Population and climate change

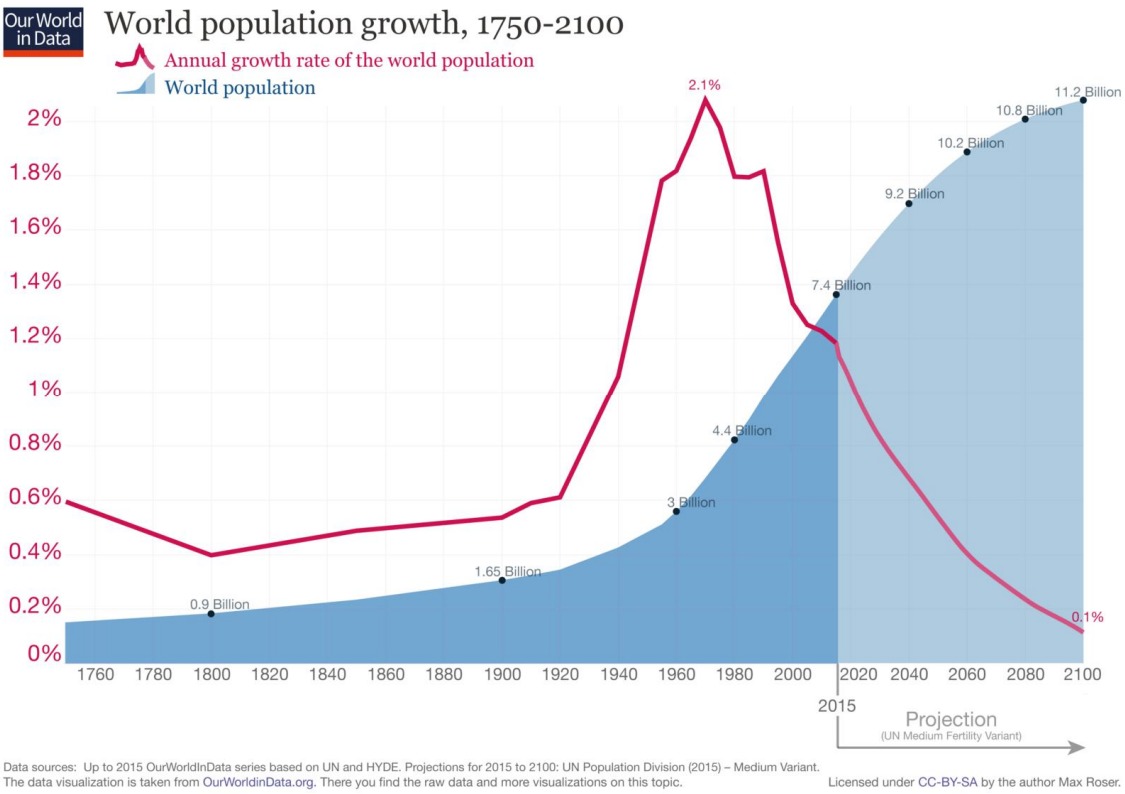
Emmanuel Pont, *Medium*, May 27, 2021

Do we have to reduce global population to "save the planet"? Many people say that limiting population size is a priority for environmental sustainability, several organizations have even been created to support this goal, and the debate regularly flares up in the ecologically-minded community. According to some studies, having a child is the worst thing one can do for the climate, by far. As a "green" individual, should one give up on having children, and feel guilty about the ones already born? How can we shed light on the subject and get closer to a rational answer? In this article we will investigate the links between climate[1] and population[2] [3].

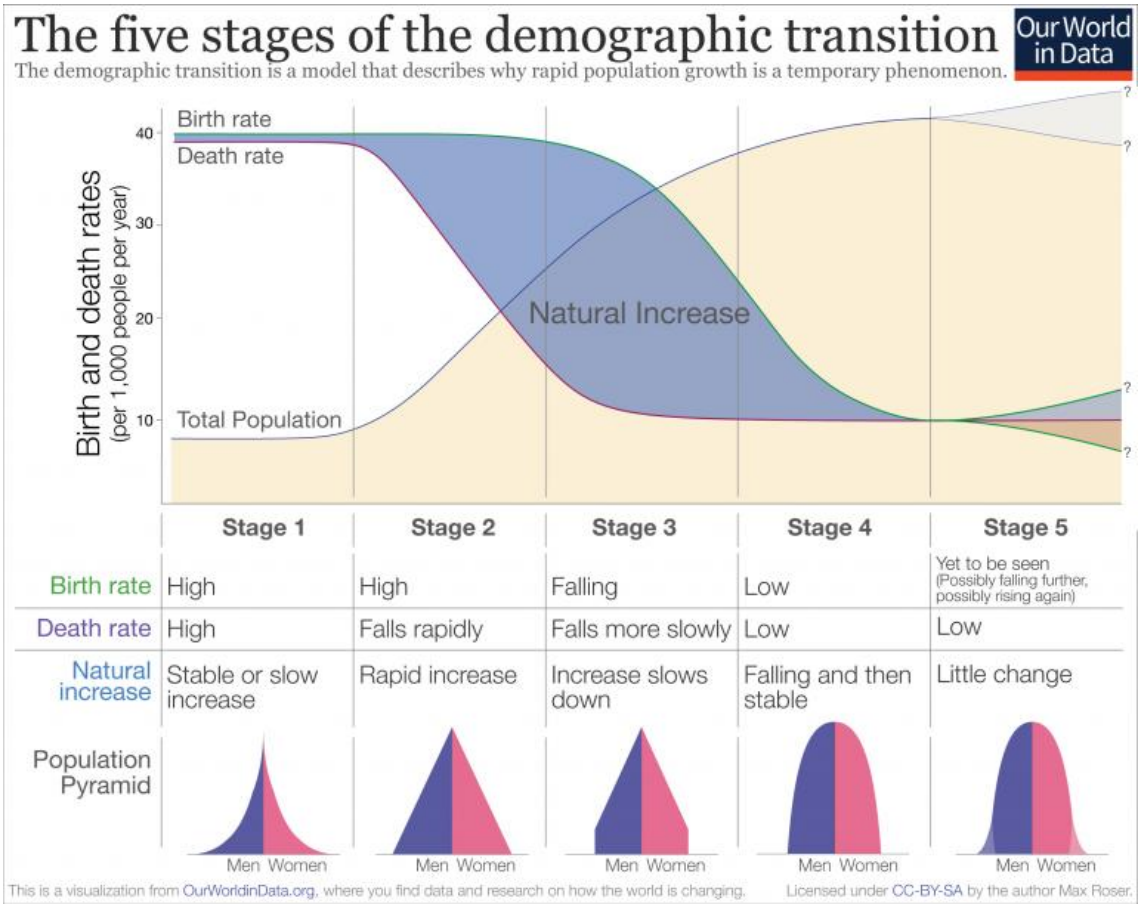
Contents

What is the state of the world's population today?

From a first glance at the data it might look as though the world's population is increasing faster and faster, like an exponential curve. Yet this is an optical illusion - or more often a misleading presentation. The growth rate[4] of the world's population has been steadily decreasing since 1970. UN projections estimate a stabilisation of the population around 2100 :



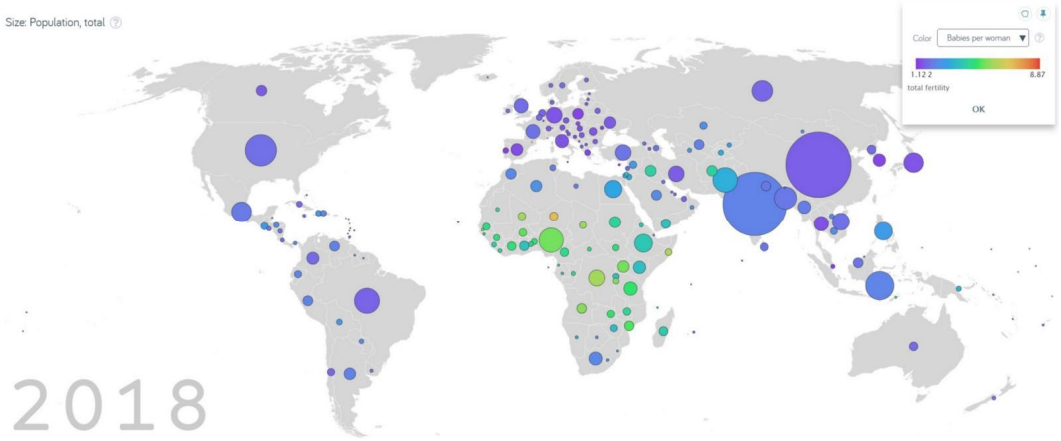
The population increases or decreases due to the difference between mortality and natality, measured by death and birth rates. It is stabilising because all countries (without exception so far) go through a process known as the "demographic transition". Birth rates start high as a result of a cultural norm that ensures population stability in a world with high mortality. As living standards, hygiene and medical advances improve, mortality begins to fall. Birth rates follow suit with a delay, resulting in a rapid population increase.



Since there is unanimous political and philosophical agreement on the decline in mortality, the room for manoeuvre that everyone is looking at is the birth rate. Its best indicator is the fertility rate (to be exact, the total fertility rate):

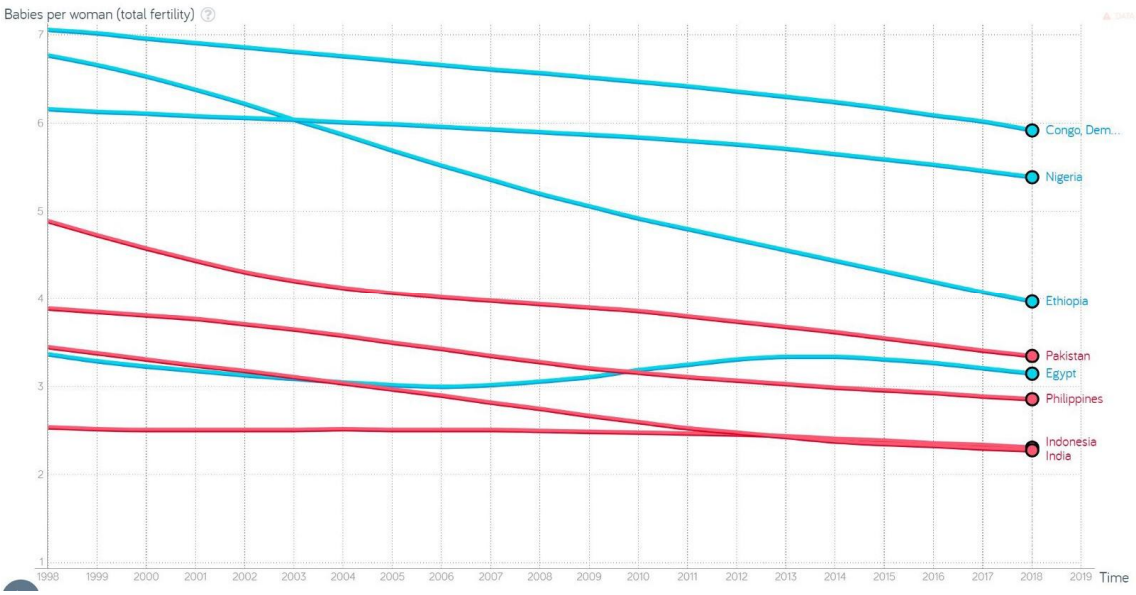
Fertility rate = average number of children per woman of childbearing age

As part of the demographic transition, fertility gradually declines to a rate such that births compensate for deaths, thus ensuring population stability. This rate, known as the "sub-replacement fertility", is around 2.1 children per woman in developed countries, 2.3 on average in the world, and in some places rises as high as 3.4: it depends on the distribution of the population between men and women, and on mortality before childbearing age. Today most countries have a fertility rate below 2.1, so that their population would decline in the long term if it were not supplemented by migration.



A number of large countries are at the end of their demographic transition with a fertility close to 2.1. For example India reached 2.28 in 2018, probably already sub-replacement because of infant mortality and gender imbalance. Moreover, India has a population of more than one billion, breaking it down by state it appears that it is not homogeneous: half of the states (totaling half the population) are below 2.1. We will also come back later to the difference between rural and urban populations. On the other hand, reaching 2.1 does not mean that the population will stabilise immediately: recent generations that were born during periods of higher birth rates will also have children, who will not be "cancelled out" by the deaths of the less numerous older generations. Stabilisation is much slower. This is called "population momentum". That's why the Chinese population is still growing slowly despite a very low fertility rate of 1.6 children per woman.

