Prospective and Retrospective Rigour: Scientific Evaluation of Environmental Policy

Kasey Markel, Department of Plant Sciences, University of Cambridge

The preservation of our environment is an ethical imperative and one of the greatest challenges of the twenty-first century. By necessity, much of the battle to protect the environment will be waged at the level of policy. However, the track record of environmental legislation shows much room for improvement, a development that will only be reliably achieved when it becomes common practice to rigorously evaluate the effects of all policies with scientifically rigorous studies, prospectively as part of the planning process and retrospectively after widespread implementation. Environmental scientists are uniquely positioned by virtue of their biological expertise, scientific training, and statistical skills to take an active role in this evaluation process.

On paper, science and engineering are completely distinct disciplines: the first attempts to understand the world, the second seeks to change it. This classification may be convenient for establishing academic departments, but it fails to capture the full scope of what many scientists and engineers really do. Engineers rely on scientific data, and frequently generate scientific data of their own. Scientists are often interested in engineering the subject of their study. Engineering and "pure" science are conceptually separate, but ultimately much research in both fields is a hybrid: applied or purpose-driven research. Purpose-driven research is particularly common in conservation and environmental science, where mitigation and prevention of anthropogenic environmental disasters is usually the primary reason to document past and current disasters [1]. Law and policy are frequently the most powerful tools to achieve this goal, so environmental and conservation scientists find themselves with a closer association to policy than many other fields of science.

Every scientist must understand the branch of policy that governs their field, but those who wish to shape policy require a far greater degree of understanding. It is necessary to understand how a change in policy will impact the behaviour of nations, corporations, and people. If a natural system is in a given state as a result of human action and we wish to change it to another, we must understand not only how human action affects the environment, but also how specific policies affect human actions. One could imagine that it is the duty of scientists to provide reports on the state of the world and allow policymakers to devise schemes to improve it, but this scheme does not mirror the current course of events, nor is it the ideal solution to the problem. Conservation and environmental scientists frequently study anthropogenic ecological problems, and their work ideally culminates in policy changes that reduce the very environmental harm they study – a goal shared by engineers. The response to environmental catastrophes creates a feedback loop where human activity changes the environment, which attracts environmental scientists who lobby to

develop policies that correct the human impacts that first caused the problem, as illustrated in Figure 1.

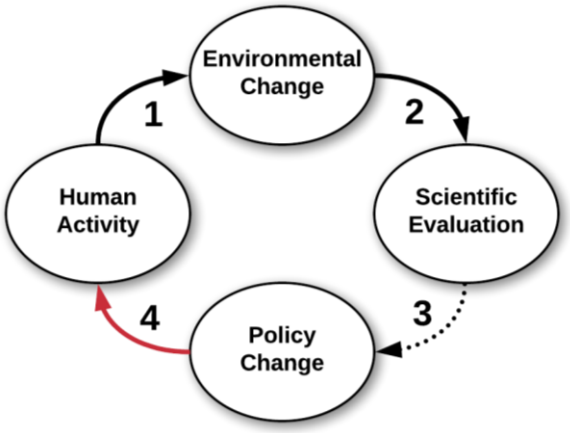

Figure 1: Feedback loop of human–environment interactions. Solid black lines denote pure environmental science, dotted black line denotes scientific input in policy, red line denotes the knowledge gap discussed here. To engineer the feedback loop, all four links must be understood.

Links 1 and 2 in this loop are firmly in the domain of environmental science, link 2 is simply the process of studying link 1. Environmental scientists often serve as advisors and advocates for policy change, and are therefore deeply influential in link 3. Link 4 in the feedback loop is how policy changes alter human behaviour, and the lack of evidence in this link is the limiting factor for understanding and controlling the whole loop. This critical final link traditionally falls into the domain of behavioural economics and behavioural sciences.

Richard Thaler won the Nobel prize in economics for his work surrounding "nudging", a branch of behavioural economics examining how subtle situational changes can alter human behaviour. The surprising truth is that small changes can radically alter behaviour, at costs often a tiny fraction of traditional "common sense" interventions. For example, assistance in filling out a financial aid form increased college enrollment 40 times more than a traditional program subsidising education [2], and another traditional program providing families with information about financial aid turned out to have no effect at all [3]. Unfortunately, these kind of experiments examining the effects of policy are the exception rather than the rule [4].

