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Demographic Theory and Population Ethics – Relationships between Population Size and Population Growth

Demographic theory aims at explaining how population systems regulate themselves given available resources. Population ethics is concerned with demography in the sense that the analytical objects of interest are births, deaths, and populations. However, demographic theory which explores theoretically when, how and why populations grow, based on empirically observed patterns, has up until now played a minor role in population ethics. Similarly, debates about population dynamics among demographers have seldom been concerned with ideas and concepts in population ethics. In this manuscript, I will give a brief outline of how population size, population growth, and welfare mutually affect each other. Theories on the endogeneity between population size, population growth, and welfare will be referred to as demographic theory. I will give a particular focus on how population growth responds with respect to welfare, as welfare, utility, well-being, and happiness are important concepts in population ethics. A key concept in demographic theory is population homeostasis (the dynamics of a system which maintains a population at a steady population size, or growth rate), in particular resource dependent homeostasis. I will also discuss demographic theory in relation to historical and future demographic change.

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Introduction

Population ethics is clearly concerned with demography in the sense that the analytical objects of interest are births, deaths, and populations.² However, demographic theory which explores theoretically when, how and why populations grow, based on empirically observed patterns, has up until now played a minor role in population ethics. Similarly, debates about population dynamics among demographers have seldom been concerned with ideas and concepts in population ethics. In this manuscript, I will give a brief outline of how population size, population growth, welfare, mutually affect each other. Theories on the endogeneity (co-dependencies) between population size, population growth, and welfare will be referred to as demographic theory. I will discuss how population growth responds with respect to welfare, as welfare or utility is an important concept in population ethics. I will discuss population homeostasis (the dynamics of a system which maintains a population at a steady population size, or growth rate), with a focus on resource dependent homeostatic mechanisms. I will pay particular attention to negative relationships between population size and welfare, and refer to such relationships as “Malthusian”, after Thomas Malthus.

Social scientists have over centuries discovered regularities in how populations grow and shrink, and developed methods to measure and model these accurately. Compared to many other domains of human interaction demographic theory is concerned with empirical phenomena such as births and deaths that are easy to measure and define, also across widely different contexts and times. Demographic theory is concerned with describing populations as analytical dynamic systems, and to find empirical patterns in how and why populations change. As such, it is descriptive and analytical and is not focused on if outcomes are preferable or more desirable than an alternative outcome. While economic demography is concerned with welfare or available resources, it is often related to resources in an ecological sense, where resources regulate population growth and size, and where the dynamics and outcomes are unrelated to ethical outcomes. There are strong overlaps between population studies and evolutionary biology, which both model births, deaths, population growth, and the relative size of different groups over time. In fact, biological evolution can be viewed as a demographic process where births and deaths change the distribution of traits in each new generation (population growth is a central concept both in ecology and evolutionary biology). Theorizing on

² Throughout this text I will use the term population and population size to refer to the number of currently living individuals at a single time point. The geographical area or definition will be left unspecified, and I will occasionally use population density analogously to population size, as for a certain (closed) area - such as Earth - the two concepts are identical.

evolution and human population systems have a shared scientific ancestry before the 20th century.

Models in demography theory assume that individuals are agents whose actions are both affected by and affect well-being, but that motivations are related to individual choices and often don't maximize population wellbeing. Therefore, the long-term population outcome of demographic systems typically is not what maximizes either average or aggregated welfare in a population. Population equilibriums in demographic theory are therefore different from calculations of optimal population size, which aims at finding the population size that maximizes welfare (from either an average individual's or a cumulative welfare perspective). As demographic change is driven by choices made dependent on individual (average) welfare, population systems will be determined by the average welfare of an individual and not by global aggregated utilitarian welfare. In this manuscript I will mostly discuss welfare from an average perspective and not from the total utilitarian perspective in population ethics (cf. Singer, 1976), however it is easy to move from an average welfare to a total welfare perspective as it simply consists of multiplying average welfare with population size (though this has interesting implications for population models where population size can change over time).

A theoretical understanding of how populations grow, decline and maintain equilibriums over long time spans are relevant for many topics in population ethics. Many of the assumptions of Population ethics, such as Malthusian assumptions of average welfare declining with additional individuals are implicit, and ethicists may want to explore other assumptions. A nuanced understanding of demographic theory may also help to understand if possible imagined scenarios are unlikely, or even nearly impossible empirically. If a theory produces possible paradoxes and unacceptable conclusions that are implausible based on demographic theory, they may be less of a concern for a theory, than other scenarios which are more grounded in demographic theory. Demographic theory may also inform population ethicists if certain population scenarios are plausible only in the short term, or if they are plausible over longer time scales.

While population ethicists can and should make thought experiments on any imaginable population and welfare combinations, understanding the basic parameters in which populations, population growth, and welfare interacts helps to ground theorizing in population ethics and makes it more applicable to empirical circumstances. There is a long (sometimes non-explicit) tradition in population ethics to assume negative welfare to larger populations following a Malthusian perspective.³ Broadly, one can distinguish two different approaches in population

³ See for example the following three quotes from population ethicists. In the quote below by Parfit (1984) he, a) takes a Malthusian relationship as an empirical fact in some contemporaneous societies,

ethics when reasoning about the effect of population size and welfare. Good illustrations of the first approach are Parfit (1984), Arrhenius (2011), and Broome (1996). They compare hypothetical populations to each other, and often the analytical treatment allows both a positive relationship between population size and welfare, as well as a negative relationship. However, typically the framing and examples of their models are to assume an explicit negative function between population size and welfare. An example of this is Parfit (1984). A reason for the implicit Malthusian settings in this school of population ethics, is that the opposite case, of increasing welfare in larger populations, does not involve trade-offs with larger populations and value infinite population sizes. A second approach can be illustrated with Dasgupta (1998) where authors create explicit models to calculate welfare based on population size. Such models typically make and motivate Malthusian relationships between population size. This illustrates how having a thorough understanding of demographic theory, and both Malthusian and non-Malthusian perspectives in population ethics, may clarify implicit assumptions in population ethics and may open up new avenues of research.