There are still two major groups of countries that are at an earlier stage of their demographic transition, shown in green on the map: intertropical Africa and the less developed Middle Eastern countries (mainly Iraq, Yemen, Afghanistan, Pakistan). It should be remembered that this also corresponds to a much higher mortality rate, particularly infant mortality, than in the richer countries. Most of these countries in transition have a steadily declining fertility rate, as can be seen from the history of the 8 most populated countries above 2.1 ... except for rare setbacks such as the economic crisis in Egypt:

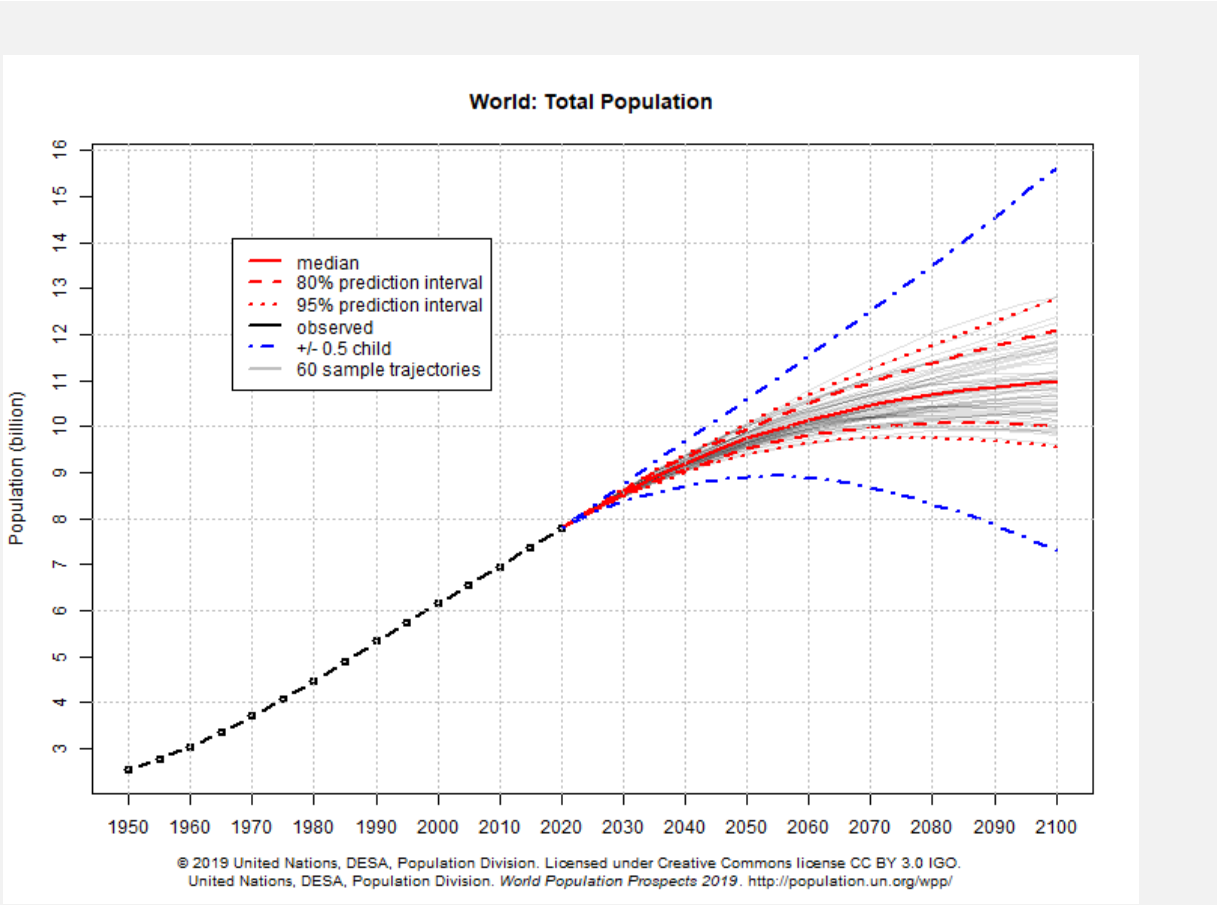


The demographic transition is caused by many elements: economic development, health, education (mainly of girls), women's workforce participation, social norms, incentives and prohibitions, contraception, pensions, health system… It is difficult to separate these different factors, and their relative importance seems to vary greatly from one country to another. I was able to find all sorts of different estimates and special cases. In any case, their combination is important, distributing contraceptives is not enough to start the demographic transition.

Can the demographic transition "reverse" in the event of a crisis, as we have seen in Egypt? When looking at a sample of countries in difficult situations, they all remain on a sharply declining slope; only Iraq and Zimbabwe have experienced a temporary fertility plateau. Looking back over 40 years there are only a few temporary increases (Somalia, Yemen, Congo, Haiti). I confess that I was very surprised to find no abrupt break: wars or famines have no significant effect on fertility, in either direction.

What can we expect for future population growth?

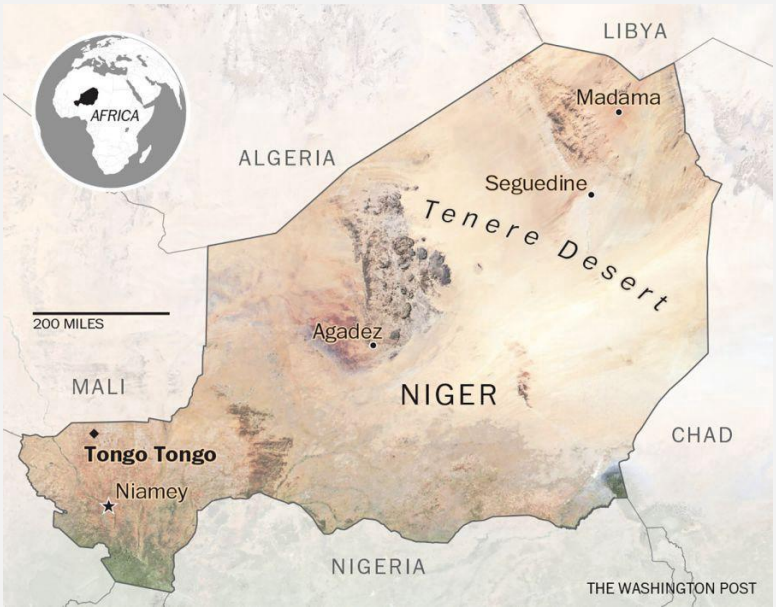
The United Nations regularly produce influential projections. Latest projections were published in June 2019:



The novelty of this report is that fertility seems to remain durably and significantly below 2.1 in developed countries, moving towards a smooth population decline. The United Nations now estimate a convergence of fertility rates towards 1.9, whereas previous versions aimed at 2.1.

However, beware of the trap[5]! The scenarios generally presented as “high” and “low”, the blue dashed lines, are in fact constructed by an arbitrary fertility difference of plus or minus 0.5 children compared to the average scenario. This is interesting for analyzing the sensitivity of other variables to fertility, but makes little practical sense: such a large variation everywhere in the world is extremely unlikely, as it would double the evolution in the median scenario. It should then be used with precaution, as we shall see later. The high and low scenarios that are most relevant for a general analysis are the small red dotted lines (95% confidence interval).

How are these projections calculated? By extending the evolution of fertility, mortality and migration rates by country. Demographers calculate “all things being equal”: they do not have a crystal ball and cannot predict the rest of the world’s evolution (politics, wars, famines, crises, etc). This is the best one can do and remain rigorous, but this poses a particularly embarrassing problem in the context of ecology: we cannot think at the same time that the world will suffer major ecological crises in the near future and that the population will continue to evolve as if nothing had happened. Some estimate that a world with 4°C warming may not be able to support more than 4 billion people. This is probably a pessimistic view, but it puts the projections of 11 billion people in 2100 into perspective. Take Niger, for example, the country with the highest fertility in the world (7 children per woman), with 20 million inhabitants today. It is also one of the poorest countries in the world, 90% desert, which regularly suffers from famines affecting the majority of the population. Who really believes that with desertification, lack of water, and political instability in the region, the country will be able to multiply its population by 8 to reach 160 million inhabitants in 2100, i.e. one and a half times the current density of France? In the case of Niger, even the projection of 60 million in 2050 looks unlikely. This is not true for all countries, in particular a certain number of African countries can accommodate a much higher population, but it is necessary to consider each local context.



So, are UN demographers idiots? Absolutely not, they are doing their job as demographers, which is to estimate population changes based on current demographic trends. This is why we talk about projections and not forecasts, and the distinction is important. The idiots reckless ones are those who take up these figures in the public debate without any hindsight. Projections are not totally useless either, as we have to know roughly where we are going.

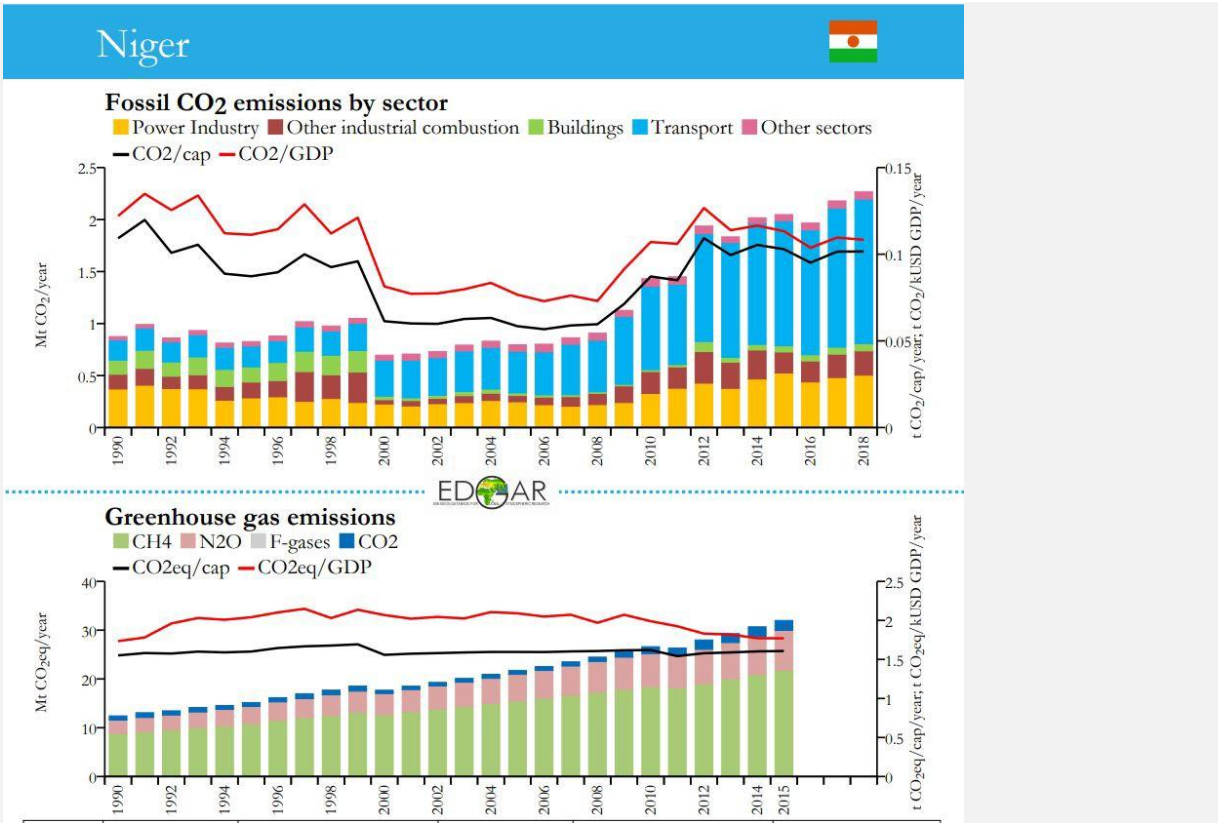
In this article I will confine myself to projections for 2050, which are close enough to remain reasonable. It is also an important deadline for climate change: to limit warming to 1.5°C we will have to be carbon neutral by that date, regardless of the number of inhabitants. Miraculously, this objective is beginning to gain unanimous support in the political and economic world. It is against this objective that we will be able to measure the relative weight of demographics for the climate.

I will not focus on projections for 2100: the world will have deeply changed anyway, either through a transition to a more sustainable society, or forced by ecological disasters, in which case we will be facing much more serious problems than overpopulation. What threatens us in 2100 is the depletion of most resources, a warming of at least 4°C, a violent drop in agricultural productivity and a large part of the planet uninhabitable. Whether we like it or not, we will be very far from "all things being equal". Finally, most ecological systems, especially climate, have a high degree of inertia: by 2100 it will be too late to avoid these disasters, so we must act now. The other problem for 2100 is that we may not have much fossil fuel left to burn!

