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Optimum population, welfare economics, and inequality[1]

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Introduction: Addressing the question "Is the planet full?"

The title of this Seminar series asks a question: "Is the planet full?" When I was a student at Cambridge I was taught that the most important thing when taking an examination was not necessarily to answer a question but to *address* it: i.e. consider how one *might* answer the question. As will become clear, I will not answer the question posed. What I shall try to do is to explain how economists have – over more than a century – sought to grapple with the issue of an "optimum population". I hope that my account, and critique, of how economists have approached the problem may help you think about what answer *you* would give.

The term "optimum" population makes evident that a central ingredient is *welfare economics,* with which I begin. What is welfare economics? Welfare economics is concerned with the interplay between ethical values and economic analysis. Non-economists may be surprised to know that such an interplay takes place – that economists have any interest in ethical issues. And it is true that the subject has been disgracefully neglected in recent years. When I was a student, welfare economics was a compulsory part of the curriculum, and leading economists were writing their doctoral theses on the subject. Today it is treated as an optional extra in most economics degrees.

But welfare economics is a central part of economics. John Broome recently wrote that

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> "Economics is a branch of ethics. At least much of it is. Part of economics is pure science … [But most economists] are interested in economic science because they are interested in finding better ways of running the economy, or of structuring the economic system, or of intervening or not intervening in the economy. All of that practical part of economics is a branch of ethics" (Broome, 2009, page 7).

This may be too strong. I would rather say that welfare economics lies at the interface between economics and moral philosophy. But I fully agree with Broome that, for this reason, economists need to pay much more attention to the ethical basis of their analysis and to examine critically the values underlying their welfare analyses. As it was put by my teacher, Jan Graaff,

> "welfare economics proceeds from a number of assumptions … which are seldom stated explicitly. If their nature were more widely appreciated by professional economists, it is improbable that the conventional conclusions of welfare theory would continue to be stated with as little caution as is at present the custom" (Graaff, 1957, page 1).

This was written in 1957 but is even truer today. Hence section 1 in my five-part paper.

In section 2, I describe the classical utilitarian approach to the optimum population, showing how it may be taken as answering "No" to the question posed, although it does not necessarily do so. However, there are many limitations to this analysis, which I discuss in the rest of the paper, beginning in section 3 with the objections to utilitarianism. One of my criticisms of welfare economics is that it has remained rooted in utilitarianism and not taken account of alternative principles or evaluative bases. A second criticism is that important considerations are missing from the economic framework within which the question is posed. There is at present a tendency, encouraged by the practices of academic journals, to focus on one aspect of an economic problem, treating this aspect in depth but ignoring other, possibly more important, dimensions, as discussed in section 4. One of the most important missing elements is global inequality, which is the subject of section 5. Population growth is taking place in a world characterised by great inequality. Although economists like to assume in their models that everyone is identical – it makes life much simpler – this will not do when discussing the optimum population. The fact that new members of the population are entering a highly unequal world may change our answer to the question posed in the seminar series title.

One final introductory remark concerns the global perspective of this seminar – which I very much welcome – and which is a distinctive feature of the Oxford Martin School as a whole. For much of the paper, I adopt such a global

approach to welfare and justice, asking whether there are too many people from the standpoint of the world as a whole. A global "yes" is however quite consistent with the population being too *small* for individual countries, or whole continents, such as Europe. The Optimum Population Trust, which believes that the world as a whole is too full by 2.3 billion people, still classifies 51 of the 162 countries studied as having the capacity to expand their population (website, downloaded October 2011).

1. The welfare economist's approach

Why welfare economics? You may say that the question tackled in this seminar series is a purely scientific one: is the current population of some 7 billion, or the 10 billion expected by 2100, the largest sustainable? Answering this question requires experts on water, food, natural resources, health, topics covered by other papers at this seminar. I am not intending to trespass on their territory. But in asking – is the planet full? – we are not simply asking whether the population is sustainable. A hundred years ago, the Swedish economist, Knut Wicksell, gave a lecture in The Hague, in which he argued that "it is possible for a country to maintain for centuries a constant population and yet be terribly overpopulated" (1910, English version, 1973, page 208). As he recognized, any judgment about "over-population" involves both technical issues and issues of value. It is rather like standing in the Banbury Road in the morning watching buses go by with "Sorry, bus full" signs. We know that this does not mean that they could not take an extra passenger. Adding one more would not render the bus unable to move. Rather the bus driver is applying rules set by the bus company and by health and safety legislation. These rules reflect judgments about safety but also social norms about the acceptable degree to which passengers may be squashed together.

The question is not therefore only one of positive economics. We have to consider the underlying normative judgments. So, how do welfare economists think about this type of question? The first point I want to make is that judgments by economists take two different forms: the statements may be about

- Quantities: we have or do too much or too little;
- Distortions: people are not making their choices on the right basis.

Now it may seem to non-economists that the first is the key issue, and that the second is a distraction, or at best a side show. But for many issues the reverse is true. Indeed in many cases, the second statement seems the natural starting point. Suppose for example that I were to say "there are too many books in the world". This would probably be regarded as a strange statement. Why pick on books rather than some other consumer products? If one were to single out books, it could be because books are (in the UK) zero-rated for VAT, whereas other

entertainment products such as CDs are taxed at 20 per cent. It could therefore be suggested that this differential tax treatment distorts people's choices. We should have a level playing-field.

How is this relevant to population policy? Some years ago, I was a member of an EU High-Level Group on the future of social policy in an enlarged European Union, which came out arguing for a "new demographic dynamism". In this report we made the rather cavalier statement that

> "History – the post-war period – and geography – the example of the United States compared with Japan – prove that demography is a key factor in the dynamism of a society: if we want to instil confidence and dynamism into our too often gloomy societies, then we should:
>
> - develop more selective and better integrated immigration;
> - allow young couples to have the number of children they desire" (European Commission, 2004, page 7).

This is an example of the second type of argument. We argued, citing evidence for a range of EU countries, that there was a significant shortfall of the number of children below the desired family size. Nor were we alone. In 2007, the OECD reported that "women generally have fewer children than they desire" (2007, page 36).

