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SOCIALLY EMBEDDED PREFERENCES, ENVIRONMENTAL EXTERNALITIES, AND REPRODUCTIVE RIGHTS

Aisha Dasgupta
(United Nations Population Division)

Partha Dasgupta
(University of Cambridge)

We review a class of adverse environmental externalities that accompany consumption and procreation. We also identify externalities that are traceable to socially embedded preferences for family size. Those preference structures can give rise to a heightened demand for children, exacerbating the environmental externalities households impose on future generations. Our analysis exposes weaknesses in basing family planning programmes entirely on individuals' reproductive rights. We use ecological data to obtain a feel for the size of global environmental externalities. We estimate the size of world population the biosphere can support at the standard of living enjoyed in the World Bank's list of high middle-income countries. Today's global population and future population projections far exceed our estimate, implying that the UN's Sustainable Development Goals are in all likelihood unsustainable. We conclude that family planning has been undervalued greatly by national governments and international agencies. Our purpose is to pose questions that continue to be neglected in the development literature. We do not offer forecasts nor make policy recommendations.

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Socially Embedded Preferences, Environmental Externalities, and Reproductive Rights

by

Aisha Dasgupta* and Partha Dasgupta**

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* United Nations Population Division
e-mail: <dasgupta@un.org>

** Faculty of Economics, University of Cambridge; and New College of the Humanities, London
e-mail: <partha.dasgupta@econ.cam.ac.uk>

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Abstract

We review a class of adverse environmental externalities that accompany consumption and procreation. We also identify externalities that are traceable to socially embedded preferences for family size. Those preference structures can give rise to a heightened demand for children, exacerbating the environmental externalities households impose on future generations. Our analysis exposes weaknesses in basing family planning programmes entirely on individuals' reproductive rights. We use ecological data to obtain a feel for the size of global environmental externalities. We estimate the size of world population the biosphere can support at the standard of living enjoyed in the World Bank's list of high middle-income countries. Today's global population and future population projections far exceed our estimate, implying that the UN's Sustainable Development Goals are in all likelihood unsustainable. We conclude that family planning has been undervalued greatly by national governments and international agencies. Our purpose is to pose questions that continue to be neglected in the development literature. We do not offer forecasts nor make policy recommendations.

Motivation

Among economists and demographers, the dominant view of the impact of growing human numbers on the natural environment has alternated between concern and dismissal. If in the years immediately following the Second World War scholars were anxious that population growth would retard economic development in poor countries, they have not worried in recent decades. In a series of influential reviews of the modern growth experience, NRC (1986), Birdsall (1988), Kelley (1988), Temple (1999), and Helpman (2004) studied cross country data and saw a negligible link - possibly even a small positive link - between population growth and growth in per capita GDP. Their analysis was convincing, but the underlying assumption that economic betterment is best seen in terms of growth in GDP per capita should be questioned. The presence of the qualifier "gross" in gross domestic product (GDP) signals that the measure does not record the depreciation of natural capital that can accompany the production of goods and services.[1] Other things equal, depreciation of natural capital reduces a nation's productive capacity, the correct measure of which is an inclusive notion of wealth. And normative economics tells us that the index we should deploy for assessing the sustainability of human development is the wealth of nations (Arrow et al, 2012), not the GDP of nations, nor the Human Development Index of nations.[2]

A rich demographic literature has offered insights into fertility behaviour in the contemporary world. Those insights have been used by the United Nations to frame family planning programmes (UNFPA, 1995). More recently they have influenced the way family planning has been placed within the UN's Sustainable Development Goals. We apply those insights to argue that the basis on which women's desired family size are elicited mis-estimate their desire. More importantly, they under-estimate their needs.

Parental desires and needs constitute one set of factors in population ethics. Another set of factors is the effect on others of a household's reproductive behaviour. Ehrlich and Holdren (1971) coined the metaphor *I=PAT* so as to trace humanity's *i*mpact on the biosphere (more generally, the Earth system) to *p*opulation size, *a*ffluence (income per capita), and "*t*echnology"-in-use (including knowledge, institutions, social capital). The authors observed that Nature responds to the demands we make of it, not to rates of change in those demands nor to rates of change in the rates of change in those demands. Their observation has not had much influence

[1] The term "natural capital" is now in routine use among ecologists and economists to remind us that Nature is a capital asset with both intrinsic and use value. In what follows we use the terms "Nature", "natural capital", and "the natural environment" synonymously. The influence of human numbers on the natural environment is beginning to be noted again in demographic writings. See, for example, Birdsall, Kelley, and Sinding (2001), Bryant et al. (2009), and Jiang and Hardee (2011).

[2] The latter index was proposed by UNDP (1990) and has been revised and updated by the organization ever since.

on either economics or demography. That the growth rate of global population has been declining in recent years is seen among development experts as a hopeful sign of a transition to sustainable development (World Bank, 2016); in fact it does not say much about the prospect of realizing sustainable development. Under foreseeable technological developments, a long run population of 10-11 billion can be expected to make a far greater demand on the biosphere than one of, say, 3 billion. Recent books that have drawn attention to the remarkable gains in the standard of living that we have enjoyed during the past century have focussed on advances in scientific knowledge and the accumulation of manufactured and human capital; the state of the biosphere and its trends accompanying that progress have for the most part gone unnoted (Micklethwait and Wooldridge, 2000; Ridley, 2010; Deaton, 2013; Lomborg, 2014; Norberg, 2016). But humanity's future will be shaped by the portfolio of assets we choose to hold and the balance we strike between them and the size of our population. It should be a concern, or so we argue below, that the enormous economic success we have enjoyed in recent decades may be a down payment for future failure.

Among the visible products of the biosphere are food, fibres, fuel, and fresh water; but many of the services it provides are hidden from view. Ecosystems maintain a genetic library, preserve and regenerate soil, fix nitrogen and carbon, recycle nutrients, control floods, mitigate droughts, filter pollutants, assimilate waste, pollinate crops, operate the hydrological cycle, and maintain the gaseous composition of the atmosphere. As most of those services are not visible, it is all too easy to overlook them. Some environmental stresses are global, many are spatially localized; some occur slowly and may therefore miss detection until it is too late, while others are all too noticeable and a cause of persistent societal stresses. The wide divergence of environmental problems may explain why there are tensions among the senses of urgency people express about carbon emissions and loss of biodiversity that extend beyond nations, regions, and continents; about degradation of the oceans arising from the energy and materials we release into them; about the hardship communities face when grasslands transform into shrub-lands; and about declines in firewood, water sources, and soil productivity that are specific to the needs and concerns of the poor in small, village communities.[3] Environmental problems differ in regard to their location, and in their spatial and temporal scales. Which is why it is possible to be optimistic about humanity's collective ability to overcome environmental problems if one studies small-scale environmental successes (Balmford and Knowlton, 2017) but to be deeply worried if one looks at continued failure to stem, say, global biodiversity loss. As we will see presently, contemporary data at the global level tell us that environmental successes have to date been few and far between.

Environmental scientists have compiled data on the state of the biosphere and its

[3] For extended discussions on the place of Nature in the lives of the world's poor, see Dasgupta (2003, 2007, 2010).

changing character over past decades (MEA, 2005a-d). Corresponding data at local levels are scattered and range from the detailed to nothing. But global happenings are an aggregate of large numbers of local happenings. Below we develop an analytical framework for studying fertility behaviour and humanity's impact on the natural environment at local levels (Part I) and use aggregate data to obtain a quantitative feel for the impact at the global level (Part II). We find that the difference between our demand of Nature's goods and services in the aggregate exceeds Nature's ability to supply them by a considerable margin. Our hope is that the framework we construct will point, at least partially, to the way the balance between population size and the portfolio of our assets could be struck.

Externalities

Processes driving the balance between population size and the portfolio of assets we hold harbour externalities, which are the unaccounted for consequences for others of actions taken by one or more persons. The qualifier "unaccounted for" means that the consequences in question follow without prior engagement with those who are affected.

The way we have formulated the notion of externalities could appear ineffective, on grounds that our actions inevitably have consequences for future generations, who by the nature of things cannot engage with us. In fact future people engage with us constantly, albeit indirectly. Parents care about their children and know that they in turn will care about their children. By recursion, thoughtful parents take the well-being of their descendants into account when choosing the rates at which they save for their children and invest in them. Intergenerational engagement would be imperfect if parents choose without adequate concern for their children (e.g. if they discount the future well-being of their children at overly high rates). Externalities across the generations would be rampant in that case. We ignore that line of analysis here. Our aim is to study systematic reasons why choices made even by thoughtful parents do not reflect adequate engagement with *others*' descendants. As they are symptoms of institutional failure, externalities cannot be eliminated without considered collective action. That is why reasoned reproductive decisions at the individual level can nevertheless result in collective failure.

Two broad categories of externalities are studied here. One consists of the consequences of household consumption and reproduction that work through open access resources ("the commons"). That's the familiar variety of externalities, much noted and studied by environmental economists (e.g. Baumol and Oates, 1975). Institutional failures in this class of externalities arise from an absence of appropriate property rights to Nature's goods and services. By property rights we mean not only private rights, but communitarian and public rights too. One reason rights over natural capital are difficult to define, let alone enforce, is that Nature is constantly on the move (the wind blows, particulates diffuse, rivers flow, fish swim, birds and insects fly, and even earthworms are known to travel undetected). No one can contain the atmosphere they befoul. That means the price paid by someone for environmental services (that's the private cost) is less

than the cost borne by all (that's the social cost). In cases involving the global environment, such as the atmosphere as a sink for our carbon emissions, the damage an individual suffers from her own emissions is negligible even though the damage to all from the climate change that arises from everyone's emissions is large and positive. From the collective point of view there is excessive use of the atmosphere as a carbon sink. The environmental externalities our use of open access resources gives rise to are adverse.

The other category of externalities we uncover here has been less studied in the literature. It arises because our desire for having children is in part influenced by the number of children others have. No doubt a single household cannot much influence others, but the aggregate effect of all households on one another is not negligible. We show that the social embeddedness of household preferences - we call the resulting behaviour "conformist" - can lead to high fertility even when those same preference structures can sustain low fertility that households would prefer. Either situation - high fertility (allied to low educational attainment of children) or low fertility (allied to high educational attainment of children) - can sustain itself by its own bootstrap. Fertility transitions can be interpreted as moves from one equilibrium to the other.