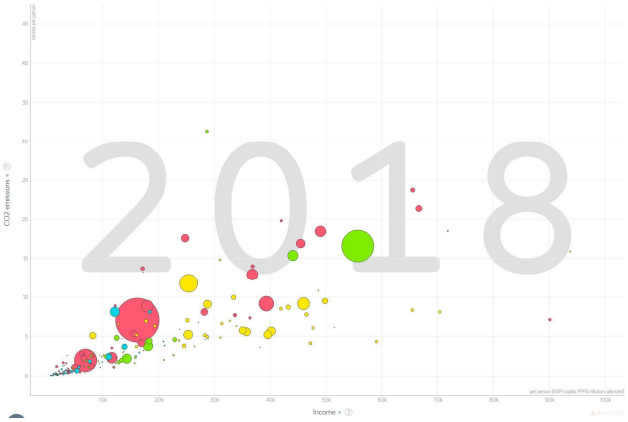
In fact, even on demography there are ongoing debates: the demographic transition is much faster in cities than in the countryside, and the world is urbanizing faster than expected (which is not really good news for the environment). These projections would see the world's population peak in 2050 rather than 2100, between 8 and 9 billion. I don't have an opinion on this, and it doesn't significantly change the figure in 2050.

How are greenhouse gas emissions distributed?

All greenhouse gas emissions must be taken into account. In rich countries we burn a lot of fossil fuels (CO2 emissions), but in some poor countries it is nitrous oxide from fertilisers and especially methane from livestock that make up the majority of emissions:



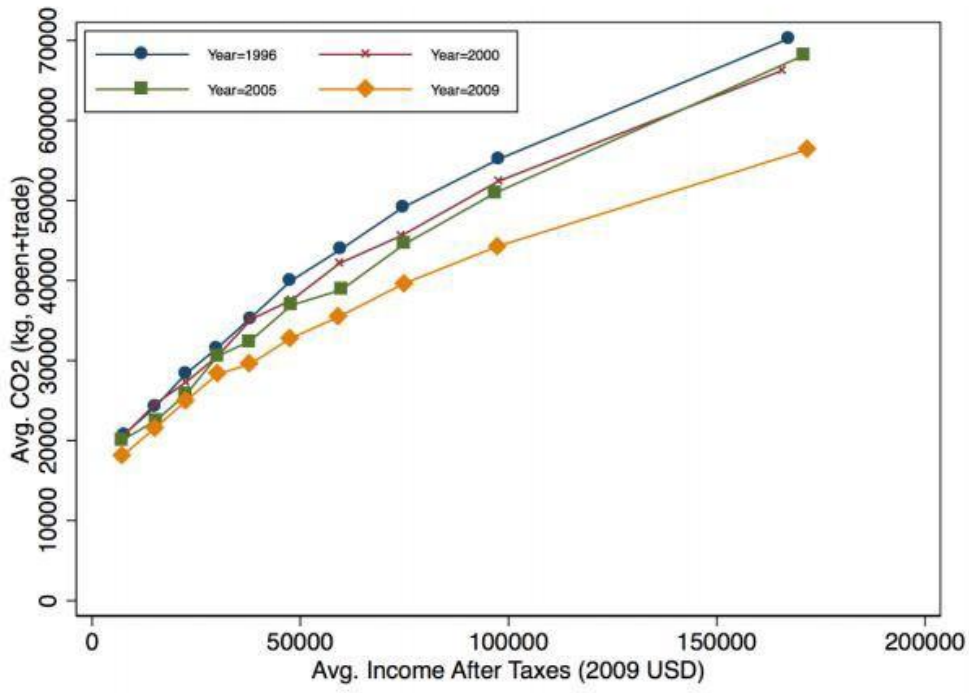
However, methane is short-lived in the atmosphere and comparing it with CO2 cannot always be summarized in a Global Warming Potential number. Unless stated otherwise, I have made the calculations based on total greenhouse gas emissions, but the graphs are only about local CO2 emissions. It can be seen that these vary very strongly between countries, and in a way that is more or less proportional to GDP per capita:



A similar result is obtained with the Ecological Footprint, an indicator that aggregates several measures of pollution, with slightly less variation between rich and poor.

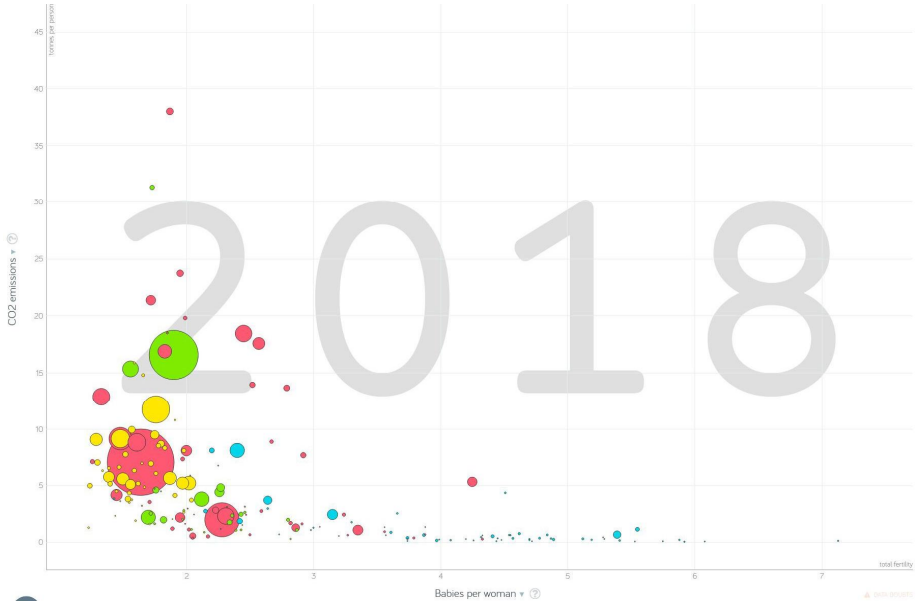
Let's forget for a moment about borders and focus on real people. This has not been studied everywhere, but the results in Canada, Germany, Hungary and globally indicate that the same proportional relationship between income and consumption-based ecological footprint applies well at the individual level. When counted on a per capita basis, the richest 10% of the world's inhabitants are responsible for as many emissions as the poorest 90%. More specifically, the graph of emissions plotted against income flattens out at a certain level, with the wealthy having higher emissions overall, but less as a proportion of their income:

Figure 1: Descriptive Environmental Engel curve – Household CO_2



These numbers are useful to put into perspective fallacious arguments such as “degrowth will prevent poor countries from developing”: today it is the “rich” (which include, on a global scale, the average European or American person) who are by far the most responsible when counting emissions from consumption. It is also one of the great difficulties of the ecology of small individual gestures, income remains by far the best predictor of the ecological footprint. Ecological awareness or most (not all) individual actions have only a minor impact today. On the other hand, the individualisation of the calculation of emissions or the ecological footprint also has its limits: a large part depends on an economic and political system over which the individual has only very limited power, especially large companies and energy. And beware of using it to depoliticise the issue.

Now let’s move on to CO2 emissions as a function of fertility:



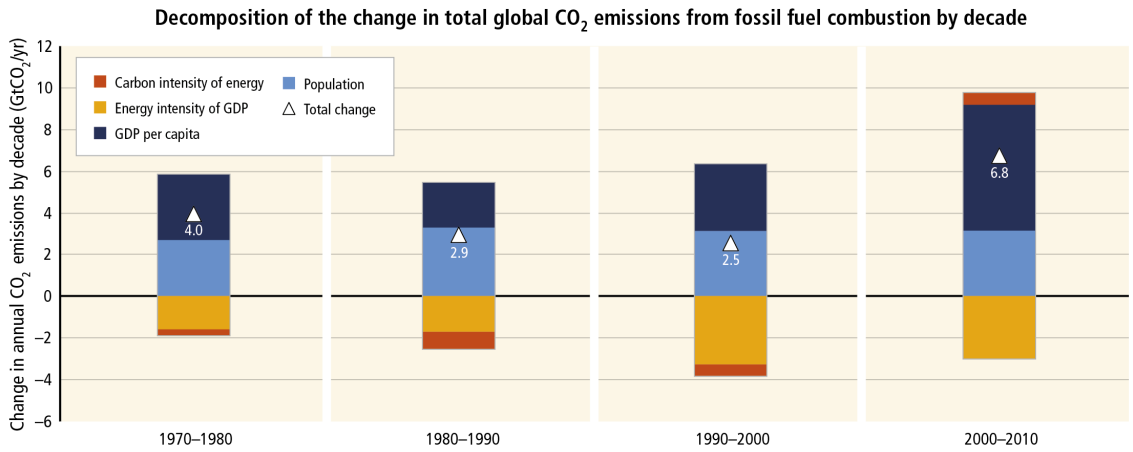
As might be expected, most of the countries with the highest emissions, both in absolute terms and per capita, are rich countries that have already completed their demographic transition. If we divide them into three groups, calculating the total greenhouse gas emissions:

- Post-demographic transition countries (fertility ≤ 2.1): 74% of global emissions (including China 27% and the United States 13%)
- Countries coming to the end of the demographic transition (fertility ≤ 3.4): 19% of global emissions (including India 7%, Indonesia 2%, Mexico 1.6%, Saudi Arabia 1.5%, South Africa 1.2%), which will soon move to the previous group (I have arbitrarily chosen 3.4, which is the highest sub-replacement fertility threshold)
- Countries in transition (fertility > 3.4): 3.5% (including Pakistan 0.8%, Nigeria 0.6%, Iraq 0.5%). Intertropical Africa accounts for only 2% of global emissions, one third of which is in Nigeria. Counting only CO2, we go from 3.5% to 2% of total global CO2 emissions.

To put these figures into perspective, air travel accounts for around 5% of humanity’s emissions (counting all the effects and not just the kerosene), whereas 80% of humans have never taken a plane. The emissions of poor countries with high population growth are negligible today compared to those from rich countries. The same is true for the history of past emissions, those that have already warmed the climate and continue to transform it today: the vast majority have been emitted by developed countries.

It is essential to break numbers down so as not to draw the wrong conclusion. We often read arguments such as “Between 1990 and 2014, CO2 emissions in the world grew by 58%, but only by 15% per capita. So population growth accounted for about three-quarters of the increase.” This is numerically true, but it is a complete misunderstanding or more likely a manipulation: this calculation mixes the increase in emissions in some countries with the increase in population in others. The classic problem of too broad averages: “when Bill Gates walks into a bar, on average all the customers are billionaires”. The illusion disappears as soon as you break it down a bit more finely, for example as I did above (it is a bit less inaccurate on past emissions, where the population may have increased strongly even if the fertility rate is low today).

The IPCC does not do any better, calculating globally (WGIII 1.3.1) the factors of evolution of emissions, and highlights this result by including it in the synthesis report:



This is all the more regrettable as the authors insist just afterwards (WGIII 1.3.1 p129, but not in the synthesis) on the limits of the global analysis and the important local differences, while the rest of the report (notably WGIII 5) proposes much finer breakdowns. I would like to see the result of the calculation by country, then summed up on a global scale. Here is the IPCC one by major region, where we can already see a significant drop in the population factor:

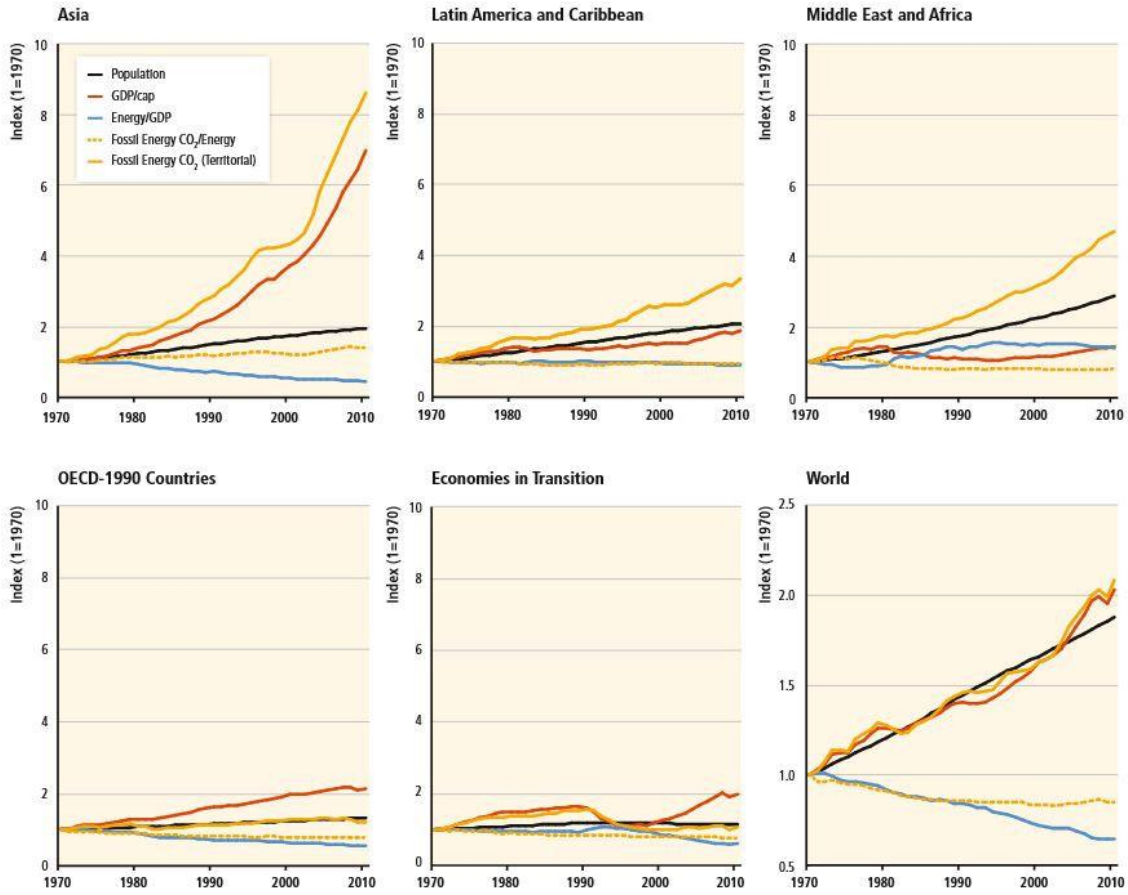


Figure 5.7 | Four factor decomposition of territorial CO_2 emission from fossil fuel combustion at regional level over 1970–2010. Note that only the bottom-right panel for the World has a different scale for its vertical axis. Data from IEA (2012) and JRC/PBL (2013); based on PPP-adjusted GDP. Regions are defined in Annex II.2.