Why we need to look at quantities

This is a "levelling the playing field" argument. However, this approach now seems to me open to question. The first reason stems from the obvious point that decisions about fertility, unlike the choice between a book and a CD, are decisions that have significant consequences for others. The consequences may be negative, such as crowding, or positive, such as increased dynamism. There are potentially large differences between private and social costs (and benefits), referred to as "externalities". (For a good discussion of externalities in this context, see Birdsall, 1988, pages 523-4.) Put in a stark form, if the EU High-Level Group believed the dynamism argument then we should have made the case for encouraging population growth, and we should not have hidden behind the distortion argument. Or, the other way round, it may be that women in Europe may be choosing fewer children than they would like because they feel an obligation not to overcrowd the planet. They may have internalised the externalities.

The second reason for rejecting the distortion approach in the case of fertility is that the theory of the second-best has long recognised that levelling one playing field is not enough, and may well be counter-productive, if other distortions exist. In the present case, this seems a serious risk. We know that the playing field is not level for women in the labour market. It could well be that the

desired fertility is affected by the reduced opportunities that women face in their professional lives. Removing obstacles to fertility, without removing unequal opportunities in the labour market, may not be a welfare-improving reform. Indeed, the EU High-Level Group's recommendation could be criticised on the grounds that it would reinforce gender stereotypes and make career advancement more difficult for women.

Thirdly, in this field more than many others, preferences may be endogenous. Preferences cannot be taken as given. Preferences change as a result of education, of specific health and family planning advice, and of societal pressures. Since each of these may be influenced by public policy, we have to ask whether we wish to shift preferences in favour of reduced population size. We are back with an argument about quantities.

Finally, the argument of the High Level Group was made from the perspective of EU Member States. But the consequences are global, and we need to allow for the difference between national objectives and a world-wide perspective. It may be, for example, that we need to shift the balance between the two elements, with EU countries seeking to maintain their dynamism by opening their doors more widely to immigration.

For all these reasons, I believe that the question is better posed in terms of quantities – is the planet too full? – rather than in terms of distortions of individual decisions.

2. The classical optimum population analysis

The quantity question has long pre-occupied economists:

> "the optimum concept … was explicitly developed as an analytical tool by some of the path-breaking theorists who established the essential foundations of modern economics" (Gottlieb, 1945, page 291).

One of those cited by Gottlieb was Wicksell, to whose lecture on "optimum population" I have already referred earlier. Another was Henry Sidgwick, who gave a very clear account of the Classical Utilitarian treatment, where the objective is to maximise the sum of utilities:

> "For if we take Utilitarianism to prescribe, as the ultimate end of action, happiness on the whole … it would follow that, if the additional population enjoy on the whole positive happiness, we ought to weigh the amount of happiness gained by the extra number against the amount lost by the remainder" (Sidgwick, 1874, (1907 edition), page 415).

Assuming for the moment that total consumption is fixed (an assumption relaxed below in section 4), the planet is too full if the average utility has fallen below the cost of an extra person. The cost of an extra person is measured in terms of their consumption (assumed equal to the average – there is no inequality at this point) valued at the marginal utility of consumption. In symbols, if total resources are denoted by C, and the total population by N, giving consumption per head of C/N, then the planet is too full if

$$U(C/N) \text{ is less than } U'(C/N) \text{ times } C/N;$$

where U(C/N) is the average utility and U´(C/N) is the marginal utility. Alternatively, this can be expressed by saying that the average utility per unit of consumption per head is less than the marginal utility:

$$U(C/N) \text{ divided by } C/N \text{ is less than } U'(C/N).$$

The optimum population, given by maximising N times U(C/N), is that where the average utility per unit of consumption per head is equal to the marginal utility.

Sidgwick's conclusion may be illustrated with a diagram – see Figure 1. Utility is derived from consumption per head, measured along the horizontal axis. With a fixed total consumption, the larger the population, the smaller is the consumption per head. So that as the population increases, one moves to the left in the diagram. The slope of the heavy curve at any point is the marginal utility from consumption, and the slope of the dashed line is the average utility per unit of consumption. At the point A, these two are equal. At any point to the left of A, the average is less than the marginal, and the population is in excess of the Utilitarian optimum. For this reason, I have shaded the area indicating the levels of population where the Planet would be regarded as full. This is not, as noted earlier, the same as unsustainable, if we interpret the maximum sustainable population as that where utility falls to zero. A zero level of utility is often taken to correspond to a "neutral" life, defined to the borderline between "a life worth living" and "a life not worth living" (Blackorby, Bossert and Donaldson, 2005, page 25). The optimum population is less than the maximum sustainable.

The discussion may seem far removed from reality, so let us put a little flesh on the bones, taking our cues from the globate debate about poverty. First, let us follow the original Human Development Index (HDI) created by the United Nations Development Programme (United Nations, 1990) and assume that well-being is governed by the (natural) logarithm of consumption per head. Secondly, let us suppose that the consumption per head is normalised by the level set in the Millennium Development Goals target for extreme poverty (MDG). Since $\log_e 1$ is zero, this means that we are attributing the base of zero utility to a person living on $1.25 a day. I should point out that this choice differs from those made by others. For example, Broome defines zero on the scale to be "the well-being of a

person who leads a life without any experience of any sort: a life lived in a coma throughout" (1996, page 177), and this might indeed be a better definition of neutrality.

Armed with this HDI/MDG specification, we can calculate that the point A corresponds to a consumption level of $3.40 a day, some 2¾ times the MDG target. (To maximise N times $\log_e(C/N)$, where N is total population and C is the (fixed) total of consumption, we have to set $\log_e(C/N) = 1$.) This suggests that there remains considerable scope for expansion – that the planet is far from full, since today's world average consumption is more than seven times this amount. (This conclusion would be further re-inforced if the neutral level of utility were to be set at a lower level of consumption.)

Does utilitarianism favour large populations?

This calculation lends support to those who argue that the classical utilitarian analysis favours large populations. The problem is that "it can recommend what could be regarded as overly large populations" (Dasgupta, 2005, page 424). This criticism underlies the "Repugnant Conclusion" famously identified by Derek Parfit (1984) and much discussed in the philosophical literature. This is summarised by Mulgan as follows:

> "*The Repugnant Conclusion.* … for any possible population of at least ten billion people, all with a very high quality of life, there must be some much larger imaginable population whose existence, if other things are equal, would be better, even though its members have lives that are barely worth living" (2004, page 23).

