population matters

for a sustainable future

ISSN 2059-5611

The Journal of Population Matters

Issue 1
Spring 2015

About Population Matters

Population Matters is a membership charity working for a global population size that can provide a good standard of living, a healthy environment and environmental sustainability. Our activities comprise education, research and policy promotion. We are funded by our members, donations and grants and receive no funding from official or commercial bodies. We welcome new members. Members receive our publications and can take part in our activities. Active members can apply to become guarantor members and vote at our Annual General Meeting. Membership fee rates are available on our website; we are grateful to those who contribute higher fees, donations or legacies. We have a wide range of promotional items available, including clothing, cards and briefing sheets. Please visit our website to see the full range.

Until 2011, Population Matters was known as the Optimum Population Trust, which remains our registered name.

We are a registered charity (no. 1114109) and a company registered in England and Wales (no. 3019081).

Registered office: 135-137 Station Road, London E4 6AG.

Submissions Guidelines

Interested parties are invited to submit, ideally by email, material to be considered for inclusion, including research articles, reviews of published academic works and letters. Subjects may include the causes and consequences of, and cures for, unsustainable human population and consumption levels. Article types that will be considered:

- In Short - Max. 250 words, 1 reference. Brief summary of academic/organisation's publications.
- Research Reports - Max. 500 words, 1 reference. Summary of academic/organisation's publication.
- Research Reviews - Max. 1000 words, 2-5 references. Reviews of academic/organisation's publication, with a critical/analytical component.
- Features - Max. 2500 words. In depth analytical articles, focussed on a specific topic, referenced extensively throughout.
- Original Research - Max. 2500 words. Report on own research. Normally should include: Abstract (max 200 words), Introduction, Methods, Results, Discussion and References sections.
- Reader's Letters - Maximum of 700 words, opinion articles.

All word counts are exclusive of references, figure legends and notes. Any figures should be provided within text as well as separate original files. Notes should be placed at the end of the article. Copy deadlines are the end of March and September. Submissions may be edited and the editor's decision is final. Please note that it may not be possible to include all submissions. Submissions should be in Word or equivalent and be accompanied by a brief description of the writer.

In order to avoid plagiarism, all facts, quotes figures or theories/ideas that are not from the author's own thoughts or own research must acknowledge the original source and follow copyright legislation. Therefore, a reference list must be provided at the end of the article, in the order they are first used in the article, and numbered accordingly. The corresponding sentence(s) in the main text should end with this number in superscript. The text should be formatted as per the following example:

Smith, A.B., Jones, D.E. and Miller, F.G. (1980) *An example title*. The Journal Name. Issue (Volume) pp.100-101

Contacting Us

Population Matters

135-137 Station Road,
London, E4 6AG

Tel: 020 8123 9116
www.populationmatters.org

Chair
Roger Martin
roger.martin@populationmatters.org

Chief Executive
Simon Ross
simon.ross@populationmatters.org

Administrator/ Membership Officer
Julie Lewis
julie.lewis@populationmatters.org

Journal Editor
Cheryl Mills
cheryl.mills@populationmatters.org

Contributors

This issue was edited by Cheryl Mills; proofread by Bay Haseler; designed by d8.uk and distributed by our administrator, Julie Lewis. Population Matters does not necessarily endorse contributions nor guarantee their accuracy.

A Message from the Editor

I hope that you find this first issue of the re-launched Journal of Population Matters an interesting and informative read. The plan for this publication is to provide a hub for the reporting of population sustainability-related topics, with the view to facilitate further research and development within the field. Necessarily, the range of disciplines dealt with in this journal is great, in itself demonstrating how complex and far-reaching the issues are that Population Matters aims to address.

Whilst many of the articles may outline findings that could usher in despair - such as the accelerated risk of extinction species face due to climate change; and correlations between population and parasitic infections or pollution - there are also nuggets of hope. For example, innovative thinking can improve sustainability - even of the most lowly of biological processes, waste management. Further, new tools such as the Global Calculator have been developed, to allow better understanding of the potential consequences of our policies and actions on the environment. And some research even outlines how, in fact, measures to reduce our impact on the world could even help us as individuals, by improving our diet and increasing living standards. Whilst there is much to be concerned about and to still learn and communicate, we must also recognise and take hope from these positive steps.

Contents

In Short

Increasing global temperatures accelerating species extinction risk

A recent meta-analysis of the effect global temperature rises will have on species extinctions, has predicted that if we continue along our current business-as-usual trajectory of a 4.3°C increase in average global temperatures, up to one in six species are likely to be at risk of extinction due to climate change. Worryingly, even if we were to meet the international targets of an increase only of 2°C, which is thought to now be unlikely by many experts, 5.2% of species are still predicted to be at risk of extinction. The regions with highest extinction risk were found to be South America, Australia and New Zealand. Species most at risk are those that are endemic and with small geographical ranges. The author also highlighted that even those species that persist will not be unaffected by climate change, and in fact are likely to experience a range of effects on their populations, in turn impacting upon species interactions and ecological communities.

Urban, M. C. (2015). *Accelerating extinction risk from climate change.* Science, 348(6234), 571-573.

Household Size Demographics

Researchers are calling for housing demographics to be more thoroughly taken into account in population-environment studies. In an article published in the journal *Population and Environment*, authors Bradbury, Peterson and Liu, suggest that an adapted I=PAT model could be used to achieve just this (Box 1).

Box 1.

A modified version of the I=PAT model, which could facilitate the incorporation of household dynamics on the environment.

Environmental impact (I) =

Population x personal goods (P) + households x household goods (HoG)

Developed nations' household sizes have been declining for several hundred years, but in the late 1800s this decrease reached a threshold and became particularly rapid. In contrast, developed nations reached this threshold later, in 1987, but the rate of decline has been even more rapid since then. The decrease in household size is thought to be driven by industrialisation and urbanisation, as well as increases in aged population, divorce rates and preferences for more privacy. The faster shift to smaller households in developing countries is thought to be linked to the fast pace of social change due to technology and globalisation.

Since household sizes are often as good, or even better, predictors of human impacts on the environment, this study could be a useful step in better understanding the impact of a variety of anthropogenic effects, such as greenhouse gas emissions, resource consumption and species endangerment.

Bradbury, M., Peterson, M. N., & Liu, J. (2014). *Long-term dynamics of household size and their environmental implications.* Population and Environment, 36(1), 73-84.

Population size linked to oceanic plastic pollution

Reports of marine wildlife entangled in packaging and their stomachs full of plastic rubbish are sadly commonplace. Less obvious are the negative effects of smaller plastic fragments that form as the waste is broken up in the seas. Such fragments may be ingested by smaller marine organisms, as well as having untold impacts on the wider marine ecology. Despite these concerns, there are limited robust estimates of the amount of plastic that is cast out to sea from coastal regions each year.

However, in a *Science* journal article researchers estimated that in 2010 the annual worldwide input of plastic into the ocean by 192 coastal populations (those within 50km of a coastline) was 275 million metric tons. The main predictors of which countries had the highest volume of plastic waste was population size and their quality of waste management systems. If the latter are not improved, the authors used population growth projections to predict that the cumulative quantity of plastic waste will increase by an order of magnitude by 2025.

Jambeck, J. R., Geyer, R., Wilcox, C., Siegler, T. R., Perryman, M., Andrady, A., Narayan, R. & Law, K. L. (2015). Plastic waste inputs from land into the ocean. Science, 347(6223), 768-771.

Living Standards not dependant on high birth rates!

Lee and Mason challenge the common assumption that higher birth rates are essential in maintaining the overall economy and suggest that, in fact, a moderately low birth rate may actually boost living standards in many countries.

High fertility rates bolster government budgets by providing a young, active workforce and population of tax payers. This in turn provides social system support for the population's elderly. However, generally it is individual families that must withstand the largest costs of raising children. The study published in *Science*, correlated birth rates with economic data in 40 countries and included the effects of age structure on families as well as government budgets. Their calculations were based on finding the birth rate and age distribution that would best balance the costs of raising children and of caring for the elderly. The authors found that a fertility rate near replacement results in the highest standards of living. They conclude "that moderately low fertility and population decline favour the broader material standard of living".

Lee, R., Mason, A., Amporfu, E., An, C. B., Bixby, L. R., Bravo, J., ... & Vaittinen, R. (2014). *Is low fertility really a problem? Population aging, dependency and consumption.* Science, 346(6206), 229-234.

How to help ourselves and the planet

Within the UK, the average adult's diet does not currently meet the World Health Organisation's (WHO) nutritional recommendations - with most struggling to get their "five-a-day" of fruit and vegetables. A study, led by researchers at the London School of Hygiene & Tropical Medicine, have highlighted how simple changes in our diet could not only improve our health, but also reduce greenhouse gas emissions at the same time.

The researchers found that altering UK diets so that they are in line with the WHO's guidelines would reduce UK food-related greenhouse gas emissions by 17%. Taking dietary modifications even further - but the authors claim, still within the realms of acceptability by consumers - could lead to greenhouse gas emission reductions of approximately 40%. This would require replacing a proportion of animal products (especially red meat and dairy) and processed, savoury snacks in our diet with more nutritious fruit, vegetables and cereals. So, food for thought for all of us interested in saving the planet.

Green, R., Milner, J., Dangour, A.D., Haines, A., Chalabi, Z., Markandya, A., Spadaro, J. & Wilkinson, P. (2015) *The potential to reduce greenhouse gas emissions in the UK through healthy and realistic dietary change.* Climatic Change, 129(1-2): 253.

What would you do if you ruled the world?

In January 2015 the UK Department of Energy and Climate Change launched the Global Calculator, a free, open-source model of the world's energy, land and food systems. Produced by an international collaboration of 150 experts the interactive tool allows users to design their own set of policies and then discover what future environmental impacts they may have. Variables that can be adjusted include lifestyle choices (e.g. travel, home and dietary behaviour), technology and fuel (e.g. which forms we use and their efficiency), food and land use (e.g. agricultural resource consumption and outputs) and demography. In the latter variable, global population can be adjusted between three different UN scenarios, where the fertility rate is 2.7, 2.53 or 1.7 children per woman by 2050. By allowing anyone to explore the different options, it is hoped that the debate on climate change will be better informed.

