

# Care to Wager Again? An Appraisal of Paul Ehrlich's Counterbet Offer to Julian Simon, Part 2: Critical Analysis

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*Objective.* This paper provides the first comprehensive assessment of the outcome of Paul Ehrlich's and Stephen Schneider's counteroffer (1995) to economist Julian Simon following Ehrlich's loss in the famous Ehrlich-Simon wager on economic growth and the price of natural resources (1980-1990). Our main conclusion in a previous article is that, for indicators that can be measured satisfactorily or can be inferred from proxies, the outcome favors Ehrlich-Schneider in the first decade following their offer. This second article extends the timeline towards the present time period to examine the long-term trends of each indicator and proxy, and assesses the reasons invoked by Simon to refuse the bet. *Methods.* Literature review, data gathering, and critical assessment of the indicators and proxies suggested or implied by Ehrlich and Schneider. Critical assessment of Simon's reasons for rejecting the bet. Data gathering for his alternative indicators. *Results.* For indicators that can be measured directly, the balance of the outcomes favors the Ehrlich-Schneider claims for the initial ten-year period. Extending the timeline and accounting for the measurement limitations or dubious relevance of many of their indicators, however, shifts the balance of the evidence towards Simon's perspective. *Conclusion.* The fact that Ehrlich and Schneider's own choice of indicators yielded mixed results in the long run, coupled with the fact that Simon's preferred indicators of direct human welfare yielded largely favorable outcomes is, in our opinion, sufficient to claim that Simon's optimistic perspective was largely validated.

In 1995, eco-pessimist Stanford biology professors Paul R. Ehrlich and Stephen Schneider offered optimist economist Julian Simon a 10-year wager based on a set of "indirect measures" of environmental conditions and human health indicators. Simon declined the proposal, claiming it lacked direct and objectively measurable connections to human welfare. Ehrlich and his supporters have since used Simon's rejection of their offer as a way to undermine his analysis. Part 1 of this article provided the first comprehensive assessment of the outcome of the Ehrlich-Schneider wager. Its conclusion was that, for indicators that can be measured satisfactorily or can be inferred from (more or less adequate) proxies, the outcome favored Ehrlich and Schneider's perspective. In this follow-up article, we extend the timeline of Ehrlich and Schneider's indicators and proxies toward the present time period, discuss in more detail their limitations and problems with their interpretation, and assess Julian Simon's proposed alternatives to this wager. In doing so, we suggest that the evidence shifts toward Simon's perspective.

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In Part 1 of this two-paper set, we analyzed the outcomes of the 1995 wager offered to the optimist economist Julian Simon by the eco-pessimist Stanford biology professors Paul R. Ehrlich and Stephen Schneider. Unlike Simon, who had left the choice of commodities and time period to his opponents in the famous 1980 bet, Ehrlich and Schneider selected all the indirect measures of environmental conditions, human health indicators, and time period (Table 1).

Simon declined their proposal, claiming it lacked direct and objectively measurable connections to human welfare. He also suggested a few alternatives that, he argued, met this criterion. Ehrlich and his supporters have since used Simon's rejection of their offer to undermine his broader analysis of the environmental impact of population and economic growth.

Our assessment in Part 1 of this article set was that, on Ehrlich and Schneider's terms, Simon would have lost the bet by a wide margin. In this Part 2, we probe deeper into the counterwager by extending the timeline of indirect measures and proxies toward the present time period, discussing in more detail their limitations, and assessing Julian Simon's suggested alternative indicators. In doing so, we suggest that the balance of the evidence shifts the outcome toward Simon's perspective.

## **Extension of the Time Frame and Assessment of Indicators**

### ***Outcomes 1–5: Temperature and Atmosphere***

Extending the time horizon for claims related to the global average temperature and the atmospheric concentrations of various molecules does change the results somewhat. Claims 1 (global average temperature), 2 (atmospheric carbon dioxide), and 3 (atmospheric nitrous oxide) remain consistent with Ehrlich and Schneider's predicted trends (Tans and Keeling, n.d.; Environmental Protection Agency (EPA), 2016; World Meteorological Organization, 2014; Medhaug et al., 2017; Met Office Hadley Centre, 2020; NOAA CDR, 2020; NOAA ESRL, 2020; NOAA GISS, 2020). Extending the time horizon for tropospheric ozone (claim 4) and sulfur dioxide (claim 5) however, indicates or strongly suggests a trend reversal. With regard to tropospheric ozone, many observation posts discussed in Gaudel et al.'s (2018) exhaustive assessment of ozone concentration suggest improvements since 2000. It is hard to assess whether levels observed for 2014 by Gaudel et al. (2018) were *globally* below those for 1994, but tropospheric ozone concentrations show decreasing trends since 2000. By 2015, sulfur dioxide concentrations were significantly below those observed in 1995 on a global scale and began falling in East Asia in 2005 (Aas et al., 2019).