As is often the case in economics, a lot turns on the phrase "other things are equal". The problem has to be fully specified in terms of what is being held constant. The formulation of the classical utilitarian problem above assumes that total consumption is fixed and that it is equally shared among everyone. An increase in the population reduces consumption per head, and hence utility, for everyone. In this context, it is evident that the recommended population depends on the form of the utility function. This is illustrated by Mulgan's demonstration of the Repugnant Conclusion:

> "Begin with a world where ten billion people all have extremely good lives. Call it A. Imagine a second world, with twice as many people *each of whom is more than half as happy* as the people in A. Call this new world B. Total utility in B exceeds that in A. Now repeat this process until we reach a world where a vast population each have a life which is barely worth living. Call this world Z. As each step

> increases total utility, Z must be better than A (Mulgan, 2004, page 23).

The key lies in the italicised assumption. It is easy to find utility functions for which this is true (for example, where U is the square root), but it is also easy to find cases where it does not hold. It fails for any utility function such that utility reaches zero at a strictly positive consumption, as shown in Figures 1 and 2. However, it remains the case that such functions can "advocate very large populations" (Dasgupta, 2005, page 438), as he demonstrates for a plausible example where $U = B - (C/N)^{-\sigma}$, where B and σ are positive constants (this form is also used in Dasgupta, 1969). But there is no necessity that this should follow. If we only require that the utility function be a non-decreasing, concave (not necessarily strictly concave) function, then we can find a utility function that generates any arbitrarily small population as the utilitarian optimum. This may be seen graphically in a diagram like Figure 1. Choose any point, with any arbitrarily small population, and draw the ray through the origin, which gives the ratio of utility to consumption per head. Concavity requires that a line joining any two points on the utility function lie everywhere below (or on) the utility function. This is satisfied by a function consisting of two straight-line segments with a kink at the chosen point, such that the left hand slope is greater than that of the ray and the right hand slope is less than that of the ray. And with that utility function the chosen population is optimal.

There is therefore no presumption towards an answer "Yes" from classical utilitarians to the question posed in this Seminar, even if it follows from the specific functional forms adopted in a number of studies. At the same time, the analysis is open to debate on several grounds. In investigating why it is controversial, and why the classical utilitarian argument may lead us astray, it is important to note that there are three key ingredients. The first are the social values that enter our judgment, or what I have referred to as the "social welfare function" (section 3). The second is the economic model (section 4). The third is that we have not allowed for global inequality (section 5). I want to argue that these are all important, and different treatments may well change the way in which we answer the Seminar question.

3. Optimum population and the social welfare function

It may come as a surprise to non-economists to learn that much economic analysis today remains rooted in classical utilitarianism, but this is the case. Robert Lucas in his 2003 Presidential Address to the American Economic Association stated that

> "To evaluate the effects of policy change on many different consumers, we can calculate welfare gains (perhaps losses, for some) for all of them, one at a time, and add the needed compensations to obtain the welfare gain for the group" (Lucas, 2003, pages 1-2).

Lucas appeared to regard this statement as self-evident: he described it as "the general logic of quantitative welfare analysis" (page 1). In this, he is followed by many economists. However, this statement disregards the many objections that have been raised to the utilitarian approach in the past century or more. It is as if a scientist were to analyse the economic consequences of climate change solely on the basis of reading Alfred Marshall's *Principles of economics* (1890), approximately contemporary with Sidgwick's *The methods of ethics* (1874).

To begin with, we may not be content to add the welfare gains: the sum takes no account of how the utilities are distributed. As it was put by Amartya Sen, "maximizing the sum of individual utilities is supremely unconcerned with the interpersonal distribution of that sum" (1973, page 16). In order to allow for these distributional concerns, the sum can be replaced by a concave function of individual utilities, where the degree of concavity captures the extent to which we are concerned about the distribution. How would such a shift – from adding utilities à la Lucas to a concave function – change our views about population? It turns out, rather surprisingly, that it may lead us – in the present context with everyone identical (see below) - to favour a larger population, as has been shown by Dasgupta (2005). He comments that "I have known this result for a long time, but still find it puzzling that the idea of *equality* should play such an influential role in normative population theory" (2005, page 438). Taking an iso-elastic function (with a strictly positive elasticity ε between zero and 1) of individual utilities (where positive), we find that the marginal utility is multiplied by ε, thus reducing the cost. Since the elasticity is less than unity, the optimum population is larger. Those concerned with equity, and not simply with summing utility, are less likely to say that the planet is full.

An alternative transformation of the utility function is that proposed by Blackorby and Donaldson (1984): "critical-level utilitarianism is a one-parameter family of principles. The parameter is a *fixed* critical level of utilities … and the criterion used to rank … is the sum of the differences between individual utilities and the critical level" (Blackorby, Bossert and Donaldson, 2009, page 485). Rather than maximising N times U(C/N), we maximise N times {U(C/N)-α}, where α is the critical level parameter. (They also propose critical-level generalised utilitarianism, which combines the introduction of the critical level with the concave transformation of utilities described in the previous paragraph.) As they note, a positive critical level is one route to avoid Parfit's Repugnant Conclusion. We can see too that the condition for the planet to be too full is that

U(C/N) is less than U´(C/N) times C/N + α;

The answer is more likely to be "yes", the larger is α. With the HDI/MDG specification used earlier, the optimal consumption level becomes (1+α) times $3.40. With sufficiently large choice of α, the optimal population would be below the current level.

Capabilities

As Blackorby, Bossert and Donaldson make clear in their discussion of the critical-level approach, they "restrict attention to welfarist principles … defined on utility distributions" (2004, page 47). More radical are proposals to shift the evaluative basis from utilities. A much discussed example is provided by the capability approach, advanced by Amartya Sen, most recently in his book *The idea of justice* (Sen, 2009). Broadly defined, capabilities refer to the freedom that people have to realise their potential: their opportunities rather than their outcomes. A shift to a capability approach can have major implications. Here I simply refer to two of the important ways in which we may need to shift our perspective.

