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Population Ethics and the Prospects for Fertility Policy as Climate Mitigation Policy

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ABSTRACT *What are the prospects for using population policy as tool to reduce carbon emissions? In this paper, we review evidence from population science, in order to inform debates in population ethics that, so far, have largely taken place within the academic philosophy literature. In particular, we ask whether fertility policy is likely to have a large effect on carbon emissions, and therefore on temperature change. Our answer is no. Prospects for a policy of fertility-reduction-as-climate-mitigation are limited by population momentum, a demographic factor that limits possible variation in the size of the population, even if fertility rates change very quickly. In particular, a hypothetical policy that instantaneously changed fertility and mortality rates to replacement levels would nevertheless result in a population of over 9 billion people in 2060. We use a leading climate-economy model to project the consequence of such a hypothetical policy for climate change. As a standalone mitigation policy, such a hypothetical change in the size of the future population – much too large to be implementable by any foreseeable government programme – would reduce peak temperature change only to 6.4°C, relative to 7.1°C under the most likely population path. Therefore, fertility reduction is unlikely to be an adequate core approach to climate mitigation.*

1. Introduction

What does the threat of climate change mean for population policy? Much of the debate on this question in the literature has been focused on population ethics, and therefore has mainly involved dialogue within philosophy and related disciplines. *Population ethics* is a subfield of philosophy that asks when and whether an increase or decrease in the size of the population is a social improvement, or would be a good goal for policy to pursue. For example, one classic question in population ethics is whether policy-makers should try to maximise average well-being or total well-being. Some philosophers have worried that, because ethicists have not settled the theoretical questions of population ethics, and because population must be an important component of climate policy, policy-makers cannot yet know what should be done about climate change.

The purpose of this special issue is to broaden the dialogue between population ethicists and empirical demographers. In this paper, we present some demographic facts and arguments, with the goal of informing debates in population ethics about climate policy.[1] For example, a recent philosophy paper begins 'In recent years increasing numbers of moral and political philosophers have argued than an adequate response to global environmental challenges, such as climate change, requires adopting policies that will either slow down global population growth or even reduce global population size.'[2] But, empirically, is it correct that such policies would be feasible and would meaningfully influence climate change? Whether or not debates in population ethics are relevant to climate policy depends, in part, on empirical questions such as this one.

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In fact, global population growth *already* has slowed down substantially from its historically exceptional peak rate of over 2 per cent per year in the mid-20th century to around 1 per cent now. The growth rate is expected to continue falling and converge to zero. Although the size of the population doubled in less than 40 years in the second half of the 20th century, it is projected to never double again (Lam, 2011). The size of the population is projected to peak shortly after the beginning of the 22nd century (Gerland et al., 2014). After that, the size of the human population is projected to decline.

In what the UN calls 'more developed regions' there are about 1.27 billion people now, and there are projected to be about 1.28 billion in 2100.[3] Asia, overall, is projected to move from 4.6 billion now only to 4.8 billion in 2100: in between, the population of Asia will peak and begin to decline. The outlier is sub-Saharan Africa, where fertility remains high, so population size is projected to quadruple from a little below 1 billion now to 4 billion in 2100.

Mid-20th century population growth was caused by a temporary excess of fertility over mortality: mortality fell quickly as a result of economic and human development and especially advances in public health, infectious disease, and sanitation. Fertility rates have taken a few decades to follow downwards. However, because mortality rates can only fall to zero and not below, this one-time transition cannot be repeated. Under any foreseeable demographic trajectory, the rapid population growth of the 20th century was a one-time event.

Therefore, the practical policy question is not whether population growth rates should decline (they already are) or whether there should be a peak size of the human population (there will be, in about 100 years or so). The practical policy question is whether steps should be taken to make the ongoing fall in fertility rates proceed *even more quickly*. If so, the region where fertility rates are high enough that there is scope, in principle, for faster decline is sub-Saharan Africa – where emissions per capita are currently low. Fertility is substantially shaped by the behaviour and choices of women and families. Survey evidence shows that, across developing countries and years, achieved fertility is highly correlated with intended fertility (Pritchett, 1994; our Figure 2, below). Although many historical fertility policies have been coercive and harmful (Connelly, 2009), we assume that readers of this paper are interested in voluntary or incentive-based policies that come at only low to moderate social cost to present generations. So, a plausible policy that substantially accelerated the decline in fertility rates would have to be implemented by states or institutions (especially in sub-Saharan Africa), to influence average concepts of *ideal or desired* fertility in those populations, rapidly enough to make a difference on the near-term timeline that is relevant to climate policy.