An accompanying report confidently asserts that it is possible to meet the UN-led target of no more than a 2°C increase in global temperatures, whilst still maintaining living standards. The report uses the Global Calculator to reveal that there are a variety of different pathways which we could follow to achieve this, such as decreasing CO^2 emissions per unit of electricity by at least 90%, and protecting and expanding forests carbon sinks by 5-15% by 2050.

You can access the Global Calculator at:
www.globalcalculator.org

Department for Energy and Climate Change (2015) *Prosperous living for the world in 2050: insights from the Global Calculator.* UK.

An exercise in excellent excrement efficiency

The sustainable management of organic waste from both humans and agriculture will be increasingly important as the population continues to grow. One innovative solution gaining favour is the use of insects to break down this waste. The resulting products can then be reused, for example the compost residue can be employed as plant fertiliser and the high-protein insect larvae may become animal feed.

A study has concluded that a strong contender for this task is the black soldier fly, which has become famed for its ability to consume extraordinary amounts of organic waste. This technique could play an important role in enhancing sustainability practices. For example, recapturing carbon and nitrogen from the waste will assist in maintaining these vital nutrient cycles. Additionally, by replacing fish meal in fish farms with insect larvae, significant pressure could be reduced on wild fish populations and may even bring fish prices down. Further, this simple solution could reduce atmospheric and aquatic pollution, by decreasing greenhouse gas emissions and the leaching of nutrients into waterways (which can cause eutrophication, leading to algal blooms and oxygen depletion). Lastly, the risk of the spread of disease caused by pathogens within the waste would also be reduced, improving general hygiene.

After further research and development, perhaps the next logical step in advancing sustainable waste management and human food chain efficiency is the direct human consumption of insect protein. Whilst likely currently unacceptable to many members of the public, future generations may not have the luxury to be so selective in their diets and insect dinners may become the norm..... Fly larvae on toast anyone?

Lalander, C. H., Fidjeland, J., Diener, S., Eriksson, S., & Vinnerås, B. (2015). *High waste-to-biomass conversion and efficient Salmonella spp. reduction using black soldier fly for waste recycling.* Agronomy for Sustainable Development, 35(1), 261-271.

Parasites and Populations

In a study based in Lake Malawi, Africa, researchers have found a direct link between increasing human population density and an increased incidence of schistosomiasis disease, a parasitic infection. They explain that this is likely due to complex ecological mechanisms triggered by anthropogenic activities.

Changes in human population drive a host of multifaceted and unpredictable effects on the environment and the ecology of other species. Such effects may then cascade out across the ecosystem, having knock-on effects on entire ecological communities. Those species influenced will inevitably include human pathogens; and therefore anthropogenic ecological effects are likely to have significant impacts on a range of global health issues.

Schistosomiasis is caused by a blood fluke that carries out its reproductive stage in humans. A variety of symptoms, including blood in the urine, pain, liver and spleen enlargement are due to a reaction to the parasites' eggs within the body. Long-term effects may include infertility and bladder cancer. It is estimated up to 200,000 deaths per year in sub-Saharan Africa are due to schistosomiasis.

The biology and transmission of the parasite is complex, involving another intermediate host – freshwater snails. When infected humans defecate in water, such as lakes, the released blood fluke eggs then go on to infect these snails found within the water bodies. The parasite develops within the snail's tissues and is then later released back into the water as a mobile life stage called Cercaria. Whilst people are bathing in infected waters, these cercaria locate and penetrate human skin and continue the parasitic life cycle once again. The parasite's survival therefore relies on a reciprocal transmission between humans and snails. Both these hosts have increased in population density in Malawi in previous decades (the human population has more than doubled in the last 30 years), correlating with an increase in the incidence of the schistosomiasis disease.

The researcher's study revealed as human population densities have increased, the resulting shifts in ecological conditions have favoured the intermediate snail hosts – which logically would lead to higher numbers of infective cercaria in the waters. An increase in agricultural activities and soil erosion have increased sedimentation and nutrient run-off into the lake, leading to optimal ecological conditions for these snails, which feed on detritus. Furthermore, an increase in overfishing in Lake Malawi has reduced the predation pressure on the snails – the previously greater fish population fed more intensively on these molluscs, and so controlled their populations. Additionally, those fish that remain appear to now prefer to feed on a different species of snail, which does not act as a host for the parasite – a snail species that was introduced to the lake by humans. Lastly, it is also noted that increasing water temperatures due to climate change may also increase the infection rates of humans by the cercaria' life stages.

This study highlights an example of how increased human population density not only impacts on the environment and organisms within it, but also the knock-on effects that can harm humans themselves when ecosystems are exploited.

Van Bocxlaer, B., Albrecht, C., & Stauffer, J. R. (2014). *Growing population and ecosystem change increase human schistosomiasis around Lake Malawi*. Trends in Parasitology, 30(5), 217-220.

The Value of Modern Contraceptives

In a study published in February 2015, four authors from the World Health Organisation revealed that across 35 countries, of 16.7 million unintended pregnancies surveyed, up to 90% could have been prevented by the correct, optimal use of modern contraceptives.

Of 210 million pregnancies experienced worldwide each year, it is estimated up to 41% of these are undesired. Other than the associated health risks of pregnancy, having children also often negatively affects a woman's future educational and employment opportunities. Family planning has therefore been recognised as an essential component in alleviating poverty, increasing sustainability, improving women and children's health and promoting gender equality. However, each year 87 million women worldwide become pregnant unintentionally because of the underuse of modern methods of contraception.

This study analysed the contraceptive behaviour of 124,175 women, of which at the time of the survey, 12,874 were unintentionally pregnant and the remaining 111,301 were sexually active, but not pregnant or trying to conceive. The data were obtained from demographic and health surveys conducted from 2005 to 2012 across 35 low- and middle-income countries.

The study aimed to quantify the association between undesired pregnancies and type of contraception used, comparing modern methods of contraception with traditional methods and the non-use of contraception. Modern methods included oral and injectable contraceptives, implants, IUDs, male and female condoms, sterilisation and lactational amenorrhoea. Traditional methods include calendar methods and withdrawal. Those women using traditional methods were 2.7 times more likely to have an undesired pregnancy compared to those using modern methods, whilst those women using no method at all, were 14.3 times more likely to have an undesired pregnancy.

The underlying reasons for not using contraceptives were also explored. Of the six main categories for non-contraceptive use, the reason most given was the 'Fear of side-effects/health concerns' (37.3%), followed by 'Opposition' either by the woman herself, her husband or due to religious prohibition (22.4%) and an 'Underestimated risk of pregnancy', which included 'husband away', 'infrequent sex' and 'marital separation' (17.6%). 'Method related reasons', including 'cost' or 'provider too far' (7.1%) and a 'Lack of knowledge' such as unawareness of types available and where to acquire, (3.5%) were less often cited as reasons for non-use.

Of 210 million pregnancies experienced worldwide each year, it is estimated up to 41% of these are undesired.

The authors conclude with suggestions of actions that would address the issues highlighted in their study. National strategies should best exploit a variety of channels to educate the public. For example, during care encounters with women and in school sex education programmes health professionals should be given the opportunity to discuss and instigate contraceptive use. Further, the use of modern media should be used to dispel myths - this is likely to be particularly effective with the younger population. The increase in demand that such actions would hopefully bring, would need to be coupled with programs that ensure a range of contraceptives are easily available and accessible to all.

Bellizzi, S., Sobel, H. L., Obara, H., & Temmerman, M. (2015). *Underuse of modern methods of contraception: underlying causes and consequent undesired pregnancies in 35 low- and middle-income countries.* Human Reproduction, 30(4), 973-986.

Turning the tables on the "Death of the West"

Oxford University researchers Professor David Coleman and Associate Professor Stuart Basten are challenging the catastrophic "Death of the West" view. This scenario asserts that declining birth rates in the West - that lead to shrinking, aged populations - will bring about its political and economic downfall. Meanwhile, less developed nations that are greatly expanding their populations and, along with it their economies, will reign supreme. However, the authors claim that in fact the fertility trends are misunderstood and that the complex, demographic, social and political issues in each country are much more nuanced than is reflected by the doom and gloom narrative that foretells the fall of the West. The authors aim to balance the views by exploring the finer details, some of which are outlined in this review article.

All is not lost for the West

One of the main misunderstood issues the authors tackle is shifts in Western fertility rates. They state that, contrary to the much publicised message of a falling European birth rate, this is actually not the case - especially in Western European, where birth rates have actually been slightly increasing since the 1980s. Whilst women who attend higher education may delay becoming pregnant, the desire to have two children still remains. Improvements in gender equality and greater women's income, enabling them to better balance their careers and family-life, has facilitated increased fertility in these older women.

Further, immigration in some richer countries is working to increase the population size, which whilst bringing its own challenges - such as social, infrastructure and housing implications - may help to moderate population aging and provision the workforce.

Death of the West proponents assert that an aging population may threaten economic stability by increasing pressure on the pensions system and elderly care, as well as resulting in a less efficient and innovative workforce. However, the adaptations countries are making to tackle aging populations, such as by increasing retirement age need to be more fully appreciated. Whilst this is clearly difficult for those individuals, it is the cost for longer, healthier lives. Additionally, older members of the population in developed countries have had access to education and health care not available to their counterparts in lower income nations, and so have a greater capacity to work into their later years.

Lastly, the study highlights that Western societies also benefit from relatively stable demographic and political regimes, as shifts in these have been slow and in line with social, economic and educational modifications. This is in contrast to what is currently occurring in many developing nations. The shift in demography in many of the non-Western countries has been rapid, whereas social, cultural, economic and political aspects have not kept-up, all leading to instability and complex problems that will not be solved overnight.

Developing nations don't have it all their own way

As non-Western countries increase in population size, the balance between East and West will shift. At its peak Europe held 25% of the global population - but this is projected to fall to around 7%. However, Coleman and Basten's paper hastens to assert that the future may not be as far in non-Western nations' favour as the doomsayer's scenario will have us believe. Low- and middle- income nations are currently facing their own set of challenges - including political and social instability as well as demographic problems.