### ***Outcomes 6, 7, and 8: Agricultural Land and Commodities***

An extension of the time window to include the most recent data points does not change the trend with regard to per capita agricultural land (claims 6 and 7 on fertile cropland and agricultural soil per person), as the quantity of land under cultivation remained stable while population increased (FAO, 2020a; United Nations, 2016). The extension of the time window, however, gives Simon a win with regard to rice and wheat per person (claim 8) which, by 2016–2018, were, respectively, 5.91 percent above and virtually equal (0.0002 percent above) to their 1992–1994 levels (FAO, 2020a).

TABLE 1  
Terms of the Ehrlich-Schneider Counterwager

1. The three years 2002-2004 will on average be warmer than 1992-1994.
2. There will be more carbon dioxide in the atmosphere in 2004 than in 1994.
3. There will be more nitrous oxide in the atmosphere in 2004 than in 1994.
4. The concentration of ozone in the lower atmosphere (the troposphere) will be greater in 2004 than in 1994.
5. Emissions of the air pollutant sulfur dioxide in Asia will be significantly greater in 2004 than in 1994.
6. There will be less fertile cropland per person in 2004 than in 1994.
7. There will be less agricultural soil per person in 2004 than in 1994.
8. There will be on average less rice and wheat grown per person in 2002-2004 than in 1992-1994.
9. In developing nations there will be less firewood available per person in 2004 than in 1994.
10. The remaining area of virgin tropical moist forests will be significantly smaller in 2004 than in 1994.
11. The oceanic fisheries harvest per person will continue its downward trend and thus in 2004 will be smaller than in 1994.
12. There will be fewer plant and animal species still extant in 2004 than in 1994.
13. More people will die of AIDS in 2004 than did in 1994.
14. Between 1994 and 2004, sperm counts of human males will continue to decline and reproductive disorders will continue to increase.
15. The gap in wealth between the richest 10 percent of humanity and the poorest 10 percent will be greater in 2004 than in 1994.

SOURCE: Ehrlich and Ehrlich (1996:100-104).

TABLE 2  
Food Supply Per Capita, 1994–2017

Data set	2017	2004	1994
FAOSTAT, world (kcal supply/capita/day)	2,913	2,751	2,640
FAOSTAT, least developed countries (kcal supply/capita/day)	2,422	2,189	1,958

SOURCE: FAO (2020).

The most obvious criticism of Ehrlich and Schneider's choice of indicators is that in 1994 all advanced economies had less soil available per capita than a century before, yet food per capita had never been so abundant. Indeed, economic historians have documented improved yields per unit of agricultural land going back at least to the middle of the 19th century (Federico, 2008). Furthermore, one should not assume that declining availability of a particular commodity per capita signals greater scarcity rather than changing consumer tastes. For instance, out of the 71 foodstuffs tracked by the FAO for the period 1994–2004, the supply declined for 15, remained stable for 15, and increased for 38 (FAO, 2020a). In the period 1994–2011, the supply increased for 47 of these items. Worldwide, positive trends can be seen in the quantities of calories supplied per day per person over the 1994–2017 period, for both the world as a whole and in the least developed countries (Table 2).

Ehrlich and Schneider's claim that "less fertile cropland per person" and "less agricultural soil per person" are indicative of a crisis must ultimately be rooted in their belief in decreasing returns, a position consistent with their catastrophist outlook. Yet, the available evidence convincingly suggests long-standing increasing returns in agricultural production. Indeed, for the period of the counteroffer, the food supply has increased more rapidly than population, thus providing more calories per capita, while the quantity of land used to produce foodstuffs has remained virtually unchanged (Deaton, 2013). The History Database of the Global Environment (Klein Goldewijk et al., 2011) further suggests that agricultural land use per capita peaked in 3000 BCE, fell rapidly to the year zero, remained more or less stable thereafter until 1940. From 1940 to 2016, hectares per capita fell from 1.55 to 0.66 while the food supply grew rapidly.

Recent projections to 2050 by Ausubel, Wernick, and Waggoner (2013) further suggest a decline in the absolute amount of farmland needed to feed a larger population, a situation they labeled "peak farmland" that further allows considerable rewilding of much marginal agricultural lands (Ausubel, 2015). Alexandratos and Bruinsma (2012) are less optimistic than Ausubel et al. (2015) and project instead that arable land will increase to 2030 and stabilize thereafter to 2050. Others, such as Folberth et al. (2020), have devised ways of using high-yield agricultural practices to reduce current agricultural land use by 50 percent, including 40 percent in biodiversity hotspots. By definition, if peak farmland is reached, Ehrlich and Schneider would win in perpetuity with a growing or stable population even though this outcome would actually vindicate Simon's outlook.