First, we have to link the mainly resource-based analysis of possibilities – as in the discussion of economic models to follow – to the impact on capabilities. As has been discussed in the literature on the definition of poverty, adoption of the capability approach means that an absolute concept of capabilities may translate into a set of resource requirements that depend on the society in question and may change over time. Absolute capabilities may require relative resources. The resources required to be able to participate in society are no longer the linen shirt and leather shoes cited by Adam Smith in *The wealth of nations* (1776) but a mobile telephone. This in turn has implications for the specification of the consumption required to achieve a neutral life, and for the specification of the critical level just discussed. For the critical level, we may need to think, not in terms of the absolute $1.25 a day of the MDGs, but of the higher level of resources required as a minimum to participate in a modern advanced society.

Secondly, in the capability approach there are many elements that determine the opportunities open to individuals. A number of these relate to personal resources, but they also depend on the provision of social goods and services. In their recent survey of "functionings and capabilities", Kaushik Basu and Luis López-Calva say that

> "in trying to empirically compare the quality of life achieved by different societies using the capabilities approach, we may need to focus on a few salient functionings … . Do people in society x have the option of a long and healthy life? Are people able to live lives free of political oppression? Are people able to read and write? … Do people have enough to eat and drink?" (Basu and López-Calva, 2011, pages 155-156).

It is clear that in each of these a key role is played by public provision. In the case of the last, food is a personal good but access to food depends on public order and public infrastructure. Pressure on public infrastructure is indeed often invoked as a reason for resisting population growth. Put the other way round, those who are willing to invest more in public infrastructure are more likely to agree that the world population can be expanded. In terms of the analysis here, we have to recognise that $1.25 a day refers to only one of the eight Millennium Development Goals. The required investments in education, health, and environmental sustainability to meet the other Goals can be seen as shifting the shaded rectangle in Figure 2 to the right, making it more likely we conclude that the planet is too full.

The adoption of a capabilities approach, in place of classical utilitarianism, may therefore render us more likely to respond "yes" to the question whether the planet is full. However, the full implications of adopting a capabilities approach become clearer in conjunction with the two other extensions of the classic analysis. The relativity of the poverty line becomes important on account of the unequal world distribution (the subject of section 5). The role of infrastructure becomes apparent when we consider how the world's resources are used. We cannot simply pose the problem in terms of dividing a cake of a given size. The ingredients have to be grown; the cake has to be baked; it has to be transported and distributed. The planet is affected by all of these activities, to which I now turn in section 4.

4. Optimum population and modelling the economy

As Keynes famously said, "economics is a science of thinking in terms of models joined to the art of choosing models which are relevant to the contemporary world" (Keynes, 1973, page 296). In modern economics, more attention seems to be paid to the first part of the sentence than to the second part. Much of modern economics treats some aspects of a problem in a highly advanced and specialised way, but at the expense of completely ignoring other relevant dimensions of the problem. The subject has, in my view, become over-compartmentalised.

Among the key elements so far missing from model are (a) the contribution of new people to production, (b) the necessary investment in private and public capital stock, (c) the using up off non-renewable resources and impact on climate change, and (d) the contribution of new people to advances in technology.

The first of these *has* been incorporated in the literature. James Meade, whose chapter on "Optimum population and optimum saving" in *Trade and welfare* (1955) is very well worth reading today, took account of the contribution to

production that new citizens would bring. This leads, in the framework adopted here, to what Dasgupta (2005) calls the Sidgwick-Meade Rule. What this says is, straightforwardly, that the cost of an additional person is equal to what they consume minus what they produce. The planet is then too full if

U(C/N) is less than U´(C/N) x {C/N – marginal contribution to production}

Taking account of the contribution to production shifts the balance to the left in Figure 1. The ratio of utility to consumption can now be less than the marginal utility. How much less depends on what one expects to be the contribution of new workers. James Martin, in his article in *Oxford Today* referred to a future time "when conventional work is done by machines" (2011, page 30). In that case, the optimal population will be smaller.

But the contribution to work is only part of the story. It is for this reason that it seems important to go beyond the Meade framework. The other considerations may operate in the opposite direction. We have already seen this to be the case with the requirement for additional infrastructural investments. Similarly, to the extent that an extra person reduces resources, or damages the environment, this imposes a cost. This cost term raises the right hand side of the equation, and makes it more likely that an increase in population is undesirable. It is important here to stress that the relevant variable is the impact of an *additional person* on resources/environment and on technological change. Of course, we are all today using up the resource-base and damaging the environment, but we are asking whether policy should be directed to preventing new members joining the planet. At the same time, the impact of an additional person depends on the actions that we take and the policies pursued. In the case of resource use/climate change, investment today in measures to limit use of non-renewable energy per person will reduce the carbon footprint of the 9 billionth inhabitant. So that a person who is willing to invest more in averting climate change is more likely to be relaxed about population growth than someone who does not believe that such investment should be made.

Technological advance

The impact on resources and the environment has been the subject of other talks in this Seminar series. Here I focus on the final element (d): technological advance. The idea that the growth rate of the economy depends positively on the growth of the population is in fact widely held. When the EU High Level Group, to which I referred earlier, argued that demographic factors made the economy more "dynamic", it was this mechanism that they had in mind. Lack of population growth did not make a country poorer, but made it less likely to grow – hence the

reference to Japan. Many years ago, the US sociologist, Seabury C Gilfillan argued that

> "Increasing population and/or industry stimulate invention, because they increase the absolute need for a device, and the number of potential finders, while the cost of finding it remains the same. … More population does not help with more portrait photographs, because more labor must go to make them … But as to invention, increasing population … entails that each inventor's work is more widely useful than before, at the same time that there are more inventors to work" (1935, pages 58-59, I owe this reference to Young, 1998).

More recently, in their essay on "Optimum human population size", Gretchen Daly, Anne and Paul Ehrlich have recognised that

> "An optimum population would be sufficiently large to provide a 'critical mass' in each of a variety of densely populated areas where intellectual, artistic and technological creativity would be stimulated. While creativity can also be sparked in sparsely populated areas, many cultural endeavours require a level of specialisation, communication, and financial support that is facilitated by the social infrastructure characteristic of cities" (1994, pages 471-2).