Of note is the possibility that in many of the non-Western countries birth rate may actually fall to a level lower than in many countries of Europe and the USA. Indeed, countries such as Brazil, Iran, Turkey and southern India already have a birth rate below replacement. In this situation the population may start aging before the country has had an opportunity to become economically rich.

> At its peak Europe held 25% of the global population

Within a notable number of non-Western countries there are also a variety of impediments to having children - such as long working hours, high costs of childcare, and little support for women. The preferred family size of many women in a number of major Asian countries, such as Hong Kong, Taiwan, Province of China, China and Thailand is below replacement. Reversing this downward trend would be a politically difficult task.

Further, in societies where social care for the elderly is constrained, those of reproductive age may choose to limit the number of children they have, as they must care for their parents. Elderly support will also suffer where the weak economy drives many people to emigrate or to take informal jobs - so not contributing to government-funded care for the aged population.

The demographic dividend is a widely held assumption that the economy benefits where the fertility rates drop due to reduced child mortality and leads to a population that has proportionally more workers than child/elderly dependants. As other countries follow this trend into the future, it is argued that they will benefit from these circumstances. However, the authors state that in fact this effect is more likely due to an education dividend - which is not a given in all low- and medium-income countries. Further, those that are educated are likely to emigrate to other countries or drive political and social discontent.

Lastly, there are a variety of further constraints on the development of low- and medium-income nations - including lack of democracy, corruption, environmental pollution and climate change and resource depletion - such as water and energy.

It is, of course, an extremely difficult task to predict what the future will bring, and this reviewed report highlights how complex the real-world issues are than are reflected by the Death of the West.

Coleman, D., & Basten, S. (2015). *The Death of the West: An alternative view.* Population Studies, 69(sup1), S107-S118.

World Population Likely to Keep Growing into the 22nd Century

Richard Vernon

Fourteen authors from four universities and the UN's Population Division have collaborated in an analysis of recent population projections. Their report indicates that concerns expressed by population campaigners are well founded: and indeed the situation is even slightly more serious than earlier projections suggested.

The study combined data from a number of sources and in particular refined analytical techniques so as to sharpen upper and lower projections. For example, traditional UN population estimates for countries gave a medium figure based on each country's Total Fertility Rate (TFR – children per woman). Upper and lower projections were then calculated by adding or subtracting half a child from the TFR. However, in this work the authors have used individual country data on fertility and life expectancy, and utilised data from other sources and countries in making projections for each particular country. The paper then goes on to summarise the revised view of trends and implications for the future.

The authors deduce that the world population is unlikely to stop growing this century and there is a 95% probability that in 2100 it will be between 9.0 and 13.2 billion people. Much of the increase is likely to be seen in Africa, due in part to higher TFR rates and a recent reduction in the rate of TFR decline. Africa is at the stage of the fertility component of the demographic transition that Asia and Latin America were at in the 1970s, but its rate of TFR decline is only about a quarter that of those continents' experience, and in some African countries the decline seems to have halted. Two reasons are offered. One is the commonly reported unmet need of contraception, which has remained at around 24% for an astonishing, to this reviewer, 20 years. The second is the persistently high level of 'fertility desire', that is the expressed average wish of family size, at 4.6 children per woman.

The paper points as an example to Nigeria, Africa's most populous country. With a current population of 174 million, UN estimates give a 90% probability that it will exceed 532 million by 2100, a more than 3-fold increase. For Africa as a whole the authors estimate that the current approximately 1 billion has a 95% probability of reaching between 3.1 and 5.7 billion by 2100, with a median projection of 4.2 billion. They point out that while in terms of population density this would equate roughly to that of China today, these extra billions could result in severe shortages of resources leading to increased mortality and migration and changes in population size.

Population aging is briefly discussed in terms of Potential Support Ratio (PSR), the ratio of working-age people to older people, or the number of workers per retiree. This is likely to show a substantial drop in all countries in the coming decades. Examples, starting with the current lowest and showing current and projected 2100 values are Germany 2.9 to 1.4, USA 4.6 to 1.9, China 7.8 to 1.8, India 10.9 to 2.3 and Nigeria 15.8 to 5.4, the latter the authors note being the only country projected to have a PSR at the end of the century higher than 3.

The strength of the paper lies in the revisions of world and country population projections derived from the authors' detailed work described in detail elsewhere in the given references. They quote from Bongaarts (2013) the potential consequences of these projections: "Rapid population growth in high fertility countries can create a range of challenges: environmental (depletion of natural resources, pollution), economic (unemployment, low wages, poverty), health (high maternal and child mortality), governmental (lagging investments in health, education, and infrastructure), and social (rising unrest and crime)".

Similarly their use of Nigeria as an example, with a projected population at the century end of more than three times its current number, can be put into perspective by a recent article in the Financial Times. It stated that despite large oil revenues and a very rich small elite, 62% of Nigerians live on less than $1.25 a day. Clearly their prospects as the century progresses along this paper's projections seem precarious in the extreme and beg the question of what can be done. Fortunately Population Matters has clear advice on this, and the paper provides the evidence for the need for such things as much greater investment in reproductive health services, equal education for girls and boys and the empowerment of women.

> "
>
> ...which has remained at around 24% for an astonishing, to this reviewer, 20 years.

Bongaarts, J. (2013) Demographic trends and implications for development. Paper presented at the International Union for the Scientific Study of Population 2013 Meeting, Busan, Republic of Korea, 26 to 31 August 2013.

Burgis.T. (2015) *"Nigeria Unravelled"* Financial Times Magazine 14/15 February 2015.

Gerland, P., Raftery, A. E., Ševčíková, H., Li, N., Gu, D., Spoorenberg, T., ... & Wilmoth, J. (2014). *World population stabilization unlikely this century*. Science, 346(6206), 234-237.

How quickly will reducing fertility shrink the human population?

Ananthi Anandanadesan

The rapid and continued rise of the human population worldwide and its associated repercussions (i.e. depletion of natural resources, diminishing biodiversity, climate change, food shortages, etc.) has led to more appeals to control population growth by lowering fertility. In their article, Bradshaw and Brook explore how effective reducing fertility may be towards decreasing human population size. They investigated this issue by projecting the size of the entire human population up to 2100 using scenario-based matrix modelling and data from the World Health Organisation and US Census Bureau International Database.

In addition to projecting population size based on 2013 vital rates that are kept constant, i.e. a "control" situation, the authors also made other scenario-based projections in which parameters such as birth and death rates and age at first childbirth were altered (both over the long-term and the short-term) to see how the population would change over time in response to various perturbations. Some of these scenarios were considered as 'not catastrophic,' for example, a scenario representing policies implemented to reduce fertility. Others were more extreme, for instance, representing consequences from catastrophic events such as world wars. They also tried to identify the regions where human population growth would be most harmful to the environment during this century, by using regional projections of the human population and relating these to Biodiversity Hotspots, where human population density and growth are typically greater than in other places (Cincotta et al., 2000; Williams, 2013).

In their results, Bradshaw and Brook show that if the world was to adopt a one-child policy or if mass mortality events took place (for example the deaths of 2 billion people occurring mid-century over a period of five years), the total human population would still be between 5 and 10 billion at the end of the current century. The results also suggested that in the future, Africa and South Asia will be where ecosystems are most vulnerable to human impact as a result of population growth unless population growth is significantly curtailed.

All in all, these results present a bleak outlook for the future. The projections made in this study indicate there will probably be no significant change to the size of the human population by the end of this century even if human fertility is reduced. The authors also demonstrate that lowering human fertility now to achieve a sustainable human population size would most likely not take effect until our great-great-great-great grandchildren are alive. In other words, there is no fast and easy way to solve the impending population crisis. That is not to say reducing human fertility is completely ineffective. The authors point out that it could potentially save millions of lives by mid-century. Although, they believe that sustainability would be achieved far sooner if society created technology and policies that dramatically lower our consumption of natural resources, thus, mitigating the effects of a growing population.

In their results, Bradshaw and Brook show that if the world was to adopt a one-child policy or if mass mortality events took place (for example the deaths of 2 billion people occurring mid-century over a period of five years), the total human population would still be between 5 and 10 billion at the end of the current century. The results also suggested that in the future, Africa and South Asia will be where ecosystems are most vulnerable to human impact as a result of population growth unless population growth is significantly curtailed.

All in all, these results present a bleak outlook for the future. The projections made in this study indicate there will probably be no significant change to the size of the human population by the end of this century even if human fertility is reduced. The authors also demonstrate that lowering human fertility now to achieve a sustainable human population size would most likely not take effect until our great-great-great-great grandchildren are alive. In other words, there is no fast and easy way to solve the impending population crisis. That is not to say reducing human fertility is completely ineffective. The authors point out that it could potentially save millions of lives by mid-century. Although, they believe that sustainability would be achieved far sooner if society created technology and policies that dramatically lower our consumption of natural resources, thus, mitigating the effects of a growing population.

However, as O'Sullivan (2014) points out, inconsistencies in Bradshaw and Brook's results make their argument less robust and therefore undervalues the impact that reducing fertility can potentially have in limiting population growth and consequently devastation to the environment. For example, the projections made using global averages for vital rates indicate little difference between the "control" scenario in which vital rates are kept constant and the scenario in which fertility gradually declines to 2 children per female and mortality declines to half its rate by 2100 in contrast to the same scenarios projected by subregion. The latter shows a 16-37% reduction in final mean population densities of the subregions when fertility and mortality are reduced gradually compared to the "control" situation where vital rates are unchanged. Yet, O'Sullivan highlights, this disparity between the global and subregional results seems to go unnoticed by the authors.

> "Some of these scenarios were considered as 'not catastrophic...'

