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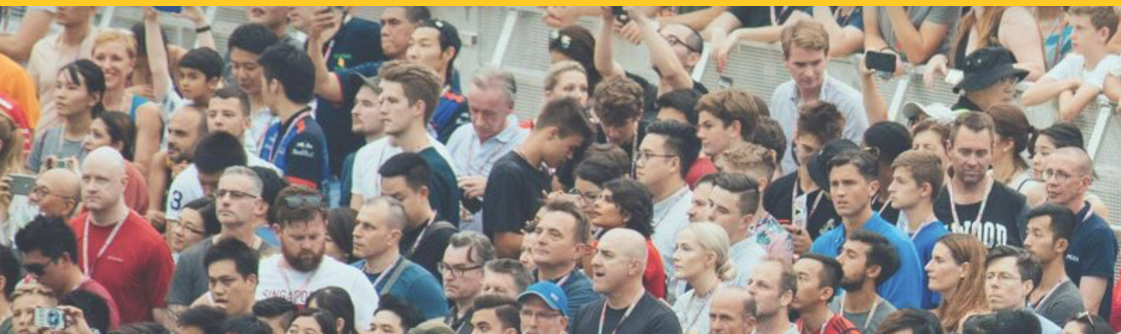

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Information

The Journal of Population and Sustainability (JP&S) is an open access interdisciplinary journal published by The White Horse Press exploring all aspects of the relationship between human numbers and environmental issues. The journal publishes both peer reviewed and invited material. It is intended that the JP&S act as an interdisciplinary hub facilitating collaboration and furthering the development of the field. While generously supported by environmental charity Population Matters, the JP&S is entirely editorially independent and welcomes contributions from scholars with a variety of perspectives on the role of population in environmental problems. The views and opinions expressed by authors are their own and do not necessarily reflect those of the editor, the editorial board or publisher.

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Editorial introduction

David Samways – Editor

The publication of this issue to the *JP&S* coincides with a particularly ugly turn in global human affairs. A combination of events including the COVID pandemic, the war in Ukraine and the effects of climate change have seen inflation in the prices of key internationally traded commodities, most notably fossil fuels and grain. For many in the rich world, inflation will result in hardship, requiring careful choices and the diversion of income toward items defined as 'essential', but for more than two billion of the world's poorest people this conjuncture of factors will lead to dire choices about meeting their most basic needs, and for many there will be no choice at all. (FAO et al., 2021; FAO, 2022)

In an article published in this journal in 2017 Joel Cohen noted that,

> Earth's capacity to support people is determined both by natural constraints, which some will emphasize, and by human choices, which others will emphasize. Many of these choices are decisions made by billions of people in their daily lives (turn off the light when you leave the room, or leave it on; wash hands before eating, or don't bother; pick up litter in the schoolyard, or add to it). The cumulative results of what may be unconscious individual actions amount to major collective human choices: consume more or less fossil fuel; spread or prevent infectious diseases; degrade or beautify the environment. (2017, 40)

This is an important observation and underpins Cohen's contention that the idea of 'carrying capacity' is a specious concept when applied to human beings – it is our manifold choices in the context of the characteristics of the natural world that determine the population the Earth can support. This goes to the heart of much of the controversy surrounding the role of human population size

in our environmental crisis. Many rightly argue that the massive expansion in consumption in the post-War period was the greatest driver of what has been called 'the great acceleration' (Steffen et al. 2015) but it is equally true, as Paul Ehrlich has commented, that concentrating on consumption without factoring in population fails to adequately describe human environmental impacts, in the same way that specifying one side of a rectangle cannot describe the area of that geometric figure (Jowit, 2011). Nonetheless, the inequitable distribution of the consumption of resources is a critical impediment to the meeting of basic needs, let alone the enjoyment of a good life, for billions of people. It is frequently noted that sufficient food is produced to meet the calorific needs of many more people than the current global population but that, amongst other factors including those mentioned above, the use of food crops to feed animals to provide meat for those who can afford it and choose to eat it, or to produce biofuels and other industrial products, means that many are priced out of the global market for food.

While the everyday practices of individuals, in aggregate, are the principal cause of environmental change, the power of individuals to affect positive environmental change is limited. Moreover, how much 'choice' is involved in the everyday and mundane aspects of life such as the food we eat, the fuels we use, the temperature to which we heat our homes and even the frequency with which we wash our clothes and our bodies, is questionable. Environmental change is largely the result of habitual behaviour rather than choice, and the enaction of these norms takes place under social and technical conditions over which we often have little choice, producing unintended consequences of which we are frequently ignorant.

However, even when we are aware of the impact of an action and have the ability to choose to act otherwise, the moral dilemma is less of a consideration than the recognition of our inability to change the actions of millions of others. Mark Beeson's commentary piece, 'The Last Lap', published in this issue, thoughtfully considers such questions in respect of his own and others' choices. The 'lap' in question is his own circumnavigation of his adopted Australian homeland, but also refers to the possibility that our civilisation may be coming to the end of its journey.

Confronting the cognitive dissonance generated by the environmental impact of his fossil-fuelled grand tour, Beeson contemplates the limited ability of the individual to have a significant impact on essentially collective global problems.

Perhaps more importantly, he points up the indifference of many individuals in the rich world to environmental degradation local to them, and their lack of empathy for the poorest half of humanity likely to experience the worst effects of environmental change, let alone the plight of other species.

Clearly, even when well informed and concerned, the individual is largely impotent in the face of such problems and Beeson argues that only global institutions can effectively tackle these issues. However, as populist nationalism increases worldwide and attitudes towards migrants harden, he is not optimistic about the ability of national leaders to see beyond the short-term interests of their electorates and establish the internationally coordinated measures he proposes to tackle the unfolding environmental and humanitarian crisis.

The history of humankind is also a history of migration. From the earliest movement of our species out of Africa (Henn et al., 2012), population growth has played its part in driving migration as people seek better prospects in new lands. The unfolding contemporary global socio-economic situation is likely to see heightened levels of human movement as the effects of climate change, economic and socio-political factors take their toll. Immigration has become increasingly politically divisive, but it would be mistaken to think that concern has been limited to reactionary or xenophobic quarters, with a number of progressive authors expressing disquiet about the traditionally pro-immigration stance of left-leaning liberals (see for example Porritt and Hines, 2017; Cafaro 2015). Several have highlighted the potential environmental costs of domestic population growth, in particular the ability of individual nation states to meet their carbon emission targets (Weber and Scuibba, 2018; Cafaro and Götmark, 2019). Thus, while immigration obviously has no immediate effect on the global population size, and hence no effect on the 'P' of the IPAT equation (impact = population x affluence x technology), it is plausible that it may change the level of consumption through the increased affluence and the adoption of higher consumption lifestyles by migrants.

However, such arguments pay little attention to the wider environmental impact that fiscal remittances from immigrants to their countries of origin might have. Remittances represent an important flow of income into developing countries and have been estimated to be three times the value of official development aid (Ratha et al., 2016). As our paper from Travis Edwards points out, while many have noted

the effects of remittances on fertility, little account has been taken of the overall effect of migration and remittances on greenhouse gas (GHG) emissions. Edwards models the effect of remittance flows on emissions using data from 127 countries collected between 1971–2012. His results suggest that, rather than increasing GHG emissions, higher remittance flows reduce them, lending credence to the notion that the use to which income is put is critically important in understanding the impact of greater affluence on environmental change. Edwards' modelling supports the claim that remittance flows from rich to poor countries are usually directed towards improving the health and education of those communities in the country of origin rather than to increasing consumption of goods or industrial output. The reduction in present and future emissions may result from a number of behavioural changes including diverting locally earned income away from consumption of goods towards education, changes in the source of fuel and lower fertility. While Edwards notes the limitations of his study and the need for further research, he argues that his modelling indicates that calls for limiting immigration on the grounds of reducing GHG emissions are likely to be misguided.

While the environmental impact of migration from one region to another may be unclear, the growth of the global population can be clearly shown to be a major factor in anthropogenic environmental change. However, it has been pointed out that demographic momentum (the forward growth of total population as the large number of offspring of a higher fertility generation go on to have (fewer) children themselves) means that population policy is a poor tool for addressing immediate threats like climate change (Bradshaw and Brook, 2014). This argument should not be confused with the mobilisation of demographic transition theory as a 'grand historical narrative' demonstrating the inevitability of the transition from high to low mortality and fertility due to macro-demographic forces taking place 'behind the backs' of individual agents. This structuralist argument is pitched at a high level of abstraction as an explanation of broad historical trends, but is also frequently employed to show the futility of population policy against powerful demographic forces. In contrast, the position frequently associated with the outcome of the 1994 United Nations' International Conference on Population and Development, usually referred to as the 'Cairo Consensus', focuses on the micro level and the right of individuals to make autonomous fertility choices. While the demographic transition and rights-based approaches come from quite different paradigms, they both reject population policy, the first out of fatalism and the second out of a fear of moral peril.

Chris Tucker's commentary piece published here, 'Bending the Curve by 2030', takes issue with all of the above arguments. Tucker builds on the argument advanced in his 2019 book, *A Planet of 3 Billion*, where he contends that an environmentally sustainable global population, at a good level of welfare for all, amounts to around three billion – the questions addressed here are how this can be achieved and how quickly.

While acknowledging the role of demographic momentum in delaying the effectiveness of population policy, Tucker rejects the fatalism of structural demographic positions and argues that an ambitious and well-funded plan aimed at reducing the global average fertility rate to 1.5 births per woman by 2030 could be achieved with policies which respect and enhance reproductive rights and welfare. Specifically, Tucker argues that improving the education of girls, the greater integration of women into the workforce, unrestricted access to family planning and media promotion of modern reproductive norms could dramatically reduce fertility rates. Tucker asserts that policy techniques and expertise already exist to achieve this ambition and that it is only levels of funding which prevent it becoming a reality.

Modelling the outcome of achieving a global average total fertility rate (TFR) of 1.5 by 2030, Tucker assumes no change in the average age at first birth (25) and an average age at death of eighty. Under these assumptions, he calculates that, while population would continue to grow for a couple of decades after achieving a TFR of 1.5, a global population of three billion could be a reality in the first two or three decades of the next century.

In the absence of such ambitious and thorough population policies, the global population is projected to continue growing throughout this century, with the majority of this growth taking place in Africa. Benjamin Ason and David Kofi Essumnag's article demonstrates the multifactorial nature of the determinants of environmental risks and how population growth and demographic change are intrinsically connected with them. Specifically, Ason and Essumnag's research addresses the levels of knowledge of the health effects of pesticides and other endocrine disrupting chemicals (EDCs) as their use grows in Africa. The growth of the presence of pesticides and EDCs in the environment is known to have important negative consequences for human health and ecosystems, but the effects are often subtle and their significance only becomes apparent over the

longer term. Examining three communities in Ghana, they show that growth in population size and urbanisation, along with associated changes in lifestyle, have been significant factors in the increasing use of pesticides and EDCs, but that the knowledge of possible risks to health is poor. In particular the extra demand created by demographic change has led to increased use of these products to enhance agricultural yields. While knowledge of the risks associated with these chemicals was generally poor, it was particularly so amongst rural communities whose exposure was the greatest. Moreover, Ason and Essumnag note that inadequate investment in education, health, employment, civil infrastructure and waste disposal is exacerbated by unsustainable population growth and that this also indirectly contributes to the vulnerability of people and ecosystems to the effects of pesticides and EDCs. Ason and Essumnag's study demonstrates how the everyday and habitual use of technologies that have played a central role in the expansion of human numbers also harbours unacknowledged dangers.

We close this issue of the *JP&S* with Pernilla Hansson's review of Johan Rockström and Owen Gaffney's *Breaking Boundaries: The Science Behind our Planet* (2021). Hansson argues that, despite the authors painting a clear picture of the extensive impact of humankind on the Earth-system, they view the future with optimism – an optimism which is misplaced in Hansson's view, due to the lack of attention to the impact of a growing population.

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COMMENTARY

The Last Lap

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Abstract

What do responsible environmental behaviour and practice look like, especially for those of us who despair of effective policies being enacted by the current generation of political elites? This paper provides a personal response to the ethical and policy dilemma of our times. I attempt to explain what may seem like – and possibly is – entirely self-indulgent behaviour on the basis that I can make absolutely no difference at the sort of macro level that is needed to 'save the planet'. In the process I try to explain why thousands of others have made similar choices and why cooperation even amongst well-intentioned and informed individuals is so hard and unlikely to succeed.

Keywords: environmental politics; leadership; progress; cooperation; values

One of the final rites of passage in my adopted homeland is driving round it. An army of 'grey nomads' constantly circles Australia, frequently driving preposterously large vehicles that contribute disproportionately to the environmental problems that threaten the very continuation of life; or its continuation in anything like a 'civilised' fashion, at least. As the driest continent on the planet, Australia is likely to suffer the ravages of climate change more than most. And yet many of its citizens remain blithely unaware of, or indifferent to, the rapidly approaching, increasingly undeniable, catastrophic impacts of

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global warming. Despite the fact that I do know something about the alarming state of the planet, I am about to embark on the 'big lap' around Australia.

With or without my monstrous new vehicle, my contribution to global environmental degradation is negligible. Rather deflatingly, however, so is my ability to address the problems that the IPCC, amongst others, has been highlighting for decades (IPCC, 2022). In the grand scheme of things, it really won't make any difference whether I undertake a farewell tour of Australia; or it won't to anyone but me and the friends I'll reconnect with on my travels. I recognise that this self-serving logic is uncomfortably similar to the sort of argument the Australian government makes to justify continuing to export coal: it's not that bad in the overall scheme of things and anyway, if we don't do it someone else will (Morton, 2021).

But even the most cloddish, self-absorbed resource minister, mining executive, or ageing academic for that matter, may experience bouts of disconcerting cognitive dissonance as a consequence of the overwhelming, inescapable evidence of environmental destruction that confronts us every day. Having to watch our collective home either going up in flames or disappear beneath the 'once in a century flood events' that have become such regular features of quotidian reality makes it hard not to connect the dots. Little surprise that the young in particular suffer from an epidemic of anxiety about their future and not unreasonably question whether they actually have one (Thompson, 2021). The real surprise, perhaps, is that the young aren't more unhappy and unhinged than they already are.

Anyone reading a journal such as this won't need me to rehearse the all-too-familiar catalogue of woe that constitutes our best understanding of what may lie ahead of us in the increasingly likely event that we fail to address the drivers of climate change and environmental degradation. You will be relieved to hear, dear reader, that I have no intention of telling you what I suspect you already know. Nor do I wish to demonstrate my own deflating scientific ignorance, or my rather humbling reliance on the work of others. This attempt at shameless ingratiation and self-deprecation notwithstanding, I fear you will ultimately still come to consider me a selfish hypocrite of the first order. Rightly or wrongly, I have come to the conclusion that the planet is also on its last lap, and there's

nothing I can do to stop it. To be sure, life will go on in some form, but would you want to be part of something that Thomas Hobbes might have described as 'nasty, brutish and short'?

What follows, I'm afraid, is not especially scholarly and certainly not very uplifting. Indeed, it's a subjective, deeply pessimistic reflection on what it's like to be a human being confronted with the end of the world; or a world worth living in, at least. I should add that I am an over-privileged white man living in what turns out to be just about the safest place on the planet (Perth, Australia). I'm nearly 70, too; if the world can't hang together for the rest of my lifespan, we're in more trouble than I thought. This is not a flippant point: where you are in the life cycle profoundly influences the way you think about what could or should be done at both the personal and the collective level (Funk, 2021). Perhaps it always has; it certainly seems to now. By the time Greta Thunberg is my age it will be 2070 and, if we haven't made profound changes to that way we live, discussions such as this will be of even less interest and relevance than they already are. Young people may be forgiven for not sharing or sympathising with my rather insouciant attitude to my own fate and that of the planet, but it's the only consolation of the ageing process I've discovered so far.

In my defence, I've done what I can. Academics write books and articles, and hope they have an impact, contribute to the debate or are read, at least. My last effort (Beeson, 2021) hasn't even been reviewed, much less changed the world. Consequently, I've come to the not unreasonable conclusion that I can do nothing to influence the future or the outcome of the concatenation of contemporary geopolitical, geoeconomic or environmental crises that threaten to engulf us. The rest of this discussion is, therefore, a transparently self-serving justification for my imminent accession into the ranks of the nomadians.

Lost illusions

I promised not to try the reader's patience with a lengthy inventory of the world's burgeoning problems, and I won't. But it's impossible not to say something, or my abnegation of responsibility is hard to understand, let alone justify. The first point to reiterate is that I have made a rather modest contribution to the mess we're in. I don't have children, (I think) I've given up flying, and I'm eating fewer of our fellow creatures. Nevertheless, Australians generally contribute more to the

drivers of global warming on a per capita basis than just about anyone else on the planet (SBS, 2021). But not many people think about their relationship to the environment that way; or not enough of them to make a discernible difference, at least. To be sure, there's quite a bit of recycling going on in Australia, and some praiseworthy individuals have entirely given up eating meat and spend their time picking up other people's rubbish from the nation's beaches and rivers. But I think we know that even the best-intentioned individuals can only do so much.

This is even more of a problem when we also know that many people in wealthy countries are not just indifferent about the fate of the environment in the part of the world they are fortunate enough to inhabit, but are positively hostile toward those living in more challenging natural and social situations. Exhibit A in support of this thesis is the increasingly unsympathetic, even brutal, attitudes taken by governments around the world toward asylum seekers (Khanna, 2021). Australian governments have been at the forefront of this policy innovation. There is no doubt that what is euphemistically known as the 'off-shore processing' of would-be migrants has been very successful, at least when viewed from the perspective of electoral popularity. Indeed, one of the few promises Australia's Liberal-National Party coalition government can actually claim to have kept is 'stopping the boats' (Munro and Oliver, 2019).