The insight that creativity may be positively related to population density has been embodied in a number of versions of endogenous growth theory, where there is a scale effect in the determination of the growth rate. The rate of technical progress is an increasing function of the size of the economy. This prediction of the theory has been criticised, but is a natural consequence if one treats invention and innovation as the outcome of an extreme value process. In other words, the productivity of an economy is determined by the "best" idea to be identified. If the probabilities of making a discovery are independent, then the maximum achieved value is a non-decreasing function of the number of draws. In a larger population, one is more likely to find a new Shakespeare or a new Mozart. Or, more prosaically, the more people working in creative activities and innovation, the faster should be the growth rate.

The problems with this – seductive – argument are twofold. First, in theoretical terms, the events are not independent. People interact, and people build on the work of others. This may mean that a larger country has a breakthrough, but is led in a direction where productivity gains are rapidly exhausted. They may led into a cul de sac: for example, getting ever better at taking finger prints, rather than supporting research on the total different field of molecular biology that led to DNA as a source of identification. In any case, while the growth rate may increase with population size, it is not clear by how much. Is

the effect proportionate, or less than proportionate, such as increasing with the square root of population size?

The second difficulty is that it is hard to find empirical evidence. Some empirical studies of growth simply assume away the possibility that growth increases with population size. As Robert Solow has remarked, such studies overlook the possibility of a scale effect on growth:

> "Usually, when we compare the R&D intensity of different economies, like Japan, the United States and the EC, we look at R&D spending per unit of GDP. This has always seemed foolish to me. … If the United States has the same R&D-GNP ratio as Japan, it should produce more innovations than Japan, because it is larger" (Solow, 2000, page 177).

In contrast, other empirical studies simply assume that technical advance is proportionate to population. When seeking to explain differences across countries in patent activity, it is common to examine patents per million of the population "scaled to adjust for the size of the economy" (Falk, 2004, page 6), but not to include population as an explanatory variable. Variables such as R+D intensity, education, GDP per capita, and patent protection and included but not population. Scale effects are simply assumed to be proportionate: 10 billion people will generate twice as many patents as 5 billion. In fact, after reviewing the limited evidence, Young concluded that "the evidence of scale effects might best be described as inconsistent" (1998, page 43).

My treatment of this subject is unduly cursory, and my main aim is to flag up the need to include this as part of the equation and to seek firmer evidence. The relation between population size and technological advance is a subject that needs further investigation.

5. Optimum population and inequality

To this point I have taken no account of inequality. Yet inequality can be an important factor influencing how we answer the question as to whether the planet is too full. Inequality has featured in the philosophical literature. Parfit (1990), for example, begins with societies A and B where everyone enjoys the same quality of life, but late introduces A+ where there are two unequal groups. Today's world is more like A+. It is made up of countries with very different per capita incomes, and within those countries incomes are unequally distributed. There is both between-country and within-country inequality.

In this section, I argue (a) that the *existence* of world inequality affects the conclusions drawn with regard to the optimum population, (b) that population

growth is projected to take place in countries that are poorer and more unequal, and (c) that the answer to the question – is the planet full? – depends on how far we are willing to increase world redistribution.

These are three separate arguments. To underline this, I begin by considering the case where population growth is spread evenly (each person is simply cloned) and where population growth leads to no further redistribution between rich and poor. People differ in the amount of resources received by them and people like them, denoted by c, where there is a distribution of c across the world population. The scale of the world population is denoted by N, so that each person belonging to the group with resources c is able to consume c/N. The condition for social welfare to be reduced if there is an increase in N is given by

> Condition A: the following expression, integrated (summed) over the distribution of c, be negative: $U(c/N) - U'(c/N).c/N$

Suppose, for example, that we start from a situation of equality where everyone consumes c*/N and that the expression in Condition A is zero. In other words, we are at the optimum population. Let us also suppose that U takes the logarithmic form, as assumed in the earlier example, which means that the second term in the square bracket in Condition A is equal to 1 (and hence integrates to unity). In this special case, the impact of inequality operates through the impact on the level of utility. Let us introduce inequality by taking x from half the people and giving it to the other half, so that they consume (c*-x)/N and (c*+x)/N, respectively. Total utility is the sum of ½ times $\log_e\{(c^*-x)/N\}$ +½$\log_e\{(c^*+x)/N\}$, which is equal to $\log_e\{c^*/N\}$ plus ½$\log_e\{1-(x/c)^2\}$. The last term is negative where x is positive, which means that the level of utility is reduced, relative to the level with equality. This means that the expression in Condition A becomes negative, so that the existence of inequality causes us to conclude that the population is too large. The impact on the optimum population in this case is illustrated in Figure 3, where the intersection of the dotted line (unity) with the average of rich and poor (on the dashed line) is to the right of the previous choice of A, indicating that the optimum population is smaller.

The effect of inequality does not, however, necessarily operate in this direction, as may be seen by replacing the choice of utility function by a quadratic. The expression in Condition A then becomes proportional to $(c/N)^2$ minus a constant, the sum of which *increases* with the extent of inequality. More generally, we can appeal to the result of Rothschild and Stiglitz (1971, page 67), which shows that a mean-preserving spread of the distribution reduces the expression in Condition A if the expression is a concave function of c/N. This property is not satisfied by the quadratic, but is shared by many social welfare functions used in the literature: for example, the form used by Dasgupta in much of his analysis (1969, equation 1.2).

Insofar as the concavity property applies to the utility specific functions employed in the literature, the introduction of inequality into the model is therefore one response to the concern that the classical optimum population analysis is biased in favour of large populations. What is more, it casts a different light on the implications of abandoning a simple summation of utilities. If the social welfare function becomes a concave function of individual utilities, then this concavity may reinforce the concavity of the square bracket, moving the optimum towards a smaller population. (For example, this happens with a transformation g() of the logarithmic utility function, where the first and third derivatives of g() are positive and the second negative.)

Where will population grow?