Asia should be broken down even further: between 2000 and 2015, 60% of the global increase in emissions was in China. Chinese emissions increased by 151%, population by only 9%.

It is better to be very careful with the concept of "world population", which mixes extremely different situations. Even at the country level it is often questionable. For example in India a poor rural family with a high birth rate will be mixed with an urban middle class family which consumes more and more but with a fertility rate below the European average.

How to reduce emissions?

We have just seen that it is very delicate to measure the "share of responsibility" of the population on emissions, so we cannot be satisfied with simplistic reasoning such as "population is a problem, so we must reduce it". Yes, the world's population exploded in the 20th century, that's a fact and we can't change the past. The relevant question is: today (rather than 50 years ago), what can be done and for what result? Applicable measures must be defined and evaluated.

Let's start with the obvious: if there were half as many of us, all other things being equal, humanity would emit half as much greenhouse gases, and produce half as much pollution overall. This line of reasoning is so common that it could be the plot of a mainstream film. But common sense can be misleading. The rebound effect may be very large, it may be a world where everyone goes to Ibiza for a weekend, while emissions per person in the US are twice the average in Europe, for a very similar standard of living. At the current rate of emissions growth, we would quickly reach the same level. It is doubtful that humanity will be able to act before it hits the wall. It would be enough to "eliminate" the richest 10% to achieve the same result on emissions, as we saw earlier. And of

course, you can't just wipe out human beings with the stroke of a pen. We must ask ourselves what are realistic and ethical ways to act on demography and emissions.

How can we go further and link emissions and population numerically? We will start with a simple equation, the Kaya identity, which breaks down emissions by individuals[6] :

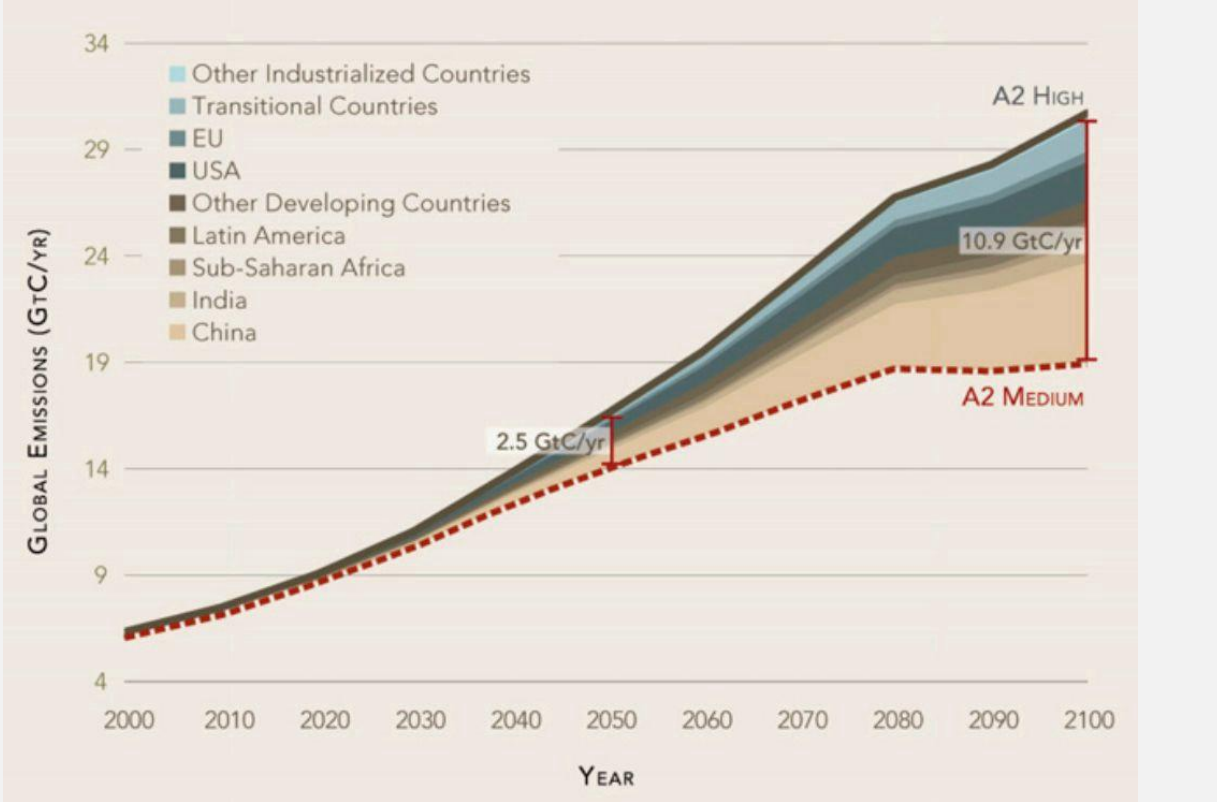
Emissions = number of people x emissions per person

It is an identity, it is necessarily true, but that doesn't necessarily make it relevant either. You could, for example, break it down by tomato production numbers, and it would be just as true but irrelevant. On population and climate, if Qatar is at the top of the emissions per capita ranking, it is not because of the decadent lifestyle of its inhabitants (85% of whom are precarious immigrants from poor countries), but because of its large gas industry.

An obvious conclusion from this equation is that reducing population by 10% and emissions per person by 10% have the same overall effect (this is actually an approximation, the variables are not independent). So we can use it to compare measures[7], putting aside the ethical complications of comparing a life and a trip to Bali on their respective carbon footprints.

So, how useful would reducing the population be for the climate? To find out, we need to simulate finely the respective evolutions of population and emissions per person. I have only found one recent study (2010) answering the question: "Global demographic trends and future carbon emissions". This is the study that is quoted everywhere on the subject, but often to the 2nd or 3rd degree.

This study uses the IIASA emissions scenarios, a complex economic model, and the difference between the UN's high and medium demographic scenarios. However, it only takes into account CO2 and not all greenhouse gases, which underestimates the share of countries with high birth rates (2% instead of 3.5%). After calculations, the result of the study is a 16% difference in emissions in 2050 in a "business as usual"[8] scenario:



What exactly does this result tell us, why does China have so much weight, and sub-Saharan Africa so little? Remember the UN high scenario, the one that is achieved by increasing the overall fertility rate by 0.5. This scenario does not correspond directly to any plausible projection or applicable policy, but does have a much greater effect in countries with low birth rates and high emissions, such as China, than in those with high birth rates and low emissions. This study therefore says absolutely nothing about the demographic transition or the real scope for reducing emissions by acting on the population, contrary to what the summary suggests: "we show that slowing population growth could provide 16–29% of the emissions reductions suggested to be necessary by 2050 to avoid dangerous climate change". This should be understood to mean "if fertility falls by 0.5 worldwide", which is therefore purely theoretical. No one is proposing to lower fertility in China by 0.5, when it is only 1.6 children per woman today, and this would have absolutely nothing to do with the demographic transition. This may be obvious to specialists of the field, but not to the rest of the world.

Unfortunately, this is the original source of this call by thousands of scientists to, among other measures, limit population. Here is the chain of quotes:

- A mainstream article among many : "Earth Needs Fewer People to Beat the Climate Crisis, Scientists Say"
- The original declaration: "World Scientists' Warning of a Climate Emergency"
- The only source cited in the population chapter: "Global warming policy: Is population left out in the cold? "(PDF), written in 2018 by Brian O'Neill and another author in Science. This article cites a single source on the impact of population on future emissions:
- "Demographic change and carbon dioxide emissions" written in 2012 by Brian O'Neill and other authors. This article mostly discusses measures of correlations between population and past emissions evolutions, for the future only one study is described and cited:
- "Global demographic trends and future carbon emissions" published in 2010 by Brian O'Neill, which we have just described above.

This should not be seen as a conspiracy or an evil plan by Brian O'Neill, but rather as a game of "Chinese whispers" that increasingly over-interprets a limited initial scientific result. Ironically, the mainstream article has the worst headline but is more accurate in substance, calling for a general population reduction without mentioning the demographic transition. The declaration, which does not explicitly mention it either, refers to means of action that are exactly those of the demographic transition. The most misleading article in this chain is probably the one in Science, which goes to great lengths not to use the term "demographic transition"[9] even though it only describes countries with high fertility, and acts as if these countries would contribute to the calculated reduction of emissions (the author is the same and should know this from his previous result). Yet this article acknowledges, without going further, that per capita emissions are low where conventional demographic measures can lower the birth rate. There is another missed opportunity in the 2012 paper, which notes that some measures on demographic transition would result in a decline in fertility close to the 0.5 variation of the UN scenarios. So why not repeat the 2010 calculation and apply it only to relevant countries ? I will do it very roughly (the data table is no longer available, so I had to measure pixels on the graph and extrapolate Africa): it would be around a 1% reduction in total emissions by 2050. It is not zero, but it probably doesn't deserve to be a top priority action[10].

Drawdown is equally bad on the subject: it similarly takes the difference between the high and medium scenarios (while acknowledging this construction as arbitrary on the site). It then splits the effect between family planning and girls' education in half (even though there are many more

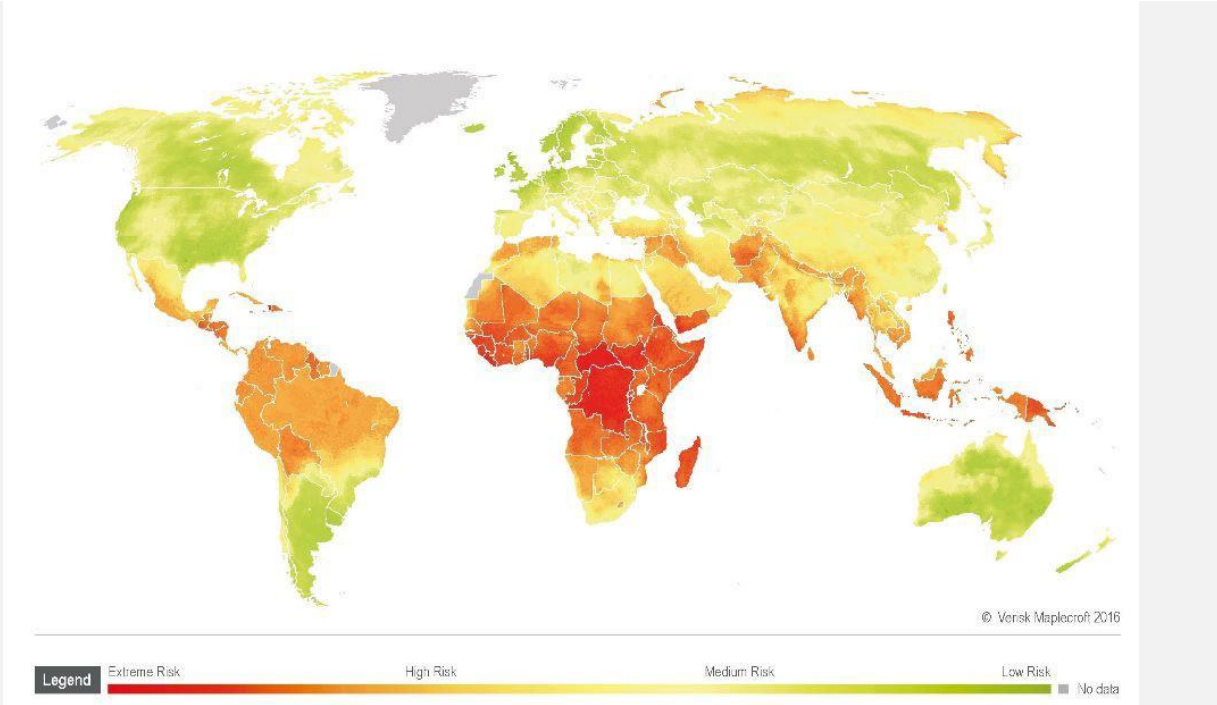
factors in the demographic transition). The total comes second in the "list of solutions", feeding the illusion that the demographic transition is a priority climate issue. No, fertility in rich countries, which are the main emitters, will not be reduced by 0.5 by increasing girls' education and family planning...