We argue, based on empirical demography, that this is quantitatively implausible as a central tool for climate mitigation policy.[5] Fertility reduction, as a consequence of human development policy, may play a part in the response to climate change, but it is not the case that population size must, should, or can be the core of a sufficient climate mitigation policy. Moreover, if fertility policy comes at the political opportunity cost of pursuing other climate mitigation policies (here, we do not argue that it necessarily would), then a focus on population as the core of an emissions-reduction strategy is unlikely to succeed.

Section 2 situates our argument within the literature on population and climate policy. Section 3 introduces population momentum and the narrow scope for change in population growth rates in coming decades. We examine the consequences for climate outcomes of one particular hypothetical population policy that instantaneously changed fertility and mortality rates to replacement levels. As a separate observation, Section 4 observes that achieved fertility is highly correlated, across populations, with intended fertility. If fertility is high in some populations due to high desired fertility (and not, for example, due to unmet need for contraception) then fertility-reduction may be hard to achieve as a policy goal. Section 5 concludes.

2. Our argument, and its place in the literature

The purpose of this paper is to highlight some empirical facts about population science and climate change, and to connect those facts to debates in the population ethics literature. In this section, we begin merely by noting that there are many mechanisms listed in the literature by which population and climate policies may interact. What population ethics will have to say about a policy option depends, in part, on which mechanism is in question.

2.1. Our question, among mechanisms in the literature

Many arguments are made about population and climate change, resulting in a literature that can appear to disagree when authors are in fact answering different questions. Here, we note at least four theoretical and empirical mechanisms by which population and climate policy could interact:

(i) **Effects of population size on emissions: Population-reduction policy as climate mitigation policy**. If there are more people, and if emissions per capita remain unchanged or similar, then the flow of emissions per time period would increase (O'Neill et al., 2012). As a result, temperature change will be greater, all else equal. This fact has motivated a debate over whether policy should attempt to reduce the size of the near-future population, as a climate mitigation policy tool, to reduce carbon emissions.

(ii) **Consequences of the exogenous size of the future population for optimal forward-looking mitigation policy**. Mechanism *ii* is a consequence of the size of the future population, in the special case where climate policy is being chosen to promote overall social well-being.[6] If there are more future people because of an exogenous difference in the population path, then more future people will be exposed to temperature changes, and therefore harmed by climate change. As a result, the harm done by carbon emissions today is greater, so the optimal level of present-day carbon emissions is lower. Scovronick et al. (2017) and Budolfson et al. (2018) show, using a leading climate-economy model, that this mechanism has a quantitatively important effect on optimal near-term emissions policy. Such an effect depends on the choice of social welfare function (that is to say, different theories in population ethics), because different social welfare functions incorporate the size of the future population in different ways.[7] To emphasise, under this mechanism the population path is not the core emissions-reduction strategy: Mechanism *ii* holds that there additionally exists a core emissions-reduction strategy, such as a carbon tax, and that the exogenous path of the future population changes how large that carbon tax ideally should be.

(iii) **Effects of climate change on the size of the future population: Empirical**. Climate change – directly through temperature or indirectly through disease, drought, and other mechanisms – could change mortality rates, including for babies, and could change fertility rates.[8] Over the long run, climate change could cause large changes in the size of the human population, relative to a future in which temperatures stayed at pre-industrial.

(iv) **Effects of climate change on the size of the future population: Population ethics**. Mechanism *iv* assumes that Mechanism *iii* is correct and that climate change will importantly change the size of the future population, such as by causing fewer lives to be lived. Philosophers who study population ethics (or, in particular, population axiology, which focuses on how population size impacts rankings of goodness) ask whether the absence of such lives worth living counts as a social cost that policy should try to avoid. In other words, if it is true that climate change will cause some lives that would have been good to instead never be lived at all (because the people are not born), does this *consequence* of climate change count as a *cost* of climate change?

