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Natacha Raffin

CEPS
Centre for Economics at Paris-Saclay

école normale supérieure paris-saclay
université evry val-d'essonne
université PARIS-SACLAY
université PARIS-SACLAY
Maison des Sciences de l'Homme PARIS-SACLAY

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Natacha Raffin*

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Abstract

The economic literature has extensively explored inter-linkages between population dynamics and changes in our environment over the past three decades. The aim of this study is to focus on the role of endogenous fertility behaviors as a key channel linking population growth, economic development and environmental dynamics. First, we review how economists have incorporated endogenous fertility decisions into growth models with environmental dynamics to assess the effects of population growth on the environment. Second, we present two different strands of the literature that investigate how environmental changes may directly affect population dynamics, specifically through i) its impact on households' reproductive health and ii) fertility choices of households, acting as an additional determinant beyond the usual ones.

JEL classification: J13, I10, 011, 013, Q56.

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1 Introduction

Population dynamics is a sensitive topic, and many of us–economists or not–hold opinions on the matter. From a macroeconomic perspective, fertility decisions are closely tied to family policies and broader societal concerns, such as the structure of pension systems and labor force availability. From a microeconomic viewpoint, fertility reflects individual or couple preferences regarding legacy and transmission. Similarly, environmental quality is both an immediate, daily concern–shaping production, consumption, and political choices– and a long-term challenge, as growing certainty about climate change raises fears about the sustainability of our standard of living. This literature review seeks to identify key channels that connect these two spheres of economic research. The papers discussed below provide analytic tools and methodologies that help us better understand the links between environmental change on the one hand and, population dynamics, on the other hand.

The economic literature has long examined the interplay between economic growth and environmental changes. While connections between population and environmental dynamics

*Corresponding author. CEPS (Centre for Economics at Paris-Saclay), ENS Paris-Saclay, Université Paris-Saclay, 91190, Gif-sur-Yvette, France. E-mail: natacha.raffin@ens-paris-saclay.fr

have occasionally been established and quantified, they are often framed through a scale effect, with the role of endogenous fertility choices largely overlooked. Notable examples include the IPAT equation (Ehrlich and Holdren, 1971) and the Environmental Kuznets Curve (initially introduced by Grossman and Krueger, 1995), both of which illustrate how economists have analyzed the impact of population size on the environment through its scale effect. According to the former, the growth process is intuitively embedded into an increasing *per capita* polluting consumption (A) on the one hand, or/and technological progress (T) – that reduces pollution–, on the other hand. Then, these two components combined with a possible scale effect (P) due to population size justify the observed environmental changes (I). In the same vein, in their article published in 1995, Grossman and Krueger (1995) aim at providing a robust empirical methodology to investigate the relationship between the scale of one economy, the economic activity and urban air pollution or water contamination, including, among controls variables, population density. They show that increase in GDP seems to worsening air and water quality in poor countries but once a sufficiently high level of GDP is reached this relationship reverses to become positive. Subsequently, this relationship became known as the Environmental Kuznets Curve (EKC) and has been widely understood as a stylized representation of how environmental quality evolves with income. Nevertheless, despite the quantification of the relationship between environmental and economic variables, population (density) is still understood as a control variable, which does not really stem from explicit choices made by individuals.

These accounting-based approaches neglect one crucial aspect of the relationship between population and the environment: the endogenous nature of demography. More importantly, they fail to account for how population dynamics interact with the growth process itself. In response, the economic literature has investigated how micro-economic choices, particularly those related to fertility decisions, can be incorporated into growth models that account for environmental dynamics. In this literature review, we offer to highlight some salient results from this strand of the literature, being mainly theoretical. We show how those studies emphasize the externalities generated by endogenous fertility choices and offer policy recommendations to internalize population-induced externalities. Moreover, they seek to identify the economic and environmental conditions that allow for both a sustained development and demographic growth.

However, all these macroeconomic studies solely focus on one direction going from population dynamics to the environment. We argue, as highlighted in the literature, that this relationship between the two spheres is rather bidirectional (Mariani et al., 2010, 2019; Constant and Raffin, 2016). Specifically, one channel through which the environment may affect population dynamics could be, broadly speaking, health. It is only recently that the economic literature has started addressing the issue of environmental health, albeit primarily through usual indicators such as life expectancy, birth weight, or the prevalence of specific diseases. In this regard, the literature has been prolific, employing both theoretical and empirical approaches.[1] By investing these links, economists or/and epidemiologists have shed

[1]While providing an exhaustive review of all related studies is beyond the scope of our contribution, we highlight, through select articles, how climate change and environmental degradation negatively impact human health and in particular life expectancy. Since the 2000's, many papers have demonstrated the adverse effects of pollution exposure on both adult and infant mortality (Pope III et al., 2002; Chay and

light on the impact of environment conditions on population dynamics, although the unique considered variable that drives population changes is longevity/life expectancy. In addition, most of the time, they overlook the analysis of population dynamics *per se*.