We have previously calculated that the countries in demographic transition account for around 3.5% of total global emissions. The IIASA scenarios used in the previous study project strong economic growth for these countries, but without catching up at all with the developed countries, which also continue to grow. The figures are not broken down by country, but Africa as a whole rises from 6% of global CO2 emissions (including 1% for inter-tropical Africa, the region with the highest birth rate today) to 8% in 2050. Whatever the room for maneuver on the demographic transition, the difference in terms of emissions will be small. However much we may fear that our unsustainable standard of living will catch up with that of less developed countries, it is far too slow today, and probably in the near future. This is the main explanation for its slow demographic transition: intertropical Africa is not developing fast enough.

Should poor countries be helped to accelerate their demographic transition?

We have just seen that the demographic transition of "poor countries" is in fact a very secondary problem for greenhouse gas emissions. Not necessarily uninteresting though, because this meagre result can be achieved very effectively, for example it would only take $6 billion per year to make contraception widely available throughout the world, for about 20 million fewer births each year. If we estimate the result at 1% reduction in emissions in 2050, as calculated previously, this is probably one of the most effective measures available. Unfortunately there are very few low hanging fruits of this order.

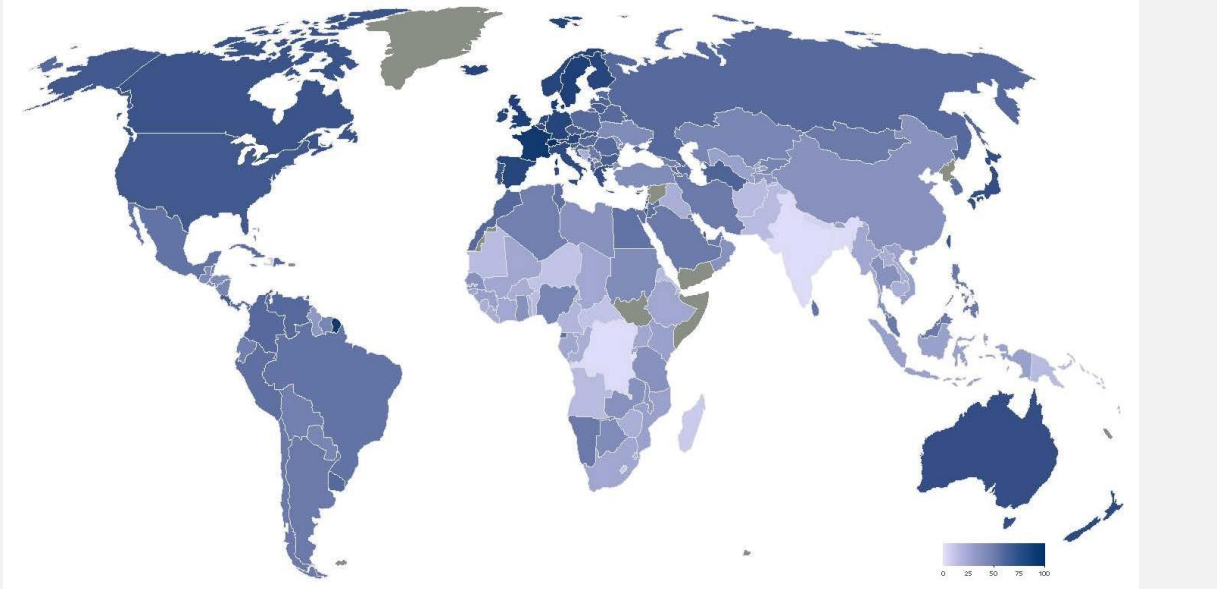
However, the main climatic fact for these countries is that they will also be the most vulnerable to global warming, and a higher population will amplify the difficulties. This is particularly the case in the Sahel, which is already suffering from the combination of global warming and population pressure.



Population remains a critical factor when the problem is extended to the environment as a whole, including water, soil, deforestation, biodiversity, waste, etc. In particular, there are smaller gaps between "rich" and "poor" in these areas than for emissions[11] :

Value	Source	USA	France	Niger	USA
CO2 emissions	EDGAR	16.1 t	5 t	0.1 t	
GHG emissions	EDGAR	20.14 t	6.98 t	1.61 t	
Ecological footprint	footprintnetwork.org	8.1 gha	4.4 gha	1.7 gha	
Biodiversity loss	Wilting et al., 2017	2.5 MSA	1.3 MSA	0.7 MSA	
Water footprint	Hoekstra et al. 2012	2842 m3	1800 m3	3519 m3	

Although it has been calculated that Africa is on average much less dense than Europe, if the deserts are removed, the density of inhabited areas is not so far off, and human expansion will be to the detriment of local natural areas, particularly forests. Many countries in the process of demographic transition already lack water and food production and are rapidly degrading their ecosystems:



Poorer countries must therefore be helped to achieve their demographic transition, but first and foremost for their own sake and that of their environment, not to reduce global warming. This avoids the neo-colonialist overtones of the infamous "we must first limit births in poor countries rather than review our lifestyle"[12]. This is all the more interesting because in these countries the reduction in population growth should also result in economic growth, unlike most ecological measures in rich countries.

Is it necessary to control the population in rich countries?

We have seen that rich countries are responsible for the vast majority of greenhouse gas emissions, so reducing their population there would have a significant effect, especially if the reduction affects rich individuals. The great difficulty is to know how, for what political acceptability, what result, and what timeline.

For countries at the beginning of the demographic transition, the main policies are known, but they are unanimously accepted and already applied in the majority of cases (within the limits of the often limited resources of states). It is possible to extend them but there will be no miracle: development takes time. A few rare short-term measures can be effective but not sufficient, for example in Africa 1/4 of women want contraception but do not have access to it. Authoritarian limitation of the number of children has only been adopted by two countries in the world, China and Vietnam. The debate is still open on the real effectiveness of the one-child policy in China, as fertility had mainly decreased before.

For countries at the end of the transition or after, the vast majority, it is much more complicated: measures that are both consensual and effective have been exhausted. The level of education is already high, women are fairly well integrated in the labour market, pensions are assured, and contraception is widely available... Moreover, fertility rates are still falling in most of these countries, often well below the sub-replacement threshold. The only ways to further reduce fertility would be through cultural changes and authoritarian measures. The former are very slow and unevenly distributed, with the latest measurement of the desire for children in the US above 2.5 children per couple. The latter seem very far from being politically acceptable today[1][3]. The demographic transition has been very fast in some countries (e.g. Iran) but it seems much easier to convince people to go from 6 to 2 children than from 2 to 1 or 0.

What would be the effect of limiting births, whether it happens voluntarily or authoritatively? I have only found a calculation at the global level, which is not really helpful because of the wide variety of situations. One can quickly calculate an order of magnitude, here for France which is a good example for rich countries with a 1.9 fertility rate. The number of children per family is available on the INSEE website (you have to extrapolate the details for families with 4 or more children). Banning children above 2 would mean reducing the total number of children in families by 13%. This figure is falling rapidly, the previous census gave 15%, so I estimate that this would be equivalent to a drop in births of around 10% today. This low figure is not surprising, with an average fertility rate of 1.9 there are not that many children above 2. All that remains is to compare this scenario on the INED simulator (in free simulation mode) with the one without modification.

Result: -5% of population in 2050. This does not take us very far, and again the calculation has been broad. As the fertility rate keeps falling, the number of children over 2 will continue to decrease too, and we have forgotten all the annoying details such as twins and other multiple births, separated or reconstituted families, or children of rape, an explosive subject in the United Kingdom, which has reduced benefits over 2 children.

What about the benefit cuts promoted by some associations? It will be less than 5% in any case. The British government has not given an estimate of the expected effects on demographics, but cites a study on the large increase in benefits in 1999. It measures an increase in fertility of 15%, but only for the poorest 20% of the population, which means an increase in the total fertility rate of 3%. By simulating an equivalent reduction, we arrive at an order of magnitude of 2% less population in 2050.

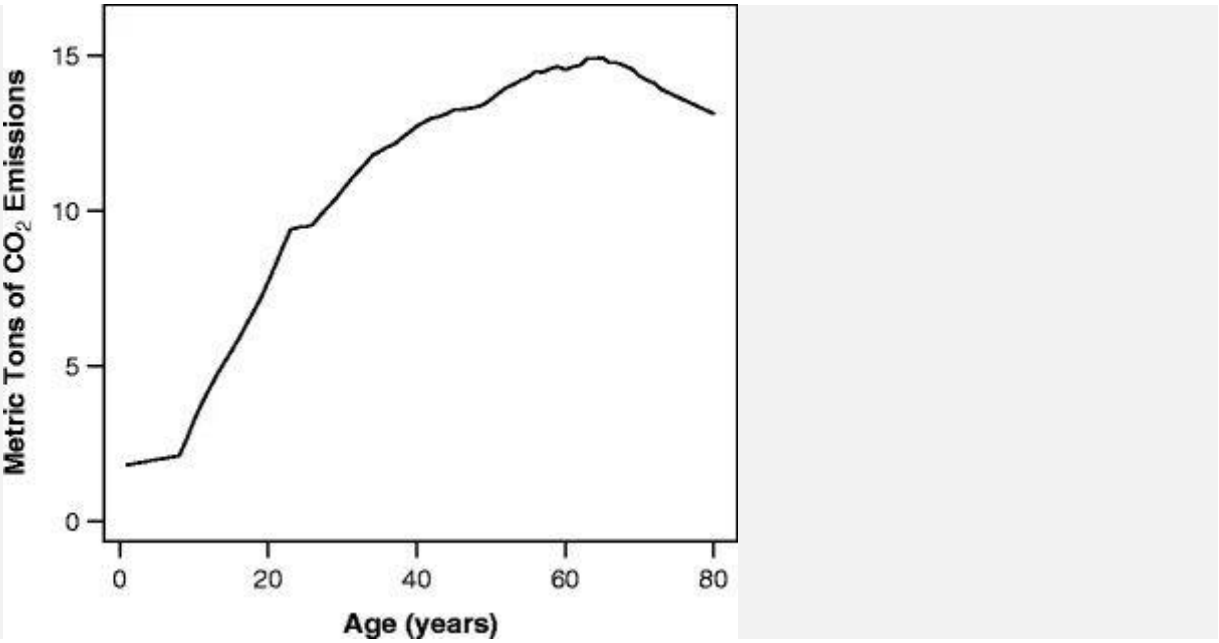
To achieve a significant effect we need to move to a one-child policy, bearing in mind that it would probably be extremely unpopular. In this case we arrive at a population reduction of about 19% in 2050, but welcome to a world without youth[14] :

And just out of curiosity, what would happen if everyone gave up having children? A 36% reduction in population by 2050.

In short, I strongly doubt the political possibility of significantly and rapidly reducing the population by acting on the birth rate in France, and more generally in rich countries that have completed their demographic transition.

The other "possibility" remains a sharp increase in mortality from war, famine and disease, which nobody wants. Let us remember that these events are not simply a "numerical reduction" of the population, but profoundly destroy society. This is what is likely to happen in Africa, which remains the most fragile continent economically, politically and ecologically.

Beware, if we apply the result of these calculations directly to the Kaya equation, we are acting as if all individuals had the same carbon footprint, whereas in practice it varies greatly by income and age, and is much lower for children and young people in particular:



Our estimated figures therefore clearly overestimate the reduction in emissions, because by 2050 it is mainly children that would have been avoided.

So, what concrete measures can be taken to reduce emissions?

We are going to calculate them in France to try to reach the objective of carbon neutrality in 2050, which requires dividing our total emissions by about 7 (the French government's objective is between 6 and 8). We arrive at the easy-to-remember figure of one tonne of CO2 equivalent per inhabitant per year, which is the level today of Bangladesh or Madagascar[15]. Dividing by 7 in 30 years is to reduce by a little more than 6% per year, and still we do not count imports, which increase the average French person's carbon footprint by 50% (i.e. a division by 12 to reach carbon neutrality).