The rise of populist politics and a rancid form of jingoistic nationalism around the world may not be solely attributable to unwanted waves of migration, but it's not unconnected either. Some of my more cosmopolitan-minded colleagues may not want to concede this, but xenophobia, revanchism and breath-taking ignorance about the past and – even more alarmingly – the present are not only increasing, but make the idea of international cooperation, much less world government, almost comically unlikely. It is becoming increasingly clear that sustaining national democracy in troubled times is difficult and far from guaranteed – even in its supposed democratic heartlands. Not only has the election of Joe Biden done next to nothing to shore up the surprisingly fragile foundations of the light on the hill, but the current attitude toward unwanted migrants from Mexico looks strikingly similar to his predecessor's (Barros, 2021).

The point here is not to lambast the United States for its litany of domestic and foreign policy failures – although that is something I could expand on if asked – but

to make the relatively uncontroversial point that, however we might define 'good governance', it is unlikely to occur without high levels of support, participation and effective leadership (Beeson, 2019). None of these is a given. Indeed, try to think of a country where the government is effective, the people are happy and the future looks bright. For many of us on 'the Left', if there is such a thing anymore, Sweden used to be the benchmark for enlightened public policy. And yet its remarkably generous offer to take in the victims of the Iraq war – a conflict they had no part in, let's not forget – created a domestic backlash, social unrest and ghettoisation (CBS, 2019). Even the best of intentions can have disastrous, unforeseen consequences in today's world, it seems.

Leadership and cooperation

If doing good is difficult domestically, it's all but impossible internationally. I make this rather bold claim on the basis of my alleged area of expertise: international relations. Anyone who knows anything about IR, as we aficionados know it, would have to admit that much of what passes for theory is either a bit abstract and of limited obvious relevance, to put it delicately, or designed to give intellectual comfort and practical policy advice to the likes of Vladimir Putin. 'Realists' are notorious for their relentlessly gloomy, power-oriented view of the world. Any ambitious defence minister or run-of-the-mill megalomaniac keen to either make a name for themselves or justify ever more spending on guns and bombs can be sure to find a willing chorus of strategic experts who will be only too happy to endorse wasting scarce resources on weapons of war. Nothing comes before the national interest, it seems, even if its actual definition is assumed, rather than demonstrated, by a handful of modestly credentialled powerholders.

The conventional wisdom notwithstanding, turning swords into ploughshares still sounds like a good idea, even if it's a metaphor in need of a makeover. The reality, of course, is that we're heading in precisely the opposite direction: the 'peace dividend' that the – entirely unexpected and bloodless – end of the Cold War was supposed to inaugurate failed to materialise. Of course, things might have been different if George W. Bush hadn't been elected President in highly contentious circumstances and surrounded himself with a coterie of neoconservative zealots bent on remaking the world in America's entirely fictitious image (Mann, 2004). Not only did some of the victims of this entirely unnecessary war of choice end up wrecking Sweden's admirable social compact, but it destabilised the entire

Middle East, wasted scarce resources and helped to enshrine the idea that powerful sovereign states have a right to try and remake the world if they have the will and capacity to do so. One might be forgiven for thinking the youthful Xi Jinping and Vladimir Putin took copious notes.

The rather sobering reality is that we really don't have many convincing examples of effective long-term, institutionalised international organisations and agreements of a sort that look indispensable if we're really going to do anything about growing international tensions, not to mention climate change. In fact, the problems created by accelerating and destructive climate change are actually making cooperation even more difficult – and unlikely. Indeed, in my – no doubt dated, male and 'Western' – view we've only had one example of effective international cooperation worthy of the name and that's the European Union. Even suggesting such a thing will no doubt induce apoplexy among woke readers, but the evidence seems reasonably uncontentious. The EU has been responsible for pacifying what was formerly the most violent part of the planet for hundreds, if not thousands of years, laying the foundations for unprecedented economic development and – most importantly, perhaps – transforming the attitudes many Europeans had about themselves, their neighbours and the prospects for their future.

And yet, despite the EU's unprecedented successes – not least in giving the lie to the claims of policymakers and grand strategists who said such things were impossible – it's not obvious the EU has the will or capacity to remain the flag bearer of human progress. Even suggesting such a thing as progress is actually possible, especially when it emanates from some of the world's most notorious former colonial powers, may also raise the blood pressures of more sensitive readers. No doubt the Europeans deserve to be held accountable for their historical misdeeds, their rather self-satisfied view of their own achievements and a sometimes-condescending attitude to what used to be described as the 'developing world'. Whatever you think of the latter as a collective signifier, though, it's uncontroversial to say that the bulk of humanity has not achieved European levels of economic or political development. With the exception of a handful of frequently corrupt and brutal autocrats who have siphoned off resource wealth for personal gain, the vast majority of people in the South are *never* going to enjoy the sorts of lives and living standards most readers of this article take for

granted, not least because of environmentally generated problems such as Covid (Beaumont, 2021). Even more troublingly, it's now not even obvious that's entirely a bad thing.

The paradoxes of progress

Of the many paradoxes and puzzles that are part of the human condition none seems more confounding than this: at the very moment when we collectively seem to have figured out how to lift millions of people out of poverty, we are forced to confront the reality that doing so will inevitably contribute to already catastrophic climate change, at least in the short-term, because of the correlation between rising incomes and greenhouse gas emissions (Bruckner et al., 2022). And as Keynes helpfully pointed out, of course, in the long-term we're all dead.

If you're the plucky optimistic type you may be comforted by the idea that some technological wonder or other will come along and save the day, transform the way we produce and consume things and allow business as usual. To be fair, the world is already awash with wonders that have had transformative effects. But many of them are dedicated to encouraging the already privileged to consume even more than they do, in ways that look not just inherently unsustainable, but like glaring, unjustifiable examples of gross inequality and indifference to the fate of strangers. The inescapable flipside of conspicuous consumption seems to be insufficiently conspicuous immiseration. Perhaps there's no inevitable causal relationship between the two, but the symbolism and *deliberate* wastefulness of the 'fast fashion industry', for example, captures part of this inequitable global zeitgeist (Monroe, 2021). This was a problem even when the world wasn't as interconnected as it is now. But when the poor are often painfully conscious of their relative depredation, it must surely engender resentment, envy, possibly even conflict.

The idea of 'structural violence' is a rather anodyne abstraction that doesn't adequately capture the manifold, interconnected problems that have an especially pernicious impact on the poor, women and children. The chances of escaping from poverty and persecution were never good in parts of sub-Saharan Africa, for example, but now they are being exacerbated by climate change, warlordism, ethnic conflicts and the sheer number of people trying to scrape a living in the same place – or trying to escape to a part of the world where such problems do

not seem to exist. I know I would in their place. No surprise, then, that Europe and America have become magnets for the energetic, the dissatisfied and the young in Africa, Asia and South America. Unfortunately, these ambitious would-be migrants are not welcome. Even the EU now turns a blind eye to the deployment of razor wire and robust policing on its southern borders (Trilling, 2021). Given the demographic drivers of these population flows, things are unlikely to change for the better in the foreseeable future – which, given rapidly deteriorating social and natural environments, in many poorer countries probably means never.

In a rationally ordered world of a sort that might resonate with Kantian idealists – supposing such people still exist, of course – Europe's ageing and declining population might be thought to benefit from an influx of highly motivated, entrepreneurial young people. If only life were so simple. As the Swedish experience reminds us, even if all of the aspiring migrants had desirable skills, spoke their host's language and respected local values, potential supply vastly outweighs demand – and it always will. In any case, actually integrating people into another culture and equipping them with the linguistic and technical skills to become productive members of society is labour-intensive and costly. Moreover, if recipient countries actually cherry-picked migrants on the basis of the host's preferences rather than the migrant's needs this would also undermine any idea of a universal right to safety and security.

It is not only cosmopolitans who might be outraged by such policies, however. More to the point, the generosity and understanding of local populations in recipient countries may rapidly erode – as it has in a number of Scandinavian countries. Whatever one thinks of such parochial attitudes, they do beg a fundamental and uncomfortable question: are there limits to the number of souls that 'developed' nations are obliged to take in? If so how, and by whom, are fate and fortune to be decided? Even more problematically, how are those excluded from such quotas – and their chance at the good life – to be discouraged, even forcefully rejected? I have no idea what the 'right' answer to such questions might be, but I suspect that addressing them will be one of the unending dilemmas confronting policymakers in the broadly conceived wealthy West. In this context, Australia offers a possible response, but it is not necessarily one we might want to see widely adopted.

Guarding good luck

The late Australian public intellectual, Donald Horne (2009), famously described his homeland as 'the lucky country'. He was being ironic: even Australia's mediocre political class could hardly fail to make a decent fist of governing a country that inherited democracy, the rule of law and seemingly endless natural wealth. Even when such wealth is shared highly unevenly, Australia's still smallish population means that things could be worse – much, much worse, in fact. One might think that Australia's people and politicians would recognise their historically contingent, entirely arbitrary good fortune and seek to share it with the world. Sadly not. On the contrary, Australian politicians in particular are possibly best known for implausible and self-serving rationales for continuing massive domestic and international environmental destruction, as well as for developing one of the most callous, even inhuman, policies toward asylum seekers in the world.

And yet it is far from clear on what basis migrant inflows should be determined, much less policed. What is clear, is that there are limits to the numbers of people that countries – especially the demographically smallish variety – can take in without overwhelming their capacity to peacefully and successfully absorb them. Once this is conceded, the policy issues become rather more technical than moral. Consequently, it is all too likely that pragmatism will trump principle, and enjoy widespread public support. One possible theoretical alternative is for the North to help the South to try and make migration less desirable in the first place by helping to stabilise and improve the latter's political, economic and especially environmental prospects. The historical record of even well-intentioned efforts to achieve such things suggests they are often too small and poorly conceived to be effective (Collier, 2007). More fundamentally, of course, even if there was a serious appetite to attempt such things and the implicit transformations in North-South relations they imply, they are likely to take a long time to make a difference and time is one thing climate scientists tell us we absolutely do not have enough of.

One might hope that the sense that time is running out, and that the entire world faces imminent catastrophe in the absence of unprecedented levels of cross-border cooperation, might focus the attention of the 'international community'. Unfortunately, it is becoming ever clearer that there is no such thing; even regional varieties of cooperation are geographically delimited, and generally

unable to act effectively. The EU was the historical exception that proved this rule, but its current panoply of problems suggests that it may not be the benchmark for effective international cooperation much longer, its often laudable efforts to address climate change notwithstanding. The discouraging reality is that the world remains composed of nation states, even the most effective and enlightened of which are constrained by domestic politics, the limitations of their leaders, and sheer material circumstances.

If only some of the bleak future scenarios painted by climate scientists prove to be accurate, then the political space in which policymakers act will become ever more unforgiving and constrained. Indeed, one doesn't need to subscribe unquestioningly to James Lovelock's (2006) Gaia hypothesis to think that what's left of the natural world is responding to problems we have created. Covid and its variants are a painful reminder of both our impact on the physical environment and the latter's capacity to harm us when mistreated (Carrington, 2020). Given that global population growth is unlikely to flatten out or reverse in time to make a profound difference to the underlying and destructive relationship between us and the natural world, then we seem likely to face a future of unending environmental calamities of one sort or another as the limits to growth are once more vividly demonstrated.

Are our leaders simply too stupid to save us?

By now we might hope or expect that even the dimmest of policymakers would have grasped the idea that there is a global environmental problem and that only a global response has any chance of doing something about it. To be fair, many of the world's leaders do seem to understand that business as usual is not an option, even if they are often less convinced that business or – more accurately, perhaps – industrial capitalism is a key part of the problem. Advocates of 'degrowth' make the cogent and seemingly incontrovertible point that current patterns of consumption and resource exploitation simply cannot go on; or they cannot go on without undermining the very material basis upon which human and other life forms depend (Hickel, 2020).

If the relative fate of human beings is determined overwhelmingly by a national frame of reference, we might be forgiven for thinking that the future of our fellow creatures would be subject to an even more exacting calculus of concern.

Generally, it is. As we blithely chomp our way through the carcasses of 19 billion chickens, as well as billions of sheep, cows and pigs each year, most of us give little thought to their comfort or – more consequentially from a policy perspective, perhaps – the impact that the mass production of meat has on the natural environment (Milman, 2021). If it is difficult to imagine political leaders taking the needs, possibly even the rights, of foreign human beings seriously, how much more unlikely is it that they would become exercised over the fate of our furry and feathered friends? In yet another paradox, however, the Australian government's neglect of cuddly Koalas and a dying barrier reef generally elicits more concern than its treatment of asylum seekers.

Rather dispiritingly, Australian leaders are far from the worst offenders when it comes to prioritising development over preservation, human over animal welfare, short-term over long-term policies or the parochial over the global. In the face of some very stiff competition, Brazil's Jair Bolsonaro probably deserves the title for the most environmentally destructive, short-sighted, stupendously ignorant leader on the planet (Menezes and Barbosa, 2021). It is simply impossible to imagine him taking part in a serious, open-ended discussion with his international counterparts on the best way to save the planet, as opposed to his own interests and obsessions. Even before Vladimir Putin began threatening to unleash a nuclear holocaust, megalomaniacs around the world were busily plotting to further their own interests, right historical wrongs or generally make their national brand great again. The fact that no country can ever be made great again when the environment is collapsing before our eyes seems to have escaped their attention.

One serious question to ask, therefore, is this: is the current generation of international leaders especially stupid, short-sighted, incompetent and incapable of rising to the challenge of climate change in particular, or would any leader from any historical epoch have been equally flummoxed by the contemporary concatenation of crises? In other words, are the problems simply too big and too difficult, and the possible remedies so technically and politically demanding as to render them impossible? Just for the sake of argument, let me run through some possible strategies that the international community might consider, if there actually was such a thing – rather than the increasingly fractious collection of competing states and economic interests that currently approximates 'global

governance'. For all the no doubt well-intentioned COP gatherings and the worthy statements they generate, next to nothing of any significance has actually been done to change the direction of travel thus far.

Saving the planet 101

There are many clever people on the planet, and some of them have good – even plausible! – ideas about what might be done to put Spaceship Earth back on an even keel, if that's still a useful metaphor. Unfortunately, none of them seem to be in positions of power within their own countries, let alone capable of designing and implementing the sorts of global policies we may need if we're to survive. What follows are some well-known and some not-so-well-known (generally my own) ideas about what might be done. Let me say at the outset that I have absolutely no expectation that any of these ideas will be taken seriously, much less implemented, and certainly not in the time available to us. Plans always seem to have 10 points; here are mine:

1. Listen to the experts. Some people know more about what's going on than others. Indeed, it's the very basis of an intellectual division of labour that has provided great achievements and an astonishing level of insight into material reality. The challenge here is to restore the credibility of (some) experts and technocrats when many potentially useful forms of knowledge have been misused and or/discredited.

2. Develop international forums where open-ended Habermasian-style communicative rationality prevails and provides the basis for disinterested problem-solving. (Just because Habermas was a man and a product of the Western Enlightenment doesn't necessarily mean he was wrong).

3. Empower the United Nations and its offshoots. Yes, the UN's track record is patchy, but it's all we've got and we don't have time to start again. Giving the UN its own income stream through a Tobin tax on (generally speculative and unproductive) international capital flows would give it the certainty and independence it needs to be more effective.

4. Allow the UN to create a permanent security force with which to guarantee the sovereignty of individual states. The UN should be the repository of a handful of nuclear weapons (with which to discourage megalomaniac opportunists), with all other states rapidly moving to outlaw them. (States are both part of the problem and possible solutions; they're not unproblematic, but we are where we are. They remain potentially effective actors, but need to focus on *collective* security not just their own.)

5. Immediately ban international arms sales and discourage the pointless expenditure on new weapons systems by individual governments. The US and China should jointly sponsor this initiative and demonstrate its potential efficacy by negotiating an arms reduction treaty and using all the money saved to restructure their domestic economies along sustainable lines. (They could also give some to countries that really need assistance, too, of course).

6. Initiate a massive redistribution of wealth both within and especially between states. Unless the security and even the relative prosperity of the South is also addressed, there is little chance truly global accords will be reached. The success of the Marshall Plan in reconstructing post-war Europe and institutionalising cooperation suggests such schemes could actually work.

7. Discourage over-consumption and tax self-indulgence within and between countries. Wealth, inheritance and especially carbon taxes should be rapidly implemented. Travel should be rationed, with every citizen of voting age getting the same allocation the world over, allowing the poor to sell their share to the rich who simply 'must' fly around the world.

8. Demand that countries such as Australia immediately close down polluting industries (like coal) and help poorer states to rapidly transition to sustainable forms of energy.

9. Prioritise efforts to limit human population growth through education (especially for women and girls) and incentives. Bribing people not to have children may be one of the least-worst options left to us.

10. Cultivate an unprecedented change in human consciousness, especially among leaders, as they finally recognise that they have no other choice than to cooperate if they want to survive. Put our plight in perspective: the fate of this planet means diddly-squat to the cosmos, but it does to us.

It's hard to say which of these is the most unlikely to be acted on, or least likely to cause outrage about possible eurocentrism, elitism, authoritarianism or the supposed perils of world government. At one level it really doesn't matter: it is difficult to imagine the circumstances in which any of them might be enacted. That is precisely why I have added the most unlikely of all: a change of human consciousness about ourselves and our collective fate. One thing does seem clear, however: without some sort of frankly unimaginable change in values, behaviour, identity and ideas about leadership, nothing will change; or nothing will change for the better, at least. In the absence of an unprecedented paradigmatic shift in the way we think about ourselves as a species, our needs and wants and our relationships with each other and the natural world, all we can be confident about is that things will get worse, possibly much worse, and much more quickly than we might have believed possible. Indeed, in yet another ironic paradox, climate scientists are now being accused of having been too cautious in their predictions about our collective fate. Ho hum.

My personal mantra these days is 'do what you can, where you can'. Neither overly ambitious nor terribly original, perhaps, but turning up and taking part is mildly therapeutic, even if you're just cleaning up someone else's shit. Identifying your tribe is the thing; just recognising that there's one out there that you could interact with at all is not nothing. 'Only connect', as E.M. Forster famously said; the challenge now is to make that happen across borders. The response of other Europeans to the crisis in Ukraine is, at the time of writing, a hopeful sign, even if it's also a reminder that no such solidarity has been shown to Syrian victims of Russian brutality. Tribal identities have their limits, too, it seems.