We have previously studied Mechanism *ii* in Scovronick et al. (2017). We have investigated *iii* and *iv* in depth in Arrhenius, Budolfson, and Spears (2019), and do not focus on them here. Mechanism *i* is the focus of this paper. Our objective is to bring facts and insights from empirical demography into the debates of population ethicists and others. In short: would fertility policy 'work' as climate mitigation policy? Can policy-makers hope to limit temperature change through a strategy of reducing the size of the population.

2.2. Our argument

We consider Mechanism *i*: the policy consequences of the possible effect of the size of the population on emissions. In fact, throughout this paper we assume for the sake of argument that there is an effect on the size of the population in a near-term time period, under near-term technology, on the rate of carbon emissions. Nothing in this paper argues against the possibility of a large effect of the size of the future population on emissions. But what would this assumption, if true, imply for population policy?

Our question is not whether current fertility levels are optimal or whether a lower fertility level would be optimal (we take no stance here). Our question is also not whether it would be a desirable policy outcome for all women to have access to reproductive health care and broad social equality (it certainly would be). Our question is: *given actual constraints on demographic change, governance, and policy-making attention, is fertility-reduction likely to be a quantitatively successful climate mitigation policy?* We argue that it is not.

Note that, because we are asking about states and related institutions, we do not take a position on the question whether parents have a right to have more than one child (Conly, 2016) or whether it is wrong to create or not to create a particular life (Roberts, 2019), or on any other question about one woman or family's procreative behaviour. To be clear: expanding access to reproductive health care and promoting human development objectives such as education and social equality are desirable goals. Moreover, these goals perhaps should receive even more resources than they otherwise would, in a tradeoff against some competing policy priorities (such as, for example, balancing government budgets), because of their implications for climate change.[9] However, reducing fertility should not be a first-order priority *as a substitute for other climate mitigation policies*. We also emphasise that our arguments depend on empirical premises: if there were a surprising opportunity to pursue a human development policy that reduced fertility while also making present-day people better-off and without crowding out more effective climate mitigation policy, then we would have no objection – but we expect that the effect of such a policy on temperature change would be small.

Our argument is based on three empirical observations, for which the body of this paper reviews empirical evidence:

(1) Population projections are highly certain over the coming decades, which is the time period when effective climate mitigation must occur.
(2) The regions where population projections are more uncertain, and therefore where fertility could fall, are places with low emissions per capita. In particular, uncertainty is highest in sub-Saharan Africa.
(3) On average, achieved fertility is highly correlated with intended fertility. So, policy to reduce fertility would have to change *intended* fertility. It is not fully understood why intended fertility remains high in sub-Saharan Africa.

So, our argument is a pragmatic one: intended as an emissions-reduction strategy, fertility policy by near-term governments is unlikely to have climate mitigation benefits that exceed the social costs, which include any opportunity costs of pursuing other climate mitigation strategies. We address two questions: what possible changes in the near-term size of the human population are plausible, and could actual governments plausibly achieve them at acceptable social costs? One seeming paradox might be an apparent contradiction between Observation 1 and Observation 3: how can the future path of the population be accurately projected, if fertility intentions remain poorly understood? The next section presents the explanation: population momentum.

3. Population momentum bounds the possible consequences of fertility policy for the coming decades

Population momentum is demographers' term for the fact that the size of the population would continue to increase even if the total fertility rate[10] (TFR) hypothetically instantaneously dropped from higher levels to replacement levels.[11] Population momentum occurs because today's baby girls will grow up to be women of reproductive age. So, if there are more girls at each pre-childbearing age than there currently are women at each childbearing age, then more babies than today will be born when those girls begin having children, even if fertility per mother is held constant. As a result, demographers can be highly certain that population in sub-Saharan Africa will continue to grow, even if the rate of decline over time in fertility intentions is suddenly accelerated. In particular, even if total fertility rates instantaneously changed to replacement levels in every country around the world (which would be an extreme outcome that no known policy could effect), the population in 2060 would still have about 9 billion people, or almost one-fourth more people than are alive today.