The main value of demographic theory for population ethics is through the understanding that population growth (and with some delay, population size) will respond to current welfare in a population. For example, a hypothetical very large population with highly negative welfare is likely to over time revert to lower population sizes with higher welfare. Similar over long periods of time, both very small and very large populations are likely to move towards intermediate popu-

and b) then after first qualifying that a Malthusian relationship might not apply everywhere (in two sentences) c) proceeds discuss the Malthusian case and implications of such a relationship (over 59 pages).

“The effect of population growth on existing people – My couple assume that the existence of an extra child would not on balance be worse for other people. In many countries, in many periods, this has been true. But in many other periods it has not been true. In these periods, if there had been more people, people would have been worse off. This is now true in many countries. In these countries, if the population grows, the quality of life will be lower than it would be if the population did not grow. These are the cases that I shall discuss” Parfit (1984, p. 382).

The quote below is the basis of a thought experiment introducing optimal population from Arrhenius and Campbell (2017):

“If the current generation continues to consume resources at the expense of future generations, and the population increases significantly, this could lead to an enormous population—ten billion people per generation—in which most people’s lives are barely worth living. Suppose we could instead create a smaller population—around one billion people per generation—with very good lives. Which population would be better?”

This is the representation of the world that Dasgupta (1998) uses to discuss the value of additional people in an ecological model on optimal population size:

“More importantly is the thought that, like everyone else, potential geniuses, if they are to flower, require resources, such as potable water, food, clothing, medical care and education. So it would seem that we cannot get very far with the idea of a desirable population size without considering resource constraints. Whether it be for a household or for an entire nation, population policy cannot be formulated without a concurrent saving and investment policy.”

lation sizes. Such insights are most important when population ethicists are interested in cumulative welfare across a large number of generations. Understanding such relationships are valuable for population ethicists, as inquiries into optimal population size for human welfare will have to make assumptions on how current population size is related to welfare, how welfare is related to population growth, and how current population size is related to future population growth. Demographic theory might also be a useful perspective to examine trade-offs between reproductive rights and optimal population size, as a population with high fertility due and unrestrained reproductive rights in some cases may be described well by resource dependent demographic theory.

A fundamental insight from demographic theory is that all population systems over many generations are going to have homeostatic characteristics. In a homeostatic system, population increases and declines will eventually revert to an equilibrium, level. Long-term unbounded population growth is unlikely; as exponential growth quickly results in an unsustainable and implausible population size. Similarly, a homeostatic population model implies that population growth rate is positive at low population sizes, and that extinctions of populations thus are unlikely.

In a Malthusian model, homeostatic regulation is related to the availability of resources. When resources are plentiful the population will grow, and when they are scarce the population will decrease. This forms a basic framework for most theorizing on both human and animal populations. Economic demographers have further theorized on positive relationships between population size and population growth, under some circumstances. Such positive effects would stem from dynamic gains from for example specialization of labor, and increases in communication and innovation in dense populations. Given that such positive feedback loops are reasonable for some population sizes, it is possible to develop models combining Malthusian negative feedbacks and positive density-dependent feedbacks applicable at different population sizes. Implications of such theories for population ethics, as well as an empirical description on the determinants of contemporary and historical population systems will be discussed in the current manuscript.

The usage of terms such as welfare, utility, wages, and resources differs between subjects. In this text, I will use all of them largely interchangeably depending on which context appear suitable, in all cases to refer to access to material resources in a broad sense.⁴ When I refer to the welfare of populations, I refer to the average welfare of an individual in that population (and not the aggregated welfare of that population). Because as I assume homogenous populations this will be the same as

⁴ Note, that this means that it is clearly different (though likely to some degree overlapping) from a concept of welfare that also include non-material sources of happiness.

the welfare of any individual. Throughout this overview, the time perspective will be comparatively large and encompass multiple generations of humans (when I use the term long-term I refer to at least 5+ generations, longer perspectives than what is used in most governmental and scientific projections on population size). The determinants of population growth, mortality, and fertility in a shorter time perspective are different and are not the focus of this overview.

In this manuscript, I will first discuss the role of exponential growth, and how it relates economic demographic theory and population homeostasis. This will be followed by a presentation of some simple models in demographic theory, and after that examine implications for population ethics of such relationships. Finally, I will discuss the determinants of population dynamics of past, present, and future human populations.

Exponential growth, economic demography and population homeostasis

A fundamental characteristic of (human) populations is that populations grow (and decline) exponentially. This creates the potential for very quick growth, and decline when analysed over multiple generations. All human (and other animal) populations will, given favourable circumstance, quickly expand at such a quick rate that there after a longer time perspective must be some other factor holding back growth. For example, the French-speaking population in Quebec had population growth rates from natural⁵ growth of around 2% for several centuries which increased the population several hundred times starting from the 17th century (Charbonneau, Desjardins, Légaré, & Denis, 2000).