I don't know if the grey nomads will prove to be my tribe, but given that I – and possibly the planet – may be on the last laps, my other motto is: see it before it disappears. It's not much of a defence for planet-destroying self-indulgence, I know. But if/when I get back, I'll sell the vehicle and donate the proceeds to Médecins Sans Frontières. Turns out you can even outsource your responsibility for saving the planet to someone who knows something useful and might actually make a difference. Not everything and everyone is stuffed up – or not yet, at least.

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PEER REVIEWED ARTICLE

Remittance flows and the environmental degradation-migration nexus

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Abstract

The net effect on the environment from migration into developed countries has received little attention in existing literature. Yet, this issue has important policy implications – e.g., nativists' support of anti-immigration policy for achieving pollution reduction targets. This research uses panel data for 127 countries from years 1971–2012 to analyse how migration affects greenhouse gas (GHG) emissions through remittance flows. The findings suggest higher remittances lead to lower GHG emissions. Further, the estimated decrease in GHG emissions more than compensates for any potential increase in global GHG emissions from migration into developed countries. These results suggest that pollution alone does not justify policies restricting immigration.

Keywords: environmental economics; migration policy; remittances; population growth

1. Introduction

The majority of migration occurs from people moving into developed[2] countries (United Nations, 2015). Cafaro and Götmark (2019), along with anti-immigration

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2 The development status of a country is determined using various metrics depending on the organisation. For consistency, this analysis uses income groups as classified by the World Bank (developed countries are considered upper middle-income and high-income).

organisations such as the Center for Immigration Studies and the Federation for American Immigration Reform, argue that population growth due to immigration hinders the ability to achieve pollution reduction targets. Weber and Sciubba (2018) agree that immigration increases the difficulty of reaching regional environmental goals, but admit limiting immigration is not a global solution to reducing pollution. In 2014, remittance flows were three times higher than official development assistance and more stable than foreign direct investment (FDI) flows (Ratha et al., 2016). How remittances affect GHG emissions in a specific country depends on several factors, including the level of economic development and stage of demographic transition. This study contributes to the existing literature by conducting an empirical investigation into the net effect of migration on global pollution levels.

The relation between remittance flows and the environment has received little attention in the literature, with no clear consensus. Heilmann (2006) discusses the relation between the environment, remittances and economic development and suggests there may be environmental benefits from migration. This paper builds upon Heilmann (2006) to show that migration, through remittance flows, may have net environmental benefits when considering global GHG emissions. Only a few empirical studies exist analysing the effect of remittance flows on the environment. Khan, Ahmad and Khan (2020) analyse remittances, FDI, income and energy consumption and find remittances are increasing CO_2 emissions in BRICS (Brazil, Russia, India, China and South Africa) countries. Conversely, Oldekop et al. (2018) conclude that remittances have environmental benefits such as accelerating the transition from deforestation to reforestation in several Global South countries. A notable issue is that these previous studies focus solely on the effect of remittances on pollution levels in the country of origin. Additional research is needed to generalise the role of remittances on pollution levels as the relationship is inconclusive in existing literature. This research contributes to filling this gap by showing that remittances have net positive environmental benefits through reduced GHG emissions.

In 2012, greenhouse gas (GHG) emissions per capita (in metric tons) were 5.9 for low and middle-income countries and 13.7 for high-income countries (World Bank, 2020a). If migrants assimilate into their host country and take on similar consumption patterns, then this implies an average increase in global GHG

emissions of 7.8 metric tons for each migrant (holding other factors constant). However, Ma and Hofmann (2019) and Price and Feldmeyer (2011) show that, in the case of the US, a higher concentration of foreign-born residents has no significant impact on certain GHG emissions. Further, Squalli (2010) found that US states with higher proportions of migrants were associated with lower levels for some GHG emissions. Additionally, assuming migration leads to higher emissions ignores any potential benefits on the countries of origin through the transmittance of both remittances and social norms of fertility preferences in the host country (Heilmann, 2006). The net effect of migration – the difference after migrants assimilate into their host country while accounting for any effect on the home country – on global GHG emissions is the more important concern and this study's contribution to the literature.

There is a vast literature on the relationship between economic growth and the environment, most notably that of the Environmental Kuznets Curve[3] and IPAT[4] equation. This study contributes to the literature by determining that migration alters the predictions of these models. Any model attempting to explain environmental impact must consider population beyond just size. Population cannot be used, on a national level, as a scaling factor since the composition of population matters. For example, population growth due to immigration may impact GHG emissions differently from domestic population growth. The possibility that migrants may affect global GHG emissions negatively – an environmental benefit – should be recognised in any future discourse on environmental quality related to immigration.

The paper is structured as follows. Section 2 discusses the literature on the environmental degradation – migration nexus. Section 3 describes the data and presents the empirical model specification. Section 4 provides an overview of the key results, robustness checks and an estimate of how migration impacts GHG emissions through remittance flows. Section 5 concludes with policy implications, potential caveats and future extensions of this work.

3 See, e.g., Atasoy, 2017; Franklin and Ruth, 2012; Rupasingha et al., 2004; York et al., 2003; List and Gallet, 1999; Grossman and Krueger 1995; Shafik and Bandyopadhya 1992; Meadows et al., 1972.

4 The IPAT equation, introduced by Ehrlich and Holdren (1971), postulates that Environmental Impact = Population X Affluence X Technology.

2. The Environmental Degradation-Migration Nexus

While there is considerable research on how social norms and remittances affect fertility rates, there has been less emphasis on how these factors influence the environment. What research does exist on the link between remittances and pollution is mixed. In examining relatives of migrants in highland Guatemala, Davis and Lopez-Carr (2010) argue that the decrease in fertility attributed to exposure to social norms of high-income countries does not offset the expected increase in consumption from receiving remittances. Further, Ahmad et al. (2019) find that increases in remittances led to increased CO_2 emissions in China. Conversely, Sharma, Bhattarai and Ahmed (2019) show, in the case of Nepal, that increases of remittances reduce CO_2 emissions. Clearly, a consensus on the relation between remittances and environmental quality has yet to be reached.

Ahmad et al. (2019) argue that remittances increase household consumption and savings, which in turn increases aggregate demand and bank savings. This increase in aggregate demand and improvement in the financial sector then leads to subsequent increases in industrial production (Ahmad et al., 2019). However, a number of studies have found that international remittances increase investment spending on education and on health in host countries (Gyimah-Brempong and Asiedu, 2015; Amega, 2018; Askarov and Doucouliagos, 2020). Adams (2006) argues, based on a survey of past research, that families receiving remittances typically have lower purchases of consumer goods and rather spend more on education than households not receiving remittances. Based on these studies I argue, contrary to Ahmad et al. (2019), that increases in consumption and savings from higher remittance flows do not necessarily lead to higher industrial production. Although there is ongoing debate about the effect of remittances on the home country, there is evidence which suggests remittances may reduce purchases of consumer goods, while also increasing investment in education.

Note that, although fertility rates have declined in middle-income countries, from 5.591 births per woman in 1960 to 2.333 in 2018, which is consistent with the demographic transition, for low-income countries the average remains at 4.506 as of 2018 (World Bank, 2020b). As previously discussed, remittances are often used for health and education services, both of which have been shown to lower fertility rates (Naufal and Vargas-Silva, 2009; Beine, Docquier and Schiff, 2013; Paul et al., 2019). The important question is if lower fertility rates – partially affected by the

transmission of social norms of high-income countries and increased spending on healthcare and education from remittances – offset any potential rise in per capita emissions of migrants once transitioning into their host country. Remittances can be used to gauge migrants' attachment to their home country and as such to measure the transmission of social norms, including fertility preferences, to their home families – the logic being that migrants more connected to their home country will send higher levels of remittances (Naufal and Vargas-Silva, 2009; Davis and Lopez-Carr, 2010; Beine, Docquier and Schiff, 2013; Paul et al., 2019).

Based on the above literature, the assumption that the level of attachment of migrants to their home country is transmitted through remittance levels is maintained. In taking this approach, the short-term effect of remittances on GHG emissions is directly captured by the inclusion of total remittances. The inclusion of total population should capture any long-term effect on GHG emissions from exposure to social norms of lower preferred fertility rates. Although Ahmad et al. (2019) assume increased industrial production necessarily results in increased CO_2 emissions, this is not the case, as many factors, such as the technological level of the economy and energy sector, must be considered. For this reason, GHG emissions are used to better capture the effects on the economy more broadly and take into consideration the level of alternative energy used in the energy sector.

3. Data and Model

3.1 Data

The data is collected from the World Bank, World Development Indicators database, and includes annual data for 127 countries over the time period 1971–2012.[5] GHG emissions, in kilotons (kt) of CO_2 equivalent, are used as a measure of economy-wide environmental impact and Gross National Income (GNI), in constant 2010 US dollars, as a measure of wealth. Total energy use, in kilograms of oil equivalent, is included to capture growth in the manufacturing and transportation sectors, as well as urban growth and the relative price of energy. Alternative energy use, as a percentage of total energy, is used as a measure

5 Annual data for 217 countries for the period 1960–2019 were collected from the World Bank. However, due to missing data on some of the key variables in the analysis, the sample used to estimate the preferred empirical specification (see section 4.1) includes only 127 countries over the time period 1971–2012 (see Table 2).

of technological advancement in the economy. The dataset includes 2,858 observations and the unit of observation is country-year. Additional information is listed in the summary statistics in Table 1.

The main variable of interest is personal remittances received. Remittances are predicted to have a negative effect on GHG emissions, since higher (lower) levels of remittances will increase (decrease) the amount spent on healthcare and education which ultimately influences consumption spending. In addition, this spending on improving healthcare and education ultimately affects fertility rates, and thus remittances account for some proportion of the long-term reduction in population growth. Although total population is included, the interaction between remittances and population is beyond the scope of this paper. Nonetheless, population is expected to have a positive coefficient, and though the proportional effect is not directly measured, lower population growth would lead to lower GHG emissions. Therefore, in the long-term remittances are expected to reduce GHG emissions.

As Ma and Hofmann, (2019), Price and Feldmeyer (2011), and Squalli (2010) show, areas with a higher percentage of migrants have either similar, or lower, levels of GHG emissions. Then the worst possible case, regarding GHG emissions, is that migrants fully assimilate into their host country with comparable per capita emissions. In this worst-case scenario the average per capita increase in GHG emissions for each migrant moving from low and middle-income to high-income countries is 7.8 (World Bank, 2020a). In section 4.3, I perform a back-of-the-envelope calculation of the effect of migration, through remittance flows, on GHG emissions to determine if potential environmental benefits on the country of origin offset this worst-case increase in GHG emissions.

3.2 Model Specification

The following empirical model is specified, which is estimated using country and time fixed effects with cluster-robust standard errors:

$$lnGHG_{it} = \alpha_i + \emptyset_t + \beta_1 lnREM_{it} + \beta_2 lnGNI_{it} + \beta_3 lnENG_{it} + \beta_4 lnPOP_{it} + \beta_5 ALT_{it} + \varepsilon_{it}. \quad (1)$$

In the above model, $lnGHG_{it}$ denotes the natural log of total greenhouse gas emissions in kt of CO_2 equivalent for country i in year t. α_i and $\varnothing_t$ are the country and year fixed effects, respectively. $lnREM_{it}$ is the natural log of total remittances in current US dollars, $lnGNI_{it}$ is the natural log of gross national income in constant 2010 US dollars, $lnENG_{it}$ is the natural log of energy use kilogram of oil equivalent, $lnPOP_{it}$ is the natural log of total population, ALT_{it} is the level of alternative energy (as percentage of total energy use), and is an idiosyncratic error term.

4. Empirical Analysis

4.1 Results

Regression output from the estimation of model (1) is presented in Table 3.[6] Five separate specifications of the model are estimated with the natural log of GHG as the dependent variable. Specification I includes the natural log of total remittances as the independent variable, specification II adds the natural log of GNI, specification III adds the natural log of total energy use in the economy, specification IV adds the natural log of total population, and specification V adds the percentage of alternative energy use. Specification V is the preferred model since the key indicators impacting pollution, as posited by the IPAT equation, are accounted for and the R-squared statistic suggests using this specification. The estimated coefficients for remittances and income, β_1 and β_2, are negative and positive, respectively, and statistically significant. These results indicate that higher (lower) income increases (decreases) GHG emissions, while higher (lower) remittance flows decrease (increase) GHG emissions, as expected. The remaining coefficients are each statistically significant and have the expected effect, β_3 and β_4 are positive, while β_5 is negative.

In the preferred specification, the estimated coefficient, β_1, indicates a one per cent increase in annual remittances in an average country in the sample results in a decrease in GHG emissions of approximately .042 per cent. While this change initially appears small, note that remittance flows account for about four per cent of global Gross Domestic Product (GDP) and migrants are only around two per cent of the world population (World Bank, 2020a). Further, a small percentage

6 The augmented Dickey-Fuller unit root test is employed to check for stationarity and results suggest all included variables are I(0). The Hausmann test, F test and Breusch-Godfrey/Wooldridge tests indicate using fixed effects and clustered standard errors.

change can have important real-world implications when considering GHG emissions, as will be demonstrated in section 4.3.

4.2 Robustness Checks

The income classification groups, low and middle-income and high-income, are estimated separately using model (1) and reported in Table 4.[7] More specifically, specification VI estimates model (1) including only low and middle-income countries, while specification VII includes only low and middle-income countries and removes total energy use and percentage of alternative energy use. Specification VIII estimates model (1) including only high-income countries, and specification IX estimates model includes the additional independent variable of FDI as a percentage of GDP. The main interest is on β_1, which is found to remain statistically significant, and negative, in all robustness checks. Further, the magnitude of β_1 remains similar across each specification, though it drops more noticeably in specification VIII, which is expected for high-income countries.[8] In specification VI, β_3 and β_5, are not statistically significant, while β_2, and β_4 remain statistically significant. Further, when removing the energy related variables from model (1), which is specification VII, β_4 is noticeably higher. For the high-income countries the estimated coefficients remain statistically significant except β_2. In addition, β_3 becomes markedly higher. There are no substantial changes to the estimated coefficients for remittances or GNI. These results suggest that population, along with GNI and remittance flows, have significant impact on GHG emissions in low and middle-income countries, while total energy use and percentage of alternative energy are more influential in high-income countries.

The amount of foreign investment flowing into a country has many possible economic implications, such as altering the types of manufacturing and pollution intensity of production processes. The inclusion of FDI in specification IX

7 Due to lack of observations for the low-income group, low and middle-income grouped are combined for this estimation.

8 Although classified as high-income, some countries may still be considered developing economies (World Bank, 2020a). That β_1 drops to -.025 and remains statistically significant for the high-income group is expected given the included countries.

acknowledges the pollution haven, and halo, hypotheses[9] which may impact GHG emissions. This robustness check confirms the results of model (1) and the output is reported in Table 4. There are no substantial differences to report on the previously included variables. For FDI, the estimated coefficient, $\beta_{6'}$ is approximately zero and not statistically significant. I note the validity of the pollution haven, or halo, hypotheses is beyond the scope of this paper and these results should not be interpreted as evidence for either case.

4.3 The Impact of Migration on GHG Emissions

The average number of migrants for the 127 countries included in the sample is approximately 1.1 million, with average annual remittance flows of about 1.7 billion. Thus, the annual amount of remittances per migrant is around 1,500 US dollars, accounting for 0.00009 per cent of average annual remittance flows.

Using the preferred estimate of β_1, -0.042, I conduct a back-of-the-envelope calculation to capture the potential effect of migration on GHG emissions through the corresponding expected change in remittance flows. The percentage change in remittance flows from restricting one migrant is multiplied with β_1 to obtain the estimated effect on GHG emissions. The result implies that an increase of 0.0000038 per cent in average GHG emissions for the sample countries, or about 360 thousand kilotons, yields an increase in GHG emissions of approximately .0137 kilotons, or 13.7 metric tons. Recall that the worst-case increase from migration is 7.8 metric tons per migrant, which is clearly lower than the estimated increase from restricting one migrant due to the loss of remittance flows.

5. Conclusion and Policy Implications

The results suggest that remittances are not merely treated as additional income, but rather allocated in such a way that GHG emissions are reduced if remittances are increased. This conclusion supports the claim that increased remittance flows likely increase expenditure on healthcare and education, rather than increasing consumer spending on consumption goods. Further, there is no indication that

9 The pollution haven hypothesis posits that firms may shift production of certain goods to less developed regions to take advantage of fewer environmental regulations and lower production costs (Garsous and Koźluk, 2017). Conversely, the pollution halo hypothesis suggests that more efficient technology, introduced as a result of foreign investment, ultimately improves environmental quality (Balsalobre-Lorente, D., Gokmenoglu, K.K., Taspinar, 2019).

increased remittance flows necessarily lead to higher industrial production due to increased aggregate savings. Also, note that increased industrial production does not strictly imply an increase in air emissions, as the level of technology used in the economy plays a large role in this outcome. As discussed earlier, the pollution haven, or halo, hypotheses are beyond the scope of this paper, but investigating the role of remittance flows in the context of industrial production and technological knowledge transfer between migrant's home and host countries is a potential extension of this work.

The estimation of migration's impact on GHG emissions through remittance flows in section 4.3 does not consider migration from low-income into middle-income countries. However, most international migration occurs from low and middle-income countries to high-income countries (United Nations, 2015). If immigration into high-income countries is restricted, then migration from low to middle-income countries is likely to increase. As per capita emissions are least in low-income countries, then an increase in GHG emissions from this migration is still expected. Additionally, remittance flows are averaged over the sample period and the data suggest that remittance flows have increased substantially in recent years. For example, annual remittance flows from high-income countries have recently been over 1,800 dollars per migrant, whereas annual amounts were barely above 100 dollars per migrant in 1970 (adjusted to constant 2010 US dollars). Still, continued growth in annual remittance flows should not affect the results since, if the amount of annual remittances increases, restricting immigration and thus reducing remittances, would then have a larger effect on GHG emissions. The International Monetary Fund (IMF) estimates the value of unofficial remittances to be at least 150 per cent of the official remittance flows (Ratha, 2020). Considering this underestimate of remittance flows, the impact on GHG emissions in the analysis is likely an underestimate.