This literature review seeks to bring forward a lesser-explored dimension of the interplay between human health and the environment: the reproductive health. This focus is particularly relevant as reproduction captures the most natural way to establish the connection between population dynamics and environmental changes. In May 2024, the WHO has estimated that almost one over six people experiences infertility worldwide and has suggested that exposure to chemicals or pollutants is one of the main driver to such a phenomenon.[2] Over the past decades already, both national and supranational regulations have been introduced to limit the use of chemicals suspected of causing endocrine disorders (see, for instance, European regulations UE 2017/2100 and UE 2018/605). For instance, in Europe, the classification of Bisphenol A and B as endocrine disruptors has had a significant impact on daily life, sparking widespread public concern. In addition, the scientific literature has extensively developed on that subject to establish a clear connection between changes in the environment and both impaired reproductive health or altered fertility decisions. Regarding the former, for instance, Sutton et al. (2010) synthesizes several epidemiological studies reporting increasing reproductive disorders or diseases –like testicular cancers– or the critical alteration of reproductive functions – as the average length for conceiving children– since the mid 20^{th} century. They clearly point out exposure to chemicals as the main cause for these alarming trends. At the same time, in industrialized economies, new social opinions has recently emerged among individuals to support *sobriety* in fertility decisions, bringing forward i) the rising and harmful carbon footprint associated with parenting and ii) anxiety over bringing children into an inhospitable world. To illustrate this point, we may cite several newspapers articles[3] that have recently documented on the raising feeling to remain child-free, due to environmental concerns or climate change. They claim that around 33 % of US men and women, currently aged from 20 to 45 years old, report climate change as a major justification for reducing family size.

In the first part of this literature review, we examine the relationship where population dynamics influence the environment, focusing on how demographic changes impact environmental outcomes. In the second part, we shift our focus to the reverse causal direction, exploring how environmental changes may affect population dynamics. Specifically, we review studies investigating whether and how environmental factors influence fertility decisions and broader demographic patterns.

Greenstone, 2003; Evans and Smith, 2005). In addition, the negative relationship between fine particulates, reflecting outdoor pollution, and life expectancy has been demonstrated in industrialized economies as well as developing countries, going through rapidly developing economies like China (Ebenstein et al., 2015). From a theoretical point of view, some papers have also explored the interactions between the environment and life expectancy (Pautrel, 2009; Mariani et al., 2010; Varvarigos, 2010; Raffin and Seegmuller, 2014).

[2]https://www.who.int/news-room/fact-sheets/detail/infertility.

[3]See Miller (2018) in the New-York Times or Fleming (2018) in the Guardian.

2 When population dynamics causes environmental pressure

For several decades now, the economic literature has highlighted the importance of studying demographic growth, and in particular, fertility decisions, as one of the key factors influencing the environmental quality and natural resources depletion, beyond the growth process it-self. As soon as the 1990s, Dasgupta (1993) suggests existing externalities related to fertility decisions on public good like natural resources. In the same vein, Dasgupta (1995) emphasizes that population growth can be both a cause and consequence of slackened economic development and deterioration of the environment, by the way advocating not to consider population as exogenous. Consequently, developing suitable analytical frameworks is essential to thoroughly examine the complex interactions between fertility, environmental factors, and economic growth, as well as their implications for public policy.

Endogenous fertility choices were introduced into growth theory, notably in the seminal work of Becker and Barro (1988). A key contribution of this strand of the literature is the modeling of a "quality-quantity" trade-off that parents face when deciding how many children to have and, *a fortiori*, how much to invest in their education, given their altruism toward their offspring. More precisely, children are considered a form of consumption good, meaning that as income rises, parents can afford to have more children while also allocating greater resources to each one. However, alongside the development process, raising children entails growing opportunity costs–whether in terms of time or money–so as the cost of child-rearing increases, parents tend to prioritize quality over quantity. Building on this, Becker et al. (1990) explicitly incorporated human capital accumulation and economic growth into this seminal framework, identifying two possible long-run equilibria: (i) a Malthusian regime, characterized by high fertility and low levels of human capital, and (ii) a sustained growth regime, where human capital accumulation is higher and fertility rates are lower. The transition from the Malthusian regime to a post-industrialized growth regime was later endogenized by Galor and Weil (2000). Therefore, by the late 1990s, economists had become increasingly aware of the challenges posed by the population-environment nexus and had developed relevant theoretical frameworks to analyze it. The following section explores how these frameworks have been used to address this complex relationship.