The two classes of externalities have very different internal structures. The problem of choice in the use of open access resources resembles the well-known Prisoners' Dilemma. In contrast, socially embedded preferences give rise to Coordination Games. The latter class of externalities can be, and has been, turned by communities to their advantage by coordinating behaviour (e.g. through an appeal to social norms); whereas the former requires, at least over the global commons, more traditional policy measures such as environmental regulations.

Plan of the Paper

When they are adverse, the moral directives that externalities point to can be at odds with the exercise of rights to protected spheres of action. In Part I (Sections 1-5) we study the clash of rights among contemporaries and between present and future people. We then study the implications of those clashes for the design of family planning programmes. In attributing "rights" to future people we mean just that. We are appealing to a widely shared view, that no matter who and how many our descendants happen to be, they will have a justifiable claim to a reasonably abundant resource base. Future people's personal identities don't matter in this context.

The question arises whether the environmental externalities we identify here are quantitatively significant. To explore that we adopt an approach that makes use of global estimates of humanity's demand for the biosphere's products and services relative to their supply. That exercise is conducted in Part II (Sections 6-10).

In Section 1 we review the legal philosopher Charles Fried's proposed distinction between positive and negative rights. We apply the distinction to study the clash between the moral directives flowing from adverse environmental externalities and the exercise of personal

rights. That acts as a backdrop for Section 2, where it is recalled that prominent social scientists have been known to insist that there are no environmental externalities arising from procreation.

In Section 3 we explore the interplay of parental motivations and socio-ecological constraints that help to explain differences in reproductive behaviour across regions and across socio-economic groups within regions. We look briefly also at what has been called "African exceptionalism" in reproductive behaviour and identify a class of inter-household externalities that may have contributed to high fertility rates in that region. Socially embedded preferences are identified in Section 4 as a source of inter-household externalities, sustaining high fertility rates. We note possible mechanisms by which behaviour stemming from such preferences can be redirected toward lower fertility rates. None of the mechanisms involves taxation or coercion.

A central plank of family planning programmes is the idea of reducing "unmet need". The way unmet need is measured, however, is hugely circumscribed, inasmuch as it is derived from the respondent's expressed wants, or desire, for biological children. There are two problems here. First, the methods that are currently deployed for measuring want underestimate it. Secondly, in matters of life and death human needs operate on a wider space than wants or desires. This is anothere reason the methods that are currently deployed for measuring unmet need underestimate it. But even if unmet need is to be inferred from expressed desires, the methods deployed underestimate it. In Section 5 we meet the first problem by suggesting ways to reframe questionnaires so as to enable family planning agencies to discover people's considered preferences for children. We show also that the UN's Sustainable Development Goals include a measure for judging the success of family planning programmes that potentially creates wrong incentives to officials overseeing the programmes. Our analysis reveals that family planning programmes are undervalued by national governments and international agencies.

By how much? To determine that, we have to go beyond measuring unmet need and try to quantify environmental externalities. Unfortunately estimates of the environmental externalities traceable to procreation are sparse. Customary methods for measuring externalities infer people's willingness to pay for Nature's products and services from their behaviour or from their expressed preferences. Those methods are unavailable for reaching global estimates; nor are they appropriate for the purpose in hand. We circumvent those problems by studying global statistics on natural capital and identify key processes that drive the biosphere (Sects. 6-7). Such information isn't sufficient for quantifying the benefits of family planning programmes, but it offers a way for estimating the annual global demand we make of the biosphere and compare it to the annual global supply. That is done in Section 8, where we report that demand has for some time exceeded supply. The finding says we are drawing down natural capital and therefore that environmental externalities are substantial. In Section 9 we provide crude estimates of the global population that the biosphere can support at a comfortable standard of living. The gap between the figure we reach and the current size of the world's population is substantial. Our estimate

could be viewed as an overestimate of what lies in the future, inasmuch as sustainable population at a comfortable living standard would be higher if future technological advances economize on the use of natural capital. On the other hand, our estimate could be viewed as an underestimate of what lies in the future, inasmuch as global population has been projected to rise to 11.2 billion by the end of the century and the United Nations via their Sustainable Development Goals have simultaneously encuraged us to expect significant increases in per capita incomes. Whether resource saving technological advances are likely to blunt humanity's demands for Nature's products and services even as economic activities increase is, of course, a matter of speculation; so we identify reasons why technological changes in the past have been rapacious in the use of natural capital and suggest policies that would create incentives to innovate in technologies that have a lighter touch on Nature's products and services.

The analysis in Sections 8-9 is based on figures based on global averages. Central to the UN's Sustainable Development Goals, however, is poverty alleviation. In Section 10 we study the impact of poverty alleviation measures on the global demand for Nature's goods and services. Our analysis uncovers yet another clash of rights among contemporaries and between present and future people.

Although the externalities we classify here arise in all contemporary societies, a salient contrast obtains between rich (high consuming) societies with low desired family-size, and poor (low consuming) societies with high desired family-size. Environmental externalities arising from the activities of people in rich countries are included in our analysis (they are due to the high consumption enjoyed by new births over their lifetime). Simple calculations show too that contemporary global environmental problems cannot be traced to high fertility in the poor regions of the world. Nevertheless, we focus our study on reproductive behaviour in the world's poorest region, sub-Saharan Africa, because desired family size there is strikingly large in comparison to standards elsewhere today and because the costs of the correspondingly high population growth rate can be expected to be borne in great measure by future Africans themselves. The benefits of family planning programmes have been routinely under-estimated by the international community, but perhaps most conspicuously, at least until recently, that too only in a few countries, by governments in sub-Saharan Africa (Section 11).[4]

[4] By providing access to subsidized contraceptive commodities and services, family planning programmes were successful in accelerating fertility declines in Asia and Latin America in the 1960s-1980s. The rationale for vigorously expanding the content and reach of such programmes today lies in the 189 million married/in-union women of reproductive age in the developing world (41 million in sub-Saharan Africa) who have an unmet need for modern methods of contraception; that is, they report they do not want to get pregnant but are not using any modern method (UNPD, 2016). In addition to reducing unintended births, contraceptive use among women enhances their own health and that of their children by spacing births. And yet family planning remains a neglected feature of public policy. Currently less than 1 per cent of overseas development assistance is awarded to it. Moreover, developing countries relegate family planning expenditures to minor government departments. Despite evidence that family planning

Part I

1 Rights

The legal philosopher Charles Fried distinguished "positive" from "negative" rights (Fried, 1978). We are to think of positive rights as a claim *to* something, a share of material goods or some particular commodity such as education when young and medical attention when in need. A negative right is a right that something *not* be done to one, that some particular imposition be withheld. Fried observed that positive rights are asserted to scarce goods and that scarcity implies a limit to their claim. He also suggested that negative rights, for example the right not to be interfered with in forbidden ways, do not appear to have such natural limitations. ("If I am let alone, the commodity I obtain does not appear of its nature to be a scarce or limited one. How can we run out of people not harming each other, not lying to each other, leaving each other alone?" (Fried, 1978: p. 110)).[5]

Fried's dichotomy is useful for studying the place of rights in family planning programmes. But his suggestion that the exercise of negative rights doesn't involve costs is questionable. The claim that one's proximity should not be contaminated by cigarette smoke is a negative right, which is violated when someone smokes in that proximity. To protect that right, governments in many countries prohibit people from choosing at will where they smoke. That's a cost to smokers. In contrast, a right to exercise one's agency would appear to be a positive right (e.g. freedom of speech), but it doesn't inevitably demand resources from others. It isn't so much that negative rights don't suffer from resource limitations whereas positive rights do, it is more that the two sets of rights have separate frames of reference. The contrasting phrases, "right to self-determination" and "right to have an imposition withheld", point in different directions.

The 1994 International Conference on Population and Development reaffirmed the language of rights in the sphere of family planning and reproductive health. The widely noted publication that reported the Conference's conclusions stated:

"Reproductive rights ... rest on the recognition of the basic right of all couples and individuals to decide freely and responsibly the number, spacing, and timing of their children, and to have information and means to do so, and the right to attain the highest standards of sexual and reproductive health." (UNFPA, 1995: Ch. 7, Sect.3).

The qualifier, "responsibly", could be read as requiring couples to take into account the adverse environmental externalities their reproductive decisions may give rise to; but that probably would be a stretch. Certainly, writings affirming the UN declaration have interpreted the passage and its intent more narrowly. For example, the fundamental right of individuals "to

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reduces poverty, the World Bank does not have family planning at its core.

[5] The binary classification of rights corresponds to Isaiah Berlin's classification of freedom into positive and negative categories (Berlin, 1959).

decide freely and for themselves, whether, when, and how many children to have" is central to the vision and goals of *Family Planning 2020* (FP2020). It is also pivotal in the reproductive health indicators of the United Nations' Sustainable Development Goals. Both positive and negative rights are in play here. Rights to information and other services pertaining to family planning and reproductive health are positive rights. The right to choose one's family size on the other hand would appear to be a negative right.[6]

Even though Fried's classification is not without problems, it is useful for studying the relationship between "externalities" and "rights". First, to insist that the rights of individuals and couples to decide freely the number of children they produce trump all competing interests is to play down the rights of all those (most especially, perhaps, future people) who suffer from the environmental externalities that accompany additions to the population. Secondly, UNFPA's statement ignores the latent need among those who do not want family planning now but would want it if others among their peer group were using modern contraceptives. We study the two in turn.[7]

2 Ours vs Theirs

That reproductive decisions may involve a clash of rights isn't self-evident. In a powerful essay that dismissed concerns on over-population, Bauer (1981: 61-64) wrote: "The comparatively high fertility and large families in many ldcs (less developed countries) should not be regarded as irrational, abnormal, incomprehensible or unexpected. They accord with the tradition of most cultures and with the precepts of religious and political leaders... Allegations or apprehensions of adverse or even disastrous results of population growth are unfounded. They rest on seriously defective analysis of the determinants of economic performance; they misconceive the conduct of the peoples of ldcs; and they employ criteria of welfare so inappropriate that they register as deterioration changes which are in fact improvements in the conditions of people."

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[6] Kumar and Hardee (2015) offer a useful manual for family planning programmes based on the protection and promotion of reproductive rights.