In recent years, there has been increasing political debate on limiting immigration in many high-income countries (e.g., the US and Germany which host the first and second highest migrant populations, respectively). Further, the use of alternative energy since 2015 has noticeably increased. Unfortunately, due to the lack of availability the data from these trends are not included in the analysis. However, these recent trends suggest that more research is needed as the environmental degradation – migration nexus continues to increase in relevance to public policy.

The ambiguity in previous research on migration and pollution has many policy implications. For example, if policymakers assume that immigration in high-income countries raises global pollution levels, then anti-immigration policies could be argued for to help achieve environmental and sustainability targets. The analysis shows the positive benefit of remittance flows on the environment, through lowering GHG emissions, outweighs any potential increase in GHG emissions caused by migration into high-income countries. These findings suggest that limiting immigration on the grounds of reducing pollution is misguided.

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Appendix

Table 1. Summary Statistics

Variable	Mean	Std. Dev	Min	Max
Greenhouse gas emissions (1,000s of kilotons)	360	1000	1.6	1200
Remittances (billions current US dollars)	1.71	3.9	.000006	68.8
Gross National Income (billions 2010 US dollars)	490	1430	1.44	1570
Energy Use (billions of kilotons)	91.3	281	.598	2910
Alternative energy (% total energy)	7.25	9.82	0	55.58
Population (1,000,000s)	51.2	152	.318	1350

Table 2. Countries in Sample

Low Income	Lower Middle Income	Higher Middle Income	High Income
Mozambique	Vietnam	Turkmenistan	Hungary
Congo, Dem. Rep.	Senegal	Botswana	Estonia
Ethiopia	Sudan	Namibia	Cyprus
Niger	Cote d'Ivoire	Colombia	Trinidad and Tobago
Bangladesh	Ghana	Mauritius	Portugal
Cambodia	Cameroon	Jamaica	Oman
Nepal	Yemen, Rep.	Bosnia and Herzegovina	Czech Republic
Togo	Nicaragua	Iraq	Malta
Tanzania	Zambia	Iran, Islamic Rep.	Saudi Arabia
Eritrea	Sri Lanka	Panama	Israel
India	Uzbekistan	Bulgaria	Greece

Low Income	Lower Middle Income	Higher Middle Income	High Income
Kyrgyz Republic	Bolivia	Costa Rica	Slovenia
Haiti	Nigeria	Malaysia	Spain
Tajikistan	Honduras	Lebanon	New Zealand
Kenya	Egypt, Arab Rep.	Kazakhstan	Hong Kong SAR, China
Pakistan	Philippines	South Africa	Italy
Zimbabwe	Morocco	Romania	Germany
Benin	Moldova	Chile	Finland
Myanmar	Armenia	Argentina	France
	Ukraine	Russian Federation	Austria
	Mongolia	Turkey	United Kingdom
	Azerbaijan	Mexico	Belgium
	Guatemala	Brazil	Iceland
	China	Latvia	Australia
	Tunisia	Poland	Netherlands
	Congo, Rep.	Uruguay	Sweden
	Thailand	Korea, Rep.	Japan
	El Salvador	Gabon	United States
	Jordan	Lithuania	Ireland
	Dominican Republic	Croatia	Canada
	Indonesia	Slovak Republic	Kuwait
	Angola	Venezuela	Denmark
	Peru		Qatar
	Georgia		Norway
	Paraguay		Switzerland
	Belarus		Luxembourg
	Algeria		

Low Income	Lower Middle Income	Higher Middle Income	High Income
	Ecuador		
	North Macedonia		
	Albania		

Notes: Total of 127 countries, grouped by 2012 World Bank income classifications, GNI per capita: Low: less than $1,025; Lower Middle: $1,026 to $4,035. Upper Middle: $4,036 to $12,475; High: above $12,475.

Table 3. Regression Output

	Specification				
Variable	(I)	(II)	(III)	(IV)	(V)
Remittances	0.098***	-0.023+	-0.034*	-0.044**	-0.042**
	(0.013)	(0.013)	(0.014)	(0.015)	(0.015)
GNI		0.705***	0.360**	0.326**	0.352**
		(0.057)	(0.126)	(0.115)	(0.114)
Energy Use			0.462 ***	(0.103)	0.278*
			(0.130)	0.261*	(0.131)
Population				0.512*	0.493*
				(0.231)	(0.233)
Alternative Energy					-0.008**
					(0.003)
Constant	8.553***	-5.875***	-7.879***	-10.910***	-10.849***
	(0.234)	(1.489)	(2.487)	(1.277)	(2.511)
Country Fixed Effects	yes	yes	yes	yes	yes
Year Fixed Effects	yes	yes	yes	yes	yes
R^2	0.26	0.75	0.82	0.87	0.87
N countries	177	165	136	136	127
N observations	4,663	3,219	2,890	2,890	2,858

Notes: Dependent variable is the natural log of GHG emissions. Unit of observation is country-year. Robust standard errors, clustered by country, are shown in parentheses. + p<0.1; * p<0.05; ** p<0.01; *** p<.001.

Table 4. Robustness Checks

	Specification			
Variable	(VI)	(VII)	(VIII)	(IX)
Remittances	-0.040*	-0.030*	-0.025*	-0.042**
	(0.019)	(0.014)	(0.014)	(0.015)
GNI	0.469***	0.449***	-0.061	0.354**
	(0.141)	(0.087)	(0.104)	(0.114)
Energy Use	0.114		0.743 ***	0.259+
	(0.158)		(0.101)	(0.131)
Population	0.528+	0.700***	0.435+	0.494*
	(0.066)	(0.195)	(0.222)	(0.036)
Alternative Energy	0.006		-0.008**	-0.008***
	(0.012)		(0.003)	(0.003)
FDI				0.000
				(0.000)
Constant	-10.904***	-10.812***	-11.186***	-10.845***
	(3.026)	(0.000)	(2.970)	(0.000)
Country Fixed Effects	yes	yes	yes	yes
Year Fixed Effects	yes	yes	yes	yes
R^2	0.79	0.83	0.97	0.87
N countries	80	116	47	127
N observations	1,763	2,121	1,095	2,847

Notes: Dependent variable is the natural log of GHG emissions. Unit of observation is country-year. Robust standard errors, clustered by country, are shown in parentheses. + p<0.1; * p<0.05; ** p<0.01; *** p<.001.

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COMMENTARY

Bending the Curve by 2030: On the Path to a Population Safe Harbour

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Abstract

Half the global population has birth rates below replacement and several advanced nations already have birth rates half that. There is no question that restoring a sustainable population via low birth rates is feasible. There is even a scientific consensus around the non-coercive, empowering strategies focused on women and girls that could expedite the inevitable process of bending the global population curve. The question is simply the level of investment required to make it happen. As such, this article explores the 'art of the possible', walking us through how we could approach a safe harbour population of three billion soon after 2100 – a new lower population plateau that would enable humanity to pay down the massive ecological debt it has accrued over recent centuries.

Keywords: population; population restoration; 1.5 TFR by 2030; empowering women and girls; climate restoration

We have been lulled into thinking that our ever-growing population has no role in driving the destruction of our planet. We have also been lulled into believing that the only way modern, prosperous societies can function is through perpetual economic growth that is fundamentally dependent on perpetual population growth. Of those who understand that neither of these propositions are true, still

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too many seem convinced that nothing can be done about it, short of unethical and coercive measures. This article rejects these notions.

Here we seek to draw attention to the art of the possible in bending the global population curve, in order to avert climate catastrophe, ecological annihilation and the untold human misery, instability, conflict and insecurity born of runaway population growth. This paper will strike many as strange and unrealistic, based on their reading of the many different efforts to 'predict' population growth, typically centred on validating or challenging the United Nations population projections. This paper is explicitly not an effort to predict, but rather an effort to determine what demographic dynamics might be desirable for the wellbeing of future generations and feasible with regard to achieving a long-term sustainable human population.

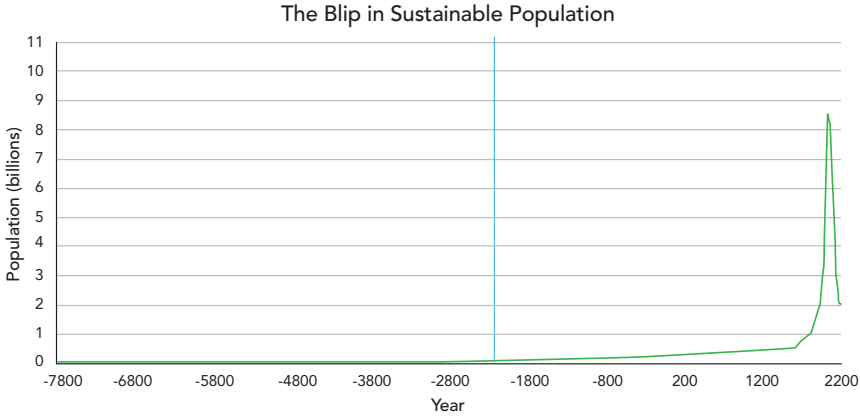
In a world where half the global population has birth rates below replacement and several advanced nations already have birth rates half that, there is no question that restoring a sustainable population via low birth rates is feasible. The question becomes, what is a sustainable population for humanity, and how we might achieve this goal without coercion. For those that say bending the population curve is unfeasible without coercion, we respectfully disagree, and undertake this analysis with a sober commitment to the wellbeing of our planet, our species and the families and children that will comprise the future of humanity. For those that say it is too late, and that even bending the population curve will not be enough to avert climate and ecological catastrophe, we again respectfully disagree that every action possible should not be taken to increase probability of our collective survival over the coming decades.

Demography runs 'open loop', meaning that the modeler sets parameters such as education levels, the average starting date of childbearing, access to family planning technologies, assumptions on longevity and the like, and sees what happens. In this exercise in 'restoration modelling' we ask, what Total Fertility Rate (TFR) would need to be encouraged and normalised in order to restore something akin to the historically sustainable population plateau that preceded the runaway population growth of the past two centuries, through ethical, non-coercive and empowering strategies.

For those who believe that we have not yet overshot the carrying capacity of our planet, this will appear a silly exercise. And, for those who believe that there is no such thing as just, ethical and empowering strategies for nudging reproductive behaviours and norms toward a more sustainable future, and that any initiative is necessarily coercive in nature, this will seem to be a morally repugnant exercise. To be clear, we reject both of these notions. Humans long ago exceeded our planet's carrying capacity. There are non-coercive, indeed empowering, strategies available for bending the curve. There is no reason to resort to coercive measures to achieve this goal, as has been attempted in the past. It is important to note that these coercive measures never actually worked at bending the population curve.

We recommend conservative goals regarding the survival of humanity, as we may only have one chance to fail. The most conservative baseline is to return to the stable global population at the start of the industrial revolution (1740, roughly 800 million), which was a population our planet sustained for centuries. A less conservative, more aspirational baseline would be roughly three billion (Tucker, 2019a).

Figure 1. The Blip in Sustainable Population from 8800 BCE to the end of the twenty-first Century



We consider this lower population plateau a 'safe harbour' which we should all strive for. Per person consumption is far higher now than in the distant past, but there are good reasons to believe that a newer, more sustainable technology mix

is possible that would allow a more efficient use of many natural resources with a safe harbour that is, say double the sustainable population plateau that existed before the historic population 'blip' that we are currently experiencing. Of course, it would take decades to come close to any such safe harbour, leaving us plenty of time to calibrate our long-term target.

In the case of restoration modelling, there is a recognised feedback loop. This feedback loop is based on our appreciation of the scientific consensus that shows that more resources applied to initiatives around girl's education, integration into the workforce, access to family planning and the promotion of modern reproductive norms can indeed have a powerful impact on TFR. (Ripple et al., 2019).

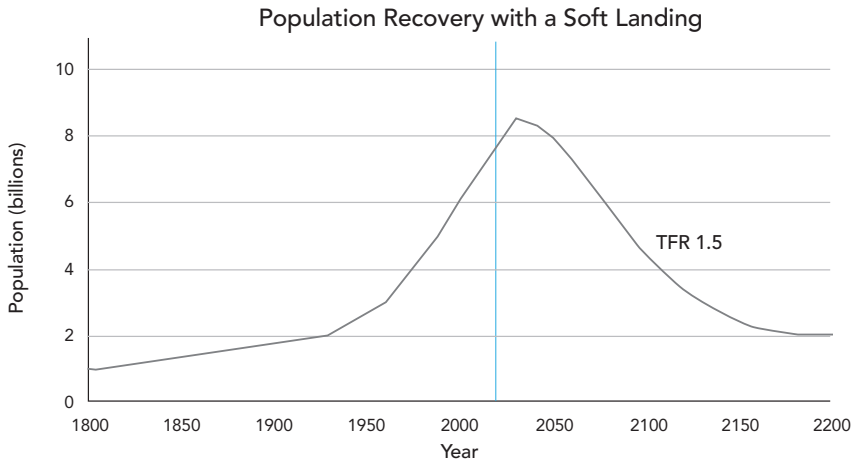
While some may say that it is impossible to ethically achieve a global 1.5TFR over the next decade, from the 2.3TFR (2021) of today, we will assert that the current reproductive norms are much more malleable than most appreciate (PRB, 2020). We argue that ethical, just and empowering investments focused on women and girls – in their education, their integration into the workforce and their access to family planning technologies and programmes, as well as reproductive norms shifting media investments could rapidly change the fertility patterns in most, if not all, nations. This, plainly, includes investments in boys and men which would coax more just, equitable and empowering behaviours toward women and girls. There is a large community of thoughtful practitioners, who have spent decades building data-driven foundations for their programmes' effectiveness, who would simply argue, 'Give us the budget to do it, and we will achieve the goal – ethically'.

Modelling the Art of the Possible

This exercise is illustrated in the simple plot below. Total population change is births minus deaths. As in the recent past, mortality levels continue to improve gradually over the coming decades. The total fertility rate (TFR) is assumed to be 1.5 births per woman, i.e., approximately a half child less than the fertility replacement level of about 2.1.

Even in this exercise's assumed peak TFR of 1.5 by 2030, so-called 'demographic momentum' would delay any decrease in total population by two decades after the 1.5 TFR change is achieved.

Figure 2. Population Recovery with a Soft Landing – prospects for population decline through achieving a TFR of 1.5 by 2030.



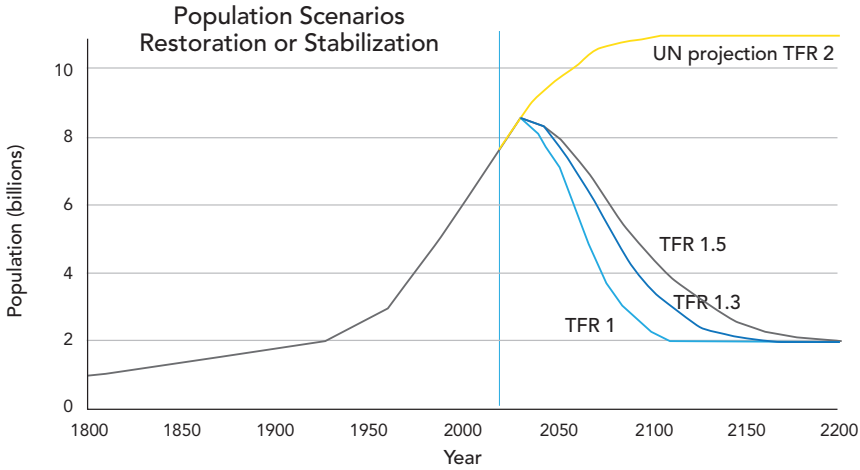
It is important to note that this model assumes that the age of first birth will remain at today's global average of 25. Measures to end child marriage and children having children would see this average age drift upward slightly. This is certainly a global cultural norm we should all strive to achieve through proactive investment. However, we do not need to rely on that change to occur for us to reach a total population of about three billion in about one hundred years, or around 2125.

Some will point out that all the people who will have children by 2050 are already born, and there is no real opportunity to bend the curve. In order to accept that observation, we would need to accept that all of their reproductive behaviour will and must mirror that of previous generations. That notion is rejected. Indeed, that notion is rejected and replaced with a call for investments that will expedite the bending of the fertility curve downward to a TFR of 1.5 over the next decade.

Many, including the United Nations leadership, seem to think that achieving replacement value fertility is the most ambitious goal we might reasonably consider – mostly because they believe that a TFR of 2 will just kind of happen without the UN doing anything beyond the current Sustainable Development Goals. This graphic shows the stark contrast between a TFR of 2 and a TFR of 1.5 or lower. Quite simply, settling for a TFR of 2 is unacceptable and will crush

our planet and put our species in peril. At the eleven billion global population that would result, the probability of massive discontinuous change that would involve unimaginable human suffering is extremely high. However, even if these catastrophes crushed the lives of billions of people, we would likely still have far more people than the earth can support over the long term without incurring even more ecological debt than we have already accumulated.

Figure 3. Population Scenarios – Restoration or Stabilisation. Alternative pathways for population growth or degrowth to sustainable levels (average age at first birth = 25, average age at death = 80).



What this Means for Humanity's Carbon Footprint

If we are able to achieve the Paris goals for carbon emissions - a goal of eighty per cent emission reduction by 2050 – within their assumed framework of continuous population growth, then it stands to reason that a move toward a 1.5TFR by 2030 would further reduce these emissions.

For those that think that the trend lines for our use of fossil fuels are inexorable, you should become familiar with the reality that the costs of wind and solar electricity are already as low as $.01 / kWh, a quarter the cost of natural gas or coal, which means that the transition away from fossil fuel will be rapid – even with politically retrograde forces seeking to further enrich entrenched fossil fuel interests. The

emergence of a greater variety of cheaper and more effective long-term storage solutions means that almost all parts of the world will be using renewable energy and electric vehicles by 2040.

While it may seem as though a mix of ethical, just and empowering population strategies will simply amplify existing energy market trends, leading to a wonderful outcome, the situation is actually somewhat more complex.