To this point, I have assumed that world inequality remains the same as the population size varies. The above analysis posited a – fixed – degree of inequality and asked how this affected the welfare implications of a growing population. But inequality may rise as a result of population growth. The projected population growth is not spread uniformly. Taking the UN projections from 2011 to 2050 (the Medium variant from the United Nations, 2011, File 1B), we can see that there will be little population growth (or negative) in Europe. Growth in US is predicted as 110 million. This is part of the overall projected increase, from 7.1 billion to 9.7 billion, but only a modest part. The projected increase is much larger in India (plus 486 million) and in Nigeria (plus 230 million). Together they account for over a quarter of the world's projected population growth. The increase in these countries is so large that I have left them out of Figure 4. This shows the 30 countries where population is projected to increase by 20 million or more from 2011 to 2050 and their 2006 levels of Gross Domestic Product (GDP) per capita adjusted for differences in purchasing power (data for Afghanistan are missing.) The 30 countries account for over three-quarters of the 2.6 billion increase in population expected between now and 2050. Of these 30 countries, only the US and Mexico have mean incomes above the world mean. As shown in Figure 4, 14 of the 30 countries have mean incomes below the lowest quartile of the world income distribution (calculated from data for 2006 supplied by F Bourguignon). Much of the population growth will be in poor countries.

The countries where population is projected to grow are also in many cases more unequal. That is, we have to bring in the second element that leads to global inequality: the differences within countries. The world is unequal both because Zambia is poorer than Britain but also because within Zambia there is high inequality. In Figure 5, inequality is measured by the Gini coefficient (or half the relative mean difference). Suppose that a new person in Zambia could have the income of anyone chosen at random from the Zambian population, what is the expected difference in their income from yours – where you are a randomly chosen

citizen of Zambia? The expected difference, expressed as a percentage of mean income and divided by 2 gives the Gini coefficient. For Zambia, it is close to 50 per cent, according to World Bank data. On average the difference between the incomes of any two Zambians chosen at random is equal to twice 50 (= 100) per cent of the mean. 50 per cent is quite high by international standards, as may be seen from Figure 5, which shows the distribution among all countries. What about the 30 countries where population is projected to grow by 20 million or more? Although there are a number of the 30 countries with values below 35 per cent, the median is above 40, and there are 7 countries with values in excess of 45.

Taking together the low per capita incomes and the within-country inequality, we can see that the projected population growth will add significantly to world poverty. It may be calculated that, if per capita incomes and the distributions within countries were to stay the same, then the population growth would add ¾billion to the number below the $1.25 a day poverty line. Of course one hopes that there would be income growth, but it means that growth would have a larger gap to fill. In effect the population growth would add to the scale of the problem by a third.

What does this mean?

Does this mean that only countries with above-average incomes should be allowed to expand their populations? As Parfit (1990, page 145) asked rhetorically, would it "be best if in future only the best-off nation – such as the Norwegians – have children"? No, since there is a further element. The extent of global inequality is not immutable. The calculations above assume that the cost is borne by the country in question: the birth of an additional Zambian reduces the average consumption of Zambians but no one else. But if the cost is shared throughout the world, then the calculation may look rather different. An expansion of the world population may raise social welfare if it is accompanied by increased redistribution between countries. To revert to my transport metaphor, but switching from buses to the railways, it may be that a train cannot squeeze in any more passengers in standard class but that there are empty first class seats. This may not be a problem if those in first-class are willing to move their briefcases off the empty seats next to them and make room for some standard class passengers.

The classical utilitarian analysis may have been biased the conclusion in favour of overly large populations in part because it assumed that taxes and transfers would equalise incomes (see, for example, Meade, 1955, page 90). So far in this section I have gone to the opposite extreme and assumed that the existence of inequality has to be taken as given. This second-best view may be realistic, as was argued by Daly, Ehrlich and Ehrlich:

> "we are sceptical that the incentives driving social and economic inequalities can ever be fully overcome. We therefore think that a global optimum should be determined with humanity's characteristic selfishness and myopia in mind" (Daly, Ehrlich and Ehrlich, 1994, page 471).

The train seat metaphor may give a misleading impression of the ease of making such transfers. There may be those who would be willing to reduce their own consumption but doubt whether the resources can be effectively transferred. For them, the deep-seated nature of global inequality may be a barrier to accepting population growth.

But this may be too pessimistic. The very fact that many of the increased world population will be found in countries that are both poor and highly unequal may lead to greater efforts to combat world poverty and inequality. People may therefore differ in their judgments about whether or not the planet is full according to their willingness to accompany an increase population with further redistributive transfers.

Conclusions: Is the Planet Full?

In this paper I have argued that it is right to pose the question in terms of the number of people, not as a matter of levelling the field of individual choice. The central issue concerns the size of the world population, not untrammelled parental choice. The way in which economists have thought about the optimum population over more than a century has considerable value, but the standard classical utilitarian analysis has been criticised as biased in favour of large populations, as saying too readily "No" to the question "Is the planet full?". I have argued, however, that such a response is not necessarily implied, and that the conclusion follows more from the specific assumptions than from the underlying framework.

At the same time, there remain serious shortcomings to the classical utilitarian analysis and I have examined three ways in which it needs to be developed: we need to take account of alternative social objectives, to enrich the economic framework within which the question is posed, and to consider the implications of inequality between and within countries. Each of these developments may incline us more towards saying "Yes". With the critical-level utilitarian approach, we are in effect raising the bar, and making a "Yes" more likely. With a capability approach, absolute requirements in capability space may translate into a set of requirements for resources that are increasingly demanding, again shifting the baseline. The capability approach highlights the need for social infrastructure as well as private resources. The impact of additional people on

resources and climate add to the cost side of the equation. (Although, operating in the opposite direction may be a positive impact on technological creativity.) The existence of inequality in the distribution of resources may well (although does not necessarily) give us pause about the desirability of expanding the world population. The pattern of population growth will tend, other things equal, to increase global inequality and poverty. Whether or not we welcome this population increase depends on whether we are willing to take steps to ensure that "other things are not equal" by expanding global redistribution.