Furthermore, O'Sullivan demonstrates the significant effect that lowering fertility has on reducing human population growth. In her projection of the human population with fertility declining to below replacement levels, the human population size in 2050 would be 15% lower compared to the "control" projection (that O'Sullivan calculated), and in 2100 would be 45% lower compared to the "control" projection (14 billion by 2100, which is the same as Bradshaw and Brooke's "control" projection). Thus, it is evident that lowering human fertility may have significant capacity to reduce human population size, yet its short-term impact on population size and consequently the environment is trivialised by Bradshaw and Brook (O'Sullivan, 2014). While Bradshaw and Brook do make a case for reducing consumption to diminish humans' impact on the environment, lowering human fertility is just as important and crucial. If sustainability is to be achieved, society must do whatever it can to mitigate the damage that humans have done to the environment.

Bradshaw, C. J., & Brook, B. W. (2014). Human population reduction is not a quick fix for environmental problems. Proceedings of the National Academy of Sciences, 111(46), 16610-16615.

Cincotta R.P., Wisnewski J., Engelman, R. (2000) *Human population in the biodiversity hotspots.* Nature 404(6781):990-992.

O'Sullivan, J. (2014) *How much environmental pressure can family planning avert?-A commentary on projections by Bradshaw and Brook.* Population Matters, UK.

Williams, J. N. (2013). *Humans and biodiversity: population and demographic trends in the hotspots.* Population and Environment, 34(4), 510-523.

Can UK national GDP growth sustain personal GDP growth for a growing population?

Leopold Neuerburg[1], Jeffrey Jones1, Stephen Bown[2]

1 London School of Economics -Department of Management

2 Population Matters

Abstract

It is often claimed that growth in national GDP leads to a rise in real income per person, and ultimately to higher living standards. However, both inflation and population growth counteract this effect. The latter, in particular, is usually overlooked. Any increase in the nominal (current market prices) national GDP can only increase the real GDP per capita for a growing population if the national GDP growth exceeds the combination of inflation and population growth. From 2009-2013, the economy grew by 3.4% p.a. but with inflation at 3% and population growth at 0.7% p.a., the real GDP per capita only increased by 0.3% p.a. Predictions indicate that the real GDP per capita (which represents the purchasing power of the money in each individual's pocket) will gradually fall over the next 5 years and will only return to 2004 levels sometime in the 2020s, the date depending on the rate of population growth.

For the ordinary citizens of the UK to benefit fully from an increased national GDP, the size of the population should be stabilised or reduced. Predictions for Germany show that with a falling population, everyone benefits with a steadily increasing real, per capita GDP. GDP does not reflect income distribution and current data show that the inequality of income in the UK is getting worse, indicating that for the majority of the population, it may take even longer for the real GDP per capita to get back to 2004 levels. Many of these conclusions are shared by the Sheffield Political Economy Research Institute (SPERI).

Introduction

The Gross Domestic Product (GDP) measures the monetary value of all finished goods and services produced within a country over a given time-period. It represents the gross value added by all private and governmental consumption, business investments, and exports minus imports. Simply put, it aggregates the total economic activity of a country, although it does not consider black market activities or other factors such as environmental damage, loss of natural resources or depreciation of assets[1].

$$\text{GDP} = \text{Consumer Spending} + \text{Governmental Spending} + \text{Investment} + \text{Net Exports}$$

The nominal GDP is the GDP calculated at current market prices, most often measured in US Dollars. The real GDP is the nominal GDP adjusted to account for changes due to inflation. These are usually measured by one of the inflation metrics 'Consumer Price Index' (CPI) or 'Producer Price Index' (PPI). In this paper the real GDP is calculated using the CPI, which measures the annual change in cost the average consumer faces when acquiring a standard basket of goods and services[1].

$$\text{Real GDP} = \frac{\text{Nominal GDP}}{\text{Price Index}}$$

The GDP per capita reflects the mean income of individuals in each country.

$$\text{GDP per Capita} = \frac{\text{Nominal GDP}}{\text{Population}}$$

It is often argued that national economic growth leads to rising income per person and ultimately to a higher living standard. However, this does not always hold true. To judge the living standard of a nation's society, not only its real economic growth needs to be considered, but also the nation's population growth. For example in Kenya, the real GDP increased strongly by 1.6% p.a. from 1991-2013. However, the real GDP per capita decreased by 1.1% p.a. due to the population growth of up to 3.3% p.a..[2] To shed light on the situation in the UK, an economy with a growing population, the main objectives of this paper are to investigate the development of the GDP in relation to population growth since 1991 and review predictions for the UK's population and economic development until 2030. The specific focus is to compare the GDP per capita in inflation-adjusted terms, with changes in national GDP.

Throughout this paper the terms used for Gross Domestic Product (GDP) are:

- *The nominal GDP is the GDP calculated at current market prices,*
- *The real GDP is the nominal GDP adjusted to account for changes due to inflation*

Changes in the real GDP best represent changes in the purchasing power of the money available to governments and individuals.

For the period 1991-2013, adjustments for inflation are from a baseline of 1991, whilst for the period 2013-2030, adjustments for inflation are from a baseline of 2013. It is for this reason that there is apparent inconsistency between the figures quoted for the periods 1991-2013 and 2013-2030

All figures for national and per capita GDP are quoted in US dollars as this is the currency used by the main reference source, the World Bank.

Methodology

The historical data (1991 – 2013) for the inflation rate (CPI), the GDP (in US$), and the population have been obtained from the World Bank's online databases[3,4,5]. The real (inflation adjusted) GDP was calculated using 1991 as the basis year. The forecast data for GDP growth rates and inflation rates (CPI) from 2013 to 2030 were obtained from the 'Trading Economics' online databases[6,7]. The real GDP forecast was calculated using 2013 as the basis year.

The relationships between the nominal and real national and per capita GDPs from 1991 to 2013 for the UK and Germany were studied in the context of population growth. The low, median and high population growth predictions were used to predict GDP per capita until 2030.

Historical trends in GDP

Changes in the UK nominal and real GDP nationally and per capita from 1991 to 2013 are shown in figure 1. The UK experienced a 16-year period of economic growth up to a nominal peak of $46,000 per capita in 2007, although the per capita GDP did not grow quite as fast as the national GDP due to the 0.4% per annum population growth. Due to the financial crisis in 2007-9, both GDPs fell back below the 2004 level and only stabilised in 2013[2]. Up to 2009, the national and per capita curves are roughly similar. Since 2009, the nominal GDP per capita has grown by 3.4% annually, but the real GDP per capita has grown by only 0.3% annually. Over the whole period since 1991, the nominal GDP per capita has grown annually by double the rate of the real GDP (3.5% v 1.6%).

Figure 2 compares the real GDP per capita with population growth for the UK and Germany. The fall in the German GDP in the late 1990s was related to the 'dot-com bubble'. The financial crisis of 2007-9 hit the UK much harder than Germany[2]. The German real GDP per capita has exceeded the UK's since 2008. The UK real GDP per capita has hardly changed since the low of 2009.

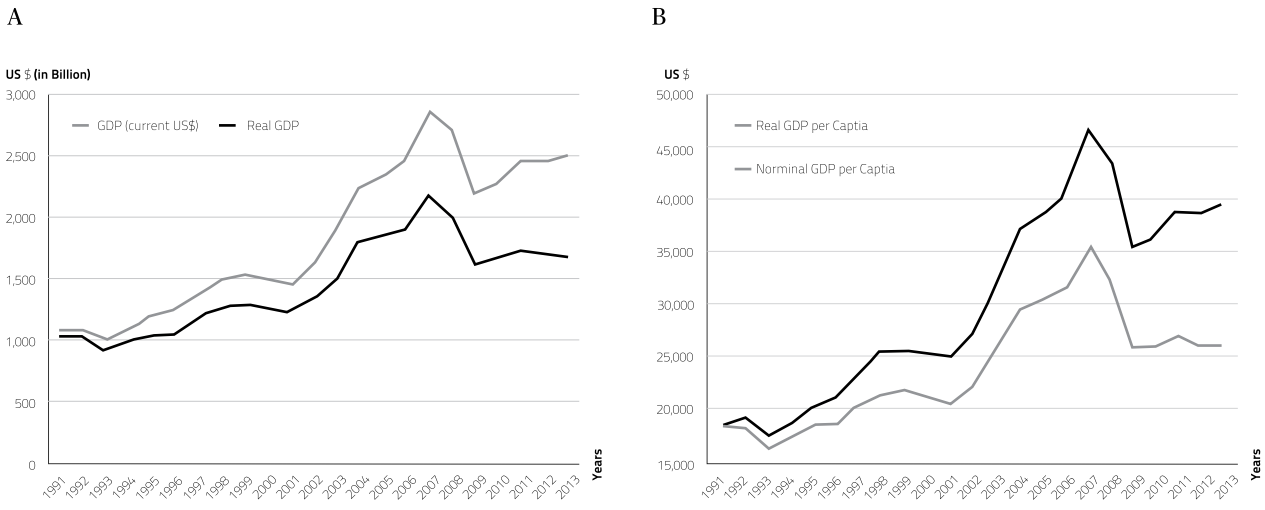

Figure 1: Nominal v. Real GDP nationally (A) and per capita (B) for the UK (Base year: 1991)[3,4,5]

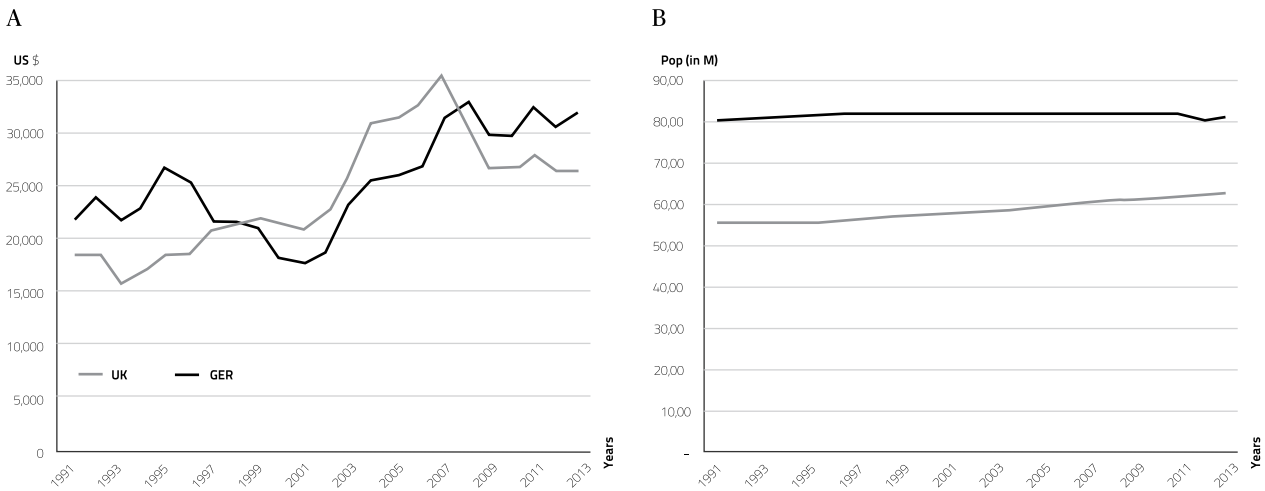

Figure 2: Real GDP per capita (A) (Base year: 1991) and Population (B) for UK and Germany[1,2,3]

Historical trends in GDP *cont...*

For both Germany and the UK, the real GDP per capita developed at roughly the same rate as the real GDP nationally. From 1991-2001 there were comparable increases in the populations of each country. However, since 2005, the UK population growth has accelerated whilst the German population has started to decline. Figure 3 shows the real national GDP versus the real GDP per capita since 1991 for both countries.