Rights had been deployed as an ethical category in discussions on family planning and reproductive health previous to the 1994 International Conference on Population and Development. Hardee et al. (2014) provide an excellent account of the history. The authors also provide a framework for achieving the goals of FP2020. Cottingham et al. (2012) offer an account of the power of the language of rights in encouraging governments and international agencies to provide the resources needed to meet women's "unmet need" for family planning and reproductive health facilities (see Section 5).

[7] Brock (2010) contains an interesting discussion of possible clashes between parental rights and societal interests and how societies variously resolve them. But he was not concerned with the clash that is embodied in environmental externalities. The tension between reproductive rights and sustainable development has been commented upon rece ntly (e.g. Hardee, 2014; Newman et al, 2014), but it would appear not to have influenced development thinking within the Unitd Nations, at least not so far.

One problem with Bauer's critique is that it gives the impression that societies in past eras were characterized by large families. But if fertility rates were high then, so were mortality rates high; and high fertility rates are a rational response to high mortality rates. The contemporary demographic problem in the world's poorest regions is that fertility rates remain high even though mortality rates have fallen considerably (Sect. 3). The main problem with Bauer's critique, however, is that even when men and women at the household level prefer large numbers of children to small numbers, it doesn't follow there isn't a resource allocation failure they themselves would acknowledge if only they were asked. As in every other field of personal choice, we should ask whether a collection of reasoned decisions at the individual level may harbour collective failure. This is the central question raised by externalities, and it has particular potency in the case of adverse externalities and socially embedded preferences.

That family planning services bring in their wake many benefits (health, education, income, women's empowerment) to those who make use of them has been documented repeatedly in recent years (Koenig et al., 1992); Debpuur et al., 2002; Cleland et al., 2006, 2012; Tsui et al., 2010; Canning and Schultz, 2012; Sonfield et al., 2013; Bongaarts, 2016; Miller and Babiarz, 2016). Our focus on externalities points to the fact that they bring benefits to others as well. Those additional benefits should be included in the design of social policies. We will find that indicators currently in use by governments and NGOs of the value of family planning services underestimate it.

Policies for curbing adverse reproductive externalities can in principle take several forms. Education, especially female education, is one route; many argue it is the most effective route (Lutz et al., 2014). But that can take time, and female education is not the only factor driving fertility.[8] Another tool involves demonstrative persuasion, which can be attempted through community discussions on the need for behavioural change. The agency of persuasion could be the community, NGOs, or the state.[9] A further tool is taxation, which permits people to choose as they wish, but at a price. Although taxation as a device for curbing environmental externalities is familiar in wealthy countries, it is not an available tool for reducing the demand for children in poor countries, where the poorest households are most often the ones that have the highest demand. A further policy tool is quota, such as China's previous directive of one-child family, or the government's recently revised two-children-per-couple directive.

Quotas are an extreme form of non-linear tax schedule: zero tax up to the quota,

[8] World Bank (2012) reported that in 2010 the proportion of people who completed primary education was, in India 96%, in Pakistan 67%, and in Bangladesh, 65%. Total fertility rates (TFRs) in those countries were 2.6, 3.4, and 2.2, respectively. It should also be noted that in Bangladesh non-governmental organizations at work on social matters have a far more extensive reach than in India and Pakistan. Reproductive behaviour is not mono-causal.

[9] Nudge theory advocates a weak version of that idea. See Thaler and Sunstein (2008).

followed by a severe tax beyond it. (The "tax" need not be monetary, it could be strong collective disapproval.) An alternative to taxing people if they exceed their quota is to reward people if they stay within their quota. We are thinking of "quota" here in the same way as people think of quotas when they are imposed as food rations in periods of extreme shortage, compulsory vaccination against communicable diseases, and prohibition on smoking in public spaces. The former policy ensures equality in the distribution of a positive right; the latter pair protect and promote negative rights. Forced sterilization is a distorted and repugnant application of quotas. Coercion should remain unacceptable.

The classification of externalities we uncover here suggests a variety of policy tools for reducing fertility rates. The tools differ in terms of the extent to which the right to self-determination is compromised. None are likely to prove uncontroversial. The issues remain unsettled.[10]

3 The Demand for Children and African Exceptionalism

People have children for many reasons. The mix of motivations depends on the customs and institutions we inherit, as well as on our character and circumstances. That children are valuable in themselves is emotionally so compelling that it may seem too obvious to require acknowledgement, but social anthropologists have shown that children are valuable to us not only because of our innate desire to bear and rear them, but also because they represent the fulfilment of tradition and religious dictates and because they are the clearest avenue open to self-transcendence. One such injunction emanates from the cult of the ancestor, which, taking religion to be the act of reproducing the lineage, requires women to bear many children.[11] This latter motivation was used by Caldwell and Caldwell (1990) to explain why sub-Saharan Africa has for the most part proved so resistant to fertility decline.

A weakness of the argument is that, although it explains why fertility rates in sub-Saharan Africa are high (total fertility rate there is 5.1 today; in contrast to 2.5 in India, 1.6 in China, and the global TFR of 2.5), it does not explain why the rates have not responded as much to declines in infant mortality as one could have thought on the basis of evidence elsewhere.[12] Even in sub-

[10] Sen (1982) likens the emission of persistent pollutants to torturing future people. The clash between reproductive rights and adverse environmental externalities allied to new births is at its most striking under his reading.

[11] Writing about West Africa, Fortes (1978: 125-6) said "... a person does not feel he has fulfilled his destiny until he or she not only becomes a parent but has grandchildren... (Parenthood) is also a fulfilment of fundamental kinship, religious and political obligations, and represents a commitment by parents to transmit the cultural heritage of the community ... Ancestry, as juridically rather than biologically defined, is the primary criterion ... for the allocation of economic, political, and religious status."

[12] Between 1965 and 2015 the infant mortality rate in sub-Saharan Africa declined from about 150 per 1,000 live births to something like 60 per 1,000 live births.

Saharan Africa fertility rates have been below the maximum possible rate. Below we study possible reasons why the response has been slower than was expected. We should expect the force of the reasons to vary across regions within the sub-continent. Under increased urbanization some will have also weakened over time (e.g. the cult of the ancestor). But because quanttative evidence of their relative significance aross regions is patchy, we merely list them here.

In places where formal institutions are underdeveloped, children also substitute for other assets, and are thus also valuable for the many benefits they bring to their parents. This is most apparent in the poorest regions of the world. Children serve as security in old-age in places that have neither pension schemes nor adequate land markets. They are also a source of labour in households possessing few labour saving devices. Children mind their siblings, tend to domestic animals, pick berries and herbs, collect firewood, draw water, and help with cooking. The need for additional hands is especially strong among rural communities in dry and semi-arid regions of the world. Children in poor countries are valued by their parents also as capital and producer goods. (In South Asia children have been observed to be at work from as early an age as six.)

Caldwell (1981, 1982) put forward the hypothesis that the inter-generational transfer of resources is from children to parents in poor societies, but from parents to children in rich societies. The suggestion has been easier to confirm in rich countries, where the rate of investment in children's education has been found to be as high as 6-7 per cent of GDP (Haveman and Wolfe, 1995). Confirming the reverse flow in poor countries has been a lot harder, in part because data are sparse but in part also because even within poor regions there are significant differences in attitudes toward reproduction. Those differences are traceable to kinship structures, marriage practices, and rules of inheritance. The implied line of thinking says that over the long run it is differences in institutions and social norms - originating perhaps in some measure in geography - that are the reasons behind differences in reproductive behaviour among groups. This form of analysis says that high child mortality rates spur fertility because of parental need to increase the probability of not being childless in old age. Theoretical models have been built on the premise that institutional failure, broadly defined, is the deep cause of pro-natalism. Causality isn't traced to differences in income or wealth. It is not that fertility and mortality rates are high and health status and education attainments are low in poor regions because people there are poor, it's that very low incomes go hand in hand with those features of life. Each variable influencs the others over time; in the long run they are mutually determined.[13]

A potential source of reproductive externality is the wedge between the private and social

[13] For theoretical models that speak to the mutual determination, see Dasgupta (1993, 2000), Brander and Taylor (1998), Harford (1998), Dasgupta and Ehrlich (2013), and Bohn and Stuart (2015). The mutual determination doesn't entail a demographic trap, but it may. See in particular Dasgupta (2000: Appendix).

costs of child rearing. The costs borne by parents are lower when child rearing is shared among the kinship than when households are nuclear. In sub-Saharan Africa fosterage within the kinship is a commonplace. Children are not raised solely by their parents, the responsibility is more diffuse within the kinship group (Caldwell, 1991; Bledsoe, 1990, 1994). Fosterage in the African context is not adoption. It is not intended to, nor does it in fact, break ties between parents and children. The institution affords a form of mutual insurance protection in semi-arid regions. As savings opportunities are few in the low-productivity agricultural regions of sub-Saharan Africa, fosterage also enables households to smooth their consumption across time. In parts of West Africa up to half the children have been found to be living with their kin at any given time. Nephews and nieces have the same rights of accommodation and support as do biological offspring. There is a sense in which children are seen as a common responsibility; which makes it important that in surveys that seek to identify desired numbers of children (Sect. 5) it is made clear that what the questionnaires mean is biological children. However, the arrangement creates a free-rider problem if the parents' share of the benefits from having children exceeds their share of the costs. The corresponding externalities are confined to the kinship. Other things equal, reduction in those externalities would be accompanied by a fall in the demand for children and all households would benefit.[14]

Related to this is a phenomenon that has been observed by Guyer (1994) in a Yoruba area of Nigeria. In the face of deteriorating economic circumstances, some women bear children by different men so as to create immediate lateral links with them. Polyandrous motherhood enables women to have access to more than one resource network. Children are a further form of wealth for their mothers. Desired fertility is consequently higher.