That population size eventually stabilizes after a period of growth is a phenomenon that is repeatedly observed both in animal populations and for historic human population. This realization goes back to Malthus and served as inspiration for what Darwin called the “struggle for existence”. Negative exponential growth is similarly powerful and can decrease population size very quickly. Even in a population where no individual ever dies would quickly stop increasing if each woman gave birth to less than two children during her lifetime,⁶ as each new generation would be smaller than the former. For example, a population in which all

⁵ Natural growth refers to population changes arising from births and deaths, not taking migration into account.

⁶ Demographers use the concept of Net reproductive rate (NRR), which is typically defined from only a female perspective, and is the average number of surviving daughters of a woman, at a given level of mortality and fertility of the woman. If the NRR is larger than 1 a population will grow, and if it is smaller than 1 it will shrink. For example, a NRR of 1 would arise if a woman on average give birth to two children, a sex ratio of 0.5, and that no woman dies before the end childbearing ages.

women have one child (or half of all women have a daughter) in their life would stabilize at twice the original size in a population where no one ever dies.⁷

Any fast-growing human populations will stop growing rapidly at some point due to the nature of exponential growth. The world population growth rate observed in the 1960s of 2.2% implies that earth's population would be 53,143 times bigger if this growth would be constant for another 500 years.⁸ Most population can grow at times at similar speeds, but such growth rates will inevitably come to an end. A useful interpretation of the demographic transition, the shift from a high fertility-high mortality society, to a society with reduced mortality and consequently high population growth, to a low fertility-low mortality society, can be seen as an inescapable outcome of a process in which exogenous factors reduce mortality permanently. The demographic transition is then a (homeostatic) way for a society to once again reach population balance and escape unsustainable population growth (Wilson & Airey, 1999). A very demographic definition of overpopulation can be said to be the population size for which population growth turns negative.

In a homeostatic population model, population growth must in some way be related to population size itself. That populations are bounded by available resources is a key insight of Malthus in the 18th century,⁹ and that human population growth reacts favourably to abundant resources, while decreasing when resources are scarce. A Malthusian relationship is central in ecological models applicable to all species, and there is clear evidence that such mechanisms regulate population size in historical agricultural and hunter-gatherer societies (Lee, 1987). This is an example of population homeostasis, in which population growth responds to population size,¹⁰ in this case through a positive association between resource availability and population growth and a negative association between resource availability and population size. As discussed earlier, Malthusian assumptions remain dominant when population ethicists have incorporated demographic theory in demographic models.

⁷ This results from a NRR of 0.5, as

$$a + ar + ar^2 + ar^3 + ar^4 + \dots = \sum_{k=0}^{\infty} ar^k = \frac{a}{1-r}, \text{ for } |r| < 1.$$

gives a sum of 2 if a is equal to 1 and r equal to 0.5. This geometric series represents cumulative population when every new generation is half the size of the previous one.

⁸ After 2000 years there would only be enough matter on Earth for 1 gram per person.

⁹ Though ideas of a positive relationship between number of people and wealth have been common in many societies long before Malthus, and such ideas were a part of a broader scientific discourse in 18th century Europe (Hutchinson, 1967).

¹⁰ A stable population equilibrium is when all individuals are living at subsistence level, but it is possible that the function between welfare and population growth is different, and that for example societies would regulate reproduction so that a population equilibrium would take place at welfare levels above subsistence minimum.

However, a Malthusian model cannot explain how human population size has increased from millions to billions in the last few thousand years. In the last 10,000 years the global population has not only grown exponentially, but in addition, the growth rate itself has been growing exponentially (Livi-Bacci, 2007). This implies that there must have been some development of human culture that has allowed an increasingly large population size over time, breaking a strict population homeostasis. Population growth seems to be in some way be related to population size itself in some way. It is plausible that an increasing population size or density¹¹ can also be associated with increasing living standards and population growth. A higher population density encourages specialization, which can be an efficient way to organize labour, encourage higher human capital. Higher population density may also increase the demand for new technology.¹² Transportation, communication, and access to ideas would also increase with increasing population density. Similarly, if innovations appear largely by chance, more people imply more novel ideas and innovations. A larger population can also maintain more knowledge at the same time (S. Ghirlanda, Enquist, & Perc, 2010; Lehmann, Aoki, & Feldman, 2011). Throughout the 19th century, a number of political economists criticized Malthus¹³ and suggested that increasing population pressure might stimulate adoption and innovation that could counter diminishing returns (Hutchinson, 1967, pp. 152-202). The economist Ester Boserup examined the relationship between population density and innovation in Sub-Saharan Africa (Boserup, 1965, 1981), and found that higher population density on average increased the adoption of better agricultural techniques and technology, and increased both welfare and population growth. Any such positive dependencies between population size and welfare will be referred to as Boserupian in contrast to a negative dependency in a Malthusian model.

To illustrate both Boserupian and Malthusian relationships, consider as an example the population of medieval Europe. The population varied around 50 million inhabitants between 1000 and 1500 C.E (Livi-Bacci, 1999). If we assume a population over 700 million, similar to the population in the 2010s, living standards

¹¹ Note that throughout this manuscript I will treat population density and population size as analogous concepts. AIn the short-term populations will likely resort to migration when facing resource constraints, but in the longer run the destination population will face similar demographic pressures. At equilibrium population density and population size can then be treated as analogously. Most obviously Earth itself is for the foreseeable future a closed population system, in which population density and population size are identical. However, migration remains an important practical concern when attempting to test population theories using empirical data.