GDP per capita Regression Analysis

The value of the GDP per capita depends on the population size and the value of the main economic components, namely Consumer Spending, Governmental Spending, Investments, and Net Exports. A linear regression analysis was used to investigate the effect of each of these components on the growth of the GDP per capita and to correlate these findings with population growth[2]. This led to the conclusion that a 1% increase in population leads to a 1.15% decrease in real GDP per capita. The additional production from the additional population does not compensate for the growth in population.

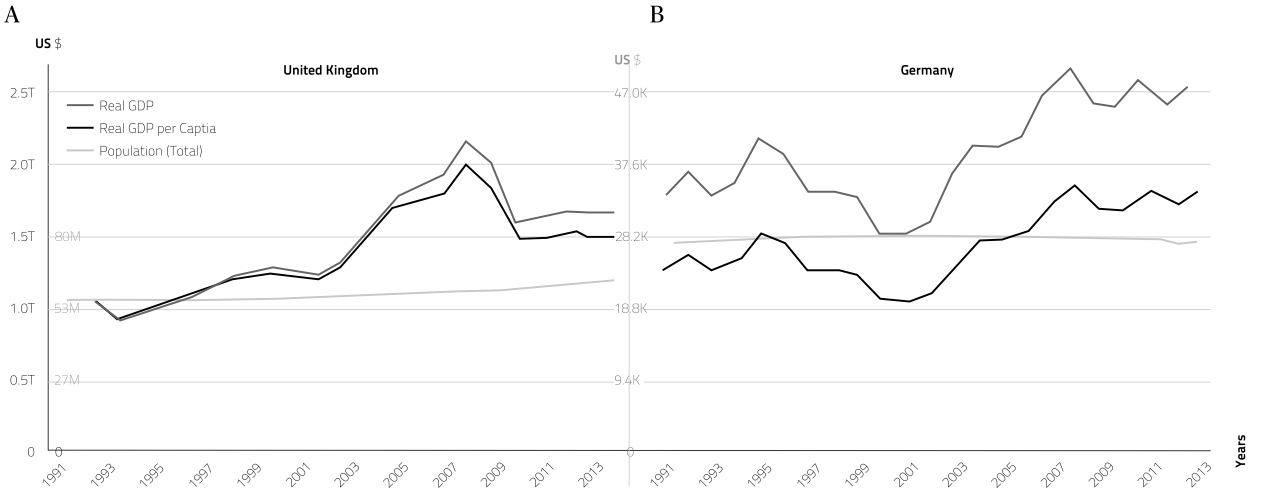

Figure 3: Real GDP and Real GDP per capita compared with population (Base year: 1991) for the UK (A) and Germany (B)[3,4,5]

Forecast of GDP per capita
Development from now until 2030

The economic forecasts from 2015 until 2030 are[6,7] presented in Table 1. Note that the base year to calculate the inflation adjusted GDP (=real GDP) is changed to 2013 (previously: 1991). Thus absolute figures differ compared to the previous section.

The demographic projections on population size for the UK and Germany are shown in figure 4. Low, expected and high predicted levels are given for each country[9,10]. Since 2003, the German population has decreased by about 0.3%, whereas the UK population has increased by more than 5% (figure 2). These trends are expected to continue in both countries. Growth of the UK population will lead to a predicted increase in the labour force of 1.8-3.0M by 2030. In contrast, the German labour force is predicted to shrink by up to 3.7M by 2030.

Economic Forecast (T = Trillion, B = Billion)	UK			Germany		
	2015	2020	2030	2015	2020	2030
Inflation (CPI)	1,65%	1,95%	2,30%	1,32%	1,93%	2,20%
GDP Growth	1,35%	2,81%	2,81%	1,99%	2,84%	2,87%
Nominal GDP (US$)	2,61T	2,83T	3,73T	3,77T	4,16T	5,51T
Real GDP (US$, Base Year 2013)	2,56T	2,57T	2,84T	3,72T	3,85T	4,29T

Table 1: Economic Forecast for the years 2015, 2020 and 2030

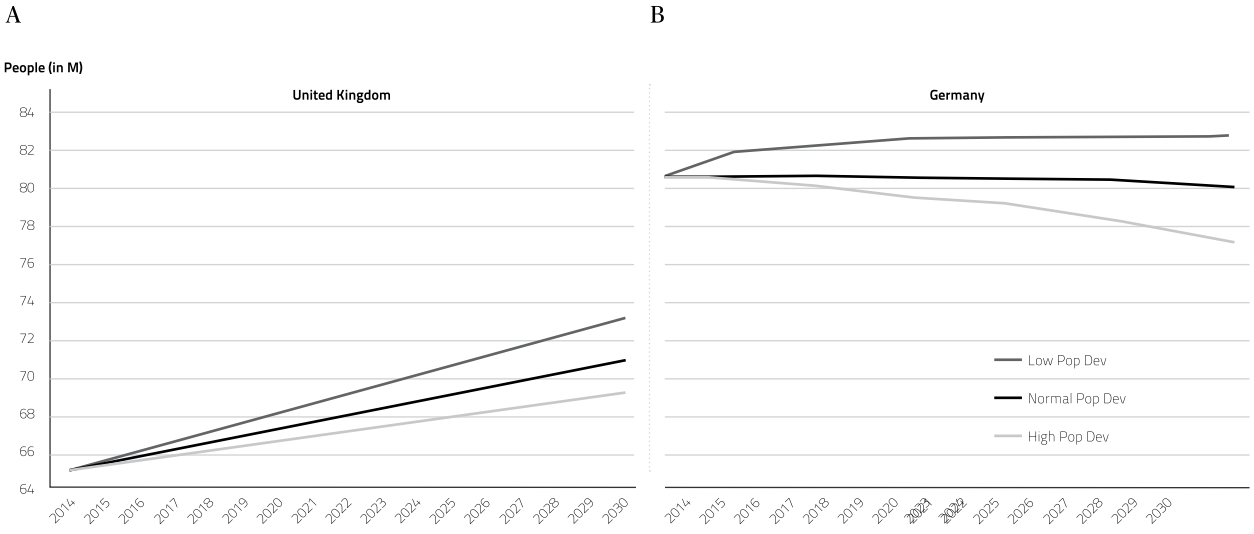

Figure 4: Population Forecasts for UK (A) and Germany (B)[9,10]

Real GDP per capita for UK and Germany till 2030

The real GDP per capita forecasts for the UK and Germany until 2030 based on the above predictions are shown in figure 5. This figure also shows the predicted Real national GDP for each country. The UK real national GDP is predicted to remain about constant until 2020, after which it is predicted to grow more strongly than the population, resulting in a gradual increase in real GDP per capita. In all scenarios, the UK real GDP per capita is predicted to fall between now and 2019 and only slowly get back to the level of 2014 after that (by 2025 for the low population prediction and not until after 2030 for the high population prediction). Consequently, the strong positive nominal national GDP growth prediction of up to 2.81% p.a. for the UK will not lead to an increase in the real GDP per capita for many years to come. In contrast, the prediction for Germany is considerably more favourable. In all scenarios, the Real GDP per capita for Germany is predicted to grow strongly. The national economic outlook is similar in the 2 countries with likely comparable inflation. The difference is due at least in part to the growing population in the UK and the falling population in Germany.