2.1 Endogeneous fertility and the environment

Harford (1998) has provided a two-period theoretical model of endogenous fertility where population growth negatively impacts the environment. More precisely, aggregate consumption generates pollution, which, in turn, lowers individual agent's well-being. Then, the author investigates the optimal design of a public policy whose aim is to to correct for the consumption-induced externality. He shows that, while taking into account this endogenous channel from population size to the environment, a usual Pigouvian tax on polluting activities does not allow for decentralizing the social optimum, since individuals do not internalize the induced effects of their own fertility choices on population dynamics. This constitutes the *ultimate externality*. Said otherwise, agents do not account for the cumulative nature of population over time, while solely considering the consumption externality.

Although this modeling by Harford (1998) addresses important issues, it abstracts from the "quantity-quality" trade-off and it fails to incorporate sustainability concerns.

Keeping this main argument in mind, de la Croix and Dottori (2008) further explore how the so-called *population race* may display dramatic consequences on the ambient ecosystems, taking the Easter Island collapse as the most striking example. In their setting, fertility choices become indeed strategic choices, whose final goal is to gain more bargaining power to exploit natural resources in a conflicting context. Therefore, the over-exploitation of natural resources does no longer result from myopic agents decisions or consumption externalities rather than rational fertility choices. In addition, they depart from the Malthusian mechanism according to which fertility rates increase with available resources meanwhile the amount of resources required to sustain standards of living exhibits decreasing returns. This literature on conflict-driven fertility decisions and resources exploitation[4] certainly contributes to the debate on the relationship between population dynamics and changes in the environment. However, in this literature review, we choose to focus on more "standard" fertility choices, driven by the mere desire of parenthood.

Then, we may draw the reader's attention on the policy tools available for decision makers to mitigate those impacts involved by population growth on the environment. In this regards, de la Croix and Gosseries (2012) have proposed an OverLapping Generations (OLG) model showing how considering endogenous fertility is crucial to value the implications of pollution control. In particular, while the authors abstract from perfect altruism when assessing individuals' choices, they assume a warm-glow altruism. Moreover, they explicitly consider the quantity-quality trade-off of children and they dwell at length on the sustainable nature of the development process, by incorporating an environmental component into their model. By doing so, they complete the seminal approach by Harford (1998). The key assumption in their model lies in the possible substitution between production and procreation activities, since households allocate their time between labor, leisure and parenting. In addition, they consider Pigouvian taxes or tradable quotas in order to control pollution. They show that pollution control entails a *natalist bias*, and thus a sneaky effect on the environment, as fertility is endogenous. Indeed, for a given technology, any environmental policy pushes agents to shift away from production to tax-free activities such as parenting, thereby boosting the demographic pressure on the environment and gradually impoverishing successive generations.

In a more recent study, Gerlagh et al. (2023) also consider the interactions between population dynamics and climate change while focusing their analysis on the interplay between family planning and climate policies. As in de la Croix and Gosseries (2012), parents are altruistic towards future generations. Moreover, the authors assume that each additional child may be considered as an additional incumbent in the competition for natural resources and space. Therefore, fertility decisions involve external costs that go beyond the intra-family sphere. They also assume that this new individual is a future worker, bringing-up human capital on the labor market and thus further contributing to the growth process. Following the insights from de la Croix and Gosseries (2012) or Mariani et al. (2019), their model offers original policy recommendations to promote women' social status, human capital or health. In particular, they examine how family policies can be used to achieve environmental

[4]See, for instance, Prskawetz et al. (2003) or Maxwell and Reuveny (2005).

goals. They claim that family planning is essential to reduce harmful emissions and contributes to the efficiency of any climate policy. In addition, they highlight that whether a planer would not be able to implement an efficient climate policy, family control should be more stringent. Consistent with the studies previously mentioned, they also emphasize that carbon taxes should be reduced when the planer can not implement any family planning policy. More precisely, while carbon taxes involve income reduction and promote higher fertility (through the quality-quantity trade-off), higher population turns out to impoverish individuals, further reducing family size.

All these studies examine the interactions between population growth and the environment, primarily through resource depletion or pollution accumulation. They also offer public policy tools to correct for several market failures. However, the link between fertility decisions and environmental conditions is indirect, largely operating through externalities. A few notable exceptions, which will be reviewed in the following section, explicitly incorporate endogenous fertility choices while also allowing households to invest in environmental preservation. In these contributions, microeconomic decisions – consumption, fertility, and environmental maintenance – are optimally interrelated, together shaping the broader dynamics of the economy, encompassing development, demographic evolution, and environmental change. Moreover, incorporating environmental decisions allows to better examine the sustainable development issue and provide additional results as far as public policy tools are assessed.

