can be rewritten as

$$(1+\xi)\psi(\overline{g}\psi-1)-\underline{g}(\overline{g}\psi-1)>(1+\xi)(\overline{g}-\psi)-\underline{g}\psi(\overline{g}-\psi)\Rightarrow$$

$$(1+\xi)[\psi(\overline{g}\psi-1+1)-\overline{g}]>\underline{g}(\overline{g}\psi-1-\overline{g}\psi+\psi^2)\Rightarrow$$

$$(1+\xi)\overline{g}(\psi^2-1)>\underline{g}(\psi^2-1),$$

which holds by virtue of $\psi>1$ and $\overline{g}>\underline{g}$. Next, note that from the expression in (24), and as long as $n_{t,EY}>0$, the requirement for $n_{t+1,LY}>0$ is

$$\psi>\frac{1+\xi+h_t}{\underline{g}+\overline{g}h_t}\Rightarrow$$

$$h_t > \frac{1+\xi-\underline{g}\psi}{\overline{g}\psi-1} \equiv h^*,$$

meaning that the non-negativity constraint on fertility implies that $n_{t+1,LY} > 0 \quad \forall h_t \leq h^*$. Similarly, given (23), and as long as $n_{t+1,LY} > 0$, the requirement for $n_{t,EY} > 0$ is

$$\psi\left(1+\frac{\xi}{1+h_t}\right) > \frac{\underline{g}+\overline{g}h_t}{1+h_t} \Rightarrow$$

$$h_t < \frac{(1+\xi)\psi-\underline{g}}{\overline{g}-\psi} \equiv h^{**},$$

meaning that the non-negativity constraint on fertility implies that $n_{t,EY} > 0 \quad \forall h_t \geq h^{**}$. Together with $h^{**} > h^*$, these complete the proof of Lemma 1. □

### A.3 Proof of Lemma 2

Given (26), when $h_t \leq h^*$ we have $\frac{h_{t+1}}{h_t} = \frac{\eta}{\psi}\left(1+\frac{\xi}{1+h_t}\right)$. For positive growth, it is sufficient to show that $\frac{\eta}{\psi}\left(1+\frac{\xi}{1+h^*}\right) > 1$. Substituting (21), this condition can be rewritten as

$$\frac{\eta[\overline{g}(1+\xi)-\underline{g}]}{\psi(\overline{g}-\underline{g})+\xi} > 1, \tag{A5}$$

which holds by virtue of Assumption 4. Now consider $h_t \in (h^*, h^{**})$. Given (26) we have

$$\frac{h_{t+1}}{h_t} = \frac{\eta}{1+\psi}\left(1+\frac{\xi+\underline{g}+\overline{g}h_t}{1+h_t}\right). \tag{A6}$$

The RHS of the expression in (A6) is increasing in $h_t$, because (from Assumptions 1 and 3) it is true that $\overline{g}-\underline{g} > \psi - 1 = \frac{\delta}{1+\beta} > \xi$. Therefore, the growth rate will be positive as long as the RHS is greater than 1 when $h_t = h^*$. Substituting in (21) in (A6) yields $\frac{\eta[\overline{g}(1+\xi)-\underline{g}]}{\psi(\overline{g}-\underline{g})+\xi}$, which is indeed greater than 1 by virtue of Assumption 4. It follows that $h_{t+1} > h_t \quad \forall h_t \in (h^*, h^{**})$. Finally, note that for the expression $\frac{\psi(\overline{g}-\underline{g})+\xi}{\overline{g}(1+\xi)-\underline{g}}$ to be greater than 1, it must be $(\psi-1)(\overline{g}-\underline{g}) > \xi(\overline{g}-1)$. This is indeed the case by virtue of

Assumption 1 and $\underline{g} < 1$. It follows that Assumption 4 implies $\eta > \frac{\psi(\bar{g} - \underline{g}) + \xi}{\bar{g}(1+\xi) - \underline{g}} > 1$; thus, for $h_t > h^{**}$, the expression in (26) reveals that $\frac{h_{t+1}}{h_t} = \eta\left(1 + \frac{\xi}{1+h_t}\right) > 1$, as $\lim_{h_t \to +\infty} \eta\left(1 + \frac{\xi}{1+h_t}\right) = \eta > 1$ □

### A.4 Proof of Lemma 3

From Lemma 1, we know that $n_{t,EY} = 0$ when $h_t \geq h^{**}$, whereas, for $h_t < h^{**}$, straightforward differentiation of (23) can reveal that $n'_{EY}(h_t) < 0$ irrespective of whether $n_{t+1,LY} = 0$ or $n_{t+1,LY} > 0$. Similarly, Lemma 1 reveals that $n_{t+1,LY} = 0$ when $h_t \leq h^*$, whereas, for $h_t > h^*$, we can differentiate the expression in (24) to show that $n'_{LY}(h_t) = 0$ if $n_{t,EY} = 0$ and $n'_{LY}(h_t) > 0$ if $n_{t,EY} = 0$. Finally, we can use (25) and differentiate to show that $i'(h_t) > 0$ if $h_t < h^{**}$ and $i'(h_t) = 0$ if $h_t \geq h^{**}$. □