3.1. Global population uncertainty, relative to the urgency of climate mitigation

Figure 1 puts population possibilities in context by plotting possible population futures against the size of needed climate policy. Future population paths are taken from the 2017 UN World Population Prospects. For each year, for each projection, the graph plots the percent reduction in the size of the population, under that path, relative to population in that year under the UN's median path. Four population reduction paths are plotted. Two are for the UN's low 80 per cent trajectory and two are for the UN's low 95 per cent trajectory. These low trajectories are the bottom of 80 per cent and 95 per cent confidence intervals, respectively, for the future population.

To clarify, these probabilities reflect the UN's formal *statistical model* of population uncertainty (Gerland et al., 2014), Such a model is constructed by making and testing a range of assumptions about the possible uncertainty in future fertility and mortality rates, and especially about the correlations in the possible futures for these rates across populations. This permits the construction

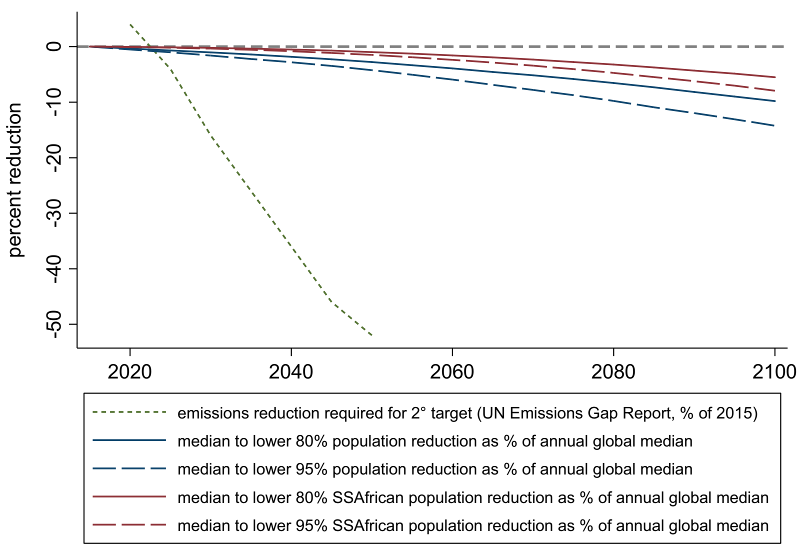

Figure 1. Population uncertainty is small relative to emission decline targets.

Note: Authors' computations from UN data. Population projections for illustration are taken from UN World Population Prospects probabilistic projections, which are not intended to represent alternative policy paths. Emissions reduction from 2017 UN Emissions Gap Report. SSAfrican = sub-Saharan African.

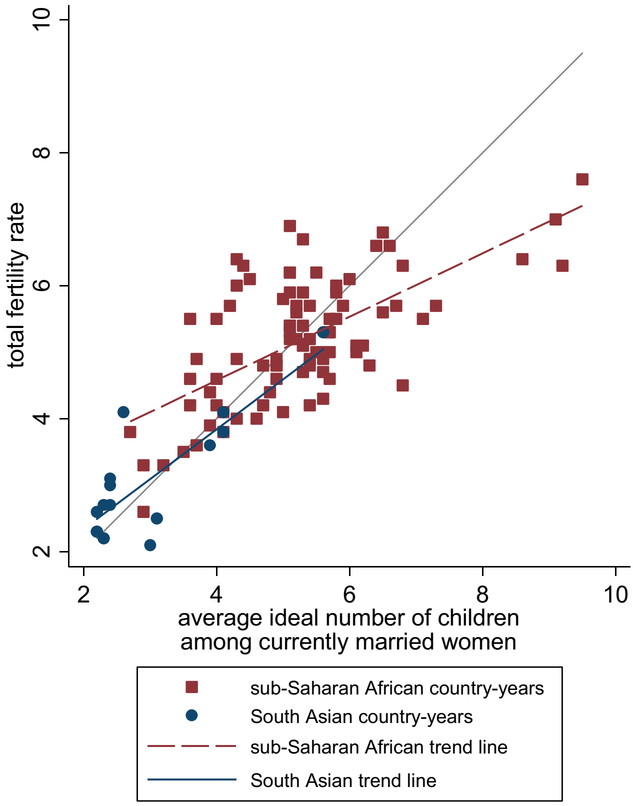

Figure 2. Survey-reported ideal fertility is highly correlated, across developing country-years, with achieved total fertility rates.