2.2 Endogenous fertility and environmental maintenance

Mariani et al. (2019) build an extension of Mariani et al. (2010), which allows them to revisit some key results of the literature, in particular de la Croix and Gosseries (2012). In their study, the authors provide new insights on the unintended consequences of policy measures such as environmental taxes and educational subsidies on environmental dynamics and the growth process. On the one hand, they identify the factors that favor a possible *natalist bias* of environmental regulation. But, they also emphasize the possibility of relying on educational subsidies as an effective policy tool to alleviate the pressure on natural resources. Finally, they highlight the existence of poverty traps related to human capital and environmental quality as in Mariani et al. (2010), although they add the population dimension. The crucial starting point of their works is that environmental care reflects some concern for the future, be it one's own or that of future generations. Anyway, the way people value the future is affected, among others, by their own longevity. Therefore, a higher life expectancy drives people to grant more weight on the future generations and/or their future selves. This concern for the future leads individuals to invest more in a private environmental maintenance – to restore environmental quality or at least to stop its deterioration – as well as to engage more in the quantity and/or quality of their offspring. In addition, population dynamics is embedded into the evolution of both life expectancy as well as endogenous fertility choices. Eventually, these investment decisions drive the future dynamics of the economy, shaping its demographic and economic trajectories, and further the state of the environment. Then, the authors conclude that only when the initial environmental quality is good enough, population growth may become less binding. More precisely, along the transition path towards

a desirable stationary equilibrium, one economy featured by a better environmental quality first experiences a decline in population as parents favor human capital accumulation over the quantity of children and a limited deterioration in the environment. Once the economy reaches a sufficiently high level of human capital, parents earns enough to increase the size of their offspring while improving environmental quality. This paper represents an important step in examining the bidirectional interactions between population dynamics and the environment.

In the same spirit, Constant et al. (2014) incorporate environmental concerns as well as fertility into the households' utility function, beyond the usual consumption component. Specifically, in their OLG setting, parents derive warm glow from leaving an environmental bequest to future generations – an expression of environmental altruism. As a result, parents determine the level of pollution to be inherited by their offspring based on the expected level of wealth/development. They conclude that a sustainable stationary equilibrium, characterized by a high capital intensity, population growth and pollution, may emerge if initial conditions for wealth and population size are sufficiently favorable. As in some aforementioned papers, long-run development is not necessarily threatened by population growth; However, differently from Mariani et al. (2019), population growth does not coincide with improved environmental conditions. Indeed, since they assume a constant cost of rearing children, it turns out that capital intensity and population growth evolve in parallel. However, in the mean time, parents are willing to leave a more damaged environment to future generations, if the level of development is deemed high enough.

Despite some attempts to consider the linkages between population, economic and environmental dynamics, most studies tend to neglect the possible direct feedback effects of environmental conditions on fertility choices. Yet, the literature–whether epidemiological or economic – has extensively but separately explored this dimension. In the following section, we review several contributions that specifically address this question.

3 Environmental deterioration: a new key driver of human fertility

As mentioned previously, the economic literature has widely explored fertility decisions, as the later are closely related to socio-economic or cultural incentives. Here, we aim at adopting a positive approach and describe how fertility decisions may be influenced by the environment, through two distinct channels: i) the changes in the human reproductive health due to environmental deterioration; ii) the newly emerged environmental-friendly fertility decisions.

3.1 Environment and reproductive health

The environment is multi-dimensional, and so is its impact on reproductive health. The empirical literature has extensively examined how various pollutants, chemicals, and even climate factors harm reproductive health. Beyond these direct health effects, research has also highlighted how environmental concerns can influence fertility behaviors. Drawing on

these two strands of literature, we can establish a reverse relationship, in which environmental conditions shape population dynamics.

In this section, we first examine the impacts of environmental changes on the biological notion of fertility, defined as an individual's ability to conceive when desired. In a first step we review the extensive empirical literature on this topic and then present theoretical contributions that account for impaired reproductive health. Next, we explore the influence of environmental and climatic factors on fertility decisions. Similarly, we start by highlighting key findings from recent empirical studies and then discuss theoretical frameworks that integrate those concerns.

3.1.1 Empirical evidence on the decline in the human reproductive health

Despite the world population is increasing, infertility is also expanding, independent of income consideration: Unintended infertility has been steadily increasing over the twentieth century and after so that, nowadays, around 17,5% of couples are declared infertile worldwide (World Health Organization, 2023).[5] Infertility can impose not only significant financial costs but also a heavy psychological burden. Moreover, addressing the rising prevalence of infertility has become a political priority, driving the need for health policies that both fulfill couples' desires and respond to the challenges posed by aging societies. In particular, (very) low fertility rates in many industrialized countries raise concerns for the governments to sustain pension or public health systems, ensure sufficient labor force on the labor market, among others.

Based on epidemiological evidence, we first emphasize the observed decline in the human reproductive health since the beginning of the 20^{th}, thanks to several indicators or objective measurements of both male and female reproductive dysfunctional endocrine systems. Then, it remains to establish the contribution of environmental factors. To that end, we may rely on both epidemiological but also empirical economic studies.