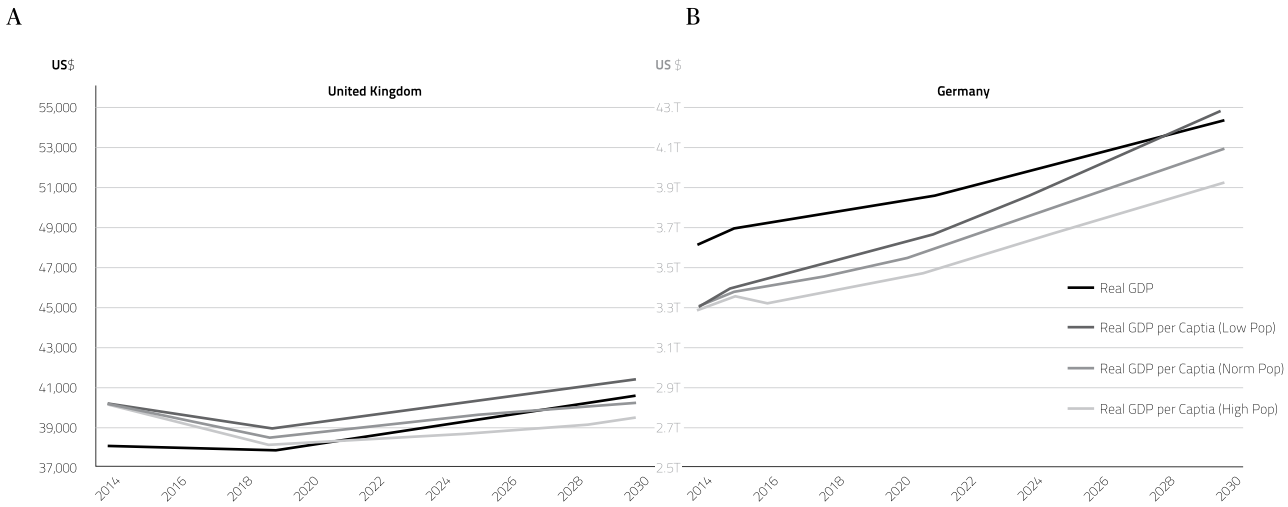

Figure 5: Forecast of Real GDP per capita for the high (light green), median (black) and low (green) predicted population levels for the UK (A) and Germany (B). The Real national GDP for each country is shown in blue.[6,7] (Base year: 2013 compared with a base line of 1991 for the graphs covering the period 1991-2013)

Limitations on the value of GDP

GDP is currently the most used indicator of the financial health of nations and individuals. However, it has some important weaknesses. It does not reflect the distribution of income. While in 2007, the income of the bottom 10% in the UK increased by 1.4%, the income of the top 10% increased by 5.9%, and the income of the top 1% increased by 18%. This means that despite national GDP growth, inequality in society increased significantly[11,12]. In recent years a growing number of scientists doubt the usefulness of the GDP to measure the welfare of nations[13]. It does not reflect factors such as leisure time and the general quality of life. From as far back as 1759, Adam Smith argued that the acquisition of wealth has only a limited bearing on human happiness[14]. Robert F. Kennedy famously said, that GDP "measures everything (...) except that which makes life worthwhile"[15] Perhaps the greatest weakness in these times of concern about climate change, over-population and over-consumption is that GDP takes no account of the way economic activity affects the environment. Nevertheless, for all its faults, numerous researchers have shown that GDP per capita, as a mark of financial status, heavily influences personal well-being[16].

Conclusions

An increasing national GDP can only maintain the true value of the GDP per capita in times of a growing population if the national GDP growth exceeds the combination of loss of value due to both inflation and an increasing number of citizens. While this was the case in the UK from 1991 until 2007, since then, the real per capita GDP has only shown an annual increase of 0.3%.

This analysis has shown further that the real, per capita GDP in the UK is predicted to fall over the next 5 years and will not return to the 2014 level until at least the mid 2020's. The comparison with Germany strongly suggests that this is at least partly due to the rising population in the UK when compared with the falling population in Germany.

It is easy for the government to say that the GDP per capita is now going up and nominally this is true, but in real terms, exactly the opposite is happening, which is what so many ordinary people have been saying for years. The money in their pockets buys less than it used to. For the ordinary citizens of the UK to benefit fully from an increased national GDP, the size of the population should be stabilised or reduced. The current increase in numbers is due partly to immigration and partly to an increasing number of children being born to women living in this country. The predictions for Germany show that with a falling population, everyone benefits with a steadily increasing real, per capita GDP. The national GDP fell due to the financial crisis, but the problem has been significantly exacerbated for individuals by the increasing growth of population in this country over the last 10-15 years.

A recent report from the Sheffield Political Economy Research Institute (SPERI) entitled "The relationship between economic growth and population growth" has come to essentially the same conclusions[17].

Acknowledgements

This paper is a shortened version of a dissertation submitted as part of the requirements for an MSc in the Department of Management at the London School of Economics and Political Science in September 2014[2].

References

1. Blanchard, O., Illing, G. (2009). Macroeconomics, Pearson Stadium

2. Neuerburg, L. Can national GDP growth maintain personal GDP growth in times of population growth? An empirical investigation of the UK. http://populationmatters.org/documents/gdp_growth.pdf

3. The World Bank (2014a) GDP per capita (current US$) http://data.worldbank.org/indicator/NY.GDP.PCAP.CD

4. The World Bank. (2014b) Population, total http://data.worldbank.org/indicator/SP.POP.TOTL

5. The World Bank (2014f) Inflation, consumer prices (annual %) http://data.worldbank.org/indicator/FP.CPI.TOTL.ZG

6. Trading Economics (2014a) United Kingdom | Economic Forecasts | 2014-2030 Outlook www.tradingeconomics.com/united-kingdom/forecast

7. Trading Economics (2014b) Germany | Economic Forecasts | 2014-2030 Outlook www.tradingeconomics.com/germany/forecast

8. Congdon, T., Davies, J., Fatih, H., Lilico, A., Sierra, R., Warburton, P. & Williams, T. (2013) *The UK economic experience of the last five years - stagnation*. Institute of Economic Affairs.

9. Office for National Statistics (2013) *National Population Projections, 2012-* based Extra Variants Report. www.ons.gov.uk/ons/dcp171776_338113.pdf

10. Statistische-Bundesamt (2011) *Bevölkerung Deutschlands bis 2060 - Ergebnisse der 12.* Koordinierten Bevölkerungsvorausberechnung. www.destatis.de/DE/Publikationen/Thematisch/Bevoelkerung/VorausberechnungBevoelkerung/BevoelkerungDeutschland2060_5124202099005.html

11. Cribb, J., Hood, A., Joyce, R. & Phillips, D. (2013) *Living Standards, Poverty and Inequality in the UK: 2013.* Institute for Fiscal Studies.

12. Alvaredo, F., Atkinson, A. B., Piketty, T., & Saez, E. (2013). *The top 1 percent in international and historical perspective (No. w19075).* National Bureau of Economic Research.

13. Munda, G. (2013). *Beyond GDP: an overview of measurement issues in redefining 'wealth'.* Journal of Economic Surveys.

14. Smith, A. (1759) *The Theory of Moral Sentiments.*

15. Kennedy, J. F. (2014) *Robert F. Kennedy Speeches Remarks at the University of Kansas, March 18, 1968* www.jfklibrary.org/Research/Research-Aids/Ready-Reference/RFK-Speeches/Remarks-of-Robert-F-Kennedy-at-the-University-of-Kansas-March-18-1968.aspx

16. Stiglitz, J., Sen, A. & Fitoussi, J.-P. (2009) *The Measurement of Economic Performance and Social Progress Revisited -* Reflections and Overview. www.stiglitz-sen-fitoussi.fr/documents/overview-eng.pdf

17. Sheffield Political Economy Research Institute http://speri.dept.shef.ac.uk/wp-content/uploads/2014/09/Brief7-the-relationships-between-economic-growth-and-population-growth.pdf

Kaya's Equation: Policies to Improve Technology & Behaviours

Max Kummerow

Climate policies focus primarily on technology, but attempts to reduce carbon emissions have been overwhelmed by growth of world demand for energy. Comprehensive initiatives including both technology as well as curbing economic and population growth could aim for climate stability at far lower cost and with better long run outcomes. This paper explores Kaya's equation - an alternative way to express I=PAT, which helps to draw some specific insights.

Climate change warnings and growing cumulative carbon

The 2014 Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report calls for reductions in Greenhouse gas (GHG) emissions to half of current levels by 2050 and to near zero emissions by 2100.[1,2] Consequences of higher cumulative GHG levels include rising temperatures and sea levels with flooding of major cities, ocean acidification, species extinctions, forest fires, storm damage, and risks to food crops and water supplies. In brief, a planet less hospitable to human life.

Climate scientists advise a trillion metric tonnes of cumulative carbon dioxide emissions as a prudent maximum to keep "likely" global average temperature increase below 2 °C. At current emissions rates, that cumulative total would be exceeded by 2039.[4] Despite scientists' warnings, Greenhouse gas (GHG) emissions grew at 2%/yr. over the past 40 years, accelerating to 3%/yr. during 2000-2010 (figure 1). Subsidizing the world economy with coal, oil and gas resembles living on a dwindling savings account that will end when the wells run dry. [5]

Kaya's equation, developed by an engineer from Tokyo University is a tool that can be used to calculate the total CO^2 generated by humans and reveals options for reducing carbon emissions.[6] Increases in C (or more broadly, GHG emissions) have been driven by the interactions of the four right hand side terms. Table 1 shows growth from 2000-2010 of the Kaya equation terms calculated from World Bank data.[7]

Kaya's Equation

C = *Carbon emissions*

E = *Energy generated and consumed by humans*

Y = *Economic output (goods and services, GDP)*

P = *Population*

$$C = \frac{C}{E} \times \frac{E}{Y} \times \frac{Y}{P} \times P$$

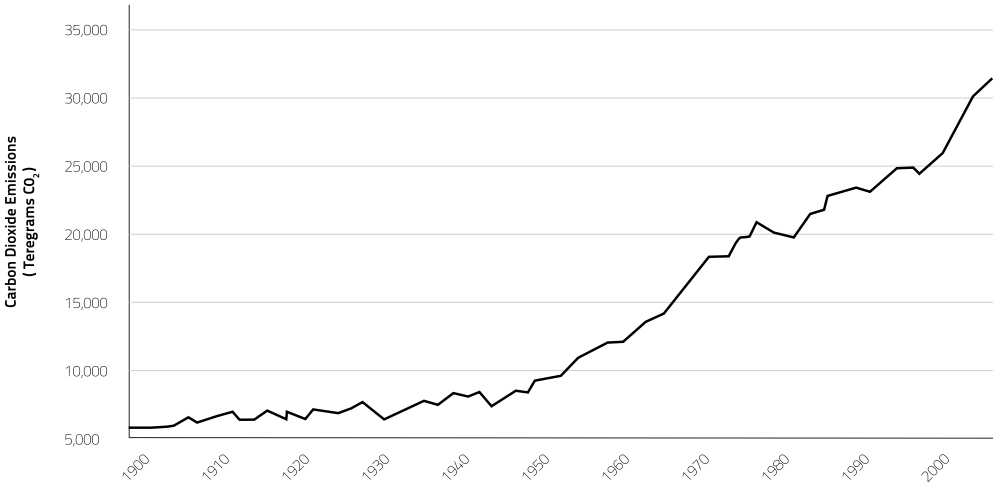

Figure 1. Annual Global Carbon Dioxide Emissions 1900-2010
Source: U.S. Environmental Protection Agency

www.epa.gov/climatechange/ghgemissions/global.html

Term	C	C/E	E/Y	Y/P	P
Growth	3.1%	+0.6%	-1.3%	+2.5%	1.2%

Table 1. Compound Average Annual Rates of Growth/Decrease during 2000 - 2010.
Source: World Bank, World Development Indicators

Carbon intensity of energy sources, C/E

The C/E ratio is GHG emissions per unit of energy produced. Over 33.6 gigatons of carbon are currently released annually by humans in producing and consuming over 13,100 megatons oil equivalent of energy.[7] This C/E ratio can eventually be reduced by switching to non-carbon energy sources such as wind and solar. But C/E grew by +0.6%/year compounded during the century's first decade due to growing use of dirtier energy sources such as coal and tar sands (Table 1).