I said at the outset that I would not answer the question. I have however tried to identify some of the factors that are likely to lead to different conclusions: the answer depends on

- The social welfare function: the classical utilitarian specification used by economists has tended to point towards saying *No*, but alternative approaches to evaluation may point towards *Yes*;
- How important we expect labour to be as a productive factor in the future: people who believe that robots will largely replace humans are more likely to say *Yes*.
- How much we are willing to invest in infrastructure and in offsetting climate change: low investors more likely to say *Yes*;
- How far we believe that a large population leads to greater technological creativity: Optimists more likely to say *No*;
- How far we are concerned with global inequality: Those with greater concern are more likely to say *Yes;*
- How much global redistribution we are willing to undertake, or believe to be effective: Those who believe in the desirability and effectiveness of more redistribution are more likely to say *No*.

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Figure 1 Optimum population to maximise the sum of utilities

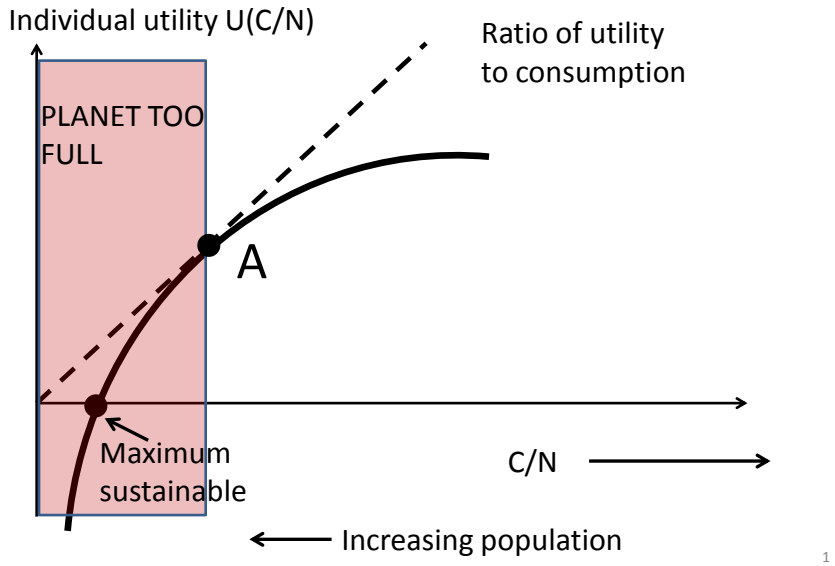


Figure 2 Utilitarian optimum population: an empirical application

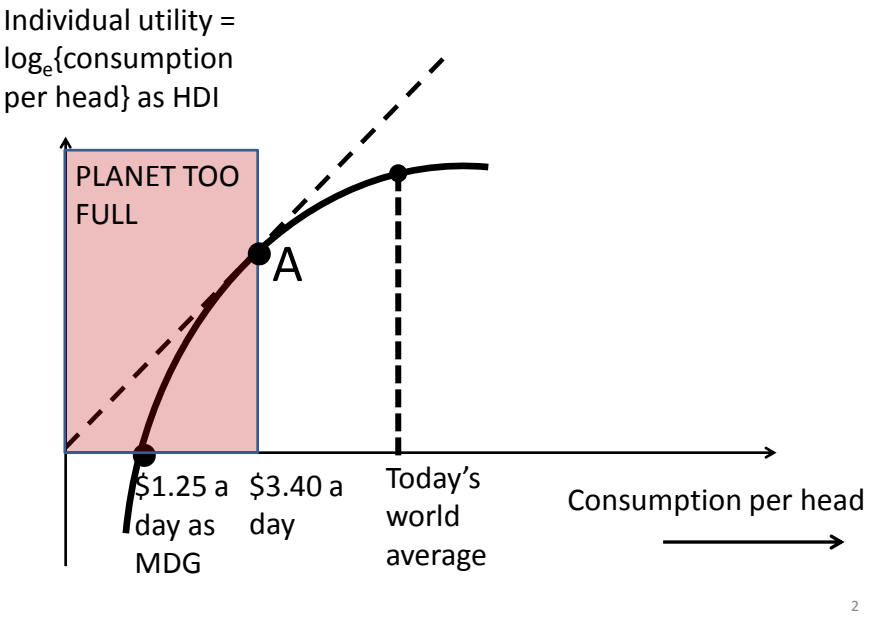
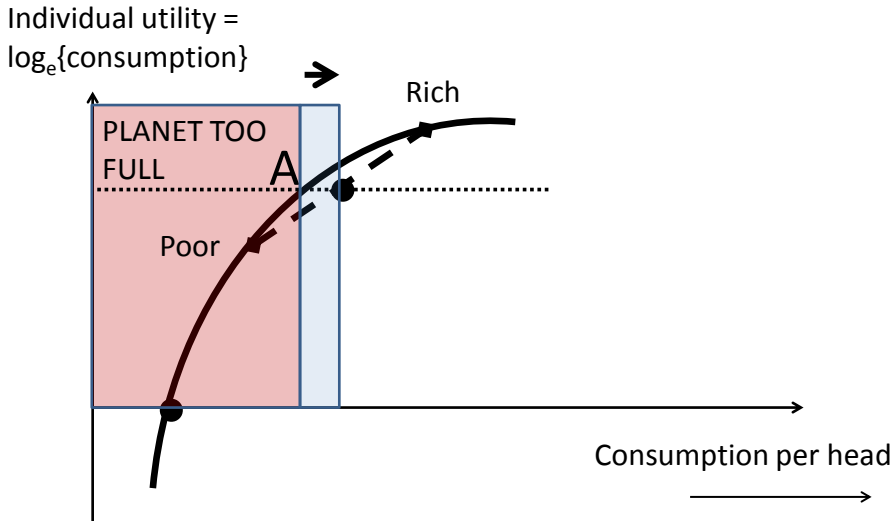
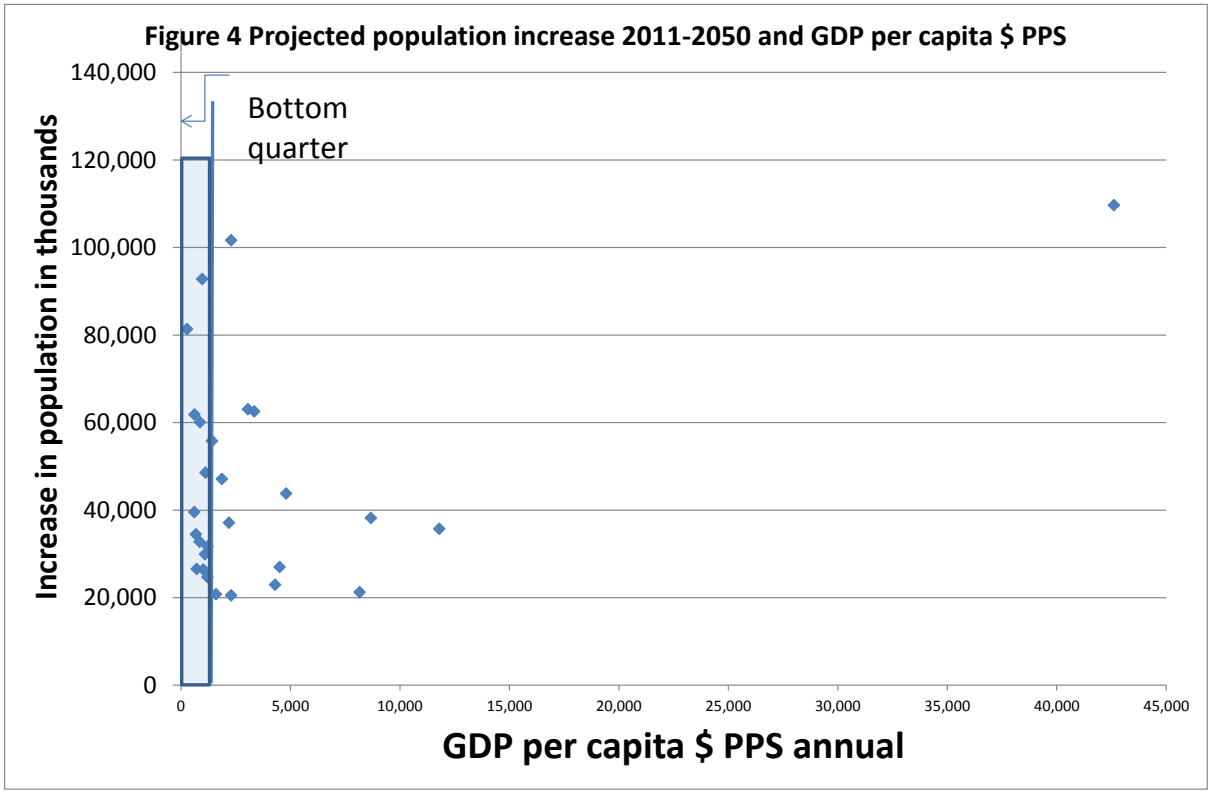