As for men, various biomarkers and disease prevalence can be used to track changes in reproductive health over time. For instance, following the seminal paper by Carlsen et al. (1992) that gave birth to the famous "falling sperm counts" story, many studies have established a global declining quality of the spermatogenis. This phenomenon has been assessed over quite long-periods in many industrialized countries like the US, France, UK, etc. and is considered as a good predictor of reproductive health. (Swan et al., 2000; Romero-Otero et al., 2015; Levine et al., 2017; Le Moal et al., 2014; Jørgensen et al., 2006). In the meantime, the prevalence male specific cancers, linked to reproductive functions, also tend to increase during the last decades (Bray et al., 2006; Shah et al., 2007). As for female reproductive health, there are ongoing researches with respect to the use of recent bio-markers like antral follicular count and antimuëllerian hormone (Nelson, 2013). At the same time, new epidemiological studies have emphasized the prevalence of endocrine disorders, such as polycystic ovarian symptoms (PCOs) or diagnosed endometriosis, which are also among the main causes of women infertility. As an illustration, March et al. (2010) show that PCOs are diagnosed for around 15% or more of reproductive-aged women.

[5]Infertility is defined, by the WHO, as a disease of the male or female reproductive system which entails a failure to achieve a pregnancy after 12 months or more of regular unprotected sexual intercourse.

These studies are crucial to our focus, as they examine changes in human reproductive health during periods of rapid economic development—times often associated with increased exposure to lifestyle factors that may harm fertility. Among them, pollution or diet have been often identified as major contributors to explain the current worldwide infertility. A growing body of toxicological research supports the hypothesis that exposure to environmental contaminants negatively affects reproductive health in both men and women. One prevalent explanation is *the Endocrine Disruptor Chemical (EDC) hypothesis*, which suggests that ubiquitous chemical pollutants (Persistent Organic Pollutants (POPs), pesticides, metals, textiles, air particulates and the like) disrupts the hormonal system and interfere with developmental processes. Human exposure-be it occupational or non-occupational- to EDCs occurs via ingestion of food, dust and water, inhalation of gases and particles in the air or through dermal uptake (Bergman et al., 2013; Sifakis et al., 2017). Many empirical studies provide concrete examples of these adverse effects. For instance the papers by Rosa et al. (2003), Martenies and Perry (2013) or Zhou et al. (2014) establish a link between air pollution and Particulate Matters on the male reproductive health in Italy and China, respectively. Other researches examine the impact of environmental pollutants on female reproductive functions (Bolden et al., 2017; Mendola et al., 2008). Non-occupational exposure to metals, *e.g.* Molybdenum, has also been related to poor semen quality (Meeker et al., 2008). Similarly, pesticides like Polychlorinated Biphenyls (PCBs), have been shown to affect male reproductive health, even at low levels. This includes both occupational exposure (Tuc et al., 2007; Recio-Vega et al., 2008), non-occupational one (Swan et al., 2003; Perry et al., 2011; Bouvier et al., 2006; Aneck-Hahn et al., 2007) as well as dietary intake through fruits, vegetables, meat, fish (see Mehrpour et al., 2014; Chiu et al., 2015, among others). At the couple level, studies like Slama et al. (2013) or Kahn et al. (2021) find that exposure to air pollution or EDCs can reduce the couple probability to pregnancy. Furthermore, early-life exposure to pollutants is associated with reduced testicular volume and delayed puberty, affecting future fertility (Cargnelutti et al., 2021). Beyond the direct effect of pollution, climate also plays a role in reproductive health. On long-term US data, Barreca et al. (2018) estimate unusual increases in temperature on the birth rate. They show that one additional hot day, that is measured by a temperature superior to 26.6°C, causes a decrease by 0.4% 9 months later. Broadly speaking, this temperature peak first induces a harsh decline in birth rates that may be partially offset few months later, up to 32% of the initial decrease. Overall, this evidence underscores the complex pathways through which environmental and climatic factors influence reproductive health and fertility outcomes.

There is ample evidence that ambient environmental quality is a major determinant of human reproductive health. Incorporating the climate component further supports the idea that the environment, viewed as a composite good, significantly influences population dynamics through its effects on reproductive health. However, while the literature discussed so far is exclusively empirical, we now review theoretical frameworks from the economic literature that explore this aspect of the bidirectional relationship between environmental change and population dynamics.

3.1.2 The theoretical assessment of an impaired reproductive health

As mentioned previously, the economic literature has developed on the determinants of fertility, even childlessness, but somehow has neglected the possible undesired infertility issue. Only recently, the economists handled it, and mainly theoretically.[6] In many theoretical models though, one common feature on that specific subject is the focus made on the fairness issues raised by infertility, rather that its impact in terms of population dynamics and, further on the environmental evolution (see, for instance, Leroux et al., 2024; Momota, 2016).