¹² When using technology throughout the article it is defined in very broad terms as any cultural institution, idea, capital investment, or way of live, which is associated with productivity. As such, it also reflects institutional and cultural change broadly and not only technical engineering inventions.

¹³ Thomas Sadler in 1830, Friedrich List in 1841, and John McCulloch in 1846, all clearly and forcefully argued that better innovation and better agricultural techniques could and would be applied to counter diminishing returns (Hutchinson, 1967).

would have been very low. If, however, the population would only have been 10 000 individuals in all of Europe, it seems clear that such a population would not have been able to maintain the specialization and technology that Europe had during the middle ages, and that all the spare land and abundant resources would have been of relatively little use. A higher living standard, and plausibly higher population growth, would lie somewhere in between those extreme cases. Accounts of the economic and demographic history of Europe in the middle ages makes it plausible that Europe was close to its maximum population size given available resources around 1340, before the plague reduced the population of Europe (e.g. Livi-Bacci, 1999). The large population size in European before the plague resulted in that much sub-standard land and over labour-intensive cultivation was used, and that average living standards would have been higher at a lower population density. This implies that at some point, between 50 million and 10 000 average living standards would have been higher than at 50 million, though exactly at what point is very hard to estimate. It also implies that at the lower bound of that range, an increasing population, increased welfare and population growth, while at the upper bound (and above that range) the opposite would be true.

A homeostatic Malthusian model in which population growth is negatively correlated population size, and growth is high at low population size, and negative at higher population sizes, is described in figures 1-3. A key assumption of a Malthusian model is that higher population size is associated with lower welfare (figure 1). The relationship between welfare and population growth is assumed to be positive as vital rates (births and deaths) respond to greater abundance of resources (figure 2). This gives a negative relationship between population size and population growth (figure 3). The point at which population growth is about 0 is the equilibrium population size, around which a population would oscillate. In an animal population this would be the carrying capacity of the population, and this is also plausible for humans. However, both industrial and pre-industrial human populations may regulate reproduction in ways that would not necessarily result in a population on the brink of population collapse where welfare and wages are close to a subsistence minimum. This was likely the case in pre-industrial Europe, as for example, marriages responded negatively to increasing population size and decreasing welfare. Technological growth can be seen as an exogenous process which would gradually shift the line in figure 1 upwards, which would result in a period of population growth, followed by oscillation around a new higher equilibrium population size.

Figure 1: Malthusian relationship between population size and welfare

Figure 2: Malthusian relationship between welfare and population growth

Figure 3: Relationship between population size and population growth in a Malthusian model

It is, as discussed early, likely that for some population levels an increasing population or higher population density could increase welfare. If such a relationship is true for any population size (as in figure 4) this would create a model with population size increasing towards infinity. If such a Boserupian relationship is dominant at lower population sizes (figure 4), but that ecological pressures would result in a negative relationship at higher population sizes (as in Figure 2), the relationship between population growth and population size would instead be roughly curvilinear as described by figure 5.¹⁴ In figure 5 a combined Malthusian and Boserupian relationship is described at a given technological level, but it is possible that such processes would also increase the equilibrium population size over time. Boserupian processes such as increased intensification of land or adaptation spurred by increasing population density may stimulate technological growth, and allow higher and higher equilibrium population sizes. It is easy to construct such a model in which population size will grow forever. However, given the nature of

¹⁴ It is not necessary to make any assumptions on the functional form of the relationships in any of figures 1-5 except that below some population level, an additional person increases welfare monotonically, and at above that population level there is instead a monotonic decline for each additional person. It also seems reasonable that population growth is above 0 for a very tiny population (though this is not necessary, there are examples on animal species that face extinction if population size fall below a small population size, a famous historical case is the North American passenger pigeon). There must also be some population level for which population growth turn negative, as the model would otherwise predict a population size that would move towards infinity.

exponential population growth, it is clear that a population cannot increase infinitely, and at some point each new individual must have a negative effect on the average welfare in a population. This implies that at some population size the relationship between population and welfare must turn negative also in such a model, and a relationship roughly like what is described in figure 5 should be accurate. As in a Malthusian model such a combined Boserupian-Malthusian model would have an equilibrium population size, at which the population would eventually oscillate around. However, unlike a Malthusian model, increasing population size would at lower population sizes increase population growth.

Demographers have empirically estimated how welfare is affected by population size, and how demographic rates, and consequently population growth, responds to changes in welfare. Economic demographers and historians examining European historical population have used wages in agriculture as a measure of welfare and resource availability, and found that when population increases this is associated with lower wages (as in figure 1). The elasticity of this effect seems to be about -1 (a 1% increase in population size, decreases wages by 1%), which is very substantial (Lee & Anderson, 2002). Social scientists have also examined how vital rates (i.e. population growth) have responded to changes in wages, primarily for fertility but also mortality. Researchers have consistently found that increasing prices and lower real wages reduce population growth (as in figure 2, e.g. Bengtsson, Campbell, & Lee, 2003; Lee, 1987; Tsuya, Feng, Alter, & Lee, 2010), though the magnitude of this relationship is weaker than for the effect of population size on wages. Similar relationships underpin ecological models on animals where similar strong effects between resources and population growth are observed (Lee, 1987; Sibly & Hone, 2002).