First, while this strategy may reduce humanity's active carbon emissions to a manageable level over the long term, it does nothing to eliminate the more than a trillion tons of carbon already trapped in our atmosphere and oceans. This will leave the CO2 PPM level well over 400, which will continue to drive median temperature well above two degrees Celsius – leading to ecological annihilation of unimaginable scale, and climate catastrophe in many forms. This will require investment in so-called 'climate restoration' strategies. The good news is that there are permanent, scalable and financeable climate restoration strategies based on biomimicry – accelerating those natural processes that have already demonstrated their ability to extract carbon from our atmosphere and oceans (Fiekowsky and Douglis, 2022).

Second, it is important to make an obvious point that is often overlooked in climate discussions. While humanity's carbon footprint deserves our focused attention, carbon represents only one small portion of our larger footprint (Tucker, 2019b).

Runaway population growth, and its cumulative ecological footprint, has been actively deleting nature, hectare by hectare, for centuries – steadily depleting the natural production of ecological goods and services that we rely on, while demanding more and more of them each year. Most people are unaware that the world's population has more than quadrupled over the past century, adding approximately eighty million additional humans to our finite planet in each recent year – the equivalent of ten New York Cities, or one additional Germany each year – with no clear end in sight.

Furthermore, humanity has managed to burden what natural resources remain with debilitating forms of pollution – from ocean plastics to endocrine disrupters,

and so many other forms of ecological burden. Together, the accumulated ecological debt (far beyond just the accumulated carbon) demands that we bring humanity's numbers back in balance with our planet's long-term ecological carrying capacity. This is about our larger human footprint, not just our carbon footprint (Penna, 2009).

Of course, it is important to note that the Global North's (GN) carbon footprint is much higher, per capita, than that of the Global South (GS) – and that the GN is responsible for some ninety per cent of the historic carbon emissions that are driving our current climate crisis. Still, it is foolhardy to ignore the ongoing explosive population growth in many nations of the GS, given the billions of humans that will be entering the global middle class over the coming decade, and adopting consumption patterns resembling those of the developed world. While the developed world has committed to reducing its carbon footprint, this energy transition has a long way to go. Given the 10:1 GN:GS emissions ratio, the substantially lower TFR in the GN does not absolve the GN. Indeed, it suggests that the GN should abandon the remaining relics of coercive pronatalism in their policy structures and cultural institutions and seek even lower TFRs if they are to help global humanity achieve a productive balance with the natural world, as the GS continues on its delayed journey of demographic transition.

Getting to 1.5 TFR by 2030

There is still hard work to do to calibrate the levels of investment in the various kinds of policy interventions outlined above, if we are to achieve 1.5 TFR by 2030.

There is the well-documented and well-understood decrease in fertility that would occur in a number of high TFR nations if only investments were made to address their 'unmet need' for family planning technologies. This not only refers to servicing the existing desire for access to family planning technologies and programmes that, in this day and age, are inexcusably unavailable to many women and girls (and even men and boys) all over the world. It also refers to those sexually active women who report not wanting to have more children, or wanting to delay the next child, but who, for some reason have no intention to use contraception. There is something called the 'S Curve' of contraceptive use. Where use is low, often demand is also low – so doing more to change social norms is important (The Track 20 Project, 2019).

This is separate from policy measures that would end child marriage and the trend of 'children having children'. Not only would this shift the average age at which females begin childbearing, but it would increase the status of countless women in their societies, since they would be able to finish secondary school, creating more financial autonomy and therefore bodily autonomy for the rest of their lives. On the other side of the same coin, of course, investing in the education of girls helps set norms that combat child marriage and children having children. Investing in the education of women, over the age of eighteen, means more prosperity, wellbeing, security and stability.

Integrating women into the workforce, and providing financing mechanisms for female entrepreneurs, also reinforces such fertility dynamics. Quite frankly, this would also increase economic prosperity and wellbeing.

Investments in reproductive norm-shifting media interventions have been proven, time and time again over the past half century, to have amazing transformational effects on fertility by encouraging small family norms which then reinforce all the dynamics outlined above. Of course, without ensuring that women and girls (as well as men and boys) have comprehensive access to family planning technologies and reproductive health programmes, such media interventions will needlessly be less effective than they otherwise could be (HIP, 2017).

When paired with the fertility and childbearing themes dominating today's global youth culture as the next generation grapples with the existential issues of climate change, we have a real chance of reducing fertility rates, year over year, at a pace not seen since the 1960s – expediting the demographic transition that our global society must achieve if it is to live in balance with the planet. Having one less child is indeed the most impactful choice an individual can make to reduce their carbon footprint, and their larger ecological footprint – and this is now being openly discussed by the younger generation (Shao, 2021).

It seems that achieving the goal of 1.5TFR by 2030 is indeed possible, if only the global community invests more robustly in ethical, just and empowering 'nudges' toward a more sustainable population plateau.

Conclusion

The 'World Scientists' Warning of a Climate Emergency' article of November 2019, which had 14,000+ cosignatories from the global scientific community, made it clear that:

> Still increasing by roughly 80 million people per year, or more than 200,000 per day, the world population must be stabilized – and, ideally, gradually reduced – within a framework that ensures social integrity. There are proven and effective policies that strengthen human rights while lowering fertility rates and lessening the impacts of population growth on GHG emissions and biodiversity loss. These policies make family-planning services available to all people, remove barriers to their access and achieve full gender equity, including primary and secondary education as a global norm for all, especially girls and young women. (Ripple et al., 2019, 11)

It is critical that we begin investing in stabilisation and reduction of humanity's numbers if we are to avert climate catastrophe. This includes the reduction of fertility in many wealthier nations that are already below replacement value fertility. After all, the carbon footprint of children in wealthier nations can be eight to thirty times the size of that of children in developing nations. A sustainable population that lives within the carrying capacity of our planet must be achieved if any of our other climate and ecological interventions are to have the desired effect. The only foreseeable way to achieve this goal is to empower women and girls in a way that encourages small, educated and prosperous families through the end of the century. This will require achieving a global birth rate in the 1.5 range, sooner than later – recognising that some countries will lag in this demographic transition. The suggestion that we must all passively await some immutable population peak of more than nine billion, ten billion or even eleven billion (as the UN projects) sometime after 2050 is insulting, disempowering and misguided.

In the end, women and girls should enjoy gender equity, everywhere on Earth – as a good in and of itself. In the end, small families – on average – live better. In the end, small families are better for the climate and for the natural world in general. It is entirely possible for humanity to step up to this challenge. But first, we must all collectively embrace the art of the possible.

Acknowledgements

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PEER REVIEWED ARTICLE

Increasing Pesticide Use and Knowledge of the Health Effects of Endocrine Disrupting Chemicals in the Environment: A Study of Three Communities in Ghana

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Abstract

Population growth and urbanisation are contributing to the growth of the use of pesticides in Africa. However, poor understanding of the health and environmental effects of these chemicals represents a significant risk to both human health and ecosystems. Knowledge of health effects of pesticide use and endocrine disrupting chemicals (EDCs) was assessed using 300 respondents in three communities of Ghana. The data were fitted to bivariate and multivariate ordinary least squares regression models. About 76 per cent of the respondents used pesticides while

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82 per cent had no knowledge of human diseases associated with pesticide use and EDCs. At the bivariate level, individuals who used pesticides had less knowledge of health effects of EDCs and pesticide use compared to their counterparts who did not use pesticides. Urban residents had more knowledge compared to rural dwellers and this robust relationship persisted at the multivariate level. Females of all ages had more knowledge of pesticides and EDCs' effects than their male conterparts. Formal and informal education is required to improve knowledge on appropriate chemical use.

Keywords: knowledge; endocrine disruptors; pesticides; environment; urbanisation; population growth.

Introduction

Hormone mimicking substances referred to as endocrine disrupting chemicals (EDCs) comprise a wide variety of environmental contaminants including pesticides, pharmaceuticals, metals, industrial chemicals and natural compounds (Foster, 2001; Choi et al., 2004). EDCs interfere with metabolic functions that are responsible for homeostasis, reproduction and developmental processes (Thomas Zoeller et al., 2012; Diamanti-Kandarakis et al., 2009).

Studies indicate an adverse effect of this group of substances when found in food, consumer products and the environment (Frye et al., 2012; Kumar et al., 2020; Yilmaz et al., 2020). As early as the 1930s, the ability of both natural and synthetic chemicals to interact with endogenous hormone receptors was already well established (Marty et al., 2011). However, most individuals are unaware of the health risks. EDCs have such subtle effects that they may be extremely difficult to detect instantly and yet have significant impacts on human health over an extended time period where they remain 'out of sight out of mind'.

Despite significant advances in understanding of EDCs, gaps still exist in the knowledge required to protect humans that cannot be overlooked. For example, exposure of an adult to EDCs may have very different consequences compared to exposure of a developing foetus or infant. Similarly, there is a lag between the time of exposure and the manifestation of a disorder (Arendrup et al., 2018; Heindel and Vandenberg, 2015). Effects of EDCs may also be additive or even

synergistic (Diamanti-Kandarakis et al., 2009; Bergman et al., 2012). Indeed, any level may cause endocrine or reproductive abnormalities if exposure is during a critical developmental period (Sisk et al., 2016; Diamanti-Kandarakis et al., 2009). Humanity as a whole, and Africa in particular, is faced with activities that make it susceptible to the effects of EDCs (Bornman et al., 2017). Lack of sound management of chemicals as well as poor hazardous waste disposal systems pose risks to human health (Taherzadeh et al., 2019).

Demographic changes have considerable influence on consumption patterns through population growth, urbanisation and lifestyle changes. These factors principally influence the demand for chemicals and products that contain EDCs, further increasing the likelihood of human exposure (WHO, 2018). Additionally, developing countries seem to attract the development of economic sectors that are among the most polluting (UNEP, 2012). Africa is faced with rural to urban migration by its youths in search of jobs due to rapid population growth (Moses et al., 2017; Mutandwa et al., 2011) with accompanying shifts in lifestyle and consumption patterns (Cockx et al., 2018). The shift to urban living in Africa and other developing countries continues to increase the amount of contaminants and EDCs released into water, air and soil (Miller et al., 2016). Moreover, high rates of population growth also result in inadequate investment in human capital: education, health, employment, infrastructure and poor waste disposal systems (Ganivet, 2020) which exacerbate the problems associated with the increased use of EDCs.

Africa has the fastest-growing rate of population, which is directly related to the growth in size and intensity of agricultural production (United Nations, 2019). The use of pesticides has increased in an attempt to increase food production in response to increased demand from population growth whilst reducing poverty. This trend is exacerbated by urbanisation, which leads to a continuous decline in the available area of agricultural land through housing, fully-fledged industry, cottage industry and the provision of other social amenities.

In Ghana, pesticides applied in agriculture for pest control constitute a widely used category of EDCs (Denkyirah et al., 2016; Dinham, 2003; Mattah et al., 2015). Dinham (2003) estimated that 87 per cent of Ghana's vegetable farmers use chemical pesticides for pest and disease control. There are also indications of adverse effects on productivity, environment and human health due to overuse and

misuse of pesticide in Ghana (Denkyirah et al., 2016; Gerken et al., 2001; Mattah et al., 2015). Farmers and consumers are also faced with health problems from the effect of these chemicals (Owusu-Boateng and Amuzu, 2013; Ntow et al., 2006). This puts every Ghanaian at risk and thus there is a need to properly regulate use.

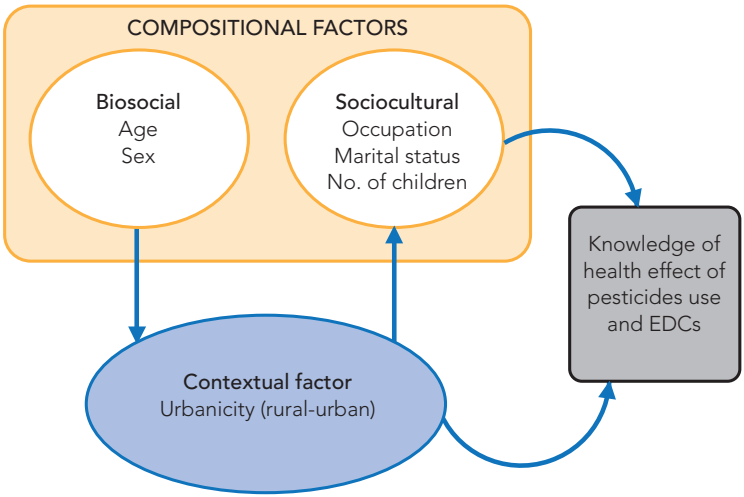
The Government of Ghana has enacted standards aimed at regulating imports of pesticides and ensuring their proper use; however the use of pesticides by individuals remains difficult to control (Onwona Kwakye et al., 2019). Illiteracy and apathy of farmers about the health risks and environmental implications results in greater reliance on chemically-synthesised pesticides and increased use of cheap, mislabelled and adulterated pesticides in Ghana (Onwona et al., 2019; Imoro et al., 2019). Furthermore, rural poor who are employed to work as farm hands, and also smallholder farmers, fail to wear protective equipment and observe good agricultural practices (Wumbei et al., 2019).

Despite the reported adverse health effects of pesticides and EDCs, public awareness is low in Ghana. In 2019, the Government of Ghana launched the Health and Pollution Action Plan (HPAP), seeking to regulate EDCs and other types of pollutants that affect human health in an effort to sensitise the public and regulate the use of EDCs.

Despite advances made, few studies exist on exposure and perception of communities. Community perception is important as it underpins behavioural responses to the adverse health effects of exposure to pesticides. This study looks at general pesticide use and public understanding of health effects of EDCs in three communities in Ghana in the context of the changes in lifestyles of urban and peri-urban dwellers. Though the use of pesticides, personal care products and other chemicals cannot be done away with entirely, it is imperative to ensure their proper use. Pesticide use within three communities of Ghana and knowledge of the health effects of EDCs on humans and the environment is conceptualised as being composed of three main factors – biosocial, sociocultural and contextual factors, as shown in Figure 1. Biosocial factors (age and sex) are intrinsically personal. These personal attributes are ascribed at birth and not easily amenable to change (Pol and Thomas, 2013). The second set of compositional factors, namely sociocultural attributes, reflects the position of individuals within the social structure. These attributes are achieved rather than ascribed. Further, these attributes are inherently 'cultural', in that those affected

take on characteristics assigned by society (Pol and Thomas, 2013). Some cultural and nature-based practices that protected rural people from excessive exposure to EDCs are being phased out through urbanisation. For instance, in the rural setting, food was cooked and served in earthenware bowls; however with rural-urban drift and increased population, food is mostly served in plastic packs that may contain chemicals that are endocrine disrupting.

Figure 1. Conceptualisation of the relationship between Knowledge of health effect of EDCs and compositional and contextual factors.



Material and methods

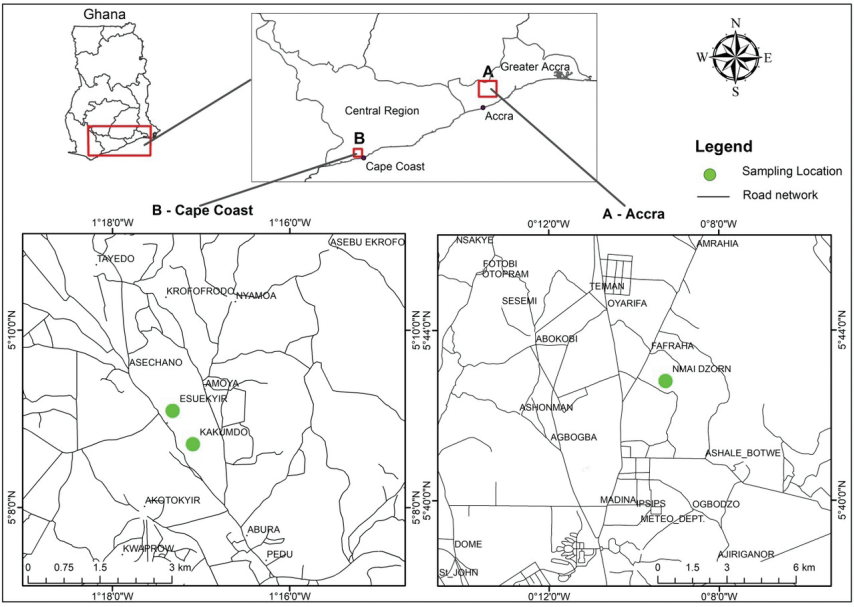
Study area

This study was conducted in three communities in two different regions of Ghana. Two communities, Kakumdo and Essuekyir, are in the Central Region and the third, Nmai Dzorn, in Greater Accra Region. Kakumdo and Essuekyir are adjoining communities within the Cape Coast metropolis with Cape Coast as the regional capital. The Cape Coast Metropolitan area is one of the oldest districts in Ghana and is bounded to the South by the Gulf of Guinea. It occupies an area of approximately 122 square kilometres, with the farthest point at Brabedze located about seventeen kilometres from the regional capital (Ghana Statistical Service, 2010). The population of the

Cape Coast Metropolis, according to the 2010 Population and Housing Census, is 169,894 representing 7.7 per cent of the region's total population. Males constitute 48.7 per cent and females 51.3 per cent (GSS, 2010).

The metropolis has a few rivers and streams including its major waterway, the Kakum. This serves as the main source of water for domestic and industrial purposes. Kakumdo and Essuekyir take their names from the river Kakum that separates the communities. Kakumdo means 'on' the Kakum and Essuekyir means 'behind the river' in the local Fante dialect and indicates their location. They are at outskirts of the regional capital, about eight kilometres from the Cape Coast castle and close to one of the forest reserves of Ghana (Kakum National Park). These communities are mainly residential and can be classified as peri-urban. The inhabitants are mostly traders, artisans and peasant farmers.

Figure 2. Map of Ghana showing regions, districts and study area.