Etner et al. (2020) offer a first attempt to model the undesired infertility issue, related to the economic development and somehow to the deterioration of the environment. They propose an OLG model to conduct a welfare analysis of unintended infertility, while considering exogenous fertility. The analysis focuses on the inequities induced by infertility, which is assumed to cause utility loss. Importantly, agents are not held responsible for this health heterogeneity. This is true all the more if we think to intra-utero pollution exposure or adverse living conditions during childhood, both of which significantly affect the adult endocrine system. To account for the possible link between environmental deterioration and reproductive health, the model assumes that the probability to be infertile is an increasing function of capital accumulation. This relationship is interpreted as reflecting the negative impact of contemporaneous life styles, including diets and/or pollution on reproductive health. At the same time, Etner et al. (2020) also consider the opportunity of medical treatments, in particular, Assisting Reproductive Treatments (ARTs) to overcome infertility, that also may come along with wealth accumulation over time. The paper further explores the most efficient ways to correct for the externalities inherent in the economy, particularly the capital-induced reproductive health externality. To do so they consider at first a utilitarian social planner and then an inequality averse regulator, since health heterogeneity is mainly due to circumstances, rather than the results of individuals' choices. The authors conclude that taxing capital accumulation – or equivalently pollution – can restore optimality, especially when considering equal opportunities criterion of public social evaluation.

The impact of environmental conditions on human health is well established and while the focus on reproductive health is recent, the positive correlations between environmental quality and procreation abilities appear robust. At the same time, incorporating these linkages between the environmental and economic spheres provides insights into how population dynamics may evolve in response to environmental changes over time while it raises fairness issues that deserved to be more deeply explored. Regarding this epidemiological literature, there is room for additional empirical studies, particularly those led by economists, to examine how the environmental burden is distributed across different segments of the population. Further research could explore the extent to which socio-economic factors such as income and education affect the relationship between environmental conditions and reproductive health.

[6] For instance, Baudin et al. (2015) investigate the gradients of childlessness on US data and mention some environmental factors that could be a cause of such a phenomenon, among others. However, the authors rather relate fertility choices, and specifically childlessness, to socio-economic factors like income, then performing a calibration exercise.

In addition, other channels may also shape this former relationship. The idea that population growth exerts pressure on resources and the environment may has resonated with individuals beyond academia. In recent years, individuals have increasingly shown eco-anxiety when it comes to deal with their future. The same is probably true about the negative impact of pollution on health outcomes. This raises the question of how individuals incorporate such considerations into their decision-making, specifically regarding fertility choices. This relationship going from observed or expected environmental changes to fertility decisions constitutes the core of the following section.

3.2 Environmental concerns and fertility decisions

As already mentioned, early in the literature, some theoretical articles have considered the environment as a component of individuals' utility function thereby reflecting some concerns for the future at least (Mariani et al., 2010, 2019). Meanwhile, individuals increasingly express concerns about climate change and its potential link to their procreation choices. In real life, this concern has manifested in political discourse and activism, with social movements such as "birth strikes" gaining attention.[7] While these discourses may not yet be fully reflected in the data, they find echoes in the media and appear to have a certain degree of credibility. In addition, various surveys conducted in the U.S., Australia, and elsewhere consistently highlight an increasing trend toward remaining childless, driven by environmental concerns (Schneider-Mayerson and Leong, 2020).[8] The decision to be child-free is often motivated by factors such as the carbon footprint of a new human being or the potential suffering future generations may face due to the climate crisis. This phenomenon raises concerns about the effectiveness of family policies aimed at promoting demographic growth, particularly in contexts where fertility rates are already very low. As a matter of example, we may wonder about the efficiency of the new parental leave policy associated with higher financial compensation, alongside with the ambitious national plan to counteract a declining birth rate officially announced in January 2024 by the French President, E. Macron while ignoring the impact of environmental concerns on fertility intentions.[9]

In this subsection, we aim at reviewing academic papers, both empirical and theoretical, which deal with such a new determinant of fertility choices, namely environmental concerns.

3.2.1 How environmental concerns empirically affect fertility decisions?

Despite fertility intentions and choices may reflect many psychological, sociological or economic considerations, empirical analysis on the link between environmental concerns and fertility intentions/choices may offer new and relevant insights. In particular, changes in the

[7]The "birth strikes for the future" movement, which originated in the UK in 2018, was promoted by former musician and Extinction Rebellion activist Blythe Pepino. https://www.theguardian.com/lifeandstyle/2019/mar/12/birthstrikers-meet-the-women-who-refuse-to-have-children-until-climate-change-ends

[8]See Miller (2018) or the Australian Conservation foundation survey: https://www.acf.org.au/women_will_change_their_lives_and_votes_for_climate_action.