The idea of wealth-in-people has been developed by anthropologists to reflect the additional status and other social advantages that are conferred on women in some African societies by having children (Guyer and Eno Belinga, 1995). There is a formal resemblance here to Veblen's account of status in an entirely different context, namely, conspicuous consumption in the Gilded Age in America. In the present context, desired fertility is higher because of the

[14] To see that there are no externalities if the shares were the same, suppose c is the cost of rearing a child and N the number of couples within a kinship. Assume that each child makes available y units of output (this is the norm) to the entire kinship, which is then shared equally among all couples, say in their old age. Suppose also that the cost of rearing each child is shared equally by all couples. Let n^* be the number of children each couple other than the one under study chooses to have. If n were to be the number of children this couple produces, it would incur the resource cost $C = [nc+(N\text{-}1)n^*c]/N$, and eventually the couple would receive an income from the next generation equalling $Y = [ny+(N\text{-}1)n^*y]/N$. Denote the couple's aggregate utility function by the form $U(Y)\text{-}K(C)$, where both $U(.)$ and $K(.)$ are increasing and strictly concave functions. Letting n be a continuous variable for simplicity, it is easy to confirm that the couple in question will choose the value of n at which $y\mathrm{d}U(Y)/\mathrm{d}Y = c\mathrm{d}K(C)/\mathrm{d}C$. The choice sustains a social equilibrium when $n = n^*$. It is easy to check that this is also the condition which is met in a society where there is no reproductive free-riding. It follows that there is free-riding if the parents' share of the benefits from having children exceeds their share of the costs.

competition fueled by the desire for status. It leads to a collective loss in well-being.

Communal land tenure of the lineage social structure in sub-Saharan Africa has offered yet another inducement for men to procreate: a greater amount of land can be claimed by a larger family. In addition, conjugal bonds are frequently weak, so fathers often do not bear their fair share of costs of siring a child. Anthropologists have observed that the unit of African society is a woman and her children, rather than parents and their children. Frequently, there is no common budget for the man and woman. Descent in sub-Saharan Africa is, for the most part, patrilineal and residence is patrilocal (exceptions are the Akan of Ghana and the Chewa of Malawi). That depresses women's voice; and because women bear a disproportionate amount of the costs of reproduction, it raises the fertility rate. Patrilineality, weak conjugal bonds, communal land tenure, and a strong kinship support system of children, taken together, have been a broad characteristic of the region. In principle they provide a powerful stimulus to fertility. Admittedly, patrilineality and patrilocality are features of the northern parts of the Indian sub-continent also. But conjugal bonds are substantially greater there. Moreover, as agricultural land is not communally held, large family sizes lead to fragmentation of land-holdings. In contrast, large families in sub-Saharan Africa are (or, at least were, until recently) rewarded by a greater share of land belonging to the lineage or clan.[15]

4 Socially Embedded Preference Structures and Conformism

That children are a parental end (and not just a means toward other parental goals) provides a potentially powerful mechanism by which reasoned fertility decisions at the level of every household could lead to an unsatisfactory outcome from the perspectives of all households. It arises from the possibility that traditional practice is perpetuated by conformity. Reproductive decisions are not only a private matter; they are subject to social mores, which in turn are influenced by both family experiences and the cultural milieu. But social mores are shaped by the behaviour of all. There is circularity in this, which we can unravel by supposing that household preference structures are socially embedded. Behaviour is conformist when the family size each household desires is positively related to the average family size in the community

[15] In an early review of fertility intentions Cochrane and Farid (1989) noted that both the urban and rural, the educated and uneducated in sub-Saharan Africa have more, and want more, children than their counterparts in other less-developed regions. Even young women there expressed a desire for an average of 2.6 more children than women in the Middle East, 2.8 more than women in North Africa, and 3.6 to 3.7 more than women in Latin America and Asia. Updated versions of these figures are available, but we are presenting data from the mid-1980s because the income gap between Africa and the rest of the developing world was smaller at that time than it is now.

African society's exceptionalism has been much written about. See in addition Goody (1976), Bledsoe and Pison (1994), Bongaaarts (2011), and Bongaarts and Casterline (2013). But changes have been observed, at least in East Africa. Fostering is declining, land registration is increasing, and urbanization is eroding pronatal institutions. Whether those changes will markedly influence fertility rates in the near future isn't clear. And delay matters to Africa's future prospects (Sect. 11). We are grateful to John Cleland for helpful discussions on this.

(Dasgupta, 1993: Ch. 12).

Douglas and Ney (1998) urged us to regard consumption as an expression of social engagement. Taken literally, that would appear odd, but what authors were pointing to is that a meal taken alone is a different activity from a meal taken communally. Fads and fashion may be short-run expressions of social engagement, what Douglas and Ney showed us is that our need to belong is deep and enduring and expresses itself in a wide variety of ways. We rely on one another for safety, consolation, information, companionship, and governance. Much of our actions are undertaken in a social setting, and all our actions are influenced in part by attention to others.

Whatever the basis of conformism (we discuss that below), there would be practices encouraging high fertility that no household would unilaterally desire to break. Such practice could have had a rationale in the past, when mortality rates were high, population densities were low, natural resources were aplenty, the threat of extermination from outside attack was large, and mobility was restricted. But practices can survive even when their original purposes have disappeared. One reason they can survive is that if all others continue to follow the practice and aim at large family sizes, no conformist household would on its own wish to deviate from the practice; however, if all other households were to restrict their fertility rates, every household would wish to restrict its fertility rate as well. Conformism can thus be a reason for the existence of multiple social equilibria. A society could get embedded in a self-sustaining mode of behaviour characterized by high fertility and low educational attainment, even when there is another potentially self-sustaining mode of behaviour characterized by low fertility and high educational attainment and which is preferred by all.

Socially embedded preferences for children are drawn in Figure 1. The curve ABCDE is the representative household's desired number of children, plotted against the average number of children per household (the horizontal axis). The curve is upward sloping and intersects the 45^{o} line OF at three points: B, C, D. Each is a social equilibrium, at TFRs n_1, n_2, and n_3 respectively. To interpret ABCDE with concrete numbers, imagine that each household regards 5 to be the ideal number of children if all other households have 5 children (n_3 on the horizontal axis)); 4 to be the ideal number if all others have 4 (n_2); and 2 to be the ideal number if all others have 2 (n_1). Imagine now that each household prefers the outcome where all households have 2 children. It can nevertheless be that their society is stuck in a situation where each household has 5 children. It can get stuck because no household would have a reason to deviate from 5 if all other households have 5; which is another way of saying that 5 is a self-enforcing choice. It is easy to confirm that both 2 and 5 are stable equilibria, in that a small deviation from 2 (respectively, 5) would in time return to a situation where each household chooses 2

(respectively, 5). It follows that 5 would be just as tenacious a TFR as 2.[16]

That does not mean society would be stuck at 5 forever. As always, people differ in the extent of their absorption of traditional practice. There would inevitably be those who, for one reason or another, experiment, take risks, and refrain from joining the crowd. They are the tradition breakers, and they often lead the way. Educated women are among the first to make the move toward smaller families.[17] A possibly even stronger pathway is the influence that newspapers, radio, television, and now the internet play in transmitting information about other life-styles (Freedman, 1995, was one of the first to detect that pathway). The idea here is that the media could be a vehicle by which conformism increasingly becomes based on the behaviour of a wider population than the local community (the peer group widens). And that disrupts behaviour.[18]

There have been a number of studies on fertility that point to choices that are guided in part by attention to others. In her highly original work on demographic change in Western Europe over the period 1870-1960, Watkins (1990) showed that differences in fertility and nuptiality within each country declined. She also found that in 1870, before the large-scale declines in marital fertility had begun in most areas of Western Europe, demographic behaviour differed considerably within countries. Differences among provinces within a country were high even while differences within provinces was low. Spatial behavioural clumps suggest the importance of the influence of local communities on behaviour. In 1960 differences within each country were considerably less than in 1870. Watkins explained this in terms of increases in the geographical reach national governments enjoyed over the 90 years in question. The growth of national languages could have been the medium through which reproductive behaviour was able to spread.

Watkins' was a historical study, as were the studies Montgomery and Casterline (1998) made use of to distinguish various pathways by which reproductive practices diffuse within a society. In a commentary on West Bengal (India) where fertility rates declined in the early 1970s ahead of the northern states of India and neighbouring Bangladesh, Basu and Amin (2000) attributed the West Bengal experience to historical and cultural facts there that combined to promote interaction between the elite and the general public. Jensen and Oster (2009) in contrast

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[16] Formally, we are studying Nash equilibria in a coordination game (Dasgupta, 1993; Kohler, 2000). It can be shown that the social equilibrium in which each household has 4 children (n_2) is unstable. It would take us far afield to explain why, but see Dasgupta (2002) for the reason.

[17] Farooq et al. (1987) is an early study that spoke to the phenomenon in West Africa. Lutz et al. (2014) is a collection of essays on the effect of education on fertility behaviour. Interactions among the elite and the general public can be a vehicle by which fertility behaviour among the poor changes.

[18] The media are increasingly used to such end. For example, the Development Media International runs media campaigns aimed at changing behaviour.

have studied a natural experiment. They found that state level fertility rates declined in step following staggered introductions of cable TV in Indian states.[19]

It is a feature of historical studies of the diffusion of behaviour across space and time that they don't necessarily identify the fundamentals on which the diffusion process is built. They also differ from one another in terms of the transmission mechanism. The behavioural fundamentals (or "drivers", as some would call them) could be knowledge acquisition, they could be pure mimicry, they could be what Cleland and Wilson (1987) called "ideation", they could be the advent of modernity, they could be the desire to belong to one's (possibly expanding) group, they could be the force of celebrity culture, and so on. These fundamentals are not unrelated of course, but they are not the same. Regarding transmission mechanisms, it could be that people observe successful behaviour and copy it, it could be that the language in which newspapers are read spreads, it could be that people discuss and debate among themselves, and so forth.[20]

The model in Figure 1 is built on the common structure of all such diffusion processes. Leaving aside the virtue of parsimony, studying the common structure offers the advantage that we are able to analyse the resting (i.e. equilibrium) points of a wide variety of diffusion processes without having to identify the processes themselves. Our model is analytical, not a historical narrative. It assumes that fertility preferences are socially embedded, but it doesn't specify the reasons households are influenced by the behaviour of others. Being analytical, the model is able to entertain counterfactuals. It allows us to ask how a household's behaviour would differ if the social parameters underlying the curve ABCDE were to be otherwise. That's a necessary exercise in policy analysis, because policies can be used to shift the curve ABCDE (therefore the equilibrium points n_1, n_2, and n_3) as well as influence the beliefs on the basis of which households act. The common structure also tells us that fertility transitions can be interpreted as disequilibrium phenomena (Dasgupta, 2002), where practices change slowly in response to gradual changes in the social environment, until a tipping point is reached from which society transits rapidly to a new stable equilibrium, say from high fertility to low fertility.

Socially embedded preference structures don't entail multiplicity of equilibria. We could have so drawn the curve ABCDE in Figure 1 that it intersects the 45^o line OF at a single point. We are interested in multiple equilibria because there is empirical evidence that societies support

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[19] For a wide ranging discussion of the role of societal norms on fertility behaviour, see Bongaarts and Watkins (1996).