Note: Authors' computations from DHS sample survey data. Observations are all Demographic and Health Surveys conducted since 2000. For earlier data, see Pritchett (1994) and Lam (2011). The vertical axis, total fertility rate, is a period rate for the three years prior to the survey, based on period age-specific fertility rates of women 15–49.[4] The thin line is the 45° line of equality between achieved and intended fertility.

of a statistical confidence interval, such as the 80 per cent interval that we use. In other words, the UN projects that there is an 80 per cent chance that the future population path will be within the low path and the high path (the high path is not used to produce this figure). That said, this confidence interval, like any, is model dependent: if the UN's model is mistaken, or if the future is more radically different that demographers can project, then there is a possibility of deeper uncertainty. (This is one reason why we investigate a momentum-only path below, which is a mechanical, rather than a statistical, low path for plausible future population size.)

For each of these 'low' paths, the figure plots the percent by which the low path is below the median path. In this way, the figure is intended to roughly quantify approximately how small the future population could plausibly be, relative to the most likely path. The graph includes two versions of each low path: a version in which the whole world takes the low rather than the medium population path, and a version in which only sub-Saharan Africa take the low path, while the rest of the world remains on the medium path. Although it is not plausible that only sub-Saharan Africa would deviate in this way, this exercise is useful for demonstrating that a large fraction of the uncertainty in the size of the future population comes from uncertainty in the size of the future African population.

Also plotted in Figure 1 is the percent reduction in emissions needed to meet a 2° climate change target, according to the 2017 UN Emissions Gap report (UN Environment, 2017). The graph compares percent reductions in population with percent reductions in emissions, because O'Neill et al. (2012) empirically compute an elasticity of approximately one: a one percent reduction in the size of a population would result in an approximately one percent reduction in emissions. However, there is still an important dissimilarity between the emissions line and the population line: the emissions line plots percent reductions *relative to what emissions were in 2015*, while the population lines plot percent reductions *relative to population in that year on the median path*. Even on the lower 95 per cent path, population size is expected to increase over the 21st century and be well above 9 billion in 2100.

Two conclusions are evident in Figure 1. First is that, for the coming decades, the uncertainty in the size of the future population is small. Even by 2100, the UN projects that it is unlikely that the population would be even 10 per cent smaller than the most likely path. Of course, these probabilistic projections are not designed to reflect alternative population policies. Nevertheless, they show that the size of the population is substantially fixed over the coming decades.

The second conclusion from Figure 1 is that the possible variation in the size of the future population is small relative to the needed decline in emissions. The Emissions Gap requirements stop at mid-century, by which time emissions are needed to have fallen dramatically. By 2050, the lower 80 per cent population path is not even 3 per cent below the median path. Any fertility-reduction policy that seeks to meet a large fraction of this emissions gap would have to cause a reduction in the size of the near-term population that would be much larger than even a slowdown in the growth of population size that demographic projections consider very unlikely.

3.2. Separating Mechanism *i* from Mechanism *ii* in a climate-economy model

Figure 1 presented possibilities for future population size in contrast with needed emissions reductions, but did not compute the consequences of alternative population paths for climate change. That is the task of this section. Here, we use Nordhaus's Dynamic Integrated Climate-Economy (DICE) model, a core part of the work for which Nordhaus shared the 2018 economics Nobel Prize (Nordhaus & Sztorc, 2013). The DICE model takes an exogenous population path as an input and computes an optimal path over time of carbon taxes, which results, in the model, in an optimal path over time for mitigation policy and decarbonisation. DICE can also be used to project economic and temperature consequences under business as usual,[12] where it is assumed that there is no large intensification of mitigation policy.