[9]https://www.lemonde.fr/societe/article/2024/01/17/emmanuel-macron-annonce-un-conge-de-naissance-et-un-plan-contre-l-infertilite-pour-le-rearmement-demographique-du-pays_6211291_3224.html

environment provoke fear or concern about the future, and the literature has already established a negative association between uncertain or risky environments and fertility decisions, leading either to a clear reduction in fertility or, to a lesser extent, to postponement (de la Croix and Pommeret, 2021; Low, 2024). In this regard, it is reasonable to consider that both observed and anticipated environmental changes may indeed influence fertility decisions. As an illustration, the study by Smith et al. (2023) supports our intuition. The authors use a specific methodology, borrowed from ethnography, which consists in interviewing individuals about photographs related to specific themes, here environmental changes. Most of the respondents have reported eco-anxiety about childbearing decision making, along with economic factors, like the cost of living.

Using a more standard econometric approach, Arnocky et al. (2012) constitutes an inspiring study to estimate how environmental concerns affect fertility intentions, which gave birth to an expanding literature among which (among which Davis et al., 2019). Interviewing Canadian students, the authors show that environmental concerns, measured either through polluted-related health concerns or the New Ecological Paradigm (NEP) score scale[10], are good (yet indirect) predictors of personal and consistent fertility intentions. In particular, higher NEP or/and polluted-related health scores are positively correlated with anti-reproductive attitudes. Following this work, Schneider-Mayerson and Leong (2020) tested how young individuals factor the environment into their reproductive choices. In a survey of 607 US citizens above 27 years old, they found that more than a half of the respondents were concerned about the carbon footprint associated with parenthood and more than 95% were highly concerned about the environmental legacy their offspring would inherit. This exploratory survey primarily considers subjects who were already connecting procreation choices with climate change. Thus, the aim of the study is to quantify somehow how those pro-environmental individuals may consistently weight the climate change issue into their fertility decisions. Despite a sampling methodology that lead to quite homogeneous subjects, the study brings into the light that parents are less concerned by their children' carbon footprint than respondents who plan to have children, who are less concerned than those who are undecided about parenting. They also bring forward, thanks to open-ended questions, that beliefs about the future state of the environment may have a crucial role into the decision process. This does not of course abstract from the usual suspects that drive fertility decisions, like income, socio-economic factors, gender, age and so on. Even more, it may not be so easy to measure the environmental factor among all possible ones, although it appear for some respondents that climate change issue has sometime a top priority for remaining childless.

Following this contribution, others empirical studies, still on US respondents have been conducted. Interestingly, to identify the causal impact of environmental changes on decisions, Rackin et al. (2023) examine how supporting political actions, like environmental expenditures, influence fertility choices. Not surprisingly, they emphasize that respondents who consider that governments should deal with environmental issues, despite it may involve higher taxes, exhibit a decreased desire for larger families. The study by Helm et al. (2021) was also conducted by interviewing respondents from both the US and New Zealand. First, the authors examine comments about online press articles to identify and list several opin-

[10]See Dunlap et al. (2000) for a more details presentation of this evaluation tool.

ions regarding free-child motives. Second, the authors interviewed individuals who chose to remain child-free and aim at eliciting the environmental gradient for such a fertility decision. They show that the motivations behind choosing a child-free life can be ranked, with concerns about over-consumption and overpopulation ranking at the top. The feeling of guilt associated with leaving future generations to inherit an uncertain environment emerges as a secondary consideration.

On longitudinal data in UK this time, Powdthavee et al. (2024) recently showed that individuals deeply committed towards green lifestyles are more likely to delay childbearing, thus narrowing the natural windows for having children. Environmental concerns may not only directly reduce fertility rates by influencing decision-making, but they can also indirectly affect fertility behaviors by lowering the likelihood of successful procreation. Specifically, delaying childbirth makes conception more difficult as individuals get older. In their study, the authors estimate a Probit regression to assess how environmentalism influences the probability to procreate six years after. They show a negative coefficient, even after controlling for usual predictors of fertility. In addition, they provide a measure of this negative relationship and estimate that one standard-deviation from the average measure of environmental-friendly attitudes entails a reduction in the probability to have children by 21,5%.

Regarding the empirical literature on how environmental factors influence fertility decisions, it is clear that theoretical models addressing this question are relatively scarce. Nevertheless, some studies do explore this issue, and we briefly present and summarize them in the following section. The main challenge is thus to model how these fertility behaviors at the individual levels impact the dynamics of population and the economy at a macroeconomic level (see Schneider-Mayerson and Leong, 2020).

3.2.2 Environmental concerns and fertility in theoretical growth models

When it comes to consider environmental concerns, as we shall see below, endogenous fertility choices modeling may depart from the usual quality-quantity trade-off, as the main objective is not to warrant demographic transition nor the industrialization of the economy.