Our third study area, Nmai Dzorn, is an urban community within the Adentan Municipality. The population of Adentan Municipality, according to the 2010 Population and Housing Census, is 78,215. Males constitute 50.3 per cent and

females 49.7 per cent. The Total Fertility Rate (TFR) for the metropolis, at 2.2, is the lowest in the Greater Accra Region. The Adentan Municipal Assembly, with Adentan as the Central Business District, lies ten kilometres to the Northeast of Accra and it is specifically located on latitude 5′ 43″ north and longitude 0′ 09″ west. The Municipality has a land area of about 928.4 sq. km. (GSS 2010). It is mainly a residential area with few commercial activities. These communities were selected to represent the lifestyles of individuals in urban and peri-urban setting.

Data collection

Respondents who volunteered for and participated in the study were drawn from three different communities made up of homogeneous and heterogeneous localities in terms of ethnic and cultural diversity. Residents who were of sound mind, either household heads or their wards, were selected to participate in the study. Respondents who migrated to their current location less than a year before were classified based on their former place of residence. In all 300 participants were selected randomly and interviewed. The sample consisted of 211 females and 89 males between the ages of eighteen and fifty. Modified Cochran formula for sample size calculation at 95 per cent confidence level was used (Bartlett et al., 2001)inadequate, or excessive sample sizes continue to influence the quality and accuracy of research. This manuscript describes the procedures for determining sample size for continuous and categorical variables using Cochran's (1977, as shown in equations (1) and (2).

$$\mathrm{n} = \frac{n_0}{1 + \frac{(n_0 - 1)}{\mathrm{N}}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(1)}$$

Where n_0 is Cochran's sample size recommendation,

N is the population size, N= 1350

n is the new, adjusted sample size.

n_0 is Cochran's sample size recommendation, n_0 =385

Considering the target population of 1350 households, equation (2) was used to determine sample size.

385 / (1 + (384 / 1350)) = 300 …… (2)

The questionnaire was tested before it was administered after approval from the ethical clearance review committee of the Ghana Medical Association, due to the sensitive nature of some of the questions.

Stratified surveys, informal interviews and individual interviews were used to gather information about the prevalence of pesticide use and the level of awareness of EDCs. Stratified sampling was used to select the proportion of male to female interviewees based on the health impact of EDCs on gender. Informal and individual interviews dealt with the interviewee's pesticide use and level of awareness of EDCs. The questionnaire focused on four thematic data areas: (1) personal information; (2) knowledge of the effects of EDCs by listing possible diseases; (3) lifestyle change, i.e. nutrition, social life and work history; and (4) possible reproductive irregularities (though it was not used as an indication of possible EDC effects).

Knowledge on the specific adverse health effects associated with exposure to EDCs and pesticides was measured using a 5-point Likert scale. Responses to the questions were: strongly disagree, disagree, neutral, agree and strongly agree. A Likert scale is composed of a series of four or more Likert-type items that represent similar questions (adverse health outcomes) combined into a single composite score/variable. Likert scale data can be analysed as interval data, i.e. the mean is the best measure of central tendency (Sullivan and Artino, 2013).

Other questions were a combination of closed and open-ended questions in a multiple choice format so that respondents had to select 'yes' or 'no' as an answer. However, some questions demanded explanation for the answer. The questionnaire was administered to the general public by the principal investigator at various locations, including homes, churches/mosques and schools. The objectives of the study were explained to the respondents and their consent to participate in the study was obtained. Respondents were at liberty to withdraw from the study any time they felt they could not respond to sensitive questions. In instances where respondents were not English language literate, the questions were translated into a local language understood by the interviewee without altering their original meaning. In situations where the principal investigator could not speak the preferred local language of the respondent, an interpreter was employed. The identities of respondents were coded and data recorded manually. Respondents' knowledge of human health effects of pesticide use and

EDCs were gathered based on whether they agreed, were unaware or disagreed with indicated human related diseases.

Statistical analysis

Data collected were first cleaned to eliminate double entries, missing values and other irregularities. Inferential and multivariate techniques were applied to examine the relationship between knowledge of the health effects of EDCs and pesticide use while controlling for theoretically relevant sociocultural and biosocial variables using STATA 13SE software. The ordinary least square technique was employed for the analysis. Analyses were preceded by diagnostic tests to establish whether variables met the assumptions of the regression model. Univariate analysis of the predictors on each of the questions that measured knowledge of health effect of EDCs was operationalised using Pearson's Chi-square statistics. Bivariate analysis was initially performed to examine zero-order correlations between the dependent variable and theoretically relevant independent variables. A further three models were employed for the data analysis. Model 1 is Bivariate and biosocial factors, model 2 comprises Bivariate, biosocial and sociocultural factors and model 3 is Bivariate, biosocial, sociocultural and contextual factors. The analysis has a hierarchical structure with respondents nested within survey clusters, which could potentially bias the standard errors. STATA 13 SE (Stata Corp, College Station, TX, USA), which has the capacity to address this problem, is used by imposing on our models a 'cluster' variable – that is, the identification numbers of respondents at the cluster level. This in turn adjusts the standard errors (SE), producing statistically robust parameter estimates. Multivariate models were estimated to explore the net effects of the predictor variables using the stepwise selection approach. For analytical purposes, the unstandardised regression coefficients were estimated. Positive coefficients for any of the predictors indicate higher knowledge of the health effects of EDCs and pesticide use while negative coefficients show lower knowledge of the health effects of EDCs and pesticide use.

Results

Relationship between knowledge of health effects of pesticides and EDCs and demographic attributes

The distribution of responses on knowledge of health issues associated with the use of pesticides and EDCs is shown in the appendices. Pesticide use is

widespread in the communities; 76 per cent of the respondents interviewed used pesticides, though there were differences in the way the pesticides were actually employed. The majority of the respondents (82 per cent) had no knowledge of the health effects of pesticides use and EDCs. The remaining eighteen per cent demonstrated they had some knowledge relating to one or more human diseases, mostly cancers. Different age groups of respondents showed varied levels of knowledge with respect to cancers while married respondents also demonstrated more knowledge of health effects of EDCs with respect to cancers only. The results show that higher percentages of males (48 per cent) know that pesticide use and EDCs could lead to prostate cancer and other forms of cancers than their female (22 per cent) counterparts. Only one per cent of males and four per cent of females know that pesticides and EDCs could lead to behaviour disorders. A few individuals, eleven per cent of the 82 per cent with no knowledge, had doubts about possible adverse health effects and disagreed with the notion that pesticide use and EDCs could cause diseases.

Table 1 shows zero-order relationships between the explanatory variables and knowledge of health effects of endocrine disruptors and pesticide use. Individuals who use pesticides had less knowledge of the health effects of EDCs and pesticides compared to their counterparts who did not use pesticides. There were differences in the knowledge that pesticide use could disrupt the function of the endocrine system based on age groups. The younger respondents had greater knowledge of health risks than the older counterparts. Individuals above 45 years were less knowledgeable about the health effects of EDCs than respondents in the 15–25 age groups. Similarly, females had more knowledge of the health effects than their male counterparts. The evidence demonstrates that urban dwellers have greater knowledge of the health effects than respondents in rural communities. Unmarried individuals were also more aware than married respondents as indicated in Table 1. Robust standard errors used accounted for heteroskedasticity in the model's unexplained variation.

Table 1. Bivariate OLS regression model of the relationship between knowledge of health effects of Endocrine disruptors and pesticide use, and compositional and contextual factors.

Variables	Coef.	Std. Error	p-value	[95% Conf. Interval]	
Pesticide use (ref: No)					
Yes	-0.338	0.135	**0.013**	-0.602	-0.073
Age (ref:15–25 years)					
26–35 years	0.003	0.153	0.982	-0.299	0.306
36–45 years	0.080	0.155	0.606	-0.229	0.385
Above 45 years	-0.350	0.173	**0.043**	-0.690	-0.010
Gender (ref: male)					
Female	0.621	0.121	**0.000**	0.3817	0.860
Marital Status (ref: not married)					
Married	-0.459	0.113	**0.000**	-0.681	-0.238
Children (ref: No Child)					
1–3 children	0.134	0.130	0.302	-0.121	0.390
4–5 children	-0.115	0.175	0.511	-0.460	0.229
Above 5 children	-0.449	0.240	0.058	-0.913	0.016
Occupation (ref: unemployed)					
Self-employed	-0.149	0.133	0.263	-0.410	0.112
Formally employed	0.052	0.190	0.786	-0.323	0.427
Residence (ref: Rural)					
Urban	0.369	0.148	**0.013**	0.078	0.660

The multivariate model (Table 2) shows that gender was a significant predictor of knowledge of the health effects of EDCs, even when socioeconomic and contextual factors were taken into account. However, the relationship between pesticide use and knowledge was not robust and disappeared, indicating that biosocial and contextual factors completely mediated the relationship. Females of all ages had greater knowledge of the effects of pesticide use and EDCs than their male counterparts. Unmarried women demonstrated more knowledge of health effects of pesticides and EDCs than their married counterparts and remained statistically significant; however, it was not robust when contextual factors were taken into account. The age group of 36–45 years was significant in model 2, though not in model 1, signifying a suppressed relationship between biosocial factors and knowledge of health effects of pesticides. Suppression occurred when the relationship between an independent variable and the dependent variable was increased following the statistical removal of variance associated with a third variable.

The place of residence of respondents was significant when all factors were considered, indicating that it fully mediates the relationship between compositional variables and knowledge of the health effects of pesticides. This shows the effect that the independent variable has on the dependent variable via its association with a third variable. Urban residents had higher levels of knowledge of health effects of EDCs and pesticide use compared to rural dwellers and this robust relationship persisted when sociocultural and biosocial variables were introduced.

Discussion

The vast majority of the respondents (82 per cent) were ignorant of the diseases associated with pesticide use and EDCs, which is comparable to a similar study conducted by Hui et al. (2017). This is attributed mainly to poor information dissemination and regulatory policy. Our research shows that people who knew more about pesticide toxicology were less likely to use pesticides. Other studies, such as Dasgupta and Meisner (2005), Gesesew et al., (2016) and Sabran and Abas (2021), also support our observation. We also found that, besides the relationship between pesticide knowledge and use behaviour, there were other individuals who did not use pesticides simply because they could not afford them and/or they preferred natural methods of pest control.

Table 2. Multivariate regression model of the relationship between knowledge of health effects of endocrine disruptors and pesticide use, compositional and contextual factors.

	Model 1 (pesticide use + biosocial factors)					Model 1+ socioeconomic					model 2 + contextual				
Variables	Coef.	Std. Error	p-value	[95% Conf.	Interval]	Coef.	Std. Error	p-value	[95% Conf.	Interval}	Coef.	Std. Error	p-value	[95% Conf	Interval]
Pesticide use (ref: No)															
Yes	-0.197	0.134	0.141	-0.461	0.066	-0.161	0.133	0.225	-0.422	0.100	0.131	0.130	0.316	-0.388	0.126
Age (ref:15–25 years)															
26–35 years	0.111	0.150	0.458	-0.184	0.406	0.161	0.176	0.363	-0.186	0.507	-0.011	0.180	0.952	-0.365	0.344
36–45 years	0.269	0.155	0.083	-0.035	0.573	0.407	0.203	**0.046**	0.008	0.807	0.239	0.205	0.246	-0.165	0.643
Above 45 years	0.299	0.185	0.871	-0.334	0.394	0.278	0.250	0.267	-0.214	0.769	0.089	0.251	0.724	-0.406	0.583
Gender (ref: male)															
Female	0.602	0.139	**0.000**	0.329	0.875	0.487	0.147	**0.001**	0.198	0.776	0.542	0.145	**0.000**	0.256	0.828
Marital Status (ref: not married)															
Married						-0.496	0.151	**0.001**	-0.792	-0.200	-0.473	0.148	**0.002**	-0.764	-0.182
Children (ref: No Child)															
1–3 children						0.328	0.160	**0.042**	0.012	0.643	0.243	0.160	0.129	-0.070	0.556
4–5 children						0.974	0.219	0.656	-0.333	0.528	0.088	0.215	0.683	-0.335	0.511
Above 5 children						-0.075	0.280	0.790	-0.625	0.476	-0.098	0.275	0.722	-0.638	0.443

Table 2. continued

Occupation (ref: unemployed)										
Self employed	-0.019	0.165	0.907	-0.344	0.306	-0.053	0.162	0.743	-0.373	0.266
Formally employed	0.097	0.203	0.635	-0.303	0.496	0.042	0.200	0.834	-0.351	0.435
Residence (ref: Rural)										
Urban						0.559	0.162	**0.001**	0.239	0.879

There is no coordinated plan to evaluate and disseminate information on health and environmental effects of chemicals that are endocrine disrupting in nature. The government, in a bid to address this challenge, launched the Health and Pollution Action Plan (HPAP) that seeks to regulate EDCs and other types of pollutants affecting human health with the aim of sensitising individuals to the effects of EDCs. Dinham (2003), indicated that low level of knowledge and how pesticides are handled hinder the overarching goal of protecting human health and the environment from the adverse effects of EDCs. Knowledge gaps that exist are too important to overlook considering the low dose effect and time lapse between exposure and development of disease later in life. The current 76.3 per cent prevalence of synthetic pesticide use is partly attributed to ignorance of health effects as well as urbanisation and its associated problems. Several studies have reported improper use of pesticides and disposal of waste from EDCs (Amoako et al., 2014; Onwona Kwakye et al., 2019; Oteng-Ababio, 2012; Wumbei et al., 2019. For example, spraying household pests when food and cooking utensils are not properly covered, spraying pests without proper Personal Protective Equipment (PPE) and individuals not properly washing themselves after use of pesticides are some of the behaviours that predispose individuals to the various health effects. There is a lack of sound management of chemicals for industrial, agricultural and household use as well as poor hazardous waste disposal systems. This results in high levels of pesticide residues within the environment, thereby posing a risk to humans and the environment.

The finding that females of all ages are more knowledgeable about the effects of pesticide use and EDCs than their male counterparts was difficult to assign a specific reason. Females are generally provided with information on EDCs and pesticides during pregnancy as part of health education during antenatal care. Antenatal care is one of the three most important forms of welfare provided to women during pregnancy (Choi et al., 2004) to keep mother and unborn child safe. Pregnancy is a sensitive window for toxicant exposure and EDCs are of particular significance to pregnant women, since foetal development is sensitive to maternal nutritional, chemical and environmental stressors. EDCs may disrupt the maternal immune system, which may lead to poor pregnancy outcomes (Kelley et al., 2019). In Ghana, two-thirds of women who utilise antenatal care received information about the danger signs of pregnancy complications (Wang et al., 2011) and hospitals and health centres have served as one of the main sources of information on the adverse health effects of EDCs and pesticide use. Again, healthcare facilities and

the provision of services are improved in the urban centres compared to rural areas. It therefore showed that individual female respondents who lived in the urban centres have more knowledge than their counterparts in the rural areas as a result of the better provision of healthcare (and hence antenatal care) in the urban centres compared to rural areas. This is supported by studies that revealed the existence of urban-rural differences and regional disparities between providers of antenatal care services (Afulani, 2015; Abor et al., 2011).

Study Limitations

Questionnaires have the advantage of quick, cheap and easy administration and can be crafted to capture specific items, aiming at evaluating knowledge, attitudes and perceptions. One obvious limitation of questionnaires is that they are subject to social desirability bias. There is also the likelihood of response bias in this study. Response bias is a widely discussed phenomenon in behavioural and healthcare research where self-reported data are used; it occurs when individuals offer self-assessed measures of some phenomenon (Rosenman et al., 2011), in this case diseases associated with pesticide exposure. Educational attainment of the respondents was not included in this study.

Conclusion

Demographic changes in the form of population growth, rural to urban migration and changes in lifestyle have had a considerable influence on the consumption of pesticides and EDCs. In particular, population growth and urbanisation have influenced the increase in the use of these chemicals in agriculture in order to increase yields. As the population becomes increasingly urban, some cultural and nature-based practices that protected rural people from excessive exposure to EDCs are being lost. Furthermore, unsustainable population growth has exacerbated the effects of insufficient investment in education, health, employment, infrastructure and poor waste disposal systems, increasing the vulnerability of people and ecosystems to the effects of pesticides and EDCs.

This study revealed low levels of knowledge of the health effects of endocrine disrupting chemicals among the three communities, especially amongst those in rural areas where pesticides are widely used. Indeed, it showed some individuals to be dismissive of any possible adverse health effects. Considering the low dose effect and the time-lapse between exposure and development of disease later in life, these knowledge gaps cannot be ignored.

Recommendation

Practical and effective measures are needed to reverse this disturbing trend among the populace. A coordinated plan is required to evaluate and disseminate information on health and the environmental effects of chemicals that are endocrine disrupting in nature. The Ghanaian government's Health and Pollution Action Plan (HPAP) seeks to regulate EDCs and other types of pollutant that affect human health; however there is also the need for an integrated and coordinated effort to define the role of pesticides and other EDCs in human health. Health institutions must be encouraged to scale up education on the adverse health effects of pesticides and other endocrine disrupting chemicals that have become part of everyday life.