***Outcomes 9 and 10: Firewood and Virgin Forests***

Extending the time window does not change the outcome on firewood per person in less developed countries (claim 9), for there has indeed been a decline in firewood production per capita in those regions and in “woodfuel ‘hotspots’ [... where] nearly 300 million people live with acute woodfuel scarcity” (Bailis et al., 2017:2). Reduced consumption of wood fuel, however, is not necessarily problematic for both humanity and the environment as long as it is associated with increased prosperity and a fuel transition up the “energy ladder” from polluting biomass fuels (e.g., animal dung, crop residues, wood), which are inconvenient, inefficient, and severely harmful to human health (Bruce, Perez-Padilla, and Albalak, 2000). Various authorities in developing nations have long tried to reduce pressures on forests caused by subsistence-scale firewood procurement (World Resources Institute, 2003). Typically, however, a transition to more efficient and less polluting energy sources such as carbon fuels occurs spontaneously with greater material affluence (Goklany, 2009). Until, or whether, such a transition occurs in the world’s poorest regions, the demand for fuelwood is expected to increase with increasing population and income (FAO, 2010).

It seems legitimate to ask why Ehrlich and Schneider did not assume, or at least make allowances for, the fact that growing affluence in the developing world would facilitate beneficial energy choices and transitions. Indeed, FAO (2010) acknowledged that the overall exploitation of forests worldwide has shifted from production to conservation, reaffirming Simon’s prediction that prosperity and innovation would extend and ultimately spare natural resources.

Using the proxy of tropical forest area loss since the 1990s does hand the long-term win for claim 10 to Ehrlich and Schneider on the remaining area of virgin tropical moist forests. As Song et al. (2018:639) stated, however, “contrary to the prevailing view that forest area has declined globally—tree cover has increased by 2.24 million km<sup>2</sup> (+7.1% relative to the 1982 level). This overall net gain is the result of a net loss in the tropics being outweighed by a net gain in the extratropics.” Thus, the long-term trend for the “virgin” moist forest area is that of a moderate decline in the tropical areas, including the Amazon, but a decline that has been outweighed by afforestation in other areas of the world.

Furthermore, Ehrlich and Schneider’s concept of “virgin” tropical moist forests is highly contentious in light of recent scholarship that documents past human disturbances of ecosystems once considered untouched by human activities (Williams, 2008; Heckenberger and Neves, 2009; Levis et al., 2017; Lombardo et al., 2020). In the words of botanist Knut Faegri (1988:1–2), apart from “some small and doubtful exceptions, all vegetation types were created or modified by man.”

Much of the Amazon basin is thus now considered to be the recent rewilding of once massive orchards made up of hundreds of different crops of fruit, and palm and nut trees domesticated, planted and maintained by significant indigenous populations decimated by European diseases and conquest a few centuries ago. Indigenous Amazonian agriculturalists profoundly altered local tree compositions and densities but also their genetic makeup (Heckenberger and Neves, 2009). The development of domesticated tree varieties paralleled the transformation of wild wheat varieties into domesticated ones (Heckenberger and Neves, 2009). Native agriculturalists also created the so-called fertile Amazonian (anthropogenic) Dark Earths (Golińska, 2014; Heckenberger et al., 2008) that allowed “garden city” agriculture to flourish (Heckenberger et al., 2008). The lead author of another recent Amazonian study thus declared: “This is Amazonia, this is one of these places that a few years ago we thought to be like a virgin forest, an untouched environment. Now

we're finding this evidence that people were living there 10,500 years ago, and they started practising cultivation" (quoted in McGrath, 2020). "The 'natural' landscapes of preceding generations," Faegri (1988:1–2) explained, "are now understood for what they really are: relics of earlier types of land-use [...] By abandoning these methods and discontinuing traditional land-use, the landscape was left to regenerate in response to other uses or non-use." In other words, the notion of "virgin" forest in most parts of the world, particularly in the Amazon, has been shown to be inaccurate.

Ehrlich and Schneider's professed rationale for including the reduction in virgin tropical moist forest area was these forests' function as a repository of genetic material for pharmaceutical research. "Biodiversity prospecting" is the practice of broadly surveying genetic and biochemical materials for potential commercial value (Simpson, 1997:12). The marginal value, or the incremental benefit, of additional species would be high if there were no substitutes for their biochemical properties (Craft and Simpson, 2001; Simpson, 1997). In nature, however, many species are capable of producing similar chemical compounds: "[S]pecies are very likely to prove redundant when there are large numbers from which to choose for testing" (Simpson, 1997:13). Commercial pharmaceutical research is not the best rationale for biodiversity preservation and valuation (Costello and Ward, 2006; Craft and Simpson, 2001; Simpson, 1997). In fact, Bartkowski noted (2016:1): "the overall picture drawn by available biodiversity valuation studies is rather inconsistent."