In preindustrial populations, it is clear that the relationship between population and welfare was Malthusian, and for most of human history it seems clear the human population size was regulated by welfare dependent homeostatic mechanisms (Lee, 1987). However, equally striking is the great, though gradual, increase in global population size over time. The rapid increase in population size during and after the industrial revolution is particularly striking. A explanation for this observation is that technological growth is exogenous and that human innovation increased largely independent of population size or density. This increase in technology resulted in increasingly high productivity allowing higher population size. Such a relationship could be seen as exogenous shifts to the right in the relationship shown in figure 3, allowing higher and higher equilibrium population sizes. However, both theoretically and from empirical evidence (e.g. Boserup, 1965) it seems plausible that a growing population size itself could stimulate adoption of innovative behaviours increasing welfare.

Figure 4: Boserupian relationship between population size and welfare

Figure 5: Combined Boserupian and Malthusian relationship between population growth and population size

If this is the case, technology, and in extension population growth, is under some circumstances positively associated with population size. The broad characteristics of such a relationship combined with a Malthusian relationship at higher population sizes were described in figure 5, but a number of researchers have created more sophisticated models examining such relationships.

Demographers have created analytical models, incorporating dynamic processes in which increasing population size increases welfare. Simple Boserupian models will result in both technology and population size both growing at increasingly rapid pace forever (e.g. the combination of figure 2 and 4) if there is no Malthusian mechanism. However as discussed earlier, population growth has to be bound by some factor eventually. More sophisticated analytical models combine Boserupian and Malthusian processes, and give further insights into how population size and growth interact endogenously and requires formal analytical notation or simulations (Chu & Tsai, 1998; Stefano Ghirlanda & Enquist, 2007; S. Ghirlanda et al., 2010; Lee, 1986; Pryor & Maurer, 1982; Simon, 1977). Such models include further assumptions than the very general relationship described in figure 5.¹⁵ The relationship described in figure 5 has only two necessary assumptions; that for some population size (given abundant resources) there is a positive effect of a larger population to welfare, and that at some much higher population size this relationship must reverse.

Implications of Malthusian and Boserupian population models

Demographic theory on the relationship between population growth and population size has implications for how population ethicists think about the relationship between population size and welfare. If broad implicit assumptions such as a Malthusian relationship between increasing population size and welfare are used to formulate a scenario, it is important to understand why one makes such assumptions. Population ethicists commonly make thought experiments comparing populations of different sizes, with different levels of well-being. For such assumptions, on shape of the function between population size and wellbeing are relevant, which differently predict the effect of one additional person in a population on wellbeing. A common assumption in thought experiments is a Malthusian relationship between high population size and lower well-being. In many

¹⁵ Examples of such additional assumptions in the models are: population sizes necessary to maintain technology, technological knowledge gradually lost over time, and technological growth is made possible from any surplus of resources above what is necessary for pure subsistence.

cases researchers also present a monotonic Malthusian relationship for any population size, and present examples with the highest welfare in populations with only a single individual.

A central conclusion from demographic theory, is that for very large population sizes an additional person will often decrease welfare. While this is not by necessity true at lower population sizes, it will probably always occur at some population size. The very broad relationships sketched in figures 3 and 5 can (at least in the long run) be interpreted as an universal aspect and feature of all biological life, and therefore something that theories on human behaviour should relate to. To analyse contemporary demographic and ethical issues in the present, such theory might give few guidelines to if the population of Earth is too small or too large, as the fundamental relationships described for contemporary societies are contested and many interpretations are plausible (see the following section).

It is important to distinguish between the concepts of optimal population size in population ethics, and equilibrium population sizes as presented here. The equilibrium population sizes do not maximize either average or total (or any other definition of) welfare in the population, unlike the concept of optimal population size. The optimal population size in both a Malthusian and a combined Malthusian/Boserupian model will be smaller than the equilibrium population size (no matter if the optimal population size is based on average or aggregated welfare). A Malthusian population equilibrium where the population size is close subsistence levels, is probably what Parfit (1984) had in mind when he described a thought experiment of a very large population with very low welfare as a setting for “the repugnant conclusion”. The reproduced illustration for the repugnant conclusion of populations of different size with varying welfare (Parfit, 1984, p. 388) is the same as in figure 1 above.

The philosophical concept of welfare or happiness is different from an economic resource perspective on welfare, in which welfare is closely linked to surplus resources. It is plausible to distinguish a concept of a “life worth living” as discussed in population ethics, as different (and in income terms plausibly higher) than an individual with a salary just above subsistence minimum. However, non-material and material treatments of welfare are most likely interrelated, and many researchers assume that they to some extent overlap. A resource-based concept of welfare based on demographic theory suggests that the concept of a “life not worth living” is an unstable and short-term (though possibly recurring) deviation from a population equilibrium. According to demographic theory, population size will revert to intermediate equilibrium size in cases with very high and very low welfare. Adding people with very low welfare, will if a Malthusian model is applied, lower

welfare for everyone and at some point the demographic response of an additional individual would be negative future population growth.

The concept of unlimited reproductive rights gives a high priority to the free choice over reproduction also when significant (Malthusian) externalities exist. Demographic theory suggests that a population with high fertility preferences will move towards a situation with high population size, and low welfare. The equilibrium population size that results is higher, and the (both average and total) welfare is lower, than optimal population size derived from either a total or average view of welfare. Given unlimited reproductive rights, resource availability will regulate eventual population size.