[20] Diffusion processes had been studied long before, in connection with technology adoption. In a classic paper, Griliches (1957) conducted an empirical study of the spread of hybrid corn in the US. In his model farmers observed the successful adoption of new varieties before adopting them themselves. The process gave rise to the now-familiar logistic pattern of adoption. On the effect of the diffusion of ideas brought about by family planning programmes on reproductive behaviour, see Babalola, Folda, and Babayora (2008) and Krenn et al. (2014).

a multiplicity of stable fertility choices (e.g. n_1 and n_3). Historical studies of the diffusion of fertility behaviour point to that (Watkins, 1990). Fertility transitions are an expression of the phenomenon.

The common structure of diffusion processes that we are studying proves useful also for interpreting statistical regularities between wanted fertility (Sect. 5) and actual fertility. Pritchett (1994) for example regressed actual fertility on wanted fertility in a sample of 43 countries in Asia, Africa, and Latin America. He found that about 90 percent of cross-country differences in actual fertility (TFR) are associated with differences in wanted fertility (WTFR). He also found excess fertility not to be systematically related to actual fertility, nor to be an important determinant of it.

Pritchett concluded from his study that high fertility is due entirely to the strong desire for children. Our model draws a different conclusion. That fertility preferences are socially embedded tells us that we should expect the correlation Pritchett obtained, but it also warns us not to attribute causality to the relationship. It would be as true to say fertility rates in those countries in Pritchett's sample where they are high are high because people have a strong desire for children as it would be to say that people there have a strong desire to have children because fertility rates are high.

5 Unmet Need, Desired Family Size, and the UN's Sustainable Development Goals

UNFPA (1995) took it that family planning and reproductive health policies should address "unmet need", meaning that they should be made to serve women aged 15-49 who are seeking to stop or delay child-bearing but are not using modern forms of contraception (Bradley et al., 2012; Alkema et al., 2013). Although the idea of "unmet need" could appear straightforward, it has in practice proved to be complex and has been interpreted in different ways over the years. It is currently measured using more than 15 survey questions, including questions on contraceptive use, fertility intentions, pregnancies, postpartum amenorreah, sexual activity, birth history, and menstruation. Women's reported fertility intentions are inferred from such questions as: "Now, I have some questions about the future. Would you like to have a(nother) child or would you prefer not to have (any more) children?" That is followed by a question on how long the women wants to wait should she have responded to the previous question that she does not want a(nother) child.[21]

There are deep problems here. Unmet need as calculated from responses to survey questions is based on the respondent's expresed wants for biological children. The need for family planning is then inferred from the unmet need. But in matters of life and death resource needs assume an independent status, they even serve as the basis on which commodity rights are founded. The philosopher David Wiggins has argued that a statment of the form "person A needs

[21] Casterline and Sinding (2000) discuss ways in which the measure of unmet need can be used to inform family planning policies.

commodity X" is tantamount to a challenge to imagine an alternative future in which A escapes harm without X (Wiggins, 1987: 22). Expressed wants or desires for children - used for calculating unmet need for family planning - may not adequately convey her true need for family planning, that is, for her own best interests. A poor woman, suffering from iron deficiency and living in a setting where she is more or less compelled to have sex, has a need for contraception for her own benefit that could remain undetected in her responses to questions on the expressed wants for biological children. To infer needs solely from wants is therefore to undervalue the significance of family planning. Moreover, none of the survey questions is conditioned on the behaviour of others. As we see below, that too is limiting. The line joining need to expressed wants is toruous.

Closely related is the notion of "desired family size", which is obtained from answers to the following question:

"If you could go back to the time when you did not have any children and could choose exactly the number of children to have in your whole life, how many would that be?"

The "wanted total fertility rate", or WTFR, is calculated by first dividing the number of observed births into those that occurred before and after the desired family size is reached (the former are considered as wanted, the latter unwanted). WTFR is then obtained with the same procedure as the one used in calculating TFR (that is, from age-specific fertility rates), but only wanted births are included in the numerator of these rates.

There are dangers of biases in responses to the question at the basis of desired family size, but the need for family planning programmes to have quantitative estimates of it is clear enough. Notice though that the questionnaire does not ask of someone what her desire would be if the prevailing fertility practices of others were different. In fact there is no mention of the prevailing fertility rate. As respondents are not invited to disclose their conditional desires, it is most likely they disclose their desired family size on the assumption that fertility will remain at its prevailing rate. A direct way to discover socially embedded preferences would be to reconstruct the questionnaires by asking a series of conditional questions, which we collapse here for convenience into one:

"If you could go back to the time when you did not have any children and could choose exactly the number of children to have in your whole life, how many would that be, assuming everyone else in your community had *n* children over their whole life?"

The survey could pose the conditional question in an ascending order of *n*, say from 0 to 10 (thus 11 conditional questions in total). The example in Figure 1 imagines that the answers to $n = 2$, 4, and 5 are, respectively, 2, 4, and 5. It also imagines that answers to the questions in which $n = 0$, 1, 3, 6-10, respectively, differ from 0, 1, 3, 6-10; which is why the latter numbers are not social equilibria. No doubt responding to a string of conditional questions would tax

respondents, but to not ask them is to misread fertility desires.[22]

Fabic et al. (2015) defined "total demand" for modern contraception to be the number of women who want to delay or limit child-bearing (i.e. the sum of contraceptive users and women with unmet need). The role of family planning, the authors argued, is to supply that demand. The suggestion is that the success of family planning should be measured by the ratio of family planning users to the total demand. The United Nations have adopted this measure in their Sustainable Development Goal 3.7.1. It is known as "demand for family planning met with modern contraceptive methods", or "demand satisfied" for short. Formally, if X is the number of women between 15-49 who are users of modern contraceptives, Y is the number of women with unmet need, and Z is total demand for modern contraception, then $Z = X+Y$ and the UN's "demand satisfied" is $X/Z = X/(X+Y)$.

Reproductive rights are at the heart of X/Z, which is its attraction. The indicator reflects voluntarism, rights and equity, informed choice, and the imperative of satisfying individuals' and couples' own choices with regard to the timing and number of children. But there are problems. The use of X/Z as the measure of success could create perverse incentives among programmes managers. A programme's performance would improve if more women were to declare that they want to get pregnant. So long as women want many children, Y (unmet need) remains small, and therefore Z (total demand) is only marginally greater than X (the number of modern contraceptive users). The country scores well in the indicator "demand satisfied" and appears not to need further family planning programming. The success could mask a situation where contraceptive use is low and stagnant and high fertility rates persist. Moreover, as we saw in Section 4, fertility preferences, which contribute to the measurement of Y, are themselves influenced by the behaviour of others. Y could therefore be small in a society that harbours another equilibrium in which Y is large.

The concept of reproductive rights, as currently framed, undervalues family planning. There are collective benefits to be enjoyed if members of a community are enabled to alter their fertility desires in a coordinated manner. Family planning can help to bring about changes in such social norms. Our analysis doesn't run against rights as a plank for family planning; it expands the sphere in which rights are acknowledged, protected, and promoted.[23]

Part II

[22] Because people's preferences differ, we should expect the responses to differ but discover that each individual's preferred number of children is an increasing function of n. That would reveal socially embedded preferences.

[23] Moral philosophers would argue that the evaluation of family planning programmes should include the quality of lives that will not be lived on account of the programmes. We avoid those further considerations by assuming that thoughtful parents reach their fertility desires by taking into account the potential well-being of their offspring and, by recursion, the well-being of their dynasty.

6 The Biosphere as an Open Access Resource

To the best of our knowledge there are no national estimates of the environmental benefits of family planning. So we make a direct approach to estimating the benefits by reviewing humanity's demand for ecological services at the global level. For that it proves useful to regard the biosphere as a single renewable natural resource. The stance involves a heroic aggregation exercise, in which billions of assets are aggregated into a single measure. If that seems an absurd undertaking, we should recall that global fisheries and forest biomes are routinely measured in units of biomass, which also involves giant aggregation exercises. No doubt problems of aggregation are magnified when we study the biosphere as a whole, but they aren't magnified that much in complexity.

One reason the biosphere is hard to aggregate is that the biogeochemical processes that shape natural capital differ widely in both speed and spatial reach. As most global environmental resources have no prices attached to them (there is an absence of property rights to open access resources), indirect methods have to be found if we are to obtain notional prices for them. All that said, there is no escaping the need for imagining the biosphere as a gigantic piece of natural capital if we are to discuss the adverse environmental externalities accompanying births. We denote the aggregate stock of the biosphere by K, a real number. K may alternatively be called the global stock of natural capital.

A concrete way to imagine the biosphere is to focus on its biomass. In that case K, measured in units of biomass, is the state variable of the biosphere. The composition of biomass (grasslands differ from agricultural fields) is reflected in the aggregate measure K. Let $K(t)$ be the biomass at time t, and let $F(K(t))$ be the net output of biomass over a brief interval of time (say, a year), starting at t. $F(K)$ is a flow, or flux (so many units of biomass per year), whereas K is a stock (so many units of biomass, period). Ecologists call F, "net primary production". When the occasion demands, we will without loss of generality refer to F as "ecosystem services".

To imagine the biosphere as a renewable natural resource requires facing a further problem. Even two thousand years ago, when global population was under 250 million and per capita income a bit over a dollar a day (Maddison, 2001), it would have been a reasonable approximation to treat humanity as a separate entity from the biosphere. Today it is no longer possible to do that. We are much engaged in transforming the biosphere, by both creating biomass and destroying it. So we have to imagine humanity as being at the same time a constituent of the biosphere and an entity that is separate from it. No doubt that's a stretch, but it is possible to do it without running into contradictions. We avoid contradiction by noting that a portion of $F(K)$, say α, is needed for the maintenance of the biosphere. So, if over a period of time $F(K)$ was to be usurped entirely by humanity, K would shrink and biodiversity would be reduced. If during an interval of time humanity was to consume even more than $F(K)$, K would

shrink even more, further drawing down biodiversity. Humanity is doing that now, which is what has led Wilson (2016) to propose that we should leave half the biosphere alone. $(1-\alpha)F(K)$ should therefore be interpreted as the *useable* flow of biomass; useable, that is, by humanity.[24]

It could be thought that $F(K)$ must be an increasing function of K for all values of K; but that would be to overlook that Earth is finite in extent. F should therefore be taken to be an increasing function of K for small values of K, but a declining function of K for large values of K. Earth's "carrying capacity" for the prevailing life-forms (a formidable notion in itself, but one that cannot be avoided) is that positive value of K at which $F(K)$ is zero.[25]

7 Ecosystem Losses in the Anthropocene

Humanity's success in raising the standard of living over the past 250 years has involved creating and then utilizing ideas and accumulating reproducible (or manufactured) capital and human capital, while mining and degrading K. The socio-economic processes that drive the production, dissemination, and use of ideas and the accumulation of reproducible and human capital are at the heart of modern growth and development economics, but the decumulation of natural capital has remained unrecognized (e.g. Helpman, 2004; Grossman et al., 2017). The decumulation is also unrecorded in official economic statistics.