Table 1 presents results for four population paths: the UN's median population projection, the two unlikely low population projections, and a conceptually-minimal population path that reflects only the effectively inevitable consequences of population momentum. The 'momentum only' path is the result of a hypothetical exercise in which fertility and mortality rates are immediately (more precisely, in 2015, when our version of the DICE model first permits policy changes) brought to replacement levels, so any future population growth is due only to the age structure of the population (as more girls age into their reproductive years).[13] To emphasise, no foreseeable policy

Table 1. Peak temperature and optimal taxes in a leading climate-economy model

	Future size		Business as usual (Mech. *i*)		Optimal mitigation (Mech. *ii*)	
Population path	2060	2100	2020 tax	Peak temperature	2020 tax	Peak temperature
Median	>10.2 b	11.2 b	–	7.1°C	$25.19	3.1°C
Lower 80%	9.8 b	10.1 b	–	6.7°C	$23.27	3.2°C
Lower 95%	9.6 b	9.6 b	–	6.5°C	$22.37	3.2°C
Momentum only	9.0 b	9.0 b	–	6.4°C	$21.58	3.2°C

Note: Authors' computations from Nordhaus' DICE 2013 model. 'Peak temperature' is the peak temperature increase relative to pre-industrial.

implementable by governments could have such an extreme outcomes as the 'momentum only' path as a plausible consequence. Moreover, because any realistic fertility policy actually could not happen 'immediately,' any actually feasible change would be much smaller than this.

The 'business as usual' column illustrates Mechanism *i*, the focus of this paper. These estimates ask how much peak temperature would change if only the population path changed, but mitigation policy did not otherwise become more aggressive. In other words, the business as usual results ask how much mitigation in temperature increase could be achieved only by reducing population growth. The result of the computation is that even a hypothetically large, more-extreme-than-achievable, instantaneous change in population growth rates would only, as the core mitigation strategy, reduce peak temperature from a disastrous 7.1°C to a still-disastrous 6.4°C. Such a reduction in the temperature change would be an improvement, but not enough of an improvement to constitute a sufficient substitute for other mitigation strategies.

The 'optimal mitigation' columns illustrate Mechanism *ii*, which was the focus of Scovronick et al. (2017), although that paper did not consider the population-momentum-only path. In these computations, Nordhaus' DICE model computes the optimal path of carbon taxes, assuming a given population path. Two facts are noteworthy about these projected peak temperatures. First, they do not vary widely; this is because the model optimises mitigation policy to avoid too-large temperature change.[14] Second, peak temperature is lower under the lower-growth population path. This is despite the fact that a larger population produces more emissions for a given level of per-capita economic activity and technology. The explanation is that, when the future population will be smaller, fewer people will be harmed by climate change, so the model finds it optimal to mitigate less aggressively. This feature of the model's optimisation is visible in the decrease in optimal near-term carbon taxes as future population size decreases. This result is the core of Mechanism *ii*: a smaller future population may not be enough to single-handedly reduce temperature to acceptable levels, but in the context of optimising policy, it could be a reason to decide to incur smaller mitigation costs.

3.3. Other possible changes in the structure of the population: regional allocation, urbanisation, migration

So far, we have only considered possible changes to the total size of the future population, and we have only considered changes within the 21st century. There may be other ways in which a Mechanism *i* effect of the population could operate on emissions, that we do not consider. For example, it may be that the very-long-term sustainability of economic development or survival of the population is improved by the steady state size of the population being 9 billion rather than 12 billion, after such a time as 'backstop' technology has replaced carbon emissions, and through a mechanism other than the effect of population size on carbon emissions and therefore peak temperature. This is a longer-term question than 21st century climate policy.

Alternatively, it may also be that the nearer-term composition of the population – its allocation across places – matters for carbon emissions. For example, the age structure of the population, the fraction of the population in the labour force, and the fraction living in rural rather than urban places all predict carbon emissions. At least one such dimension of heterogeneity, however, deepens the challenge: fertility rates are highest (and have the most room to fall) in countries where emissions per capita are low – meaning sub-Saharan Africa, in practice. A fertility policy designed to reduce carbon emissions might reasonably focus on the richest countries, but it would have to overcome the fact that in many of these, fertility rates are already historically low and below replacement levels.

In short, although these complications may be important to some questions and may present valuable policy opportunities, it remains quantitatively unlikely that fertility reduction could achieve the level of mitigation called for – in its extent and in its pace – by the Emissions Gap Report.