The scarcity of scientifically rigorous analysis of the effects of policy can result in mistakes like sex education that increases teen pregnancy [5] and criminal justice programs that increase delinquency [6]. Thankfully, these programs are being slowly phased out due to a slew of studies showing they fail to achieve their stated goals. This is a triumph of retrospective rigour, analysis of the outcome of a policy after deployment. However, policy mistakes were already widely implemented at substantial cost, and they remain difficult to eliminate for political and financial reasons. A cheaper and quicker way to discover the efficacy of a policy is prospective rigour, rigorously evaluating small-scale pilots before widespread implementation.

Though currently rare, using pilot studies to rigorously evaluate the impacts of policy before broad implementation is by no means a novel idea [7]. Prospective rigour has been widely adapted by international aid organisations such as the Abdul Latif Jameel Poverty Action Lab and the World Bank, which use small and controlled pilot studies to evaluate interventions before broad deployment. A surprising trend has emerged from these studies: many interventions completely fail to achieve their stated goals, while most others accomplish very little. Fortunately, some interventions work quite well, confirming that policy changes can indeed influence the world in the desired direction. These few highly successful

interventions are frequently more than 50 times as effective as the average intervention, ignoring those that do nothing at all.

Given the urgency of problems such as environmental degradation or global poverty, it is tempting to skip this period of assessment and optimisation, but to do so would be a mistake of the highest order. Instead, the massive variation in efficacy between different interventions highlights the importance of using prospective rigour. As one example, the World Bank Disease Control Priorities in Developing Countries working group evaluated a variety of global health interventions targeted at reducing mortality and morbidity, as measured by disability adjusted life years (DALYs). They found that childhood immunisation saved over 180 times as many DALYs per unit cost as treating hypertension and nearly 700 times as many DALYs as antipsychotic medication, as shown in Figure 2.

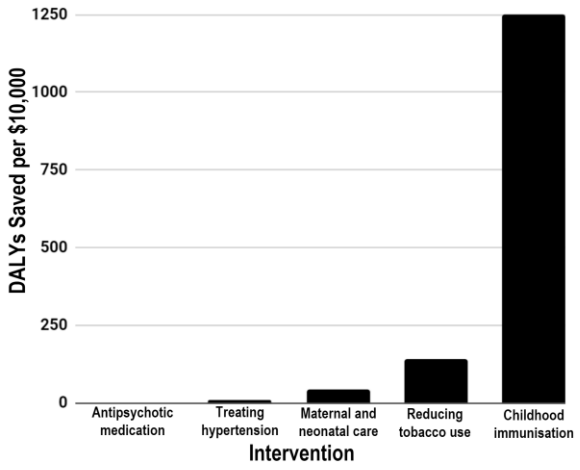

Figure 2: DALYs saved per $10,000 spent. Most interventions accomplish little or nothing, the best are orders of magnitude better. Adapted from [8].

All of these interventions are well-intentioned, and there was no way of knowing *a priori* that some would be so much less effective than others. Yet in study after study, the same pattern shows up: when different policy interventions are compared against each other, some achieve nothing, many achieve little, and a few are truly worthwhile. Given limited resources, the most effective interventions should be implemented first, until the law of diminishing returns reduces their cost efficiency down to the level of other options. Prospective rigour is the series of rigorous pilot studies required to know which interventions to prioritise.

The efficacy of environmental policy almost certainly varies over a similarly broad range, so it is critical we invest our time, energy, and money to ensure we are implementing the policies on the far right of this sort of graph – randomised pilot studies could go a long way towards achieving that goal. Environmental scientists have expertise to contribute for designing small-scale, blind, randomised controlled pilot studies appropriate for the initial evaluation of the effects of a given policy and a more systematic evaluation process after the selected policies are deployed. This approach is desperately needed because some widely-implemented environmental policies have been expensive and ineffectual.

In the United States and Europe, mandatory ethanol additives in petrol have increased the price of food, caused massive habitat loss, and increased agricultural pollution [9]. All these ills have been in hope of reducing greenhouse gas emissions, but the reduction is negligible – in the American case, less than a quarter of a percent of the greenhouse gas emissions from petrol, at a cost of over fourteen percent of the corn crop (the primary feedstock for fuel-additive ethanol) [10]. Diverting agricultural resources from food production to ethanol production increases corn prices by ~23% and increases the portion of land devoted to corn by 18%, according to the United States Department of

Agriculture [11]. In attempting to solve any given problem, many well-intentioned ideas do not work in practice, and the best are orders of magnitude more cost-effective than the others. Retrospective rigour only tells us when a policy was wrong years after the fact, when changing course is difficult. Prospective rigour before the massive infrastructural and capital costs of the fuel ethanol policy program could have directed us down a wiser path from the beginning.