I found this the most troubling statistic. More than 40 years after scientists warned about climate change, installation of renewable energy (solar, wind) still fails to outweigh the shift to dirtier, more carbon intensive fuels.[7] Most of the world's major oil fields are "mature" or in declining production phases. [8] Growing demand has been met by increasing coal burning in China, mining of tar sands, deep water drilling and fracking, all "dirtier" sources of energy with lower "energy returns on energy invested" (EROI) and therefore higher carbon emissions per unit of energy produced.[9]

Energy intensity of economic output, E/Y

The E/Y ratio shows a brighter picture. Efficiency of energy use in the global economy has been improving, decreasing by 1.3%/year (Table 1) due to investments in more energy efficient buildings, cars, appliances, motors, etc. Some European economies use less than half as much energy/$GDP as the U.S.A.[10] Energy efficiency can continue to improve as the world catches up to best practices. However, producing fertiliser, heating and cooling buildings, storing food, transporting goods, etc. all require energy inputs, so efficiency investments face diminishing returns.

Economic output per person, Y/P

Per capita incomes, Y/P, meanwhile, have been growing strongly, especially in Asia, in lockstep with growing fossil fuel consumption. Annual world per capita income growth averaged 2.5% during 2000-2010 (Table 1). Economic growth remains a central goal of governments, firms and individuals. Billions of people live in poverty and additional growth in output or redistribution of wealth and incomes would be required to meet basic needs. Growth over 3%/year of Y/P x P, will double world output in less than 25 years. If that growth rate continues, the result would be four doublings to 16 times current output within a century. [11]

Population, P

Global fertility fell from over 5 children per woman to 2.5 children between 1970 and 2010, a major cultural shift in family size norms. [12] The world's annual population growth rate fell in half from 2% to 1%. But meanwhile world population doubled from 3.5 to 7 billion, so global population still adds the same numbers, about a billion every 12 years, because lower population growth rates are offset by larger population (2% growth x 3.5 billion = 1% growth x 7 billion). Even assuming continuing declines in fertility, UN demographers project a 30% increase to near 10 billion by 2060.[13]

Policy discussions revolve around technology solutions, ignoring limits to growth

Policy still focusses almost entirely on technological fixes, ignoring the fact that growth, so far, has more than swamped progress in switching to non-carbon emitting energy sources. Even so-called "renewable" resources can be destroyed by overuse and have limits to their flows of ecosystem services. Allowing growth to continue also ignores the broader issue that growth must stop on a finite planet for many reasons. Failure to recognise that simple fact heads humanity towards another Exodus, Chapter 6 (Noah's flood), that is, a population collapse.[14]

Technology solutions to lower GHG emissions are feasible in the long run, but will take time and face resources constraints. Improving C/E by shifting to sustainable, non-carbon emitting energy and improving E/Y by efficiency gains both rely on trillions in capital investments to replace existing technologies with less carbon intensive assets. [15]

Current energy infrastructure and other physical capital whose productivity relies on fossil fuel inputs (ships, buildings, tractors, manufacturing plants, etc.) consists of long lived assets that will take decades to replace. Even if it becomes cheaper to run cars, ships, tractors, airplanes, trucks and railroads on renewable energy sources, current energy technology and capital investment ties the economy to carbon fuels for decades.[11] Over 80% of the world economy is powered by fossil fuels.[16]

Converting a complex world economy, where growth so far has doubled GHG annual emissions in less than 25 years to a two or three times larger world economy generating half as much GHG emissions by 2050, poses a challenge technology and capital investment have so far barely begun to comprehend, much less solve. OECD International Energy Agency (IEA) forecasts show continued emissions growth, meaning, if we believe the climate scientists, a world headed for calamity. [17]

A 2014 report of the IEA reveals the direction the world is headed. Of $1.6 trillion invested in energy supply in 2013, only $250 billion was invested in renewable energy.[18] Fossil fuel extraction and consumption continue to increase to meet rising world energy demand.

Considering the unaccounted for enormous negative external costs of carbon emissions, carbon prices remain far too low, perhaps the biggest market failure (mispricing) in history. Vigorous lobbying and public relations campaigns by the fossil fuel industry, which stands to lose trillions of dollars from their balance sheets, obscure the scientific consensus that the majority of remaining hydrocarbon fuels must be left in the ground to meet IPCC climate stability imperatives.[19] Efforts to put in place a carbon tax and other policies to reduce fossil fuel consumption have been effectively sabotaged by skilful management of public perceptions.[20] Energy company campaign contributions allowed Senator Inhofe's snowball in Congress to weigh more in public opinion and policy than 500 cubic kilometres of Greenland ice melting. [21]

Policies to mitigate climate change by changing behaviours could be faster and cheaper

Reducing Y/P and P require changing human cultures and behaviours, such as family size norms, tax policies and consumption choices. Cost of universal family planning would be a pittance compared to the cost of doubling world energy infrastructure every quarter century.[22] Attention to social justice issues–especially improving the status of women adds to the case for cutting growth.[23]

With continued growth, the net result of a huge effort and enormous investment to (hypothetically, for example) reduce emissions per unit of output to half current levels in a quarter century by new technology reducing C/E and E/Y would be 1/2 x 2 = 1, no net decrease in emissions. Growth in population and incomes will have doubled demand in 25 years.

Accounting for efficiency gains, the U.S. Energy Information Agency (EIA) projects a 56% growth in energy demand by 2040. [24] EIA also predicts growth in renewable energy sources from current 11% to 15% of total supply by 2040. Since 85% of 156% is larger than 89% of 100%, that scenario globally would increase current GHG emissions of 33.6 gigatons/year to 44 gigatons in 2040. By which time, as we saw above, the cumulative trillion ton CO^2 cap will have been exceeded. The world is in a "carbon trap" where technology improvements are offset by growth in demand. This resembles the "poverty traps" of countries where economic growth treads water due to high birth rates and more mouths to feed. [25]

On the other hand, if both technology and behaviours changed, so that demand (Y/P and P) fell while efficiency (E/Y) and renewables (C/E) also improved, then emissions could fall dramatically, 1/2 x 1/2 = 0.25, a 75% reduction in emissions. This understates improvements because reducing demand would enable foregoing dirtier carbon fuels developments such as tar sands and fracking for oil and gas as well as freeing more capital for investment in renewable energy. In other words, reducing Y/P and P also contributes to reducing C/E and E/Y.

A comprehensive approach to mitigating climate change must include policies to foster a steady state or shrinking economy and falling population in addition to efficiency gains and switching to renewables. Failure to reduce C/E and rising GHG emissions, despite decades of talk about sustainable energy sources, means that far more must be done and faster, in future.

As a more cheerful observation, notice that if 20% of current world energy supply comes from non-carbon sources (hydropower, nuclear, wind, solar, geothermal, biofuels), and if world population were 1.5 billion (20% of current 7.3 billion), that would mean 100% of energy needs could be supplied by existing non-carbon energy sources without cutting per capita energy consumption levels or building a single additional windmill.

Falling population as a carbon solution is not an unthinkable possibility–several of the world's most successful countries, including Japan and Germany, already have falling populations due to low birth rates.[26] However, in some countries, notably China and the Asian "Tiger" economies, demographic transitions from high to low fertility have been associated with a "demographic dividend" and accelerated growth of carbon emissions.[27] So restraining Y/P growth, that is, a steady state or shrinking economy, will also be required for population growth restraint to have a net positive effect on emissions. Restraining both population and economic growth can succeed where each alone would fail.

Conclusion

Profound cultural changes will be needed to stop growth. We must adopt David Attenborough's positive vision of a green, sustainable planet with steady state economic throughput and a much smaller human population eager to share resources with a diverse community of interdependent species and valuing ecosystem restoration. [28] Humanity has to accept scientific truths that motivate living within the ecological limits of earth's capacity to maintain human life without degrading our habitat.[29]

Instead of campaigns promising growth and jobs, leaders must convince the public to accept wealth taxes, carbon taxes, cuts to consumption, responsible reproduction, social justice and sustainability. Instead of saying, "Population growth means we need more jobs" politicians should say, "Too many jobs are wrecking the earth, we need to cut the number of people and reduce emissions per person."

Scarcity of resources such as land, energy, food and Earth's ability to accept carbon pollution caused by growth cannot be solved with more growth. We would be wise to adopt a lifeboat ethic of sharing scarce resources fairly and reviving social justice ethics. Humans can thrive through caring for nature and caring for "the least of my brethren" including future generations.[30]

Our goals should include warm human relationships, community, security and self-discipline, rather than selfishness, bigger houses and new cars on a damaged planet. Luckily research on the psychology of happiness teaches that people can, contrary to mainstream but outmoded economic theories, live good lives with sufficiency rather than more and more consumption.[31] Adler mentions "life tasks" of community, work and intimacy. He does not mention getting rich.[32] Cultural and behavioural changes required to solve CO^2 emissions could leave us healthier, more connected to nature and each other, with more joyous and secure lives.