### A.5 Proof of Lemma 4

Consider the expression in (27). It is straightforward to establish that $N'(h_t) < 0$ if $h_t \leq h^*$ and $N'(h_t) = 0$ if $h_t \geq h^{**}$. Now, let us calculate the derivative for this expression when $h^* < h_t < h^{**}$. That is

$$N'(h_t) = \frac{1}{\theta(1+\psi)}\left[-\frac{\psi\xi + \bar{g} - \underline{g}}{(1+h_t)^2} + \frac{\bar{g}\xi + \bar{g} - \underline{g}}{(\underline{g} + \bar{g}h_t)^2}\right]. \tag{A7}$$

The expression in (A7) is positive as long as

$$\frac{\bar{g}\xi + \bar{g} - \underline{g}}{(\underline{g} + \bar{g}h_t)^2} > \frac{\psi\xi + \bar{g} - \underline{g}}{(1+h_t)^2} \Rightarrow$$

$$\frac{1+h_t}{\underline{g} + \bar{g}h_t} > \sqrt{\frac{\psi\xi + \bar{g} - \underline{g}}{\bar{g}\xi + \bar{g} - \underline{g}}} \Rightarrow$$

$$h_t < \frac{\sqrt{\bar{g}\xi + \bar{g} - \underline{g}} - \underline{g}\sqrt{\psi\xi + \bar{g} - \underline{g}}}{\bar{g}\sqrt{\psi\xi + \bar{g} - \underline{g}} - \sqrt{\bar{g}\xi + \bar{g} - \underline{g}}} \equiv \hat{h}. \tag{A8}$$

To complete the proof, we have to establish that $h^* < \hat{h} < h^{**}$. To do this, we rewrite (28) and (A8) as $\hat{h} \equiv \frac{p-\underline{g}}{\overline{g}-p}$ where $p \equiv \sqrt{\frac{\overline{g}\xi + \overline{g} - \underline{g}}{\psi\xi + \overline{g} - \underline{g}}} > 1$. Taking account of (22), $\hat{h} < h^{**}$ requires

$$\frac{p-\underline{g}}{\overline{g}-p} < \frac{(1+\xi)\psi - \underline{g}}{\overline{g}-\psi} \Rightarrow$$

$$p < \psi \frac{\overline{g}\xi + \overline{g} - \underline{g}}{\psi\xi + \overline{g} - \underline{g}} = \psi p^2 \Rightarrow$$

$$\psi p > 1,$$

which is indeed true. Taking account of (21), $\hat{h} > h^*$ requires

$$\frac{p-\underline{g}}{\overline{g}-p} > \frac{1+\xi-\underline{g}\psi}{\overline{g}\psi - 1} \Rightarrow$$

$$p > \frac{\overline{g}\xi + \overline{g} - \underline{g}}{\psi(\overline{g}-\underline{g}) + \xi}. \qquad \text{(A9)}$$

Since $p > 1$, it is sufficient to show that

$$\overline{g}\xi + \overline{g} - \underline{g} < \psi(\overline{g}-\underline{g}) + \xi \Rightarrow$$

$$\xi(\overline{g}-1) < (\psi - 1)(\overline{g}-\underline{g}), \qquad \text{(A10)}$$

for (A9) to hold. Recall, however, that in the proof of Lemma 2 we showed that the condition in (A10) does hold, thus completing the proof. □

# References


1. Andersson, G. 2008. “A review of policies and practices related to the 'highest-low' fertility of Sweden,” in *Vienna Yearbook of Population Research, Vol. 6: Can Policies Enhance Fertility in Europe?*, Austrian Academy of Sciences Press.
2. Andersson, G., Rønsen, M., Knudsen, L.B., Lappegård, T., Neyer, G.R., Skrede, K., Teschner, K., and Vikat, A. 2009. “Cohort fertility patterns in the Nordic countries,” *Demographic Research*, 2009, 20, 313-352.
3. Apps, P., and Rees, R. 2001. “Household production, full consumption and the costs of children,” *Labour Economics*, 8, 621-648.