Should we look later than 2050, when demographic measures will have more effect[16]? There is no "scientific truth" on the matter but I think not, for several reasons:

- The environment does not wait, it is already deteriorating very quickly, with a significant inertia and risks of runaway change
- The further we get into the future, the more uncertain the world's evolution becomes, and the more likely it is that disasters will occur and fundamentally change the equation
- The further we get into the future, the more we suffer from the negative effects of radical demographic measures, such as a predominantly elderly population
- The further we get into the future, the less fossil fuel will be left to burn anyway

As we have seen, there will be no consensual measure on demography, and unpopular policies such as degressive benefits or even the two-child limit will have a small effect (-5% in 2050). Even the most radical measure, banning children entirely, reduces the French population by only 36% in 2050. I don't see how we can do more without killing people, and we would still have to divide individual emissions by 4.5 (-78%) after this measure if we consider (generously) that it reduces emissions by that much. Let's face it: the vast majority of the effort must be directed at per capita emissions, regardless of population growth, even if humanity gives up children tomorrow. And to

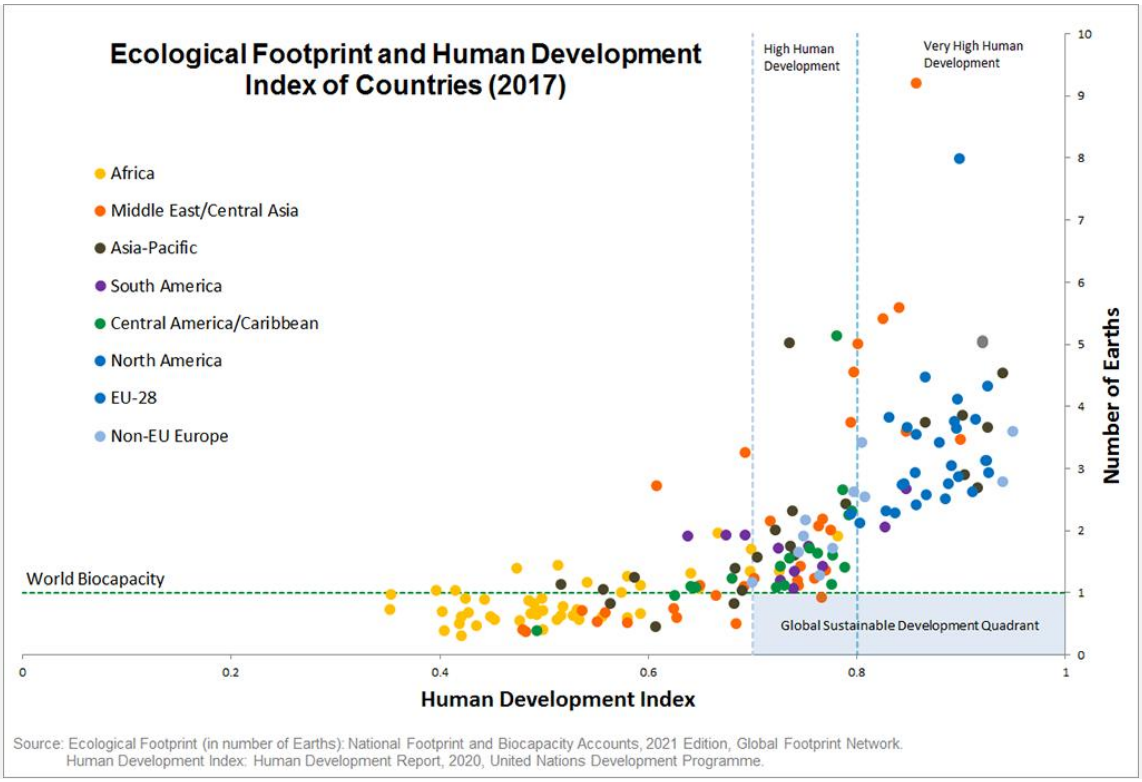
divide these emissions by 4, 7 or 12, there are no miracle: small improvements are far from being enough, profound changes in our way of life, our economic system and our culture are needed. Remember that one tonne of CO2 per person per year is the number for Bangladesh or Madagascar.

There is no "scientific truth" about the ease of implementing this or that measure either, but I will let you judge by comparing my estimates for France (which are probably overestimated) with the measures proposed by the Shift Project for Europe, which I have recalculated in relation to total emissions[22] :

Demographic measure	**Reduction**
No children	-36 %
One child	-19 %
Two children	-5 %
No benefits over two children	-2 %
Shift Project mesure	**Reduction**
Close all coal-fired power plants	-18 %
Renovate old housing	-13 %
2L/100Km vehicles	-11 %
High-speed rail services	-7 %
Post-carbon heavy industry	-5 %
Urban transport	-5 %
Sustainable agriculture	-4 %

Today it seems to me that it is politically easier to close down coal-fired power plants than to introduce the one-child rule, which looks very far from being acceptable. A total ban on children will probably never be acceptable. Population control has often been a channel for oppression and human rights abuse. The only measure implemented in rich countries, the suppression of benefits above 2 children, is already extremely unpopular even though it is not coercive. Convincing people seems to be very slow.

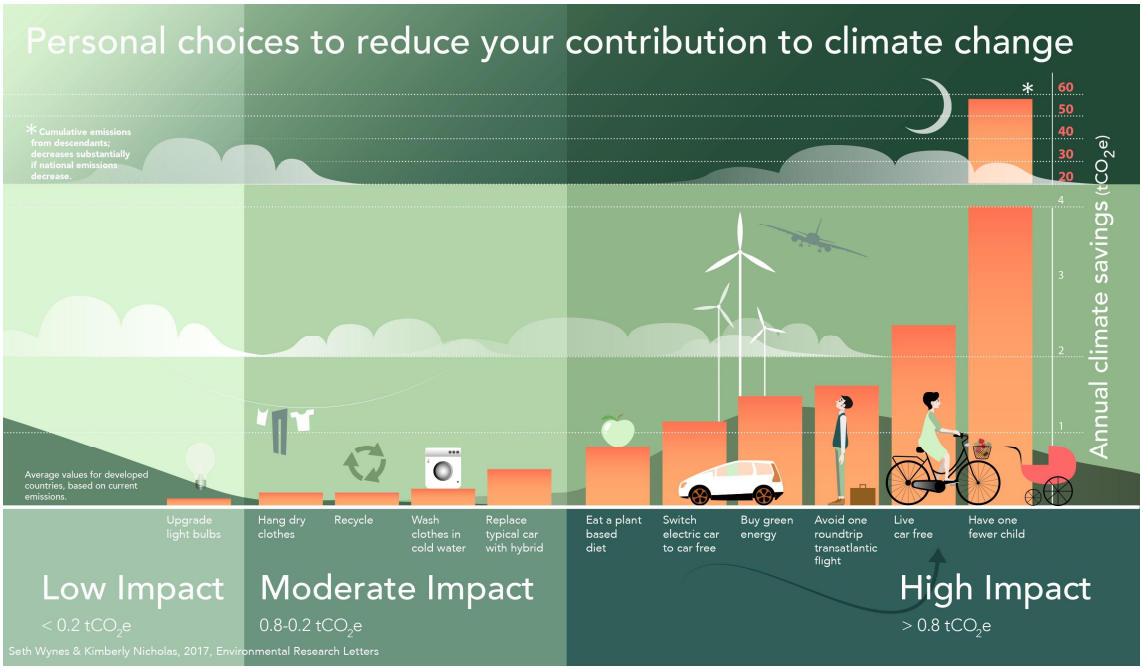
Are the measures to achieve carbon neutrality so harsh that they would take us back to the Middle Ages, which might lead to a preference for limiting children to mitigate it? Probably not. It should increase a number of costs and require huge investments in low carbon technology (notably energy and transport), but even low energy scenarios can offer a decent standard a living. There has been little reduction in emissions today, but if you broaden it to the ecological footprint, there are already "sustainable" countries with a high human development index. The stars of these rankings are unexpected countries like Costa Rica or Cuba:



What to do as an individual in a rich country?

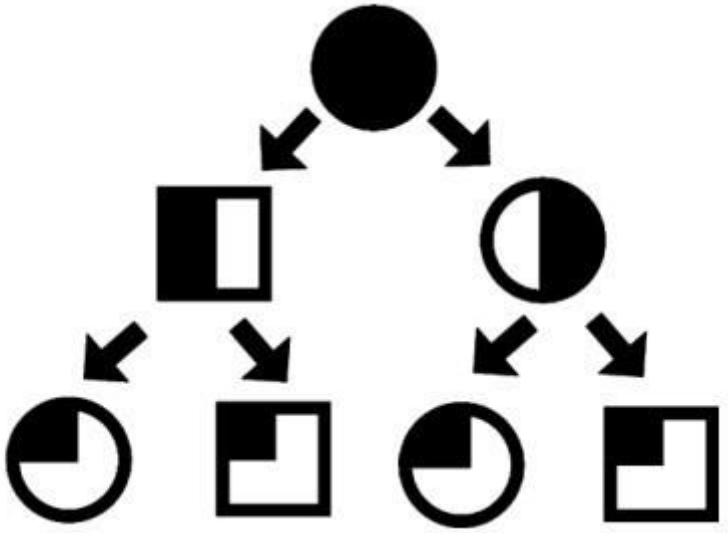
On a personal level, should you give up children to reduce your carbon footprint? You may have heard of the carbon legacy without knowing its name, for example in the following articles:

Want to fight climate change? Have fewer children
Scientists Say Having Fewer Kids Is Our Best Bet To Reduce Climate Change
More than 11,000 scientists have declared a 'climate emergency.' One of the best things we can do, they say, is have fewer children.
Here is the associated graphic:



Having a child seems by far the worst thing you can do for the climate, with a whopping 58t CO2. This figure is taken from a particularly popular scientific publication from 2017. Moreover, when reading the study faq, it appears that the figure was divided by life expectancy, and corresponds to a single parent. So one child accounts in total for about 10,000t of CO2, 1000 years of emissions with an annual average of 10t! How was this gigantic figure calculated? It comes from another study, dating from 2008, whose reasoning we will present and analyze here.

The authors have chosen to consider that an individual is "responsible" for half of the emissions of his child (estimated over his lifetime), 1/4 of his grandchild, 1/8 of the next generation, 1/16, 1/32 ... If each has two children:



These emissions are added up to the end of time, based on estimated changes in fertility rates and greenhouse gas emissions. The total is called the "carbon legacy", and corresponds to the share of future emissions for which the parent is "responsible".

This principle already poses several fundamental questions:

- Responsibility is a vague concept that can be interpreted in many ways. Are we responsible for everything we can prevent? For all the causal chains in which we participate, regardless of time, proximity or intention? Do we have to count the number several times (all my generations of ancestors would each be 100% responsible for my emissions) or share the responsibility? If so, according to what formula? The article does not even mention these questions and chooses an extreme consequentialist formula without a single ethical consideration. This is all the more dubious as the "common sense" distribution is to consider that one is primarily responsible for one's children's emissions during their childhood only, and that afterwards they are responsible for both their own emissions and their choice to have children. No, my parents are not "responsible" for the carbon footprint of my holiday in Bali.
- The responsibility for global warming is even more complex. How can it be shared between consumers, citizens, politicians, companies and cultures? Here again, there is no indisputable answer.
- Summing them does not make the possible future emissions of my possible great-grandchildren contribute to global warming today. For our goal of carbon neutrality in 2050 they do not count either. This calculation is both long-term and purely theoretical. It is then extremely

dubious to compare it with the usual carbon footprint, as shown on the graph above. These are calculated by life-cycle analysis and measure emissions that are actually taking place today or are expected to take place in the short term, and which therefore have an actual effect on current climate change.

- We need to model the population and emissions until the end of time to calculate the total. Of course, no one knows these figures and it is already very difficult to predict what will happen in the near future. This is all the more critical as the calculation method gives as much importance to the distant future as to today (the figures are not discounted).

  You may have realized that in the diagram above each generation has a total of one person's emissions. If your descendants continue to reproduce and keep the population constant, we add up one lifetime of emissions for each generation until the end of humanity ... To avoid obtaining an infinite or ridiculously large total (until the sun becomes too hot? The end of atoms?), which would not be very credible, it is necessary either that the emissions become zero, or that humanity progressively dies out.