4. Achieved and intended fertility

The 'momentum only' projection in Table 1 is merely a theoretical possibility. What would it take to achieve a large decline in fertility rates? In a population where fertility rates are high, an important question is whether women and families *intend* to have high levels of fertility, or whether they would prefer lower levels of fertility but their *achieved* fertility exceeds their intended fertility, perhaps because of lack of access to reproductive health care (Coale & Watkins, 1986). If achieved fertility exceeds intended fertility, then there may be an opportunity for policy to reduce fertility by improving access to contraception. If achieved fertility matches intended fertility, then the policy challenge may be deeper for a programme to reduce fertility. In that case, policy would have to induce women to *want* fewer children, a goal that would interact with cultural ideas about fertility as well as economic costs of and opportunities to invest in children's schooling and human capital. Changing parents' perceptions of returns to schooling or ideal family sizes may take decades, even for successful, well-designed programmes.

Figure 2 illustrates the issue. It is an update of a graph first drawn by Pritchett (1994). Here, each dot reflects the average outcome of a Demographic and Health Survey, which means that each dot is one developing country in one year. Country-years in South Asia are plotted as circles and country-years in sub-Saharan Africa are plotted as squares (countries in other regions are omitted for clarity). The message of the figure is that survey-reported ideal fertility is highly correlated with achieved total fertility rates, also as measured by demographic sample surveys. In other words, the countries where women have many children are the countries where women report wanting many children. The correlation is not perfect, but it is not small for empirical cross-country research. Moreover, the slope of the trend line is not far from one-to-one. Taken together, these results suggest that mere prevision of contraception may be unlikely to be enough to quickly and substantially accelerate the decline in fertility rates.[15]

Another conclusion visible in Figure 2 is a correlation between geography and fertility: fertility rates are higher in sub-Saharan Africa than in South Asia (where fertility in some countries is already at or near replacement levels). As Figure 1 showed, much of the entire world's uncertainty in future population growth is due to uncertainty in the size of the future African population. Frontier empirical and theoretical research in population science debates alternative explanations for why fertility remains high in sub-Saharan Africa. Africa is poorer, but its fertility is higher even when economics is held constant. Tanzania's total fertility rate in 2016, for example, was almost two-children-per-woman larger than India's was in the year when it had the same GDP per capita that Tanzania did in 2016; Nigeria's TFR in 2016 was about three children larger than India's in the year when it had Nigeria's 2016 level of economic wellbeing (The Economist, 2018). It would be a further challenge for policy to reduce intended fertility in sub-Saharan Africa if social scientists indeed do not yet fully understand its causes.

5. Conclusion

One of the core questions of population ethics is how policy-makers should weigh changes in average wellbeing against changes in population size. If fertility-reduction policy were a promising tool for reducing carbon emissions, at acceptably low social cost, in the places where emissions are high, on a time scale relevant for climate policy, then population ethicists would have an urgent open task to complete. We would need to know whether such policies were worth it: would it be an improvement, all things considered, to prevent some lives from being lived, so that climate change would be less severe? Because the theoretical questions of population ethics are far from consensus, this would be a worrying need. Fortunately – if not otherwise, at least for this aspect of practical policy-making – we have computed that fertility-reduction policy making is unlikely to be a promising use of scarce political capital and policy attention, as a focal near-term tool of climate mitigation. Of course, this does not mean that human development policy that has the consequence of reducing fertility rates might not be valuable for other reasons. Two such possibilities that we do not consider here are non-climate environmental consequences and consequences for non-human animals. We also do not consider non-climate externality effects of population size for humans, such as any effect of population size on science and technological progress.

This also does not mean that the size and the growth of the human population may not be an important input in to climate policy-making for reasons other than Mechanism *i*. However, the practical unimportance of Mechanism *i* partially deflates the argument, common in the philosophical literature, that we must resolve the theoretical questions of population ethics before knowing what to do about climate change. We suspect that, once the empirical facts are correctly registered, any plausible approach to population ethics would conclude that rapid and aggressive decarbonisation should be a policy priority. Aggressive mitigation, in technical terms, is a dominating corner solution (Arrhenius et al., 2019).