Figure 3 Classical utilitarian optimum population in the presence of inequality: special case of logarithmic utility function



3



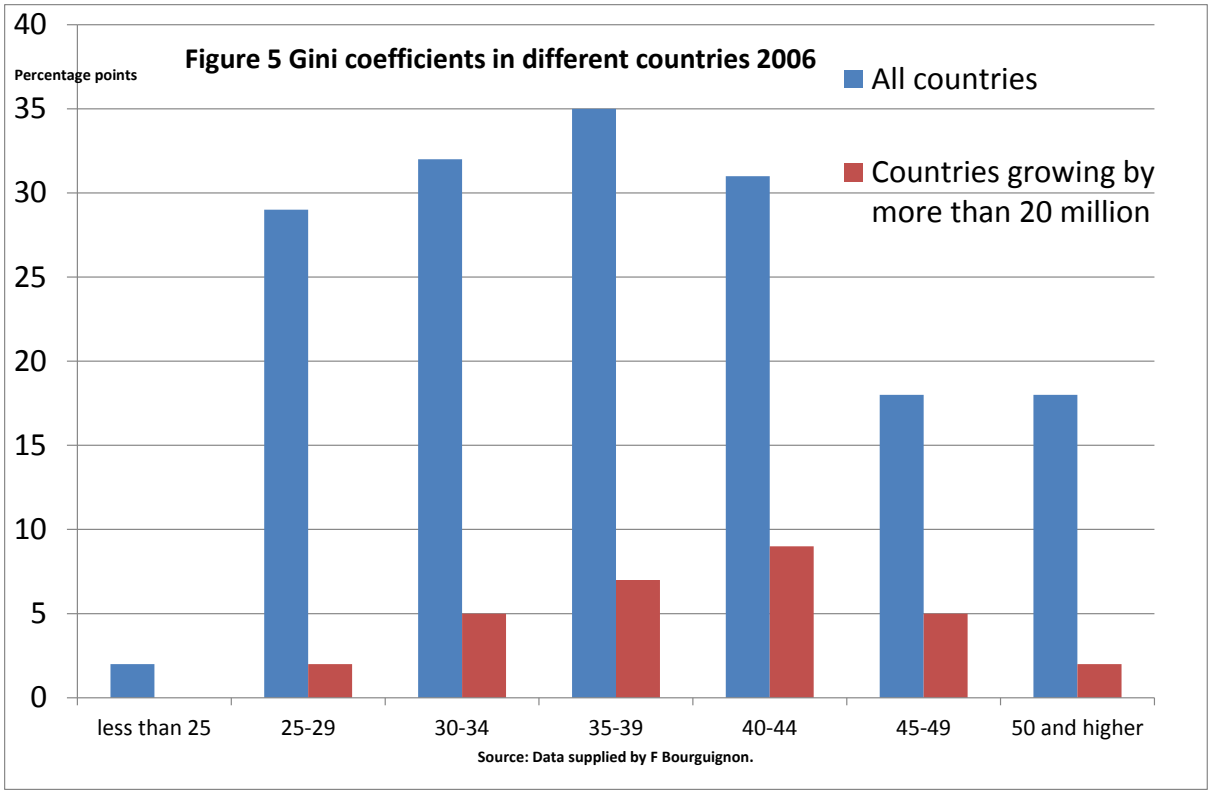


Figure 5 Gini coefficients in different countries 2006
Percentage points
40
35
30
25
20
15
10
5
0
All countries
Countries growing by more than 20 million
less than 25
25-29
30-34
35-39
40-44
45-49
50 and higher
Source: Data supplied by F Bourguignon.