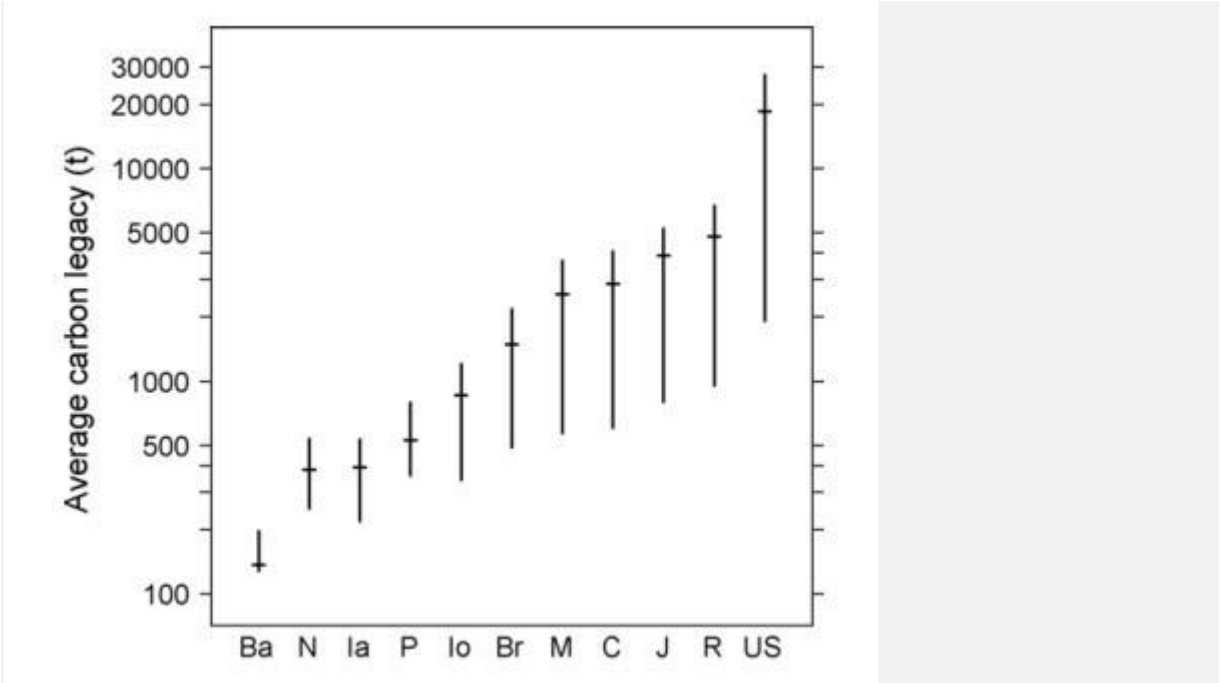
  The authors chose an assumption from one of the UN's demographic models: fertility will converge to 1.85 children per woman in all countries in 2050, and they consider that it will remain at this level until the end of time. Of course this figure is only a hypothesis for short-term projections, and makes no sense in the long term, for which no one has a crystal ball. This rate also has the advantage of decreasing the population with each generation and thus obtaining a finite result ... i.e. the extinction of humanity. Who can really believe that in the year 3000 humanity will gradually die out for lack of children?

  For per capita emissions they evaluate three scenarios:

- steady reduction of emissions to 0.5t of CO2 per person per year in 2100, stable thereafter (reasonable order of magnitude for the objectives taken since with the Paris agreement, but this would correspond to climate neutrality, so zero net emissions)
- constant emissions until the end of time (impossible for geological reasons (even in the short term), incoherent with our political objectives, and a scenario that ends quickly and very badly because of global warming)
- a steady and infinite increase in emissions, on the current slope (even less imaginable for the same reasons)

  Only the first scenario seems possible (and desirable). However, it is the second scenario, the constant emissions until the end of time, that is highlighted and presented in the summary as the "medium scenario".

  The result of the calculation for the countries studied is as follows:

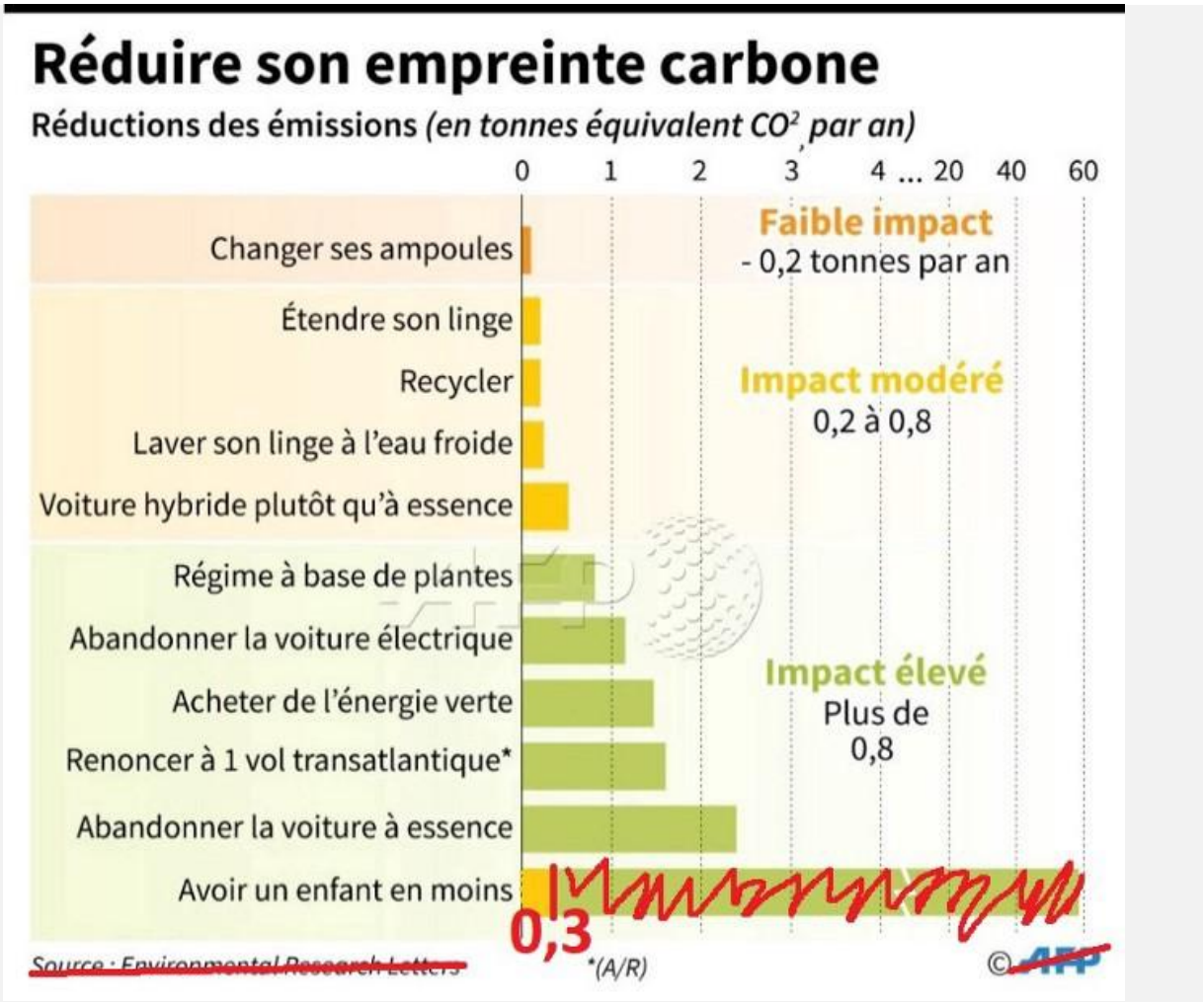


The scale is logarithmic and the figure per woman, to divide by two to get the result per parent. The horizontal bar in the middle is the "constant emissions" scenario, i.e. 18,882 tonnes of CO2 per child in the US. For comparison, the average American's carbon footprint is around 19t per year. The decreasing emissions scenario results in 1,124t, 17 times less. The 2017 study we mentioned sooner seems to take the average from a selection of rich countries, giving around 10,000t of CO2 per child.

Let us summarize: the principle of the calculation suffers from fundamental flaws and its assumptions are absurd estimates of population and emissions until the end of time. All this gives us the gigantic result of 18,882t, which has absolutely nothing to do with the life-cycle analysis figures we usually see. They should not be compared, especially in articles for the general public, as the original study on the carbon impact of lifestyle choices does. In short, it is best to forget about this carbon legacy calculation, which has no practical value and should never have emerged as such from the research world. I confess to being dismayed that this bogus figure seems to be the main inspiration for a number of people who give up on children.

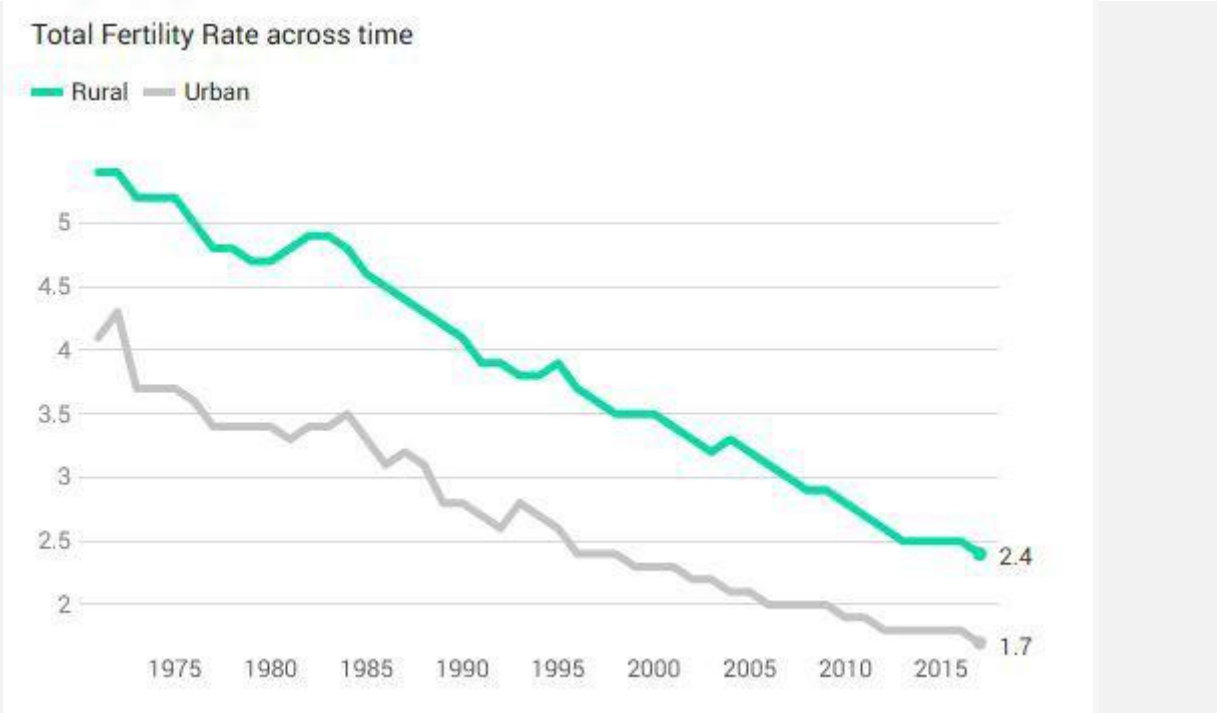
Moreover, there is no such thing as the "average child". If I feed my children steaks and take them on a plane every weekend, "their" impact will be much higher than if I transition as a family to a more sustainable lifestyle. A parent is directly responsible for the ecological impact of his or her children for about 20 years, and for a good part of his or her habits and values thereafter.

What would be the carbon footprint of the first 20 years of a child born tomorrow, assuming the same distribution of emissions by age as today and considering that emissions will decrease by 6% per year (which is obviously not the case globally today, but is not too far from the reach of a motivated parent)? Around 51t, compared to 18,882t in the initial study. So the infamous 58t would be reduced to 0.3t (which is obviously indicative only, there will be no scientific truth about the concept of responsibility, nor a crystal ball for future trajectories). Bonus: it will also concern only short term emissions, so it will be much more valid to compare with life-cycle analysis. Here is my corrected graph for the French presentation of the study:



What about other countries?

We looked at "poor" and "rich" countries, as a shorthand for countries in the process of demographic transition (fertility > 3.4, 2% of global emissions) and those that have completed their transition (fertility ≤ 2.1, 80% of global emissions). What about all the others, does it change the situation? In particular India, for 7% of global emissions? When we look at it in more detail, there is in fact an urban ("rich") India which concentrates the majority of emissions but with a low fertility rate, and a rural ("poor") India with few emissions and a higher fertility rate:



So our somewhat simplistic dichotomy still applies in this case. I have not found such precise recent data for the other large countries concerned, but it is likely that similar situations will arise. In any case, there is no large country with both high fertility (where measures for demographic transition will be effective) and high emissions per capita (where population reduction will have a significant effect on global emissions).

What about migrations?

Do we increase emissions by "transforming" an inhabitant of a poor, low-polluting country into an inhabitant of a rich, more polluting country? The question has a bad reputation because it is mainly the far right that is concerned about it (but not only). I have not found any study on the subject and many figures are missing, but a number of elements can enlighten us.

Already, only 1/3 of migrants leave a poor country for a rich one, partly because migrating far away is expensive. No figures are available on the standard of living, but a third of migrants in rich countries have a high level of education, a third a low level. A migrant can also be rich in his or her country of origin (above average emissions) and poor in the country of arrival (below average). Today, in all developed countries the total number of migrants present is increasing at a rate of 2 million per year, without deducting emigrants. Again, this is small in relation to their population (over 1 billion, or less than 0.2% per year). All these indications suggest that the problem is marginal today, and are consistent with the conclusions of demographers about the low importance of "migration from poverty to wealth". The figures are even clearer for refugees, the vast majority of whom go to neighbouring countries.