Julian Simon called human intelligence "the ultimate resource."[33] But Barbara Tuchman's book The March of Folly covers historical cases where good advice was ignored with disastrous results.[34] The future depends on our ability to use the ultimate resource wisely; perhaps human wisdom will prove to be the most limited resource of all. Jared Diamond concluded societies that fail to adapt to new conditions collapse[35]. Switching to non-carbon fuels poses a challenge of adapting to new conditions created by our own inventions on a global scale.

It used to be impossible to abolish slavery or for women to vote or to have less than six children, but good people made those major cultural changes happen. We have powerful institutions including education, mass media, international cooperation, markets and carbon taxes that could get carbon reduction accomplished and rein in growth with speed. Technologies exist to allow family planning and for making electricity from sun and wind and for running cars on hydrogen. People motivated by a positive vision of a green future earth and communities of responsible, happy, connected, empowered citizens, could get it done by attacking GHG emissions on all fronts.

A balanced, comprehensive set of Greenhouse policies should address all four terms of the Kaya equation, with fertility reduction perhaps the easiest to accomplish and cheapest, based on the experience with fertility declines in dozens of countries during the past half century. Slowing economic growth is an argument for rather than against a global carbon tax. If all four Kaya terms head in the right direction, their synergies would transform climate stability from a receding fantasy to a feasible project.

References

1. IPCC 5th Assessment Report (2014) www.ipcc.ch/report/ar5/wg2/ Over 600 authors, two thousand reviewers, 50,000 comments and 196 nations created this consensus U.N. Environmental Program report.

2. IPCC press release citing 5th assessment report, April, 2014. www.ipcc.ch/pdf/ar5/pr_wg3/20140413_pr_pc_wg3_en.pdf Full IPCC report at: www.ipcc.ch/report/ar5/wg2/

3. Shanghai, Tokyo, Rio, London, Sydney, Auckland, Buenos Aires, Rotterdam, Stockholm, New York, Los Angeles, Mumbai, St. Petersburg, Miami, Havana, Alexandria, etc. etc. If the polar icecaps and glaciers all melt, sea levels could rise over 200 feet. http://ngm.nationalgeographic.com/2013/09/rising-seas/if-ice-melted-map

4. http://trillionthtonne.org Website from Oxford University Department of Physics.

5. When the ratio "energy return on energy invested" (EROEI) falls below one, exploitation of a resource ceases regardless of prices, with some difficult-to-extract resource remaining in the ground. See Tilton, J. (2003) *On Borrowed Time?* Assessing the Threat of Mineral Depletion, Resources for the Future, Washington, DC.

6. Kaya, Y. (1990): Impact of Carbon Dioxide Emission Control on GNP Growth: Interpretation of Proposed Scenarios. Paper presented to the IPCC Energy and Industry Subgroup, Response Strategies Working Group, Paris. See also, https://en.wikipedia.org/wiki/Kaya_identity

7. All data used for calculating Kaya equation variables come from World Bank "World Development Indicators" (WDI) time series. The WDI cite U.N. population projections and the International Energy Agency as primary sources of data. http://data.worldbank.org/products/wdi

8. Bardi, U. (2013) Extracted. Chelsea Green Publishing, White River Junction, VT. Various works by Professor Charles A.S. Hall and co-authors develop the theme of world economic dependency on high energy density fossil fuels. Several "peak oil" authors, Richard Heinberg, Clifford Deffeyes, Matthew Simmons, et al. analyse how depletion of major oil fields and accessible coal and gas deposits have lifted dependence on dirtier fossil fuels.

9. www.youtube.com/watch?v=YkwoRivP17A Tar Sands Oil Extraction - The Dirty Truth

10. GDP per unit of energy use (constant 2011 PPP $ per kg of oil equivalent), World Bank Development Indicators. For example in 2011, Switzerland produced $17 of GDP/Kg oil equivalent versus $7.1/Kg oil in the U.S.A. E/Y is the inverse of this GDP/E ratio.

11. A rule of thumb for calculating doubling time is to divide 70 by the growth percentage x 100. Hence 70/3% x100 = 23.3 years to double a quantity with a 3% annual growth rate.

12. wog/indicator/DYN.TFRT.IN Fertility rate, total (births per woman)

13. http://esa.un.org/unpd/wpp/Documentation/pdf/WPP2012_HIGHLIGHTS.pdf World Population Prospects (2013)

14. See www.youtube.com/watch?v=DZCm2QQZVYk Albert Bartlett's famous lecture on the exponential function.

15. Jacobsen and Archer estimated $17 trillion for renewables (4 million windmills, 90,000 solar installations, 1% of world land area, by 2040.. http://news.stanford.edu/news/2012/september/wind-world-demand-091012.html

16. World Bank, World Development Indicators. "Fossil fuel energy consumption (% of total)" http://data.worldbank.org/indicator/EG.USE.COMM.FO.ZS Other sources claim higher figures–85%, 87%--so 80% is on the low end of estimates of fossil fuel's contribution to world energy usage.

17. Forecasts of world energy use show continued increase in fossil fuel consumption until at least 2040, implying cumulative carbon targets will be exceeded. See for example, International Energy Outlook 2014 Report Number: DOE/EIA-0484(2014) At www.eia.gov/forecasts/ieo/

18. www.worldenergyoutlook.org/pressmedia/recentpresentations/WEIO_Final.pdf World Energy Investment Outlook, IEA, 2014. And investment in renewable energy actually fell from 2012 to 2013.

19. www.rollingstone.com/politics/news/global-warmings-terrifying-new-math-20120719 This link takes you to an important article by Bill McKibben where he pointed out the huge economic stakes in carbon pricing.

20. Oreske, N. & Conway, E. (2010) *Merchants of Doubt. Bloomsbury Press, New York.* Historians of science research on how industry funded public relations campaigns advance ideologies or business profits.

21. www.dw.de/greenland-ice-melting-at-record-speed/a-17869513 and www.washingtonpost.com/blogs/the-fix/wp/2015/02/26/jim-inhofes-snowball-has-disproven-climate-change-once-and-for-all/

References

22. A graduate student studying costs of contraception I met at a Population Association of America meeting mentioned $3.50 for ten years contraception using an IUD (personal communication, 2012). A 2012 Guttmacher Institute estimate put global annual cost for unmet contraceptive needs at $8.1 billion, about 5/10,000ths of the $17 trillion cost of the Jacobson & Archer 2040 renewable energy infrastructure cost estimate cited above. www.guttmacher.org/pubs/AIU-2012-estimates.pdf

23. www.unfpa.org/icpd The 1994 UN Conference on Population and Development adopted empowering women as a global priority strongly related to reducing fertility rates and economic development.

24. www.eia.gov/forecasts/archive/ieo13/more_highlights.cfm U.S. Energy Information Agency "International Energy Outlook, 2013"

25. www.unfpa.org/resources/population-and-poverty "Population and Poverty," (2014)

26. www.ipss.go.jp/site-ad/index_english/esuikei/sh6.html Japan's demographers project a drop to about 1/3 of peak population in 2005 at 128 million to 42 million (medium fertility assumption) by 2110. National Institute of Population and Social Security Research in Japan (IPSS)

27. Kummerow, Max. (2009) "Reversing Malthus in the 21st Century" EAERE conference paper, Amsterdam. In this paper I divided over 200 countries into three fertility categories. Low fertility countries not only had five times higher incomes and 21 years longer life expectancy, they also enjoyed faster economic growth.

28. www.youtube.com/watch?v=dN06tLRE4WE David Attenborough's program: "How Many People Can Live on Planet Earth?"

29. http://steadystate.org The Center for the Advancement of a Steady State Economy (CASSE) provides access to work by Herman Daly and other Ecological Economists who advocate ending economic growth.

30. Matthew 25:45

31. www.huffingtonpost.com/news/happiness-research/ Popular summary of some of the research.

32. www.adlerian.us/tree.htm

33. Simon, J. (1996) *The Ultimate Resource 2,* Princeton University Press, Princeton.

34. Tuchman, B. (1984) *The March of Folly: From Troy to Vietnam.* Ballantine Books, New York.

35. Diamond, J. (2005) *Collapse.* Viking Press, Penguin Group. New York.

Readers' Letters

Dear Editor,

I am intrigued by the recent article by Coleman and Basten (2015) in Population Studies. It is always nice to have some 'good news' of course, but the authors actually consider rising OECD fertility to be 'good news'. I most definitely do not.

How can Coleman and Basten square their conclusions of good news with the results of the two papers - the Overshoot Index and the Depopulation Dividend? Unless the Global Footprint Network (the authors of the Index) is catastrophically wrong, only seven OECD countries are not yet in Overshoot.

The Network concludes that the European Union is already overshot by 210 Million people. Which means that we only sustain our cushy lifestyle by drawing down other countries' ecological capacity and our own natural capital, at the expense of their and our children. The Network also estimates that UK's ultimate sustainable population to be only 20 Million. England (not the UK) has now overtaken Holland and is the most over-crowded country in Europe. The YouGov polls commissioned by Population Matters have consistently shown that 80% of us would prefer a smaller population. Yet our population growth is such that the UK Office for National Statistics forecasts that by 2050, we will have the equivalent of between 7 and 46 more Manchesters.

What is it that is so unattractive about the notion of population reduction in heavily overshot countries? The Depopulation Dividend lists 18 reasons why such reduction is the real 'good news'.

I am genuinely puzzled by the indifference shown by most demographers towards the impact of current human numbers, let alone the continuing population growth, on our planetary life-support system. Is it that the trends in bio-physical sustainability are such calamitously 'bad news' that they prefer simply to blank them out? Or is it that demographers regard ecology as a subject which does not apply to the human species? Or is there some other reason? I have a very high regard for the specialist expertise of demographers, and look forward to their explanation for this blind spot.

Yours sincerely,

Roger Martin,
(Chairman, Population Matters)

Coleman, D., & Basten, S. (2015). *The Death of the West: An alternative view.* Population studies, 69(sup1), S107-S118

Overshoot Index:
http://populationmatters.org/documents/overshoot_index.pdf

Depopulation Dividend:
http://populationmatters.org/documents/depopulation_dividend.pdf