The bias is not a reflection of an indifference to the natural world, it is more a disconnect between the social and environmental sciences. It is widely known for example that even while industrial output increased by a multiple of 40 during the 20th century, the use of energy increased by a multiple of 16 (contributing to climate change and degrading the oceans), methane-producing cattle population grew in pace with human population (contributing to

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[24] α is not a constant and is most likely a decreasing function of K.

[25] A tractable form of $F(K)$, in wide use among ecologists for a wide variety of ecosystems, is quadratic:

$F(K) = rK(1 - K/K^*)$, where r and K^* are positive constants.

In this equation r is the "intrinsic growth rate" of K (because r at small values of K is the percentage rate of growth of K) and K^* is Earth's carrying capacity (because $F(K^*) = 0$).

The view that the biosphere is a renewable natural resource covers pollution as well (e.g. contemporary carbon emissions into the atmosphere). Pollutants are the reverse of natural resources. One way to conceptualize pollution is to view it as the depreciation of capital assets. Acid rains damage forests; carbon emissions into the atmosphere trap heat; industrial seepage and discharge reduce water quality in streams and underground reservoirs; sulfur emissions corrode structures and harm human health; and so on. The damage inflicted on each type of asset (buildings, forests, the atmosphere, fisheries, human health) should be interpreted as depreciation. For natural resources depreciation amounts to the difference between the aggregate rate at which it is harvested and its natural regenerative rate; for pollutants the depreciation they inflict on natural resources is the difference between the rate at which pollutants are discharged into the resource-base and the rate at which the resource-base is able to neutralize it. The task in either case is to estimate those depreciations. It follows that there is no reason to distinguish the analytical structure of resource management problems from pollution management problems. Roughly speaking, "resources" are "goods", while "pollutants" (the degrader of resources) are "bads". Pollution is the reverse of conservation.

climate change and degrading the oceans), and fish catch increased by a multiple of 35 (reducing stocks in the open seas).[26] Environmental scientists have found that the application of nitrogen to the terrestrial environment from the use of fertilizers, fossil fuels, and leguminous crops is now at least as great as that from all natural sources combined. They have also found that soil nitrogen and phosphorus inventories have doubled over the past century (nitrate levels in Greenland ice are today higher than at any time in the previous 100,000 years), and that 25-30 per cent of some 130 billion metric tons of carbon harnessed annually by terrestrial photosynthesis is now appropriated for human use (Vitousek et al., 1986, 1997; Haberl et al., 2007). That signals the stupendous presence of a single species and helps to explain why extinction rates of species since the early modern era have been far above background rates and have increased a lot further since the 19th century (RSPB et al., 2013). These all point to rates of biomass transformation in excess of the useable flux, $(1-\alpha)F$. Consequently, they point to reductions in K.

The Millennium Ecosystem Assessment (MEA, 2005a-d) reported that 15 of the 24 ecosystems the authors had investigated world-wide are either degraded or are being exploited at unsustainable rates. Population pressure on land and the habitat destruction that accompanies human encroachment are the proximate causes. The figures put the scale of humanity's presence on the planet in perspective and record that we are now Earth's dominant species (Ehrlich and Ehrlich, 2008). The statistics also explain why our epoch has now been named the Anthropocene.[27]

8 Net Demand on the Biosphere

Studying biogeochemical signatures over the past 11,000 years, Waters et al. (2016) have provided a sketch of the human-induced evolution of soil nitrogen and phosphorus inventories (more generally of polyaromatic hydrocarbons, polychlorinated byphenals, and pesticide residues) in sediments and ice. The authors reported a sharp increase in the middle of the 20th century in the inventories. Their work shows that the now-famous figure of the "hockey stick" that characterises time series of mean global temperature also characterises a broad class of geochemical signatures, and signal a sharp increase in the rate of deterioration of Earth's life support system. Waters et al. (2016) proposed that mid-20th Century should be regarded as the time we entered the Anthropocene.[28]

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[26] Carbon and sulphur dioxide emissions rose by a factor of more than 10.

[27] The term "Anthropocene" was popularized by Crutzen and Stoermer (2000) to mark a new epoch that began with the Industrial Revolution some 250 years ago.

[28] The "hockey stick" graph refers to time series of mean global temperature over the p;ast 2000 years. The variable remained more or less constant until the 20th century, when it displayed a sharp increase (by approximately 1 Centigrade). The Anthropocene Working Group has recently proposed that the immediate post-war years should be regarded as the start of the

Their reading is consistent with macroeconomic statistics. World population in 1950 was 2.5 billion. Global GDP was a bit over 7.5 trillion international dollars (at 2015 prices). The average person in the world was poor, with an annual income of a bit over 3,000 international dollars. Since then the world has prospered materially beyond recognition. Population has increased to 7.4 billion and world output of final goods and services today is about 110 trillion international dollars meaning that world income per capita now is about 15,000 international dollars. A 15-fold increase in global output over a 65-year period helps to explain not only the stresses to the Earth system that we have just reviewed, but also hints at the possibility (one that we confirm below using crude data) that humanity's extraction of biomass has for some time exceeded sustainable levels ($(1-\alpha)F$). So, in addition to the direct benefits of family planning programmes, which are currently assessed on the basis of the extent to which reproductive rights are met, we should estimate the decline in reductions in K owing to a prevented birth and placing a value on that reduction. If the reduction is estimated to be ΔK per prevented birth and the social value of a unit of natural capital is Q, then the environmental benefits from a family planning programme would be the product of $Q\Delta K$ and the number of births the programme is expected to prevent.[29]

In the field of family planning nothing is simple. Addressing one problem simply leads to several more. If Q remains largely un-estimated, determining ΔK from a prevented birth poses problems for the demographer. Some family planning on the part of women involves delaying

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Anthropocene. See Vosen (2016).

[29] Q is also called "notional price" and more often, "shadow price". The literature on valuing natural capital is now huge (see for example, Freeman, 2003; Haque et al., 2011). There are now a number of studies in which shadow prices of specific types of natural capital at the local level have been estimated (water, air quality, woodlands, mangroves, coral reefs), but economic demographers estimating the value of family planning programmes at the local level have not made use of them.

In recent years costing the consequences of carbon emissions for the global climate has been a major research topic. The basic idea is to estimate the net present value of the impact over the next 100 years (or more) on, for example, agriculture from changes to the global climate that are traceable to carbon emissions. That's Q, when restricted to the stock of carbon in the atmosphere. The net present value has been found to be negative (meaning that global climate change is expected to hurt the world economy; that is, the notional price of carbon is negative), and has been estimated using a range of plausible figures for the rates at which future costs and benefits are to be discounted. See Moore and Diaz (2015), who arrive at a figure of 220 US dollars per ton of carbon emitted into the atmosphere. In contrast, the US Government uses a figure of 37 dollars per ton. The wide difference in the estimates reflects differences in assumptions regarding the effect of carbon emissions on the global climate and in turn the effect of changes in the global climate on the fruits of human activities.

Bohn and Stuart (2015) offer various estimates of the social cost of carbon emissions owing to a new birth (that's $Q\Delta K$, but where K is restricted to carbon concentration and Q is the shadow price of carbon in the atmosphere). In contrast, the literature contains next to nothing on the valuation of changes that humanity is inflicting on the oceans and the biomass they harbour. We do not know Q for the biosphere.

births, not limiting numbers. Better spacing is a good in itself, but if numbers aren't affected, the environmental consequences would be slight (ΔK would be negligible).

In a review of the state of the Earth's life support system, WWF (2012) reported that in the early years of this century, humanity's demand for ecological services exceeded by 50 per cent the rate at which the biosphere is able to supply those services to us. The figure is based on the idea of "global ecological footprint", which is the surface area of biologically productive land and sea needed to supply the resources a human population consumes (food, fibres, wood, water) and to assimilate the waste it produces (materials, gases). The Global Footprint Network (GFN) regularly updates their estimates of the global ecological footprint.[30] A footprint in excess of 1 means demand for ecological services exceeds their supply. GFN's most recent estimate is a footprint of a bit over 1.6, which in our terminology means humanity has in recent years been consuming ecological services at the rate $1.6(1-\alpha)F(K)$. Humanity's demand for ecological services can exceed supply for a period, but not indefinitely. Our model would interpret a footprint in excess of 1 as a decline in K (i.e. $\Delta K < 0$). Sustainable development would require that the footprint over time must on average equal 1. To be sure, the entire function $F(K)$ can be made to increase by measures that reduce the footprint to less than 1. Advances in bio-technology, for example, are designed to increase $F(K)$. But the advances would be successful only if they don't have large unintended adverse consequences on the biosphere. Moreover, irreversible losses, arising say from biological extinctions (declines in K), would act as constraints on the biosphere's ability to recover. Moves toward consumption and production practices that make smaller demands on the biosphere would be a more direct approach to reducing our impact on the Earth system. We return to those possibilities in Section 11.

The greatest contributors to the ecological-footprint overshoot are the OECD countries (a club of rich nations). Estimating national footprints poses enormous conceptual and practical difficulties. And without notional prices to guide us, it isn't possible to estimate the value of environmental externalities associated with an average new birth. But for the global economy the matter is less opaque because errors in measuring national footprints that arise on account of trade in goods and services would cancel in the aggregate.