Of course, understanding how policy affects human action is not a simple challenge. Environmental scientists are used to studying complex and experimentally intractable phenomena, all while working with large and varied datasets. Their expertise in how the environment responds to human actions justifies a seat at the environmental policy-making table. This puts them in an excellent position to design and evaluate the rigorous pilot studies required for prospective rigour. At the minimum, this means sharing their unique skillset and expertise with policy makers and social scientists, collaborating to understand the fourth and final link of the feedback loop they study. It is a Herculean undertaking, but studying both the natural and the human systems involved in environmental catastrophes would massively increase environmental scientists' efficacy in protecting the environment.

Society relies on environmental and conservation scientists to prevent and mitigate anthropogenic environmental catastrophes. The primary tool for this has always been legislation and policy, and scientists have the skillset required to test which policies are most cost effective. The stakes are too large to not use the most effective policies available, and that calls for empirical analysis – for prospective and retrospective rigour.

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References

[1] M. E. Soulé, "What is Conservation Biology? A new synthetic discipline addresses the dynamics and problems of perturbed species, communities, and ecosystems," Bioscience, vol. 35, no. 11, pp. 727–734, Dec. 1985.

[2] S. Benartzi et al., "Should Governments Invest More in Nudging?," Psychol. Sci., vol. 28, no. 8, pp. 1041–1055, Jun. 2017.

[3] E. P. Bettinger, B. T. Long, P. Oreopoulos, and L. Sanbonmatsu, "The Role of Application Assistance and Information in College Decisions: Results from the H&R Block Fafsa Experiment," Q. J. Econ., vol. 127, no. 3, pp. 1205–1242, Aug. 2012.

[4] S. Macintyre, "Good intentions and received wisdom are not good enough: the need for controlled trials in public health," J. Epidemiol. Community Health, vol. 65, no. 7, pp. 564–567, Jul. 2011.

[5] P. K. Kohler, L. E. Manhart, and W. E. Lafferty, "Abstinence-only and comprehensive sex education and the initiation of sexual activity and teen pregnancy," J. Adolesc. Health, vol. 42, no. 4, pp. 344–351, Apr. 2008.

[6] A. Petrosino, C. Turpin-Petrosino, and J. Buehler, "Scared Straight and Other Juvenile Awareness Programs for Preventing Juvenile Delinquency: A Systematic Review of the Randomized Experimental Evidence," Ann. Am. Acad. Pol. Soc. Sci., vol. 589, no. 1, pp. 41–62, Sep. 2003.

[7] D. T. Campbell, "Reforms as experiments," Am. Psychol., vol. 24, no. 4, p. 409, 1969.

[8] Dean T. Jamison Joel G. Breman Anthony R. Measham George Alleyne Mariam Claeson David B. Evans Prabhat Jha Anne Mills Philip Musgrove, Disease Control Priorities in Developing Countries (Second Edition). The World Bank, 2006.

[9] D. Pimentel, "Ethanol Fuels: Energy Balance, Economics, and Environmental Impacts Are Negative," Nat. Resour. Res., vol. 12, no. 2, pp. 127–134, Jun. 2003.

[10] J. Hill, E. Nelson, D. Tilman, S. Polasky, and D. Tiffany, "Environmental, economic, and energetic costs and benefits of biodiesel and ethanol biofuels," Proc. Natl.

Acad. Sci. U. S. A., vol. 103, no. 30, pp. 11206–11210, Jul. 2006.

[11] J. Fernandez-Cornejo, A. Somwaru, H. An, M. Brady, and R. Lubowski, "Modeling the Global Economic and Environmental Implications of Biofuels Production: Preliminary Results for the Medium Term," GTAP Resource, vol. 2723, 2008.

About the Author

Kasey is a Master's student in Plant Sciences in the Synthetic Biology group. His research involves improving the tools for genetic engineering of chloroplasts, the subcellular factories that carry out photosynthesis in plants and algae. He is interested in improving global agriculture from human health and environmental perspectives. Before coming to Cambridge, he completed a Bachelor of Science at University of Miami.