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Appendix 1.Knowledge of behaviour disorders due to pesticide use and EDCs (n=300)

Variables	Strongly disagree (%)	Disagree (%)	Unaware (%)	Agree (%)	Strongly agree (%)	Measure of association
Age						Pearson chi2(12) = 22.1551 Pr = 0.036
15–25yrs	5.81	8.14	84.88	0	1.16	Cramér's V = 0.1569
26–35yrs	13.58	16.05	69.14	0	1.23	
36–45yrs	7.59	6.33	81.01	3.8	1.27	
Above 45 yrs	11.11	20.37	62.96	5.56	0	
Gender						Pearson chi2(4) = 10.2952 Pr = 0.036
Male	3.37	8.99	86.52	0	1.12	Cramér's V = 0.1852
Female	11.85	13.27	71.09	2.84	0.95	
Marital Status						Pearson chi2(4) = 3.7965 Pr = 0.434
Not married/divorced	8.78	12.16	75.68	1.35	2.03	Cramér's V = 0.1125
Married	9.87	11.84	75.66	2.63	0	
Parity						Pearson chi2(12) = 19.8910 Pr = 0.069
No child	4.42	9.73	84.96	0	0.88	Cramér's V = 0.1487
1–3 children	14.05	13.22	69.42	1.65	1.65	

Appendix 1. continued

4–5 children	6.67	11.11	75.56	6.67	0	
Above 5 children	14.29	19.05	61.9	4.76	0	
Occupation						Pearson chi2(8) = 10.8447 Pr = 0.211
Unemployed	8.33	10.71	80.95	0	0	Cramér's V = 0.1344
Self employed	11.43	13.14	70.86	3.43	1.14	
Formal employment	2.44	9.76	85.37	0	2.44	
Vocation						Pearson chi2(20) = 40.1141 Pr = 0.005
Unskilled labour	20.83	20.83	50	0	8.33	Cramér's V = 0.1828
Farmer	5.66	15.09	79.25	0	0	
Sanitary worker	0	0	100	0	0	
Beautician	18.75	3.13	75	3.13	0	
Student	6.25	7.81	85.94	0	0	
Others	8.47	14.41	72.03	4.24	0.85	

Appendix 2. Knowledge of cancer due to pesticide use and EDCs (n=300)

Variables	Strongly disagree (%)	Disagree (%)	Unaware (%)	Agree (%)	Strongly agree (%)	Measure of association
Age						Pearson chi2(12) = 41.0911 Pr = 0.001
15–25yrs	0	2.33	69.77	25.58	2.33	Cramér's V = 0.2137
26–35yrs	6.17	2.47	44.44	44.44	2.47	
36–45yrs	3.8	3.8	39.24	40.51	12.66	
Above 45 yrs	7.41	5.56	25.93	55.56	5.56	
Gender						Pearson chi2(4) = 7.7957 Pr = 0.099
Male	4.49	2.25	38.2	44.94	10.11	Cramér's V = 0.1612
Female	3.79	3.79	50.71	37.91	3.79	
Marital status						Pearson chi2(4) = 13.0682 Pr = 0.011
Not married/divorced	2.7	2.03	56.76	35.14	3.38	Cramér's V = 0.2087
Married	5.26	4.61	37.5	44.74	7.89	
Parity						Pearson chi2(12) = 49.3734 Pr = 0.001
No child	2.65	2.65	61.06	30.97	2.65	Cramér's V = 0.2342
1–3 children	4.13	0.83	38.02	49.59	7.44	

Appendix 2. continued

4–5 children	8.89	2.22	42.22	40	6.67	
Above 5 children	0	23.81	33.33	33.33	9.52	
Occupation						Pearson chi2(8) = 44.3064 Pr = 0.001
Unemployed	0	2.38	69.05	26.19	2.38	Cramér's V = 0.2717
Self employed	2.86	4.57	39.43	45.71	7.43	
Formal employment	17.07	0	34.15	43.9	4.88	
Vocation						Pearson chi2(20) = 67.0732 Pr = 0.001
Unskilled labour	0	12.5	41.67	45.83	0	Cramér's V = 0.2364
Farmer	0	3.77	28.3	54.72	13.21	
Sanitary worker	22.22	0	55.56	22.22	0	
Beautician	9.38	3.13	53.13	28.13	6.25	
Student	0	1.56	78.13	18.75	1.56	
Others	5.93	2.54	37.29	48.31	5.93	

Appendix 3. Knowledge of cardiovascular disease due to pesticide use and EDC. (n=300)

Variables	Strongly disagree (%)	Disagree (%)	Unaware (%)	Agree (%)	Strongly agree (%)	Measure of association
Age						Pearson chi2(12) = 28.3227 Pr = 0.005
15–25yrs	1.16	2.33	81.4	13.95	1.16	Cramér's V = 0.1774
26–35yrs	6.17	2.47	75.31	16.05	0	
36–45yrs	0	8.86	72.15	18.99	0	
Above 45 yrs	5.56	18.52	61.11	12.96	1.85	
Gender						Pearson chi2(4) = 19.7412 Pr = 0.001
Male	2.25	10.11	85.39	2.25	0	Cramér's V = 0.2565
Female	3.32	5.69	68.72	21.33	0.95	
Marital status						Pearson chi2(4) = 10.9754 Pr = 0.027
Not married/divorced	3.38	3.38	71.62	20.95	0.68	Cramér's V = 0.1913
Married	2.63	10.53	75.66	10.53	0.66	
Parity						Pearson chi2(12) = 17.0215 Pr = 0.149
No child	1.77	3.54	81.42	12.39	0.88	Cramér's V = 0.1375
1–3 children	4.96	7.44	69.42	18.18	0	

Appendix 3. continued

4–5 children	2.22	11.11	71.11	15.56	0	
Above 5 children	0	14.29	61.9	19.05	4.76	
Occupation						Pearson chi2(8) = 6.9335 Pr = 0.544
Unemployed	1.19	2.38	79.76	15.48	1.19	Cramér's V = 0.1075
Self employed	4	8.57	70.29	16.57	0.57	
Formal employment	2.44	9.76	75.61	12.2	0	
Vocation						Pearson chi2(20) = 44.7750 Pr = 0.001
Unskilled labour	4.17	20.83	54.17	20.83	0	Cramér's V = 0.1932
Farmer	3.77	15.09	81.13	0	0	
Sanitary worker	0	11.11	88.89	0	0	
Beautician	0	0	71.88	25	3.13	
Student	0	1.56	82.81	14.06	1.56	
Others	5.08	5.08	68.64	21.19	0	

Appendix 4. Knowledge of diabetes due to pesticide use and EDCs (n=300)

Variables	Strongly disagree (%)	Disagree (%)	Unaware (%)	Agree (%)	Strongly agree (%)	Measure of association
Age						Pearson chi2(12) = 10.2956 Pr = 0.590
15–25yrs	0	4.65	79.07	16.28	0	Cramér's V = 0.1070
26–35yrs	1.23	4.94	66.67	25.93	1.23	
36–45yrs	1.27	5.06	72.15	21.52	0	
Above 45 yrs	0	11.11	70.37	18.52	0	
Gender						Pearson chi2(4) = 29.7047 Pr = 0.001
Male	0	10.11	87.64	2.25	0	Cramér's V = 0.3147
Female	0.95	4.27	65.88	28.44	0.47	
Marital status						Pearson chi2(4) = 9.4117 Pr = 0.052
Not married/divorced	0.68	3.38	68.92	26.35	0.68	Cramér's V = 0.1771
Married	0.66	8.55	75.66	15.13	0	
Parity						Pearson chi2(12) = 20.6875 Pr = 0.055
No child	0	4.42	78.76	15.93	0.88	Cramér's V = 0.1516
1–3 children	0.83	4.13	69.42	25.62	0	

Appendix 4. continued

4–5 children	0	8.89	73.33	17.78	0	
Above 5 children	4.76	19.05	52.38	23.81	0	
Occupation						Pearson chi2(8) = 10.9077 Pr = 0.207
Unemployed	0	4.76	77.38	16.67	1.19	Cramér's V = 0.1348
Self employed	1.14	8	67.43	23.43	0	
Formal employment	0	0	82.93	17.07	0	
Vocation						Pearson chi2(20) = 59.2815 Pr = 0.001
Unskilled	0	16.67	41.67	41.67	0	Cramér's V = 0.2223
Farmer	0	16.98	83.02	0	0	
Sanitary worker	0	0	100	0	0	
Beautician	3.13	3.13	71.88	21.88	0	
Student	0	3.13	81.25	14.06	1.56	
Others	0.85	1.69	66.95	30.51	0	

Appendix 5. Knowledge of erectile dysfunction due to pesticide use and EDCs (n=300)

Variables	Strongly disagree (%)	Disagree (%)	Unaware (%)	Agree (%)	Strongly agree (%)	Measure of association
Age						
15–25yrs	1.16	4.65	81.4	12.79	0	Pearson chi2(12) = 25.0491 Pr = 0.015
26–35yrs	6.17	6.17	61.73	24.69	1.23	Cramér's V = 0.1668
36–45yrs	0	11.39	68.35	18.99	1.27	
Above 45 yrs	9.26	14.81	53.7	22.22	0	
Gender						Pearson chi2(4) = 68.5636 Pr = 0.001
Male	11.24	21.35	67.42	0	0	Cramér's V = 0.4781
Female	0.47	3.32	67.77	27.49	0.95	
Marital status						Pearson chi2(4) = 22.9389 Pr = 0.001
Not married/divorced	0.68	3.38	71.62	24.32	0	Cramér's V = 0.2765
Married	6.58	13.82	63.82	14.47	1.32	
Parity						Pearson chi2(12) = 18.6961 Pr = 0.096
No child	1.77	9.73	76.11	12.39	0	Cramér's V = 0.1441
1–3 children	5.79	4.96	63.64	23.97	1.65	

Appendix 5. continued

4–5 children	2.22	11.11	66.67	20	0	
above 5 children	4.76	19.05	47.62	28.57	0	
Occupation						Pearson chi2(8) = 24.3362 Pr = 0.002
Unemployed	0	4.76	78.57	16.67	0	Cramér's V = 0.2014
Self employed	6.29	12.57	58.29	21.71	1.14	
Formal employment	0	0	85.37	14.63	0	
Vocation						Pearson chi2(20) = 135.4692 Pr = 0.000
Unskilled	0	12.5	45.83	41.67	0	Cramér's V = 0.3360
Farmer	18.87	35.85	45.28	0	0	
Sanitary worker	0	0	100	0	0	
Beautician	3.13	0	65.63	28.13	3.13	
Student	0	3.13	82.81	14.06	0	
Others	0	1.69	72.03	25.42	0.85	

Appendix 6. Knowledge of decreased fertility due to Pesticide use and EDCs (n=300)

Variables	Strongly disagree (%)	Disagree (%)	Unaware (%)	Agree (%)	Strongly agree (%)	Measure of association
Age						Pearson chi2(12) = 33.0513 Pr = 0.001
15–25yrs	1.16	4.65	84.88	9.3	0	Cramér's V = 0.1916
26–35yrs	3.7	9.88	69.14	13.58	3.7	
36–45yrs	0	6.33	77.22	15.19	1.27	
Above 45 yrs	9.26	22.22	61.11	7.41	0	
Gender						Pearson chi2(4) = 19.7209 Pr = 0.001
Male	2.25	12.36	85.39	0	0	Cramér's V = 0.2564
Female	3.32	8.53	69.67	16.59	1.9	
Marital status						Pearson chi2(4) = 9.1725 Pr = 0.057
Not married/divorced	2.7	6.08	73.65	16.22	1.35	Cramér's V = 0.1749
Married	3.29	13.16	75	7.24	1.32	
Parity						Pearson chi2(12) = 19.2801 Pr = 0.082
No child	1.77	3.54	84.96	8.85	0.88	Cramér's V = 0.1464
1–3 children	3.31	10.74	68.6	14.88	2.48	

Appendix 6. continued

4–5 children	4.44	15.56	71.11	8.89	0	
Above 5 children	4.76	23.81	57.14	14.29	0	
Occupation						Pearson chi2(8) = 12.6806 Pr = 0.123
Unemployed	2.38	3.57	83.33	8.33	2.38	Cramér's V = 0.1454
Self employed	4	13.14	68	13.71	1.14	
Formal employment	0	7.32	82.93	9.76	0	
Vocation						Pearson chi2(20) = 42.1876 Pr = 0.003
Unskilled	0	29.17	50	20.83	0	Cramér's V = 0.1875
Farmer	3.77	20.75	75.47	0	0	
Sanitary worker	0	0	88.89	11.11	0	
Beautician	3.13	3.13	75	15.63	3.13	
Student	3.13	3.13	85.94	7.81	0	
Others	3.39	6.78	71.19	16.1	2.54	

Appendix 7. Knowledge of genital problems due to pesticide use and EDCs (n=300)

Variables	Strongly disagree (%)	Disagree (%)	Unaware (%)	Agree (%)	Strongly agree (%)	Measure of association
Age						Pearson chi2(12) = 18.2670 Pr = 0.108
15–25yrs	1.16	8.14	83.72	6.98	0	Cramér's V = 0.1425
26–35yrs	4.94	9.88	76.54	8.64	0	
36–45yrs	2.53	11.39	78.48	6.33	1.27	
Above 45 yrs	11.11	20.37	62.96	5.56	0	
Gender						Pearson chi2(4) = 8.9413 Pr = 0.063
Male	2.25	12.36	84.27	1.12	0	Cramér's V = 0.1726
Female	5.21	11.37	73.46	9.48	0.47	
Marital status						Pearson chi2(4) = 11.2451 Pr = 0.024
Not married/divorced	3.38	9.46	75.68	11.49	0	Cramér's V = 0.1936
Married	5.26	13.82	77.63	2.63	0.66	
Parity						Pearson chi2(12) = 20.2669 Pr = 0.062
No child	1.77	7.08	85.84	5.31	0	Cramér's V = 0.1501
1–3 children	6.61	10.74	71.9	9.92	0.83	

Appendix 7. continued

4–5 children	6.67	17.78	68.89	6.67	0	
Above 5 children	0	28.57	71.43	0	0	
Occupation						Pearson chi2(8) = 10.2229 Pr = 0.250
Unemployed	1.19	8.33	83.33	7.14	0	Cramér's V = 0.1305
Self employed	6.29	14.86	72	6.29	0.57	
Formal employment	2.44	4.88	82.93	9.76	0	
Vocation						Pearson chi2(20) = 37.8179 Pr = 0.009
Unskilled	4.17	25	58.33	12.5	0	Cramér's V = 0.1775
Farmer	3.77	20.75	75.47	0	0	
Sanitary worker	0	0	100	0	0	
Beautician	6.25	3.13	84.38	3.13	3.13	
Student	0	6.25	87.5	6.25	0	
Others	6.78	11.02	71.19	11.02	0	

Appendix 8. Knowledge of miscarriage due to pesticide use and EDCs (n=300)

Variables	Strongly disagree (%)	Disagree (%)	Unaware (%)	Agree (%)	Strongly agree (%)	Measure of association
Age						Pearson chi2(12) = 8.8357 Pr = 0.717
15–25yrs	2.33	5.81	80.23	10.47	1.16	Cramér's V = 0.0991
26–35yrs	2.47	13.58	74.07	7.41	2.47	
36–45yrs	1.27	12.66	74.68	11.39	0	
Above 45 yrs	0	11.11	75.93	12.96	0	
Gender						
Male	1.12	8.99	87.64	2.25	0	Pearson chi2(4) = 11.9498 Pr = 0.018
Female	1.9	11.37	71.56	13.74	1.42	Cramér's V = 0.1996
Marital status						Pearson chi2(4) = 11.4383 Pr = 0.022
Not married/divorced	0.68	9.46	72.97	14.86	2.03	Cramér's V = 0.1953
Married	2.63	11.84	79.61	5.92	0	
Parity						Pearson chi2(12) = 23.3773 Pr = 0.025
No child	0.88	4.42	83.19	11.5	0	Cramér's V = 0.1612
1–3 children	2.48	13.22	72.73	9.09	2.48	

Appendix 8. continued

4–5 children	0	11.11	73.33	15.56	0	
Above 5 children	4.76	28.57	66.67	0	0	
Occupation						Pearson chi2(8) = 9.1385 Pr = 0.331
Unemployed	1.19	7.14	83.33	7.14	1.19	Cramér's V = 0.1234
Self employed	1.71	14.29	72	10.86	1.14	
Formal employment	2.44	2.44	80.49	14.63	0	
Vocation						Pearson chi2(20) = 38.4742 Pr = 0.008
Unskilled	0	29.17	41.67	25	4.17	Cramér's V = 0.1791
Farmer	1.89	15.09	83.02	0	0	
Sanitary worker	0	0	100	0	0	
Beautician	3.13	12.5	78.13	6.25	0	
Student	1.56	3.13	85.94	9.38	0	
Others	1.69	9.32	72.88	14.41	1.69	

Appendix 9. Knowledge of obesity due to pesticide use and EDCs (n=300)

Variables	Strongly disagree (%)	Disagree (%)	Unaware (%)	Agree (%)	Strongly agree (%)	Measure of association
Age						Pearson chi2(12) = 17.1549 Pr = 0.144
15–25yrs	1.16	2.33	74.42	22.09	0	Cramér's V = 0.1381
26–35yrs	1.23	8.64	67.9	17.28	4.94	
36–45yrs	2.53	6.33	72.15	18.99	0	
Above 45 yrs	3.7	9.26	72.22	14.81	0	
Gender						Pearson chi2(4) = 21.9488 Pr = 0.001
Male	2.25	7.87	86.52	3.37	0	Cramér's V = 0.2705
Female	1.9	5.69	65.4	25.12	1.9	
Marital status						Pearson chi2(4) = 13.8302 Pr = 0.008
Not married/divorced	2.03	3.38	67.57	24.32	2.7	Cramér's V = 0.2147
Married	1.97	9.21	75.66	13.16	0	
Parity						Pearson chi2(12) = 30.0123 Pr = 0.003
No child	0.88	5.31	75.22	18.58	0	Cramér's V = 0.1826
1–3 children	3.31	3.31	69.42	20.66	3.31	

Appendix 9. continued

4–5 children	0	6.67	77.78	15.56	0	
Above 5 children	4.76	28.57	52.38	14.29	0	
Occupation						Pearson chi2(8) = 9.0683 Pr = 0.337
Unemployed	0	7.14	75	16.67	1.19	Cramér's V = 0.1229
Self employed	3.43	7.43	68.57	18.86	1.71	
Formal employment	0	0	78.05	21.95	0	
Vocation						Pearson chi2(20) = 71.8725 Pr = 0.001
Unskilled	0	25	37.5	25	12.5	Cramér's V = 0.2447
Farmer	3.77	13.21	83.02	0	0	
Sanitary worker	0	0	100	0	0	
Beautician	0	3.13	75	21.88	0	
Student	1.56	1.56	78.13	18.75	0	
Others	2.54	3.39	66.95	26.27	0.85	

Appendix 10. Knowledge of Prostate cancer due to pesticide use and EDCs (n=300)