Another implication of resource-dependent homeostatic models is that a population collapse, according to basic demographic or ecological models, results in strong population growth following the initial reduction in population size. A temporary exogenous change in population size is therefore recoverable from and temporary. Effects of population reduction on welfare are therefore also short-term. We also know of the human past that absolute extinction¹⁶ is rare, consistent with demographic theory. Resource-dependent homeostatic models are central in basic ecological models of other species (Sibly & Hone, 2002), though there are also ecological examples of inverse relationships for low population densities (Courchamp, Clutton-Brock, & Grenfell, 1999). Population ethics of future populations are interested in the risk of total population extinction (e.g. Broome, 2010). If the welfare of future populations is not (or only slightly) discounted extinction incurs massive (sometimes close to infinite) welfare losses. However, if homeostatic population models are correct, population extinctions are highly unlikely, at least from gradual processes (e.g. climate change or environmental degradation), if not for sudden discrete catastrophic impacts if they kill an entire population at once (e.g. a gigantic asteroid). Homeostatic population models also have implications for intergenerational justice in population ethics. If population levels and welfare are both likely to revert to equilibrium levels, this may reduce intergenerational inequality for many outcomes, compared.

The concept of aggregated or total welfare is uncommon in population research with both ecological and economic assumptions. In most social science research, a strict “average” view of welfare is used. One reason for such perspectives is that an

¹⁶ With absolute extinction, I mean that the population in an area declines to 0, through vital rates alone, without outmigration, cultural assimilation, or replacement by other populations in the same area. While dramatic, seemingly non-recoverable, population reductions are common, complete extinction appears rare. Famous example such as the Norse population on Greenland where abandoned through migration, and only a few (very inhospitable) Polynesian islands appear to ever have been abandoned, or even more speculatively population died out. Examples of such islands are the Auckland, Kermadec, Norfolk, and Pitcairns islands which all at some point were depopulated, though this likely took place through migration.

individual's resources are predictive of individual behaviour, and as such has explanatory power for a social system (for example the theoretical relationships described in this manuscript). Total welfare on the other hand does not correspond to a meaningful dimension to understanding why individuals in a society act the way they do. It has ethical implications vis-à-vis the concept of optimal population size for welfare, but is not very helpful in understanding the dynamics of individual actors and human population systems.

Populations change through population growth, which only indirectly affects population size, and this lagged effect has many implications. Changing circumstances will typically change mortality and fertility and through that population growth. This means that it is often misleading to look at associations between population size and welfare. This is particularly the case in a cyclical Malthusian model where the correlation between population size and economic wellbeing, differs fundamentally based on the strength of the two different assumptions of a Malthusian model (Lee, 1985). Changes in welfare, will affect population size through population growth, and that population size will respond only slowly.

Populations change through births and deaths, but births add very young people, while people that die are often older (or very young). As such both changes to the birth rate and the death rate will change the age structure, the proportion of individuals in different ages. Similarly, only some people in a population give birth (individuals that are neither very young nor very old), and the proportion of people in childbearing years will determine how many children are born. A consequence of this is that the proportion of young and old people are unlikely to ever be stable, even if in the long run birth rates and death rates are stable. In other words, all changes in vital events will also change the proportion of young and old individuals. Because humans are productive in the middle of their life and young and old individuals require more care, societies redistribute a large amount of resources across the life course in both pre-industrial and contemporary societies (Gurven & Kaplan, 2006; Lee & Mason, 2011). Therefore, an additional birth or death will also inevitably cause a change in the age structure of the population. Intergenerational justice issues related to age structure, and life course flows of resources, are central both to discussions of sustainability of pension systems in contemporary societies, as well as "obligations" or the value of more children in low fertility societies (e.g. Cigno & Werding, 2007; Gál, Vanhuysse, & Vargha, 2018).

What regulates population size in historical, modern, and future societies?

In previous sections, I gave a brief overview of how population size might interact with population growth, and technology at a theoretical level. I have also discussed some implications of such models. Below I will put the previous discussion in relation to empirical evidence from historical demography and demographic theory on how these relationships have changed over time.

Theorizing on population developments on pre-historic human societies universally assume that resource availability regulated population size. The very low global population growth rates the last 50,000 years, with the exception of the last two centuries, is strong evidence for such assumptions. However, we have close to no empirical evidence on actual population developments in the distant past, and as such the historical agricultural societies and dynamics of hunter-gatherer populations in the recent past has instead served as examples on how such relationships might have looked. Complicating such inquiries is that even populations that by all accounts must have relatively stable population size in the past, have at the time of contact with Europeans experienced explosive population growth (e.g. the Polynesians on Tikopia (Firth, 1936, 1965), and the !Kung people (Howell, 1979)).

There is more evidence from historical agricultural societies, where there is strong evidence for Malthusian population dynamics. Both studies using quantitative data relating population growth over time to economic variables (Galloway, 1988; Lee, 1987), as well as in-depth studies of various societal institutions in pre-industrial populations (Drixler, 2013; Firth, 1965) find that populations respond to resources in a Malthusian fashion.