Assuming that the global ecological footprint is 1.6, we may conclude that to maintain the current global average living standard at the prevailing distribution of income, we would need 1.6 Earths. It is against this background that we offer a quantitative account of the adverse environmental externalities humanity is inflicting on itself by allowing a substantial portion of Nature's goods and services to be free. No doubt estimates of global ecological footprint are very, very crude. Moreover, in contrast to estimates of such development indicators as GDP,

[30] For pioneering work on the idea of ecological footprints, see Rees and Wackernagel (1994) and Rees (2001, 2006). See also Kitzes et al. (2008). Wakernagel, who founded the Global Footprint Network (www.footprintnetwork.org/public), was a lead author of WWF (2008).

population size, life expectancy, and literacy, which are made by a multitude of national and global institutions, we are obliged here to rely on the estimates of a solitary research group (albeit aided by a wide network of ecologists and environmental scientists). Nevertheless, that there is an overshoot (ecological footprint in excess of 1) is entirely consistent with a wide range of evidence on the state of the biosphere, some of which we have reviewed here. As the figures are the only ones on offer, we make use of them.

9 How Many People Can Earth Support in Comfort?

Ecologists estimating sustainable world populations have sought to calculate the human numbers Earth can support at a reasonable standard of living. In an important and interesting paper Daily, Ehrlich, and Ehrlich (1994) studied the problem by quantifying the stresses to the biosphere that are being caused by humanity's use of energy. The authors considered a rate of energy consumption that would offer the average person options to pursue a wide variety of life's projects and choices. In the early 1990s world population was 5.5 billion and global energy consumption was an annual 13 terawatts (13 trillion watts). The authors took it as given that an annual consumption of 13 terawatts of energy is unsustainable (it would play havoc with *K*). As we now know from the on-going work of climate scientists, their presumption was right. The authors noted the vast differences in energy use between the world's rich and poor, but on assuming an equitable distribution of energy-use, they estimated that a population of 2 billion (world population in the early 1930s) could enjoy a very comfortable life based on an annual 3 terawatts of energy consumption; and that a population of 1.5 billion (world population at the start of the 20th century) could enjoy an even more comfortable life based on an annual 4.5 terawatts of energy consumption.[31]

The Daily-Ehrlich-Ehrlich estimates were a first cut on a neglected problem. An alternative procedure is to identify a standard of living that can be justified on grounds that it supports a high quality of life - we will identify one from surveys on "reported happiness" - and ask how many people can be supported at that quality of life. We pursue that line of enquiry here.[32]

An analysis of one set of global surveys on happiness and their relationship with household incomes has revealed that in countries where per capita income is in excess of 20,000

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[31] The Daily-Ehrlich-Ehrlich study was based on the assumption that the sources of energy will continue to be fossil fuels. Today there is hope that energy will in due course altogether be obtained from renewable resources. But that's still some ways ahead. Meanwhile *K* will have been further depleted. And climate change is not the only source of stress to the Earth system.

Cohen (1995) collated a wide range of estimates that had been published in the past century of Earth's capacity to support human numbers and their demands.

[32] The literature on reported happiness is huge. See Helliwell, Layard, and Sachs (2013) for a fine review of the large scale surveys that ask people to report their feelings and emotions and collate their responses.

international dollars, additional income is not statistically related to greater reported happiness. We work with that figure, even though we are not at all sanguine we understand the finding. 20,000 international dollars is the per capita income in Panama, Mauritius, and Uruguay today, and it is hard to imagine that happiness hits a roadblock at 20,000 dollars. On the other hand, 20,000 international dollars (at 2015 prices) was the per capita income in the early 1980s in today's high-income countries. Were people there on average less happy then than they are now (even when adjusting for increases in inequality since then)? So, for want of price estimates of natural capital (Q), we follow the lead of studies on reported happiness.[33]

World income (or global GDP) today is about 110 trillion international dollars. Using 1.6 as the figure for the global ecological footprint today and assuming that the demand on ecological products and services is proportional to GDP, we conclude that sustainable world GDP is an annual 110 trillion/1.6 international dollars, that is, 70 trillion international dollars. That level of global economic activity would be sustainable because K would not decline. If we now regard 20,000 international dollars as the desired standard of living for the average person, maximum sustainable population comes to 3.5 billion.

Notice how close this estimate is to the ones obtained by Daily, Ehrlich, and Ehrlich. Each arrives at a global population under half of what it is today. That suggests, at least tentatively, that the Earth system offers tight bounds on global population if a decent living standard is to be sustained. World population was about 3 billion in the 1960s, so we are not talking of unfamiliar figures. But suppose our goal was less demanding; suppose humanity would be content with an average income of 10,000 international dollars, which is below the global per capita income today.[34] Sustainable global population would then be 7 billion. As noted earlier, we are now 7.4 billion in numbers, moving toward a possible figure of 11 billion in year 2100. And we haven't built into the analysis deep inequalities in living standards and the human migration that are often a response to the distress that they give rise to. We turn to that now.

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[33] Layard (2011: 32-35) reports the finding and commends it. A number of explanations can be given for the finding, one being that what matters most to a household beyond a certain level of income is its income relative to the average income in its peer group. Veblen (1899,[1925]) based his theory of the leisure class on this particular psychology of consumption. Veblen's observation on human psychology found a telling expression in a remark attributed to a Garry Feldman of Stamford, Connecticut, one of the wealthiest towns in the USA: "I might be in the top one per cent, but I feel that I am in the bottom third of the people I know." (*The Guardian*, Saturday 16 February 2013)

Another explanation for happiness saturation bases itself on the idea that people are conformists even on styles of living. The problem isn't that either explanation is implausible (they are both all too believable), but that either dominates all other factors affecting the demand for goods and services beyond 20,000 international dollars. We use the figure only for illustration.

[34] To convey an idea of 10,000 international dollars per person, it is the per capita income in contemporary Albania and Indonesia.

10 Poverty and the Distribution of Global Income

By the Global Footprint Network's reckoning the world's ecological footprint in 1960 was about 0.6. The figure suggests that humanity's reliance on the biosphere in 1960 was sustainable and that the biosphere's composition was a lot different at that time from what it is now. World population in 1960 was about 3 billion and per capita income approximately 4,500 international dollars. These statistics are consistent with the finding that the Anthropocene is only a couple of generations old (Waters et al., 2016).

Central to the UN's Sustainable Development Goals is the elimination of deep poverty and reductions in global wealth inequality. How does the balance of rights change when we cease talking exclusively in terms of global averages?

Most economists believe that success in reducing the proportion of the world's population in absolute poverty from 37 per cent in 1990 to just over 10 per cent today can be traced to strong growth in GDP that prominent developing countries have enjoyed since then (China and India in particular) and the investment in health and education that was made possible by that growth.[35] In international discourses it is today almost universally taken as given (e.g. Jamison et al., 2013) that eliminating absolute poverty and narrowing health disparities require robust growth in GDP.

Related to poverty and the distribution of living standards is the question whether global ecological footprint is proportional to world GDP. In our previous calculation we assumed the answer is "yes" without comment. The assumption requires that household footprint is proportional to household income; that is, the composition of household expenditure doesn't matter to the biosphere. That is in all probability incorrect (Liu et al., 2003). So then consider by way of example the case where ecological footprint increases less than proportionately with income. If the distribution of income remains the same, growth in global GDP by g per cent would be accompanied by a less than g per cent growth in the demand for ecological services. And that's a good thing.[36]

But what if absolute poverty was to be eliminated by a redistribution of incomes toward

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[35] See for example the regular commentaries in *The Economist*. The absolute poverty line is currently taken by the World Bank to be 1.90 international dollars a day. It is an adjustment to the dollar-a-day figure that was introduced by the organization in the 1980s.

[36] To confirm this suppose population size is N; people are indexed by i (= 1,2,...,N); and y_i is person i's income. Let e_i be i's demand for ecological services. A simple way to formulate the assumed relationship between income and biomass consumption is

$e_i = Ay_i^{\pi}$, where $0 < \pi < 1$ and $A > 0$ are constants.

Global demand for ecological services is then

$E = {}_i\Sigma e_i = A[{}_i\Sigma y_i^{\pi}]$,

where "${}_i\Sigma$" denotes summation over i.

Suppose there is an increase in all incomes by g, expressed in percentages. Then the global demand for ecological services (E^*) would be

$E^* = (1+g)^{\pi}E < (1+g)E$.

greater equality? Such a policy has a strong appeal to egalitarian convictions. But policy makers would be faced with a cruel dilemma: Even if average income was to remain the same, the demand for ecological services would increase. That means improving the distribution of income among today's contemporaries, a good thing in itself, would worsen the economic prospects of future generations. There is a clash here between present and future rights.[37]

If ecological footprint increases more than proportionately with income, our conclusions are reversed: Equalizing incomes among contemporaries would improve the economic prospects of future generations, but a g% growth in global GDP would be accompanied by a more than g% growth in the demand for ecological services.[38] Either way, the environmental consequences of growth and distribution point in opposite directions. That's another problem for the hapless policy maker.

11 Dilemmas

The particular clash of rights we have identified in this paper arises from the fact that much of the biosphere is treated as a free good. Imagine it were possible to establish international agreements to charge people for the use of Nature's goods and services at rates that reflect something like their social scarcity values. If that were to come about, environmental externalities associated with consumption and reproduction would be eliminated, and policies that speak to socially embedded preferences could be used to reduce further the demands we make on Nature, perhaps even to the point where our demands are sustainable.

A further route to sustainable dependence on the biosphere is technological progress. Economic historians of the Industrial Revolution point to the role institutions have played in providing incentives to create the technological innovations that have been responsible for reducing natural resource constraints.[39] But we can be sanguine about the character of technological advances only if natural capital is priced appropriately. Understandably, entrepreneurs economize on the expensive factors of production, not the cheap ones. So long as Nature's goods and services remain under-priced, technological advances can be expected to be rapacious in their use. Moreover, technological advances that are patently good can have side-effects that are not benign. The ability to use fossil-based energy at large scales has transformed lives for the better, but it has created the unintended consequence of global climate change. Bull-

[37] To see why, we use the notation introduced in the previous footnote and consider the extreme case where there is complete equality of incomes following the redistribution. For vividness, label people so that $y_1 < ... < y_i < ... < y_N$. Write the mean global income as y^*. Then $y^* = {}_i\Sigma y_i/N$. Suppose $g = 0$ (global GDP does not change). By assumption $0 < \pi < 1$. That means $NA(y^*)^\pi > A[{}_i\Sigma y_i^\pi]$. But $NA(y^*)^\pi$ is the global demand for ecological services under complete equality.

[38] To confirm, one could use the model in foonote 37, but assume $\pi > 1$.