Variables	Strongly disagree (%)	Disagree (%)	Unaware (%)	Agree (%)	Strongly agree (%)	Measure of association
Age						
15–25yrs	1.16	3.49	82.56	10.47	2.33	Pearson chi2(12) = 27.4987 Pr = 0.007
26–35yrs	3.7	6.17	59.26	25.93	4.94	Cramér's V = 0.1748
36–45yrs	1.27	2.53	63.29	27.85	5.06	
Above 45 yrs	1.85	3.7	44.44	40.74	9.26	
Gender						Pearson chi2(4) = 22.3236 Pr = 0.001
Male	1.12	1.12	49.44	40.45	7.87	Cramér's V = 0.2728
Female	2.37	5.21	70.62	18.01	3.79	
Marital status						Pearson chi2(4) = 5.5585 Pr = 0.235
Not married/divorced	2.03	4.05	70.27	18.92	4.73	Cramér's V = 0.1361
Married	1.97	3.95	58.55	30.26	5.26	
Parity						Pearson chi2(12) = 28.0811 Pr = 0.005
No child	1.77	4.42	76.11	14.16	3.54	Cramér's V = 0.1766
1–3 children	2.48	2.48	56.2	33.06	5.79	

Appendix 10. continued

4–5 children	2.22	4.44	66.67	26.67	0	
Above 5 children	0	9.52	42.86	28.57	19.05	
Occupation						Pearson chi2(8) = 26.8001 Pr = 0.001
Unemployed	2.38	3.57	79.76	8.33	5.95	Cramér's V = 0.2113
Self employed	1.71	4.57	53.71	34.86	5.14	
Formal employment	2.44	2.44	78.05	14.63	2.44	
Vocation						
Unskilled	0	12.5	45.83	29.17	12.5	Pearson chi2(20) = 92.0091 Pr = 0.001
Farmer	0	1.89	22.64	64.15	11.32	Cramér's V = 0.2769
Sanitary worker	11.11	0	88.89	0	0	
Beautician	0	6.25	75	12.5	6.25	
Student	3.13	3.13	84.38	6.25	3.13	
Others	2.54	3.39	71.19	21.19	1.69	

Appendix 11. Knowledge of frequent urination due to pesticide use and EDCs (n=300)

Variables	Strongly disagree (%)	Disagree (%)	Unaware (%)	Agree (%)	Strongly agree (%)	Measure of association
Age						
15–25yrs	2.33	5.81	81.4	9.3	1.16	Pearson chi2(12) = 12.4863 Pr = 0.407
26–35yrs	2.47	12.35	69.14	16.05	0	Cramér's V = 0.1178
36–45yrs	0	8.86	81.01	8.86	1.27	
Above 45 yrs	3.7	16.67	66.67	12.96	0	
Gender						Pearson chi2(4) = 21.4533 Pr = 0.001
Male	0	13.48	86.52	0	0	Cramér's V = 0.2674
Female	2.84	9	70.62	16.59	0.95	
Marital status						Pearson chi2(4) = 8.4988 Pr = 0.075
Not married/divorced	2.7	7.43	72.97	16.22	0.68	Cramér's V = 0.1683
Married	1.32	13.16	77.63	7.24	0.66	
Parity						Pearson chi2(12) = 16.3333 Pr = 0.176
No child	2.65	6.19	81.42	9.73	0	Cramér's V = 0.1347
1–3 children	0.83	13.22	70.25	14.05	1.65	

Appendix 11. continued

4–5 children	0	11.11	77.78	11.11	0	
Above 5 children	9.52	14.29	66.67	9.52	0	
Occupation						Pearson chi2(8) = 14.8234 Pr = 0.063
Unemployed	1.19	5.95	78.57	14.29	0	Cramér's V = 0.1572
Self employed	2.86	14.86	71.43	9.71	1.14	
Formal employment	0	0	85.37	14.63	0	
Vocation						Pearson chi2(20) = 44.9259 Pr = 0.001
Unskilled	0	16.67	50	29.17	4.17	Cramér's V = 0.1935
Farmer	0	22.64	77.36	0	0	
Sanitary worker	0	0	100	0	0	
Beautician	0	12.5	75	9.38	3.13	
Student	3.13	6.25	81.25	9.38	0	
Others	3.39	5.93	74.58	16.1	0	

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BOOK REVIEW

Breaking Boundaries: The Science Behind our Planet.
Johan Rockström and Owen Gaffney.
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ISBN 9780241466759

Breaking boundaries but not population taboos

Pernilla Hansson[1]

The Overpopulation Project

In *Breaking Boundaries: The Science of Our Planet*, authors Owen Gaffney (analyst and journalist) and Professor Johan Rockström (influential researcher in climate and sustainability science) explore the limits to human exploitation of the Earth's systems, stressing the urgency to act and lamenting the inadequacy of actions so far. It is well-written and through the use of metaphors and personal stories the authors manage to make otherwise rather dry source material into a compelling read.

Even if some parts may be somewhat confusing and jump between topics, the chapters manage to explain technical terms so that anyone can understand them. The book is split into three sections or 'acts', through which Rockström and Gaffney take the reader on a journey exploring the way the biosphere works, important revolutions in human history and their consequences, the current state of the Earth's support systems, all the way through to what needs to be done to live within their identified planetary boundaries. The final section of the book contains references for each chapter; however, it is not always clear where any stated fact comes from.

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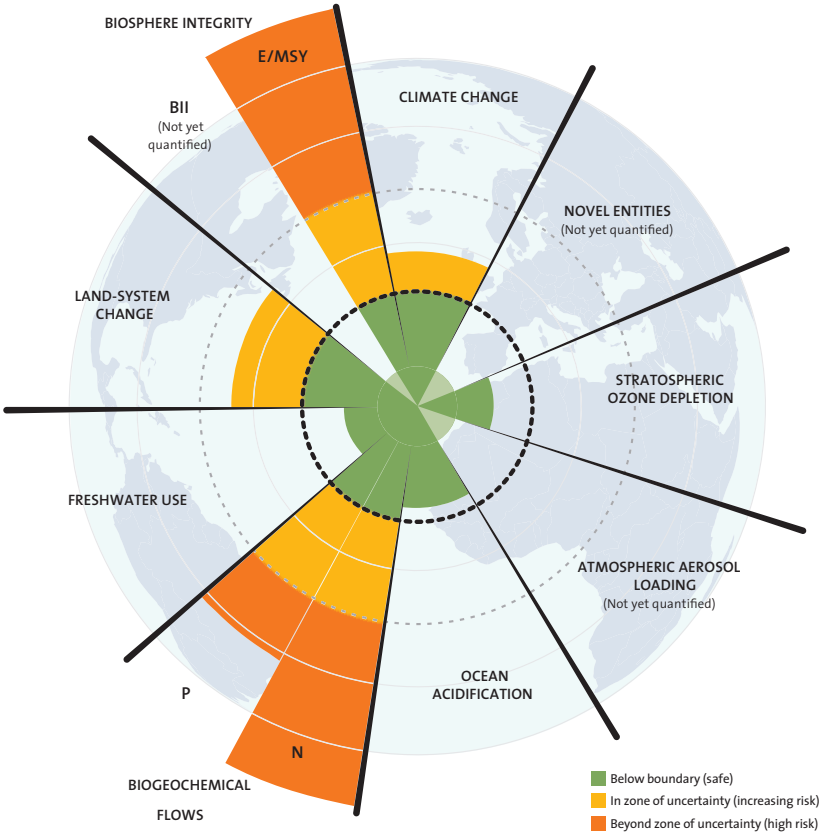
The question for this review is what Rockström and Gaffney have to say about population growth. Reviewing the table of contents, there are two intriguing chapters in Act Three titled 'Feeding 10 billion people within planetary boundaries' and 'The population bomb disarmed'.

But let's not get ahead of ourselves. The first act focuses on Earth sciences, the history of the Earth, with the advent of complex life and several mass extinctions, through to human evolutionary history. It explains the essential basics to understanding Earth science, such as the three stable 'thermostats' of Earth: hothouse, icehouse and snowball. Importantly, the first act introduces the Earth's self-regulation systems, which are discussed throughout the rest of the book. Rockström and Gaffney also highlight the disturbing transition from the Holocene, which had an unusually stable climate that allowed humanity to flourish, to the Anthropocene epoch, whose true self we have yet to see, but which we expect will not have the same stability.

Act Two explores the scientific basis for understanding the health of the planet and how we are changing it. The dangers of passing planetary tipping points for safe use of the biosphere are laid bare, as well as the risk of the domino effect if one tipping point interacts with another. It warns of the difficulties humanity will face in a warmed and destabilised world and asserts that we have already passed four of the nine planetary boundaries (see graph opposite).

In the final act, which is also the longest, the idea of planetary stewardship is established. Six system transformations are needed, according to the authors: energy, food, inequality, cities, population and health, and technology. A specific chapter is dedicated to each system transformation, exploring different aspects of what needs to be done and how we are doing. This section also explores the role of the economy. Rockström and Gaffney focus on the need to change the economic model into one that no longer promotes endless growth but rather supports societal goals for a sustainable future. They stress how the economic system is one of the most important tools for the needed transformations, and see reasons to be optimistic, as sustainable technologies and business models are becoming more profitable.

Figure 1



The planetary boundaries approach, introduced in a famous paper by Rockström et al. (2009), identifies nine major ways in which humans disrupt the biosphere, any one of which could undermine humanity's life support system if sufficiently disrupted, and attempts to quantify the limits for 'safe' disruption. Neither the original paper nor subsequent publications specify the role of human numbers or the size of the human economies in driving us past these boundaries.

Note that the existence of planetary boundaries, at least with respect to biodiversity, is the subject of much debate (see Montoya et al. 2018). Image CC BY 4.0, by J. Lokrantz/Azote based on Steffen et al. 2015.

Population reduction, the ultimate taboo

This is all well and good, and makes for excellent reading about our current predicament and possibilities for change. But what does the book say about the role of population? Unlike many recent scholars (see, for example, Dasgupta, 2019; Tucker, 2019; Lianos and Pseiridis, 2016), Rockström and Gaffney believe the current global population, or even one several billion larger, is ecologically sustainable. Unlike many population advocates, they believe population growth will cease without dedicated efforts to end it. One place they indulge this optimism is in a chapter aptly named 'Feeding 10 billion people within planetary boundaries'.

Our food system is at the centre of many of our largest global environmental problems and could all by itself undermine the goals of the Paris climate agreement. Rockström and Gaffney adequately portray the problems of our agriculture: how seventy per cent of all withdrawals of fresh water are used for food production, how the way we capture and produce our food is the main driver of the current mass extinction of species, and how food insecurity may increase due to climate change (but not that it is already increasing due to population growth). They state that fifty per cent of our planet's habitable land has been transformed for agriculture, and that we need to follow the Half-Earth principle of keeping the other half intact.

Somehow, though, the authors fail to mention that even if we only occupy half of the habitable land with our agriculture, we have already severely altered over 75 per cent of the planet's land surface, as stated in the 2019 IPBES report (IPBES, 2019). Or that people make many other demands on the landscape beyond agricultural production. Or that recent scholarship (Crist et al., 2021) suggests that achieving Half-Earth levels of biodiversity protection will demand much smaller overall human populations, perhaps two to three billion, maximum.

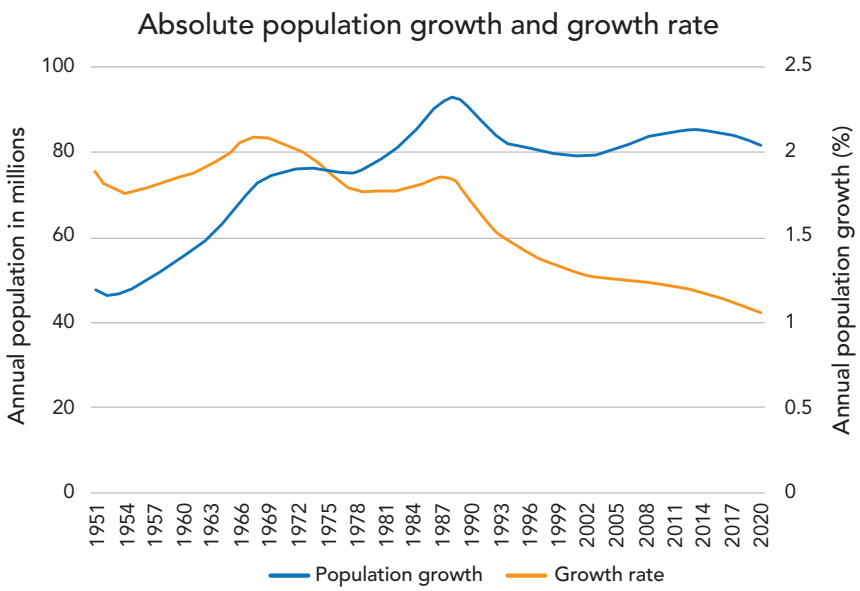
Rockström and Gaffney are optimistic that humanity will be able to feed everyone while operating within the planet's boundaries, if only we completely overhaul the current system by adopting a healthy planetary diet, reducing food waste and transitioning to more circular farming. The fact that climate change will probably decrease crop yields is mentioned, but not other instabilities, such as we have seen in disruptions to food markets after Russia's invasion of Ukraine (O'Sullivan, 2022).

In chapter 4, Rockström and Gaffney pose a pertinent question. Given that agriculture will need to draw fifteen per cent more water to provide food to our growing population, where will this come from? They don't answer the question in that chapter, nor do they answer it in the chapter on feeding ten billion people, despite having published an article which explores it (Gerten et al., 2020). In the book, they mention the worrying fact that water usage may be plateauing because there are few rivers left undammed or un-siphoned, but not where this fifteen per cent increase in water consumption will come from. Let's hope that the proposed circular farming, which the authors suggest will capture carbon while circulating nutrients and saving on water, solves this problem. And let's not forget about the effect on other species on this planet, who Rockström and Gaffney often seem to overlook.

The specific chapter in *Breaking Boundaries* that focuses on population growth, apart from being the shortest chapter, seems muddled and unclear in its message. On the one hand, Rockström and Gaffney ridicule people who say population size is a problem, implying that population activists think population will continue to grow exponentially so that we may reach 100 billion soon. They suggest that believing population is an important factor means believing that no other factor is important. These misrepresentations stand at the beginning of the chapter – not a promising start.

On the other hand, towards the end of 'The population bomb disarmed', coming out of the blue, the authors state that 'providing family planning and education to girls has the potential to avoid 85 billion tonnes (93 billion tons) of carbon dioxide emissions this century and to stabilize global population at levels that are manageable'. This is great! But that is all we get on that topic, and only after disparaging people who are advocating exactly this. There are clearly ways forward for population that can help limit climate change and help stay within other planetary boundaries, yet they remain unexplored in this chapter that is supposedly devoted to the problem. The chapter seems both to state that population is now a solved issue as the global growth rate has subsided, and simultaneously to acknowledge that efforts to decelerate growth would make a large contribution to staying within planetary boundaries. Could it be that the two authors don't agree on this issue? Either way, the message of this chapter is thoroughly muddled.

Figure 2



While population growth rate has decreased in the past 50 years, the annual growth in absolute number of people has stayed relatively stable around 80 million. Data from Worldometer (https://www.worldometers.info/world-population/world-population-by-year/).

To infer that a falling growth rate ensures population is stabilising is a misrepresentation we would not expect from a data scientist such as Rockström. Rockström and Gaffney state that the rate of population growth peaked in the 1960s and is now half of that. But they don't say that the number of people added to the global population this year will be even greater than it was in the 1960s. For fifty years it has been a fairly steady, undiminishing eighty million per year. It is a smaller percentage of what is now a much bigger population, but it's the increment that matters, not its percentage of the current population.

Suppose you are driving toward a cliff at sixty kilometres per hour. After one minute, you've travelled one kilometre. In the second minute, you increase the distance you have travelled by 100 per cent. In the sixth minute, you add another

kilometre to the five you already travelled: a twenty per cent increase. In the hundredth minute, you increase the journey by only one per cent. Do you say, 'don't worry, we'll stop before we go over the cliff: look how our travel rate has fallen'? You're still travelling at sixty kilometres per hour and the cliff is closer than ever.

Even if the peak growth increment has occurred in global population increase, this doesn't mean that there is nothing more for population advocates to do. Just ask the hundreds of millions of women in developing nations who desire but cannot access contraceptives, or who still lack bodily autonomy (UNFPA, 2020). This is a double standard not applied to other solutions Rockström and Gaffney advocate: just because positive change has begun happening in areas such as decarbonising energy or protecting forests, they don't suggest we rest on our laurels and just hope the projected trajectory continues. So why do they do that when talking about population?

Another rather unscientific statement is found in this chapter. Rockström and Gaffney state that an 'infinite exponential growth is not possible in the real world; instead, everything eventually slips into an "s curve", as growth rates slack off' (p. 166). This implies that some magic hand of restraint will lower birth rates before resource scarcity forces a population die-off. But not 'everything' has such happy endings: in nature, overshoot and collapse is a common pattern. Just ask the Greenland lemmings (Schmidt et al., 2012). A nice 's curve' stabilisation (or better still, a gradual rather than catastrophic decline) can only be achieved by making small families the norm. But Rockström and Gaffney invoke the inevitability of the 's curve' to argue that no intervention is necessary. It is a particularly odd argument in a book on how we must consciously and proactively work to avoid overshooting planetary boundaries. Another example of the double standard applied to population.

Interestingly, 'The population bomb disarmed' mentions that the population in 2100 could climb to eleven or twelve billion. Yet the authors themselves devote a whole chapter to the many challenges and difficulties of feeding ten billion people within the planetary boundaries. When they talk about feeding future populations, they say it can probably be done. Probably is not good enough when it comes to people's lives. What happened to the precautionary principle?

Rockström and Gaffney are optimistic about the necessary changes to achieve global sustainability and believe we are heading in the right direction. They seem nonchalant that this can be achieved with humanity's current population trajectory. This is great news if it is true. Then imagine if resources were also funnelled into promoting small families and providing contraceptives and education. We could create a world with a greater buffer to protect ecosystem services for people, and more habitat to share with other species. How much better off would we be if we also took population matters seriously?

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