Studies from pre-industrial Europe find that such relationships were substantial, but that they weakened considerably and disappeared during and after the industrial revolution (or at least were dwarfed by other societal changes). In order for a population to respond in a Malthusian homeostatic way to changing resources, population size must affect welfare (more people means lower wages), and welfare must affect population growth (higher wages means higher fertility and survival) (Lee, 1985). In pre-industrial Europe, the former effect was much stronger than the latter, but combined they were important enough to determine long-run population dynamics. As explanatory factors for changes in population in the short term, such dynamics had weak explanatory power, but still a consistent pressure downwards on population growth when population size was above its long-term trend (and vice-versa) was an inescapable determinant for long-term population developments (Lee, 1985). The unimportance for homeostatic tendencies as a short-term determinant relative to its still important role for long-term developments is important

to keep in mind when analysing the relationship between welfare and population growth in contemporary societies. Gradual technological development can either be interpreted as exogenous increases of equilibrium level between population and population growth, or as an endogenous process in which larger population sizes contributed to population growth. The demographic transition in itself is not really inconsistent with homeostatic resource regulation, as it essentially is a period of both rapid income growth and population growth, though at a shorter time scale there seems to be a less clear relationship between short-term income variation and demographic rates (Coale & Watkins, 1986).

Malthus wrote about different “checks” on population. Preventive checks regulate fertility and entry to sexual unions (age at marriage), and positive checks are related to catastrophic mortality and disease related to shortages of resources. The (Northwest) European marriage pattern has been described as Malthusian in that marriage ages dropped and spinsterhood decreased when economic resources were plentiful. This has been described as the most important way in which demographic rates were related to resources in for example pre-industrial England (Wrigley & Schofield, 1981). Mortality rates also increased when resources decreased. However, perhaps the most important determinant of population movements were epidemic diseases largely exogenous to population size, of which the Black Death in 14th century Eurasia is the most well-known case. The role of sudden and unpredictable mortality, and fertility which responded positively to a reduction in population size (and negatively to increases in population size) suggests that fertility was regulating populations in more predictable ways than mortality (Livi-Bacci, 2007). This is in contrast to a contemporary population where mortality is more predictable across years, while fertility cause more variation in population growth and age structure.

After and during the industrial revolution this traditional relationship between economic growth and changed dramatically. This can be interpreted that as that the rate of technological growth, or increase in living standards, for the first time out-paced population growth (though, population growth was still higher than ever). As both living standards and population growth increased simultaneously, and at an increasing pace until the 1960s, a broad homeostatic interpretation of this period is not possible. This is one reason that other factors than macro-level trends in welfare have dominated explanations to understand trends and determinants of mortality, fertility, and marriage, in the social sciences for contemporary societies. It is not possible to understand the fertility transition, the great decline in fertility in the 19th and 20th centuries in Malthusian terms, as welfare increased greatly at the same time as fertility fell. However, the fertility transition can be interpreted in broader homeostatic terms as a way for a population to regain population balance (and as a response to very high population growth).

In contemporary societies, the majority of the population on Earth lives in societies where the vast majority of mortality takes place in post-reproductive ages (United Nations Population Division, 2017). In such a context, fertility is the dominant determinant of population growth. Mortality after age 45 is not at all related to the NRR, or generational replacement. When mortality during and before reproductive ages are low, the difference in population growth between the fertility levels which maintains a stable population (just above 2 children per women), and levels of fertility in high-fertility societies are very substantial. Furthermore, in many populations in the world today the fertility rates are lower than replacement level fertility, and roughly half of the world population between 2010 and 2015 lived in countries with a Total Fertility Rate (TFR) that implied long-term population decline (United Nations Population Division, 2015). As such, fertility dynamics are clearly the major determinant to understand population dynamics in contemporary and future societies. From the individual perspective, it seems clear that people could, if they wanted, have more surviving children than they choose to have. This seems to be the case in the great majority of populations in the world today. This suggests that individual agency and childbearing preferences are the primary determinants for future population size. Individuals on average seem to at some level coordinate their fertility decisions with expectations on other aspects of lives, and on average choose fewer number of children as they judge that the economic, personal or societal costs of higher childbearing are undesirable. If global fertility levels will converge towards level above or below replacement levels seems critical for future population dynamics and the future of human population systems.

Overall, the world is still characterized by great variance in fertility, both across and within countries, and there have been great changes over time. With respect to welfare and fertility, there are many patterns that coexist at the same time that are in some aspects contrary to each other. In most societies, it appears that with respect to economic change and business cycles fertility at the population level has a pro-cyclical relationship today, similar to in the past (Sobotka, Skirbekk, & Philipov, 2011). At the same time, there is a robust cross-sectional association between low fertility and high wealth when comparing different fertility levels in different countries, though this relationship may disappear at very high levels of national wealth (Myrskylä, Kohler, & Billari, 2009). Such cross-sectional inferences from countries at different levels of development can be referred to as reading history sideways (Thornton, 2005), though such a broad relationship is also found when examining long-term time series for countries over time. Within pre-industrial societies, wealthy individuals traditionally have had higher fertility than poorer individuals have. This is partly reversed during industrialization and for a while many societies have seen negative status-fertility differentials between

groups (Skirbekk, 2008), though there is some evidence that some contemporary societies once again might see a positive wealth-fertility association at the within-society level (e.g. Andersson, 2000; Jalovaara et al., 2017). Overall, both in contemporary societies, and throughout the 20th-century female income seems more negatively related to fertility than male income.