[39] Landes (1998) is a classic on the subject.

dozers and chain-saws enable people to deforest land at rates that would have been unimaginable 250 years ago, and modern fishing technology devastate large swathes of sea beds in a manner unthinkable in the past. If technological progress is our hope, it has to come allied with elimination of environmental externalities.

The World Bank in its World Development Indicators 2016 reports that the 1.4 billion people living in its list of high-income countries enjoy a per capita income of 40,700 international dollars. Thus, the richest 19 per cent of the world's population consume over 51 percent of world income (57 trillion/110 trillion). Assuming humanity's impact on the biosphere is proportional to income, 51 per cent of that impact can be attributed to 19 per cent of world population. If the UN's Sustainable Development Goals (SDGs) are to be met, consumption patterns in these countries have to alter substantially. Our calculations in the previous section suggest that, otherwise, efforts to shrink global income inequalities will prove to be unsustainable. Consumption behaviour is influenced both by our urge to compete with others (Veblen's "conspicuous consumption") and by our innate desire to conform. Each is a reflection of socially embedded consumption preferences. As both drivers give rise to consumption externalities, the psychological cost to a person of a collective reduction in consumption is likely to be far less than what it would be if she were to reduce consumption unilaterally. The aggregate cost could even be negative, especially if the working poor were less poor relative to the working rich; as the former are far greater in number.

To see the numbers involved, recall that in Section 9 it was noted that an analysis of one set of global surveys of "stated happiness" and their relationship with household incomes has revealed that in countries where per capita income is in excess of 20,000 international dollars, additional income is not statistically related to greater reported happiness. Imagine the 1.4 billion people in today's high-income countries were to reduce their average consumption (or income) to 20,000 international dollars. The drop of 20,700 (viz. 40,700-20,000) international dollars per person in a population of 1.4 billion adds up to a total of 31 trillion international dollars. Other things equal, world income would then be 79 (viz. 110-31) trillion international dollars, a figure for global economic activity that is not far above the 70 trillion dollars we obtained (Section 9) as a crude estimate for sustainable global income under present technologies and contemporary social institutions.

But problems abound. According to the projections in UNPD (2015), world population will increase from the current 7.4 billion to 11.2 billion in 2100. More than three-quarters of that increase is projected to be in sub-Saharan Africa, from today's approximately 1 billion to 4 billion (Fig. 2). Per capita income in sub-Saharan Africa is currently 3,500 international dollars. Comprising a little over 13 per cent of the world's population, the region represents a bit in excess of 3 per cent of the world economy. So, sub-Saharan Africa cannot remotely be held responsible for the global environmental problems we face today. But to raise incomes there

even to the current global average income (15,000 international dollars) in the face of a 3-billion rise in numbers would require an increase in the region's annual output from 3.5 trillion dollars to 60 trillion dollars. That rise, assuming it is possible, will have severe consequences for the region's ecology, contributing to further societal conflicts there and to greater attempts by people to move both within the region and out of it. It is not difficult to imagine the international tensions that scale of attempted movements would give rise to. The SDGs are largely silent on population, and yet it is inconceivable that they can be met without addressing the subject.[40] Goal 13, for example, recognizes that restricting the increase in mean global temperature to 2°C will require urgent collective action; but there is no acknowledgement that the target is unlikely to be met unless population growth is reduced substantially (O'Neill, et al., 2010). The recent Paris Agreement on climate change also made no mention of population.

If family planning programmes were intensified to meet unmet need everywhere in Africa, population there would be some 1 billion smaller in 2100 than is currently projected by UNPD (2015).[41] That itself would be a substantial gain for people in that region. But it would not be nearly enough. We have argued though that want based family planning, which is the current norm, undervalues family planning. Greater investment in the service, bringing it into alliance with other social programmes, could be expected to redce the projections further.

That fertility preference structures are socially embedded (be it conformist (Sect. 4) or be it competitive as in the "wealth-in-people" thesis has it) offers hope to people of sub-Saharan Africa that population growth there can be stemmed without much personal cost to people there. That consumption preference structures are also socially embedded (and that includes the social embeddedness that encourages competitive consumption, as in Veblen's theory of the demand for status) offers hope to people everywhere that the environmental demands of the 1.4 billion people in high income countries can be reduced without too much personal cost to people there. For if relative consumption matters, a uniform reduction in consumption among all should be expected to prove not too costly to people. The population-consumption-environment nexus is one area of the human experience where the cost of necessary social change is probably a lot less than is feared by social scientists.

[40] Starbird, Norton, and Marcus (2016) contains a good discussion of this.

[41] We are grateful to John Bongaarts for correspondence on this.

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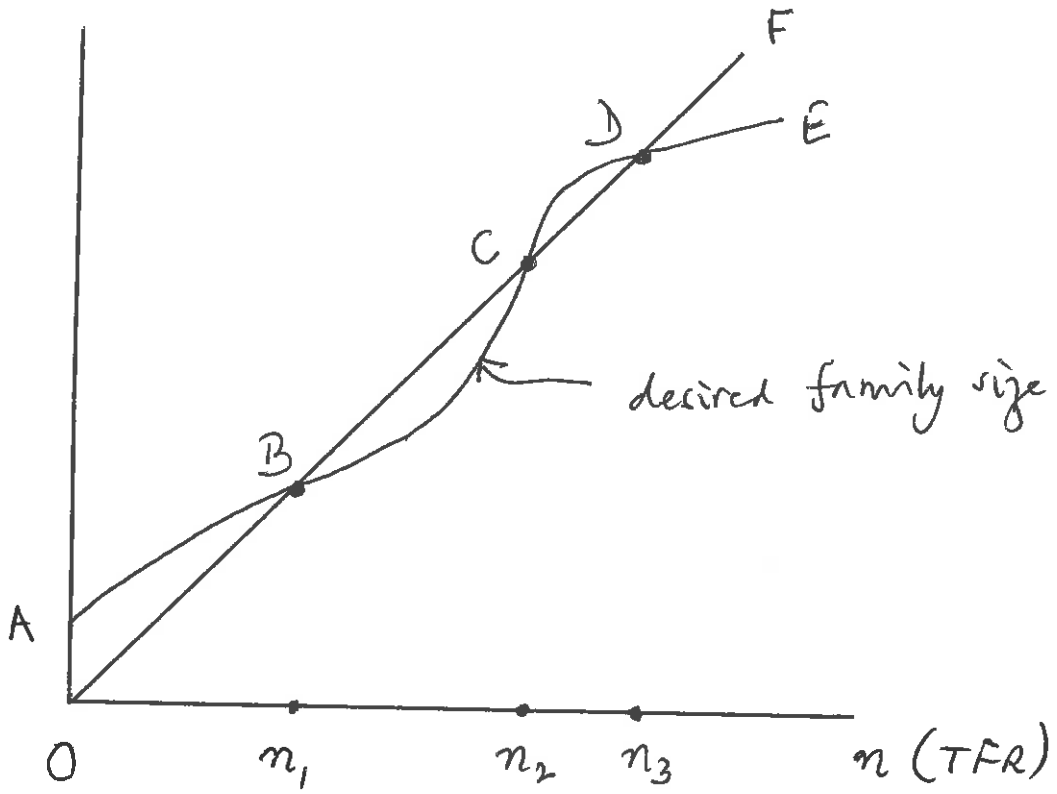

Figure 1

socially-embedded preferences

Total population by region, 2015-2100

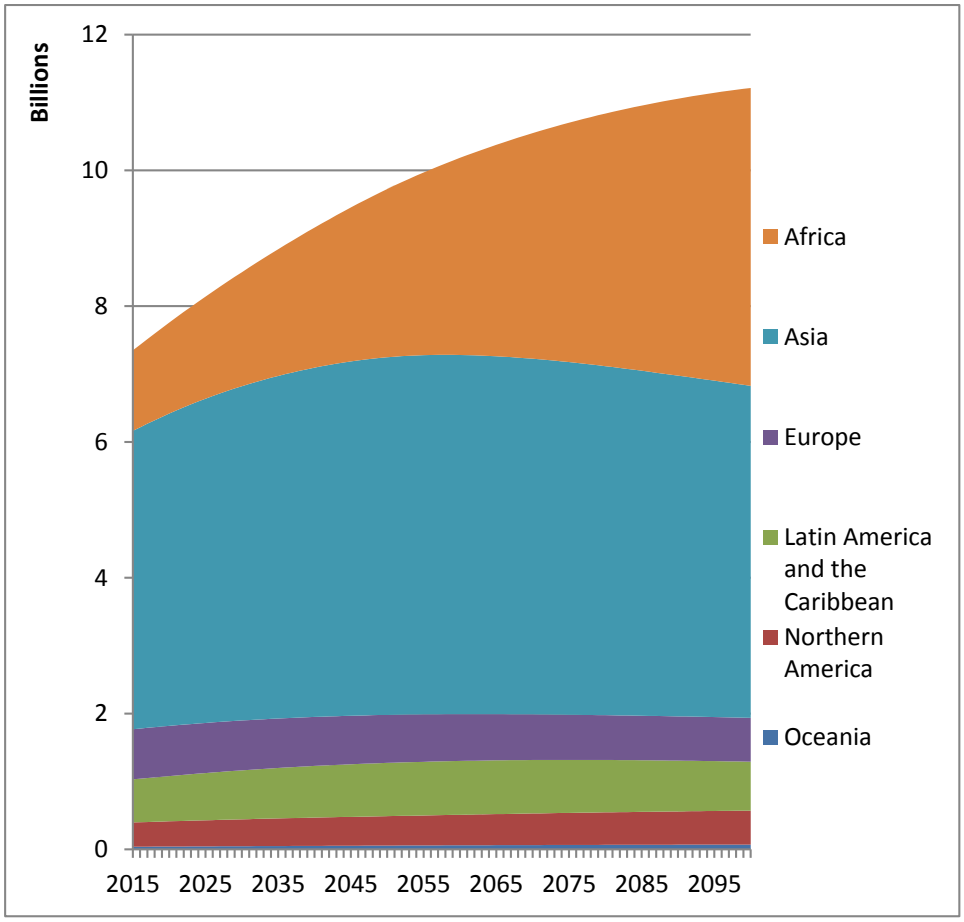

Figure 2

Source: United Nations, Department of Economic and Social Affairs, Population Division (2015). World Population Prospects: The 2015 Revision