Some theoretical contributions have attempted to examine how changes in the environment affect fertility behaviors. Their conclusion sometimes echoes some arguments previously mentioned in Section 2, sometimes contrast them. Nevertheless, those papers do not incorporate environmental concerns as a direct determinant of fertility choices. For example, Casey et al. (2019) offer a quantitative analysis of the impact of climate change on population dynamics. They consider the linkages between endogenous fertility choices, the quantity-quality trade-off, and the composition of the productive sphere. They show that increase in temperature may affect the productivity of economic activities and thus commodity prices. Then, as prices vary, so does incentives to parenthood. In particular, in agricultural economies, which are among the most harmed economies by climate change, environmental damages generate scarcity, which in turn, rises prices. This involves a re-allocation of the labor force towards less-skill activities into that sector and by the way, diminishes incentives for parents to invest in the quality of their offspring. Ultimately, parents favor larger family sizes. In contrast, Varvarigos and Zakaria (2017) consider that environmental factors can indeed directly affect economic choices, specifically regarding fertility. They develop an

OLG framework in which agents act as consumers, parents and entrepreneurs. Their conclusion on the efficiency of environmental policy like a carbon tax contrast with the papers previously mentioned. They show that an increase in taxation promotes the adoption of less-polluting production process, thereby reducing emissions per output. In turn, this shift towards cleaner production process entails higher longevity, leading larger investments in private savings, which further support development process. Alongside, households reduce their fertility. This is primarily due to the agents' effort to smooth consumption, as they allocate more labor to the market to offset their loss of income and give priority to savings. Then, by focusing on the reverse causality in the population-environment nexus, they put forward that demographics are rather slackened in the course of development and thus does not participate to increase pressure on the environment. Although these studies explore the population-environment relationship, their mechanisms rely mainly on price and substitution effects. Given the empirical evidence discussed earlier, it may be valuable to take a more integrated approach that considers environmental and fertility concerns together, offering a more direct exploration of how ecological factors shape reproductive decisions.

In their paper, Melindi-Ghidi and Seegmuller (2023) directly introduce environmental concerns into the utility function of altruistic agents and aim at exploring how this may shape fertility decisions, in particular in high-income economies. In their OLG framework, the quantity-quality trade-off is embedded into a quantity-bequest trade-off and fertility decisions are directly related to an index of environmental quality, measured by the ratio of pollution over. Interestingly, this relationship is non-monotonic. Using a CES utility function, defined over parenthood, consumption and environmental quality, they show that when environmental concerns and children are substitute, at the equilibrium, there exists an inverted U-shaped relationship between fertility and wealth, measured as the capital over labor ratio. Basically, as the stock of capital rises, so does the environment index, leading to both a lower marginal utility of children while fostering the investment in their quality – the bequests. In addition, environmental concerns are likely to reduce even more fertility, as it reinforces the driving factors of quality investment in children. This is true all the more that the stage of development is advanced. In their work, there is no demographic pressure on the environment but rather a slackening effect of environmental conditions on the population dynamics. To that extent, they depart from the old paradigm so that demographic growth and sustainable development is incompatible. This article may also pave the way for future researches that incorporates additional health dimensions related to the state of the climate or the environment.

4 Conclusion

This literature review aims to explore the intricate relationships between population dynamics and environmental changes over time, covering several key aspects. First, it examines how economists investigate demographic pressure on the environment and how public policies can either reinforce or, ideally, mitigate the negative externalities of population growth. Second, it explores how pollution and climate change may affect fertility, both through the impairment of reproductive health and through sober fertility decisions. While the literature is vast and this review is not exhaustive, it provides an important first step in shedding light

on the new challenges posed by environmental changes.

Both empirical and theoretical frameworks are employed to assess this complex and fascinating intersection of dynamics. We believe much remains to be done in order to capture the full scope of theses interconnections and derive meaningful policy recommendations.For instance, we have highlighted that agents–parents or future parents– may be sensitive to the current and future state of the environment, driving fertility rates to diminish. In the meantime, those pro-environment agents are those who may transmit green preferences to future generations and thus, sacrifice their main channel of preferences transmission by reducing the size of their own family. In a world featured by brown versus green agents, and incorporating both endogenous fertility and preferences transmission, we may highlight some interesting paradox that deserved to be explored more deeply: what about the cultural versus evolutionary advantage on the long-run process of development? In the same vein, it would be worthwhile to study green preferences consistency as lower fertility rates free resources by sparing rearing children costs. We may wonder whether sober fertility choices come along with greener consumption choices or, in contrast, induce a rebound effect, harmful for a sustainable development?

Finally, one important dimension that has been overlooked in this work – despite its potential influence on population dynamics and its close connection to environmental changes – is environmentally-driven migration. Exploring this aspect of the environment-population relationship would undoubtedly require a dedicated literature review, given the vast body of research on the topic. Nonetheless, migration represents a third key channel, alongside life expectancy and fertility, through which environmental changes can shape demographic patterns. Ambitious future research could aim at considering those three channels all together to re-examine the population-environment nexus.

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