As a final note, despite our arguments in this paper, it is good that development professionals and population ethicists are in dialogue in this symposium, because population ethics is one component of aggregate social welfare. 'Policy evaluation' has recently been implicitly redefined, in practice, as near-term, local empirical average impact evaluation. These empirical quantities, such as from a microeconometric experiment, are important to know. But a social objective or axiology is necessary to evaluate whether or not a policy is, all things considered, socially desirable. Although we have argued that the choice of population axiology would not turn out to make an important difference to near-term optimal decarbonisation policy, the choice of axiology may make a difference to other potential development policies that have further implications (perhaps including unintended implications) for population growth. So, population ethics could prove to be even more important to development policy than to climate policy.

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Notes

1. The arguments in the paper build upon, and in some places summarise for an audience of population axiologists, the work of prior empirical demographers and social scientists, including Pritchett (1994), Connelly (2009), Lam (2011), O'Neill et al. (2012), and Bradshaw and Brook (2014).
2. This quotation is the opening of Caney (2019); we highlight this thoughtful paper here not to criticise it, but to illustrate the literature in which it participates.
3. Each projection in this section is from the median of the 2017 revision of the UN World Population Prospects.
4. If readily available, we would endorse an adequate set of human development policies that have fertility reduction as a side-effect, or even some human development policies with a fertility-reduction goal as among a large group of 'climate policy wedges' (Pacala & Socolow, 2004), each making their small contribution.
5. As Scovronick et al. (2017) show, this mechanism operates for the selection of optimal policy and also for the selection of the optimal way of achieving a (potentially non-optimal) temperature target.
6. If population size is exogenously held fixed, some theories in population ethics become identical to one another. For example, total utilitarianism, average utilitarianism that averages over all time, and Ng's (1989) Theory *X*' that incorporates all time would all three rank identically any set of policies in which population size is held constant. However, other social welfare functions in the literature, such as Asheim and Zuber (2014) Rank-Dependent Generalised Utilitarianism, could disagree with these three, even in cases where population size is held constant.
7. Some recent papers that document or project effects of temperature on mortality include: Sherwood and Huber (2010), Barreca (2012), Barreca, Clay, Deschenes, Greenstone, and Shapiro (2016), and Geruso and Spears (2018). See Spears

(2019) for a review. In particular, Sherwood and Huber note that humans may not be able to survive exposure to combinations of heat and humidity that could plausibly occur under climate change, in which the human body would not be able to cool itself by sweating. Climate change might also increase the variance of the size of the future population (Spears, 2015).

8. This is what we show in Scovronick et al. (2017). Investments in human development that result in a very low population trajectory would substantially reduce the costs of climate mitigation policy, in a comparison of optimal climate mitigation policy under a very low population trajectory versus optimal climate mitigation policy under a business-as-usual population trajectory.
9. The *total fertility rate* of a cohort is the average number of children had over the course of a childbearing career by women who survive their entire childbearing career. Period TFRs are computed by assuming that a synthetic cohort experiences the age-specific fertility rates that prevail in a population in a given period.
10. This portion of our argument builds upon related prior arguments by Bradshaw and Brook (2014), although they do not apply their observation to the climate-economy modelling that is the novel contribution of this section.
11. Here and in what follows, by 'business as usual' we simply refer to the implications of the very low control rates in the 'baseline' scenario of Nordhaus's DICE2013, which involve very little mitigation.
12. Note that, for countries with negative natural population increase, this exercise could increase fertility rates.
13. Many readers may consider 3.2°C to be too large of temperature change, and disagree with DICE that this outcome is the optimal balance of mitigation costs and climate damages. We do not take a position on this debate, and only use the DICE model to illustrate the mechanisms that are the focus of this paper.
14. The horizontal and vertical axes of Figure 2 both reflect data from the women's ('individual') questionnaire from the Demographic and Health Surveys. The population base for this weighted, clustered random sample is all women age 15–49. The horizontal axis includes all surveyed women in this age range who are currently married.
15. Indeed, it is a common finding in health policy for developing countries that providing hardware is not enough, when behaviour change is necessary. Coffey and Spears (2017), for example, document the case where providing latrines is not enough to sufficiently accelerate the decline in open defaecation in rural India, because many people do not use them. In the case of open defaecation in India, like in Connelly's historical study of population policy, the unfortunately consequence has sometimes turned out to be state-organised or state-permitted coercion (Gupta et al., 2019).

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