The Journal of Population and Sustainability

ISSN 2398-5496

Article title: A Brief History of “IPAT”
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Vol. 2, No. 2, (Spring 2018), pp. 66-74.

doi: 10.3197/jps.2018.2.2.66

A Brief History of "IPAT"

(IMPACT = POPULATION X AFFLUENCE X TECHNOLOGY)

JOHN P. HOLDREN (7 SEPTEMBER 1993)

Published here with permission as an appendix to Paul Ehrlich's book review (page 63).

In late 1969, the thenprominent biologist Barry Commoner began claiming in speeches and lectures that he had sorted out the responsibility for the environmental crisis and had found that neither population growth nor rising affluence had much to do with it. The culprit, he said, was ecologically inept choices of productive technologies in post World War 2 industrial societies. He often used the figure 95 percent in these talks to describe the share of the "blame" for environmental problems attributable to faulty technology. (The 95 percent claim is also made on page 176 of *The Closing Circle*, the 1971 popular book through which his argument reached its largest audience.) During 1970 Commoner published these claims in a variety of unrefereed forums – *Saturday Review*, Congressional testimony, and the like – and in April 1971 his more detailed analysis, "The Causes of Pollution" (with Michael Corr and Paul J. Stamler) appeared in *Environment* (1971/2010). That journal was then the house organ of the Scientists' Institute for Public Information, which Commoner headed; I mention this because the transparent errors of arithmetic and logic in "The Causes of Pollution" would have precluded its publication in any competently refereed professional journal.

In the *Environment* article, Commoner and coauthors offered up, with great fanfare, their discovery that

pollution = (population) x (production/capita) x (pollution/production)

(an intellectual achievement roughly equivalent to noticing that GNP equals population times GNP per capita); and they proceeded to try – through a combination of biased selection of data, redefinition of widely understood concepts, and neglect of causeandeffect relations, and with the help of major mistakes in arithmetic – to support the proposition that 95 percent of the problem resides in the last factor. These flaws survived unscathed the expansion of the

argument to 300 pages' length in *The Closing Circle*, which appeared later the same year and hammered home relentlessly the simplistic message that neither population growth nor rising material consumption is a major cause of environmental disruption. The culprit is faulty technology, brought about by a faulty economic system. Here are some quotes from *The Closing Circle* (1971):

> It seems clear, then, that despite the frequent assertions that blame the environmental crisis on 'overpopulation', 'affluence', or both, we must seek elsewhere for an explanation. (Ibid. p. 139)

> The pattern of economic growth is the major reason for the environmental crisis. A good deal of the mystery and confusion about the sudden emergence of the environmental crisis can be removed by pinpointing, pollutant by pollutant, how the postwar technological transformation of the United States economy has produced not only the muchheralded 126 percent rise in GNP, but also, at a rate about ten times faster than the growth of GNP, the rising levels of environmental pollution. (p 146)

> [M]ost of the sharp increase in pollution levels is due not so much to population or affluence as to changes in productive technology. (Ibid. p. 177)

> [The technology factor] has a far more powerful effect on pollution levels than the other two. (Ibid. p. 211)

As it happened, prior to Commoner's initial revelation that population and affluence are unimportant causes of environmental problems, I had started to collaborate with Stanford biologist Paul Ehrlich on studies of more or less the same questions –the interactions of population, poverty and affluence, technology, and resource and environmental issues. (I was then a doctoral student at Stanford in aeronautics and astronautics and theoretical plasma physics.) Our first joint paper, "Population and Panaceas: A Technological Perspective" (written in late 1968 and published in the refereed journal *Bioscience* in December 1969), showed why technological "fixes" alone were unlikely to be able to cope with the pressures posed by the combination of population growth and rising material consumption.

We were dismayed to learn, at a conference at the end of 1969, of Commoner's determination to persuade people that population growth and rising material consumption were nothing to worry about, and we began preparing a rebuttal. It was presented as an invited paper to the President's Commission on Population Growth and the American Future in November 1970 and was published in the 26 March 1971 issue of the refereed journal *Science* under the title "Impact of Population Growth". In it, we took the position that ALL of the factors (population, affluence, technology, socioeconomic variables) are important, that they interact, and that neglect of any of them, or of their interactions, is dangerous. Here are some quotes from our paper:

> Problems of population size and growth, resource utilization and depletion, and environmental deterioration must be considered jointly and on a global basis. In this context, population control is obviously not a panacea – it is necessary but not alone sufficient to see us through the crisis. (3rd paragraph of the paper)

> 'Environment' must be broadly construed to include such things as the physical environment of urban ghettos, the human behavioral environment, and the epidemiological environment. (5th paragraph)