How fertility will respond to welfare is critical for understanding the future of human population systems. At large population sizes, it seems inevitable that a broadly Malthusian link between welfare and population growth must exist, that at some population size will reduce population growth and cap population size. From what we know about human population systems and estimates of the carrying capacity of Earth this will most likely be achieved without catastrophic drastic population change, but rather through that humans will choose to have gradually fewer children when they face resource constraints (cf. Cohen, 1996), or in other words resource dependent homeostatic regulation. While a large number children today might be affordable given how much richer we are today than in the past, they are still very costly as a share of income of parents. Economists have suggested that the relative opportunity costs of children have increased with increasing investments in education and that this can explain declines in fertility (Becker & Lewis, 1974). If people eventually globally really desire fewer than replacement level children at current, or future higher levels of development, then a shrinking and not expanding population will be a more important determinant. Under such circumstances, Boserupian relationships will be more relevant than Malthusian relationships for the relation between welfare and population size.

Another dynamic, that like Malthusian and Boserupian welfare dependencies may have a positive effect on future population growth is if subsections of a population with higher than average fertility will have children that have more children than average. Such a mechanism will increase fertility everything else equal (Kolk, Cownden, & Enquist, 2014). If a cultural trait¹⁷ of a parent both increases the number of individuals in the next generation (through higher fertility), and is acquired by those children, this will mean that the high fertility trait will be more common in each subsequent generation. This is true both if this is seen as a phenomenon arising due to shared socialization across children and parents (e.g. great love of children), if it is related to membership of sub-population with which is stable across generations with higher fertility (e.g. an ethnic or religious group), or even as a dynamic of entire populations where membership of that population is also acquired across generations (e.g. two countries with different fertility). In all cases, higher fertility individuals will increase as a share of the

¹⁷ Any cultural or sociodemographic characteristic of an individual associated with fertility.

population over time. A genetic trait is also transmitted across generations and has the same dynamics (Burger & DeLong, 2016), though the process will be much slower than for cultural information. Such inherited fertility dynamics, make very low fertility preferences unstable (unless truly universal). The dynamics will be stronger when fertility is very low and many individuals have no children (and population growth negative). In fact, high pre-industrial fertility can be interpreted as a product of such processes maintaining fertility at a high level, where fertility will always be high enough to move towards a population equilibrium. Whether fertility decline was a result of a one-time unique circumstance or represents transformation that will continue to reoccur in highly developed societies is an open question (Kolk et al., 2014). In a world of low fertility preferences, such a dynamic will serve as a homeostatic mechanism. Similar to resource-dependent homeostatic mechanisms, the effect of inherited fertility may in the short term explain quite little of variance in fertility, while still have an important effect on long-term dynamics.

To solve the puzzles and explain current fertility variation within and across populations remains a challenge to contemporary demographers, though from these empirical observations it is still possible to draw inferences for the future. The most straightforward conclusion is that if fertility remains above replacement rate, the human population will at some point encounter resource limits that will bound human populations. Population growth in all societies has often at spells of time had population growth rates of at least 1%, given harsher socioeconomic circumstances than contemporary individuals face. Such population growth rates are impossible in the medium to long range, given the nature of exponential growth. Given future above replacement fertility levels, some homeostatic mechanism is therefore a necessity. We can also be largely certain that any such mechanism will be related to fertility, as any increases in mortality to substantively affect population growth will not occur.¹⁸ We are also unlikely to run out of resources making human life possible (Cohen, 1996), so such regulations are almost certain to be welfare related as in a Malthusian model. In other words, upper Malthusian bounds exist on human populations which creates an upper bound population growth.¹⁹ If humans will desire fewer children than what is necessary to maintain population size, minimum population sizes required for maintaining current technological levels will become a more important determinant for any relationship between population size and population growth. If highly developed future societies will tend to be character-

¹⁸ For example, the great famines of the 20th century such as in China in the early 1960s and in Bengal in the 1940s had relatively little effect on long and medium term population developments.

¹⁹ Even making wild hypothetical thought experiments such as interplanar travel does not change such boundaries fundamentally (Hardin, 1959)

rized by below replacement level fertility preferences, the amount of government-induced transfers from non-parents towards parents might be one of the most important determinants of future population size and growth.

Conclusions

In this manuscript, I described how there is both theoretical as well as empirical evidence to assume that population size and population growth are endogenously related. This is not surprising as the alternative would be that population change is random and that long-term population developments would be driven by a random walk. The broad theories relating welfare with population change might have weak short-term predictive power but are almost certain to be dominant over longer time perspectives. As population ethics often takes a long-term perspective understanding and engaging with demographic theory may be very productive. Even very general models on how population change might respond to welfare, would may change analytical models in population ethics substantially. The broad Malthusian and Boserupian relationships described in this manuscript are a useful starting point to consider such relationships. To make predictions over the long term for human future populations demographic theory is useful. It gives an overall framework to think about how population change and population size is related. Most uncertainty for future population developments are related to the historically completely novel phenomena of below replacement fertility.

Population ethicists may find a broader engagement and understanding of demographic theory useful from a number of perspectives. A more nuanced discussion of possible positive (Boserupian) as well as negative (Malthusian) effects of additional people on welfare is largely absent from the field. Strong predications from demographic theory may also help population ethicists evaluate different scenarios based on if they are empirically and theoretically plausible or implausible for human populations. This would be particularly useful when population ethics is applied to contemporary policy concerns. From a different perspective, many insights from population ethics are largely absent in demographic discourses. This is particularly true for perspectives on future generations and intergenerational issues, many of which are central in economic demography. Deeper engagement with demographers and population ethicists on these issues may give many new insights.

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