4. Arpino, B., Esping-Andersen, C., and Pessin, L. 2015. "How do changes in gender role attitudes towards female employment influence fertility? A macro-level analysis," *European Sociological Review*, 31, 370-382.
5. Beaujouan, E. 2020. "Latest-late fertility? Decline and resurgence of late parenthood across the low-fertility countries," *Population and Development Review*, 46, 219-247.
6. Bernhardt, E. 1992. "Working parents in Sweden: An example for Europe?" in *Human Resources in Europe at the Dawn of the 21st Century: Conference Proceedings*, Eurostat/European Commission.
7. Bernhardt, E., and Goldscheider, F. 2006. "Gender equality, parenthood attitudes, and first births in Sweden," in *Vienna Yearbook of Population Research, Vol. 4: Postponement of Childbearing in Europe*, Austrian Academy of Sciences Press.
8. Blackburn, K., and Cipriani, G.P. 2002. "A model of longevity, fertility, and growth," *Journal of Economic Dynamics and Control*, 26, 187-204.
9. Bloemen, H., and Kalwij, A.S. 2001. "Female labor market transitions and the timing of births: A simultaneous analysis of the effects of schooling," *Labour Economics*, 8, 593-620.
10. d'Albis, H., Greulich, A., and Ponthiere, G.P. 2018. "Development, fertility and childbearing age: A unified growth theory," *Journal of Economic Theory*, 177, 461-494.
11. de la Croix, D., and Doepke, M. 2003. "Inequality and growth: Why differential fertility matters," *American Economic Review*, 93, 1091-1113.
12. de la Croix, D., and Doepke, M. 2009. "To segregate or to integrate: Educational policies and democracy," *Review of Economic Studies*, 76, 597-628.
13. Doepke, M., Hazan, M., and Maoz, Y. D. 2015. "The baby boom and World War II: A macroeconomic analysis," *Review of Economic Studies*, 82, 1031-1073.
14. Esping-Andersen, C., and Billari, F.C. 2015. "Re-theorizing family demographics," *Population and Development Review*, 41, 1-31.
15. Feichtinger, G., Prskawetz, A., Seidl, A., Simon, C., and Wrzaczek, S. "A bifurcation analysis of gender equality and fertility," *Journal of Evolutionary Economics*, 27, 1221-1243.
16. Frejka, T., and Sardon, J.-P. 2006. "First birth trends in developed countries: Persisting parenthood postponement," *Demographic Research*, 15, 147-180.

17. Futagami, K., and Konishi, K. 2019. "Rising longevity, fertility dynamics, and R&D-based growth," *Journal of Population Economics*, 32, 591-620.
18. Galor, O., and Weil, D. N. 1996. "The gender gap, fertility, and growth," *American Economic Review*, 86, 374-387.
19. Galor, O., and Weil, D.N. 2000. "Population, technology, and growth: From Malthusian stagnation to demographic transition and beyond," *American Economic Review*, 90, 806-828.
20. Gauthier, A. H., Smeeding, T. M., and Furstenberg Jr, F. F. 2004. "Are parents investing less time in children? Trends in selected industrialized countries," *Population and Development Review*, 30, 647-672.
21. Glomm, G., and Ravikumar, B. 1992. "Public versus private investment in human capital: Endogenous growth and income inequality," *Journal of Political Economy*, 100, 818-834.
22. Goldin, C., and Katz, L.F. 2002. "The power of the pill: Oral contraceptives and women's career and marriage decisions," *Journal of Political Economy*, 110, 730-770.
23. Goldstein, J.R., Sobotka, T., and Jasilioniere, A. 2009. "The end of "lowest-low" fertility?" *Population and Development Review*, 35, 663-699.
24. Greenwood, J., Seshadri, A., and Vandenbroucke, G. 2005. "The baby boom and baby bust," *American Economic Review*, 95, 183-207.
25. Iyigun, M.F. 2000. "Timing of childbearing and economic growth," *Journal of Development Economics*, 61, 255-269.
26. Jarosch, G., Oberfield, E., and Rossi-Hansberg, E. 2021. "Learning from coworkers," *Econometrica*, 89, 647-676.
27. Kohler, H.P., Billari, F.C., and Ortega, J.A. 2002. "The emergence of lowest-low fertility in Europe during the 1990s," *Population and Development Review*, 28, 641-680.
28. Liefbroer, A.C. 2005. "The impact of perceived costs and rewards of childbearing on entry into parenthood: Evidence from a panel study," *European Journal of Population*, 21, 367-391.
29. Luci-Greulich A., and Thévenon O. 2014. "Does economic advancement 'cause' a re-increase in fertility? An empirical analysis for OECD countries (1960–2007)," *European Journal of Population*, 30, 187-221.

30. Makris, M., and Pavan, A. 2021. "Taxation under learning by doing," *Journal of Political Economy*, 129, 1878-1944.
31. McCrary, J., and Royer, H. 2011. "The effect of female education on fertility and infant health: Evidence from school entry policies using exact date of birth," *American Economic Review*, 101, 158-195.
32. Mills, M., Rindfuss, R.R., McDonald, P., and te Velde, E. 2011. "Why do people postpone parenthood? Reasons and social policy incentives," *Human Reproduction Update*, 17, 848-860.
33. Momota, A., and Horii, R. 2013. "Timing of childbirth, capital accumulation, and economic welfare," *Oxford Economic Papers*, 65, 494-522.
34. Ohinata, A., and Varvarigos, D. 2020. "Demographic transition and fertility rebound in economic development," *Scandinavian Journal of Economics*, 122, 1640-1670.
35. Strulik, H. 2017. "Contraception and development: A unified growth theory," *International Economic Review*, 58, 561-584.
36. Tan, S.L., Royston, P., Campbell, S., Jacobs, H.S., Betts, J., Mason, B., and Edwards, R.G. 1992. "Cumulative conception and live birth rates after in-vitro fertilisation," *The Lancet*, 339, 1390-1394.
37. van de Kaa, D.J. "Europe's second demographic transition," *Population Bulletin*, 42, 1-59.
38. Vogl, T.S. 2016. "Differential fertility, human capital, and development," *Review of Economic Studies*, 83, 365-401.

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