> Complacency concerning any component of these problems – sociological, technological, economic, ecological– is unjustified and counterproductive. It is time to admit that there are no monolithic solutions to the problems we face. Indeed, population control, the redirection of technology, the transition from open to closed resource cycles, and the equitable distribution of opportunity and the ingredients of prosperity must ALL be accomplished if there is to be a future worth having. Failure in any of these areas will surely sabotage the whole enterprise. (conclusion of the paper; emphasis in original)

As for the "IPAT" relation, Commoner's version of the population production pollution identity had not been published yet when we wrote the *Science* article, and we chose to present the population impact relation in a way that stressed its inherent complexity from the outset. Here is our initial treatment of the subject from *Science* of 26 March 1971:

> The total negative impact of an [agricultural or technological] society on the environment can be expressed, in the simplest terms, by the relation
>
> $$I = P * F$$
>
> where P is the population, and F is a function which measures the per capita impact. A great deal of complexity is subsumed in this simple relation, however. For example, F increases with per capita consumption if technology is held constant, but may decrease in some cases if more benign technologies are introduced in the provision of a constant level of consumption…. Pitfalls abound in the interpretation of manifest increases in the total impact I. For instance, it is easy to mistake changes in the composition of resource demand or environmental impact for absolute per capita increases, and thus to underestimate the role of the population multiplier. Moreover, it is often assumed that population size and per capita impact are independent variables, when in fact they are not. (Ibid. p.1212)

The actual "IPAT" equation, using those symbols, appeared for the first time in the critique of *The Closing Circle* that Paul Ehrlich and I wrote and circulated widely in late 1971, and that was published together with Commoner's rebuttal in the April 1972 *Environment* and the May 1972 *Bulletin of Atomic Scientists*. We introduced the "IPAT" version as a vehicle for illustrating the flaws in Commoner's use of the populationproductionpollution identity, starting with the problem that "pollution" is too narrow a concept for what is being done to the environment (hence our preference for "impact") and that "production" is too narrow a term to capture the array of effects associated with rising material wellbeing (hence our preference for "affluence"). Here, in full, is the passage from our 1971/72 critique of *The Closing Circle* in which the "IPAT" equation made its first appearance in the literature:

> Commoner admits that the factors contributing to environmental impact are multiplicative, rather than additive; he offers (in a footnote to pp 211212) the equation
>
> $$\text{pollution} = (\text{population}) \times (\text{production/capita}) \times (\text{pollution emission/production})$$

> Here the second factor on the right, production per capita, is in some sense a measure of affluence, and the last factor, pollution per unit of production, is a measure of the relative environmental impact of the technology that provides the affluence. For compactness, let us rewrite this equation
>
> $$I = P \times A \times T \qquad (1)$$
>
> or, in terms of initial values and the subsequent changes, over a specified period of time,
>
> $$I + \Delta I = (P + \Delta P) \times (A + \Delta A) \times (T + \Delta T) \qquad (2)$$
>
> Here I is for impact (a better word than "pollution" for reasons already explained), P is for population, A for affluence, and T for technology. Let us also assume for a moment that the variables P, A, and T are independent; i.e., that a change in P does not cause changes in A or T, and vice versa. We shall find later that this is not true, but it is the simplest assumption and the one most favorable to Commoner's hypothesis.
>
> It is immediately obvious from equation (2), of course, that the actual magnitude of the environmental deterioration engendered by an adverse change in technology depends strongly both on the initial levels of population and affluence and on such changes in these levels as may occur simultaneously with the change in technology. A corollary is that population and affluence would be important factors in environmental degradation even if they were not growing. A change for the worse in the technology of production is more serious environmentally if it occurs in a populous, affluent society than if it occurs in a small, poor one. (Ibid. pp. 19-20)

We went on, in the critique, to elucidate many of the ways in which the factors are in fact causally interrelated, as well as showing how Commoner had mangled the logic and arithmetic even for the hypothetical case when they are independent. In our conclusion to this critique, we wrote:

> In fixing the blame for environmental deterioration on faulty technology alone, Commoner's position is uncomplicated, socially comfortable and, hence, seductive. But there is little point in deluding the public on these matters; the truth is that we must grapple SIMULTANEOUSLY with overpopulation, excessive affluence, and faulty technology. (Ibid. p. 27, emphasis in original)

Unfortunately, numerous writers revisiting "the population debate" in subsequent decades have chosen to expound at length on the content and significance of this 19691972 Ehrlich/Holdren/Commoner disagreement without, apparently, taking the trouble to read any of the original documents. The result is passages like the following (from an opeditorial essay in *Science* of 25 June 1993 by National Academy of Sciences staffer Paul Stern:

> Scientific progress has been slowed by a futile debate about which of these factors is the most important driving force, a debate that rests on the erroneous assumption that the contributions of these forces can be assessed independently. For example, in decades of sharp debate about the impact of population growth on the environment, some have argued that population growth is the primary cause of environmental cause of environmental degradation (2), others that population growth is environmentally neutral or even beneficial (3), and others that population is secondary to technological or socioeconomic factors (4). (Stern 1993 p. 1897)

Under note (2), Stern cites the 26 March 1971 Ehrlich/Holdren paper in *Science* (from which I quoted at length above), as well as a 1974 Holdren/Ehrlich paper in *American Scientist*, entitled "Human Population and the Global Environment", in which we are emphatic throughout that population, affluence, and technology are ALL important, that the "IPAT" relation conceals much complexity, that its component factors are causally interrelated and influenced by context, and so on. Stern's essay then goes on to inform the reader that:

> What has become clear is that the driving forces interact – that each is meaningful only in relation to the impacts of the others and that the environmental consequences of increased population are highly

> sensitive to the economic and technological conditions of that population (7). (Ibid. p. 1897).

But everything that Stern appears to think has only recently "become clear"(his reference 7 being a 1992 National Research Council study for which he was the staff director) was in fact already clear – and clearly stated in the literature Stern misportrays – when Paul Ehrlich and I were writing about it in 1971. Evidently Stern has not acquired the scholarly habit of reading the works he cites.

He is not alone. As another example, consider the 1992 article by World Bank analyst R. Paul Shaw on "The Impact of Population Growth on the Environment: The Debate Heats Up" (1992). Shaw writes that the "IPAT" equation was "proposed by Paul and Anne Ehrlich in 1990" (Ibid. p. 29), characterizes their position as being that population growth "is largely responsible for global environmental degradation", and cites with an apparent sense of discovery and approval the 1988 (re)statement by "leading environmentalist Barry Commoner" that "The theory that environmental degradation is largely due to population growth is not supported by the data" (Ibid. p. 11). The rest of Shaw's analysis is at a comparable level.

Consider, finally, a paper entitled "Population, Environment, and Development: Key Issues for the EndofCentury Scenario", presented by Brazilian analyst George Martine at a 1992 international conference on environment and development. Martine writes:

> A sizeable segment of the existing literature on population and environment has attempted to grapple with the intricacies of the theoretical interrelationships between environmental change and what appears to be a restricted list of variables: technology, population size, characteristics, and growth, consumption levels and patterns. These relationships are customarily summarized in the formula:
>
> I (impact) = P (pop.) x A (affluence) x T (technology).
>
> In reality, however, the relationships between population size, consumption, and technology are much more complex than suggested in this formula. [1]The heated debates which have ensued within

> what appears to be a relatively limited number of variables can be partly attributed to this complexity, as well as to divergences of a theoreticalideological character. Inspiration for different stances has come from a gamut of contrasting positions ranging from Malthusian to Marxist to neoclassical. Lack of hard data compounds the absence of consensus on appropriate methodological approaches and added fuel to the debate. What's worse, all of the different positions are correct, when examined from their own relative standpoints. [2] (Martine, 1992).

Under note [1], Martine refers the reader "for a more general discussion" to Paul Harrison, *The Third Revolution: Environment, Population, and a Sustainable World* (1992). In that book, Harrison struggles with the complexities of "IPAT", clearly handicapped by having read and talked to only Commoner on the subject, and gets some of it right and some of it wrong. He accuses Ehrlich of lack of precision – not realizing, having not actually read the relevant literature, that it is Ehrlich AND Holdren he means to be (incorrectly) accusing – and he credits Commoner with "the seminal work" in the field. He ends up saying, with Martine, that EVERYBODY is more or less right. In note [2], Martine (op. cit.) quotes Harrison as suggesting helpfully that "to overcome partial views, we treat our familiar three factors – population, consumption, and technology – as the proximate, direct determinants of environmental use which influence each other and are influenced by other factors."

This last "insight", which it appears that Martine believes Harrison discovered in 1992 (and perhaps Harrison DID learn of it only then), is of course the perfectly obvious position that Ehrlich and I took when we first wrote about "IPAT" in 1971.

As for the proposition that "all of the different positions are correct", I must insist that when one position holds that only technology is important and another holds that technology, affluence, and population are all important, both positions are NOT correct; the first position is wrong, and the second one is right. Of course, Martine may be onto something when he writes that the debate has been partly due to "divergences of a theoretical-ideological character": Ehrlich and I hold to the theory that logical argument, getting one's sums right, and reading the references one cites are important principles in intellectual life; some of the other people in the debate evidently hold to the theory that these principles can be safely ignored.

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