"What about the future?" you might ask, with its hundreds of millions of climate refugees? Maybe (more likely they will stay in the same country or go to neighbouring countries) ... unless the rich countries do what they should do anyway: significantly reduce their emissions per person! In that case the difference in emissions will be much smaller, or even zero. Let's repeat one last time that carbon neutrality in 2050 corresponds to the per capita emissions (one tonne of CO2 equivalent) of Bangladesh, a likely future source of many climate refugees. The Bengali who emigrates to the future carbon neutral Europe does not increase his emissions. Let us also remember that the richest

10% are responsible for 50% of global warming and therefore have a moral responsibility to welcome the victims of their emissions, in particular the poorest, who are both the least responsible and those who suffer the most.

Is there a maximum sustainable population?

Estimates can be found ranging from 1 to 1,000 billion depending on the assumptions, which are very forward-looking and therefore difficult to assess. In his seminal study of these estimates, demographer Joel Cohen notes that none of the authors bother to detail the standard of living this would entail, the technology, the political system, the values, and all the other criteria necessary for this sizing. He concludes that none of these authors is serious about answering the question, but prefers instead to put forward their political preferences. The thoughts on an 'optimal population' are even more questionable.

The concept of 'carrying capacity', frequently used in ecology, has little meaning for humans. Humankind is aware of the mechanisms involved, and has considerable latitude in determining what it produces and consumes. It is possible to feed 10 billion people healthily and sustainably with current technology. It won't be easy, it will require a major transformation of most of the world's agriculture, a significant reduction in meat consumption, waste and fossil fuel use, but it can be done. Carrying capacity is mostly a political issue. The studies cited even seem to take into account the first expected effects of the current environmental degradation on agricultural yields, but obviously the more we continue to destroy it the more difficult it becomes (as said before, we must act quickly).

We can probably go much higher with more effort. This is not necessarily a happy prospect, but it puts this very theoretical question into perspective. In practice, the questions of distribution within humanity and the trajectory to reach a sustainable situation are much more relevant. The world is already very unequal and "the American way of life is not negotiable".

Conclusion

When most people mention population and the environment, they imply that "if those good people in Africa or India could stay in poverty and stop multiplying, we could continue to pollute as if nothing had happened". At least that is what most of the illustrations on the subject suggest, as you may have seen if you have followed the many links in this article. We have proved how wrong this sentiment is.

The vast majority of humanity's ecological burden comes from rich countries with low fertility, so population change in poor countries will not make much difference, even if they themselves have to gain by accelerating their transition. In any case, population has too much inertia to be changed strongly and quickly enough to make a difference: the urgency is 2050. We have calculated that the main room for manoeuvre will only be in the lifestyle and economic system, which will have to change profoundly anyway. As an individual, having children is not neutral, but it can be a limited ecological burden if they live in a sustainable way.

I hope that this article will help to eliminate the many misunderstandings that one regularly reads on the subject. Numbers sometimes "lie", numerically correct calculations can present the opposite of reality, especially averages which group very different situations together. Even "science" can be misleading, we have come across several scientific publications whose abstract, without being strictly speaking false, masks important limits of the conclusions. Unfortunately these conclusions have been repeated and amplified in the public debate. It is necessary to look into the details of the articles, which are usually behind paywalls, and which requires an in-depth knowledge of the subject and a lot of time[19], and not to limit oneself to the sources that support one's opinion. As for

mainstream publications, I inflicted on myself a number of anti-natalist articles and books during my research: not a single one asks about realistic ways to reduce the population in rich countries, nor about the relative weight of this reduction in relation to climate goals...

Note that I have never denied the climatic interest of having fewer children, which is not negligible ... if one is prepared at least to introduce one-child policies in rich countries. I just put it into strong perspective in comparison with the current situation, reasonable ethical limits, and my estimation of the political feasibility of such measures. I also did not answer directly the trick questions "is population a problem" or "are we too many?", because they are not very rigorous and lead down an attractive but extremely slippery slope: it could be enough to reduce the population ("the others") sufficiently to be able to maintain our standard of living as if nothing had happened. It is obvious that we are "too much" if we consider our way of life and economic system as non-negotiable, but the right question is rather "how, from the current situation and remaining within an ethical framework, can we arrive at an ecologically sustainable situation for humanity?" I don't think that the world of 1 billion people where we have killed 7 billion (because there is no other way to reduce the population quickly) is better than the world of 8 or 10 billion people tightening their belts, but this is an ethical position and everyone is free not to share it.

My feeling is that the debate on demography is distracting many from the glaring injustice of global warming: countries with high birth rates are also the ones who will suffer the most while their responsibility is minimal. It makes it easy to forget the real issues: how to reduce our ecological footprint and how to share the ecological capacity of our planet fairly among all its inhabitants. Worse, it makes us forget our collective failure to act and leaves us hoping for a "cut the others" solution that would spare us any sacrifice of our comfort or standard of living. We know where this is going, and it does not end well. The similarity to the most compelling scenarios of ecological and social collapse is disturbing.

Finally, ecology is not only a technical issue, it is also a political dilemma of intergenerational solidarity[20]: how much are we willing to sacrifice our standard of living today to avoid a very likely catastrophe for young and future generations? In this context, having children can be a good motivation for this sacrifice[21], no matter how many. Our children are one of the few ways to have hope, to really project ourselves in the long term, to wish and build a better world. We can be irresponsible or resigned for ourselves, but we have no right to be so for our children.

Thanks to Jacques Véron, Director of Research in Demography at INED and author of the Démographie et Ecologie reference book, for his review of the article.

If you speak French I gave a long interview on the subject (1h40), which brings some clarifications and further perspectives compared to the article. You can find it on https://www.youtube.com/watch?v=ku0t12EfuIc

Notes

1] Why limit ourselves to the climate? Several reasons:

- The article is already far too long, I actually started out broader but it was going in all directions
- Climate change is the most easily measurable and comparable element in the ecological crisis we are experiencing

- Global warming is an existential risk in itself
- Climate is a global issue, whereas most pollution is local and therefore much simpler politically
- Many pollutions are comparatively easier problems to solve, e.g. the drop in biodiversity is mostly linked to agriculture. Climate is more cross-cutting and calls into question most of our economic system
- Many pollutions are correlated to the first order with greenhouse gas emissions
- In aggregate measures, emissions are the most important element (e.g. half of the ecological footprint)

2] I will not go into the history of the subject, everything has already been written. We will try to analyze it on its own merits rather than its history (which usually begins, depending on the author's opinion, with "Malthus was already warning of the risk ..." or "reactionaries like Malthus and Ehrlich were always wrong"). Arguments about the risks of population are not true or false in absolute terms, they can only be judged in relation to a demographic and ecological context. I did not use the term Malthusian, which is too connoted and highly debatable: Malthus was not really a Malthusian in the current sense!

3] This article is the second version, revised in May 2020, and slightly revised in April 2021. The original version, published in French in July 2019, is available on archive.org.

4] Why is it more relevant to look at the growth rate than the number? Because biologically children are born of parents, rather than "delivered" in total quantity. Also because extending the evolution of the growth rate gives a better view of the future than extending the number of humans added (slightly decreasing in recent years), which has not always been true (the growth rate peaked in the 1960s). This is the case today because humanity is globally at the end of its demographic transition.

5] This calculation of the scenarios is now clearly visible on the graph, but in previous versions you had to dig through the 300 pages of methodology to see it. It may be obvious to specialists in the field, but it is clearly not to the majority of non-demographers who have written about it.

6] You may also have come across his brother IPAT. If you speak French I have since written in more detail about the interests and limitations of these equations.

7] Studies on this issue actually find very variable figures depending on the country, the context, or the direction of the variation. Many of these results are cited here.

8] The "business as usual" scenario continues the current increase in emissions. The percentage changes are similar with an emission reduction scenario.

9] I do not think that writing for the general public is a good argument to avoid it. One cannot discuss demography without knowing the broad outlines of the demographic transition, any more than one can discuss global warming without knowing the greenhouse effect.

10] How is this different from the usual fallacious argument that "France only accounts for 1% of emissions and is therefore not a priority"? France is 1% of the world's population, the countries in demographic transition 25%. In any case, France will have to tighten its belt like everyone else. The 1% reduction per demographic transition is a specific measure that is not particularly expensive or complex, and is therefore interesting.

11] All data is per person per year. List of sources:

- Emissions Database for Global Atmospheric Research

- The Footprint Network- Quantifying Biodiversity Losses Due to Human Consumption: A Global-Scale Footprint Analysis. Harry C. Wilting, Aafke M. Schipper, Michel Bakkenes, Johan R. Meijer, and Mark A. J. Huijbregts. Environmental Science & Technology 2017 51 (6), 3298–3306-

- The water footprint of humanity. Arjen Y. Hoekstra and Mesfin M. Mekonnen. PNASFebruary28, 2012 109 (9) 3232–3237 (Why does Niger consume so much water? Hot country and low productivity agriculture! This is not always the case in other poor countries. Probably the same reason with livestock for high methane emissions per person).

12] Many "anti-natalists" complain that there is a taboo on the subject. I see several possible reasons for this:

- their ease in questioning the reproductive freedom of others
- The lightness of their thinking (even in the world of research), which is naturally exploited by racist currents. More rigorous reasoning leaves much less to be interpreted. The approach has similarities with some common racist tropes: when faced with a complex problem, find 'obvious' culprits in others and stop at this simplistic reasoning to avoid questioning oneself too much

Many public figures in ecology have expressed their amusement that at every conference someone asks the question and insists on the "taboo". For my part, I think it's primarily a question of pedagogy: as long as a complicated subject is not understood as a whole, it is considered obscure, and therefore potentially taboo. Hence this article.

13] I have not found any polls on the question of the acceptance of an authoritarian limit on the number of children for ecological reasons, but most people seem (few sources) to be very attached to the freedom of reproduction. They also seem to want a few more children in rich countries than they have on average, and this number seems stable. On the other hand, there is a variable majority in countries that have completed their transition to limiting population growth by international treaties, i.e. in the others.

14] which is not really a problem for the dependency ratio, as the decrease in the number of children mostly compensates for the ageing

15] Tropical countries that do not need heating, which in France today emits on average one tonne of CO2 per person per year.

16] One way to keep the calculation rigorous without considering only the year 2050 would be to calculate the cumulative emissions of both ecological and demographic policy scenarios against carbon budgets, but this is much more complex. The shared socieoeconomic pathways do this partially, but by mixing demography with many other variables.

17] This is less true for the rest of Europe, where the fertility rate is much lower, at 1.6.

19] The articles we have seen have limitations in general reasoning that are simply detectable, but the technical details are only accessible to specialists, which I am not. It is impossible to critically read most of the scientific literature without already knowing the subject very well. The limitations of articles are also often mentioned in the body of the article by the authors, but the full text and its notes must be read carefully.

20] This last paragraph has been the subject of much debate and questionable interpretation. Obviously, it does not mean "have as many children as you can". I think that even if this is not the main focus of the article, the political question (why do something for the environment and how to get there) is just as important as the technical question, and is inseparable from it. "There are too many of us, so stop having children" is technically true (all else being equal it reduces emissions) but

highly questionable politically. It is a video game or dictatorship solution, unwelcome and probably counterproductive in a democratic world full of real human beings who want to choose their own path to a sustainable world.

21] This hypothesis ("legacy motivation") is debated in the research world and only partially measured. In particular, it is proven false in the short term: parents have more practical concerns in the early years, that slightly increase their environmental impact. The first few paragraphs of "Does having children increase environmental concern?" summarize the field well, or this twitter thread. The motivational effect is positive but slight on parents who are already ecologically inclined. I do not think we should overstate the significance of these results, which are only in the short term, in a world where that has only begun to decarbonize. I am waiting for longer term studies, and I keep this appeal as a conclusion, which remains an effective way to raise ecological awareness.

22] A similar comparison can be made for used space, the first factor in biodiversity loss (the second being global warming). There are 150Mkm² of land, about 38% is used for agriculture, 2% for other human activities, and 60% is mainly wild. Making humanity vegetarian would reduce the use of agricultural land by around 75%, freeing up 30% of the total area. Now how much would we have to reduce the population to achieve the same result, keeping the same ratio of agricultural land? Also by 3/4. I'll leave you to ponder the relative difficulties and speeds of changing humanity's diet from killing 6 billion people, or changing the birthrate hard enough and long enough for the population to decrease by the same amount (same calculation as for the climate).

To be continued

- Calculate more precisely the possible emissions reductions in countries by accelerating the demographic transition
- Propose a century-scale warming model where emissions are limited by available fossil fuels, and their use is regulated by demand and environmental policies. An additional child would both be an incitation to drill more, proportionally to his fossil fuel use, and also a possible political influence.
- Calculate rigorously the population decline in France according to demographic measures
- Calculate carbon budgets under different emissions scenarios and demographic measures
- Find more sources and surveys on the desire for children and ecological renunciation. Can cultural change in this area be rapid enough to have a significant effect?
- Long-term measures of the legacy motivation