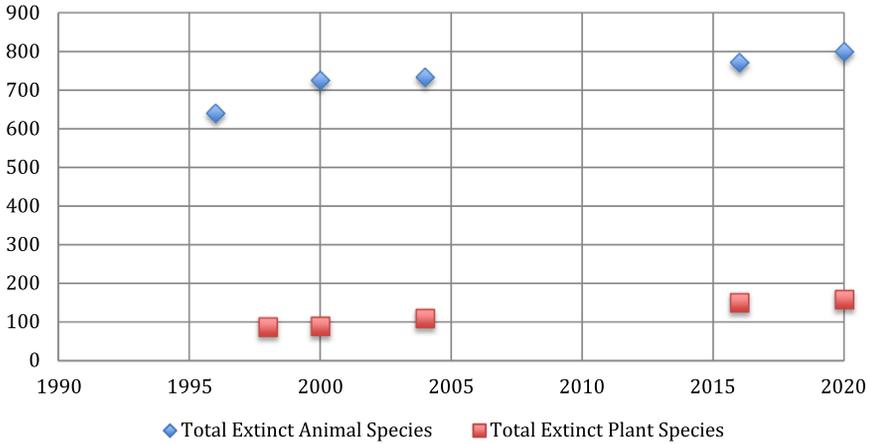
In the end, "peak farmland," a global move up the energy ladder, and sustainable wood fuel management have set the stage for a global forest expansion as a result of greater agricultural productivity releasing marginal agricultural lands, improved management of timber lands and the creation of tree farms, better use of wood as a material, the development of substitute products from hydrocarbons, and afforestation and reforestation initiatives (Kauppi et al., 2006).

### ***Outcome 11: Fisheries***

As predicted by Ehrlich and Schneider, oceanic fisheries harvest per person (claim 11) have continued their downward trend since 1994 as oceanic capture has remained relatively constant during a time of population growth (FAO, 2020b). Yet in the last three decades the world has also witnessed a continuous increase in the quantity of aquatic, fish, and seafood products supplied per capita. This outcome can be explained by the development of aquaculture that increased the total supply, in tonnes per capita, by 7.6 percent from 1994 to 2004 and 26.5 percent from 1994 to 2015 (FAO, 2020b). In 2014, for the first time in human history the aquaculture sector's supply of fish for human consumption overtook that of wild fish (FAO, 2016: 2). As a result, the world per capita "fish supply reached a new record high of 20 kg in 2014" because of "vigorous growth in aquaculture, which now provides half of all fish for human consumption," and a "slight improvement in the state of certain fish stocks due to improved fisheries management" (FAO, 2016:ii). According to Gentry et al., (2017:1317), the potential for growth in aquaculture remains significant.

Even after applying substantial constraints based on existing ocean uses and limitations, we find vast areas in nearly every coastal country that are suitable for aquaculture. The development potential far exceeds the space required to meet foreseeable seafood demand; indeed, the current total landings of all wild-capture fisheries could be produced using less than 0.015 percent of the global ocean area (Gentry et al., 2017:1317).

FIGURE 1  
IUCN 1996 Through 2020 Species Extinctions



SOURCE: Baillie et al. (2004) and IUCN (2016, 2020).

While a number of fish species or populations are still under stress, many have stabilized or rebounded so that there are signs of long-run improvements that are globally favorable to Simon but have not yet handed him a victory (FAO, 2016).

**Outcome 12: Biodiversity**

As discussed in Part 1 of this two-paper set, Ehrlich and Schneider’s claim on “fewer plant and animal species still extant” (claim 12) is extremely difficult to assess. Simon had a long-standing interest in this topic (Simon and Wildavsky, 1995). The issues surrounding the drivers and measurement of plant and animal species extinction are also very complex. Some of these, including pollution, overharvest, habitat conversion, and the introduction of invasive species, are directly related to various economic activities (Young et al., 2016:339). Much evidence also suggests that several areas in developed countries are seeing recovery in biodiversity which, while too small to compensate for the losses elsewhere, are nevertheless significant (Primack et al., 2018; Vellend et al., 2017; Elahi et al., 2015; Moreno-Mateos et al., 2017).

The biodiversity expert Nigel E. Stork’s work is particularly relevant to this discussion as his early efforts were set against the backdrop of Ehrlich and Ehrlich’s (1981) book *Extinction: The Causes and Consequences of the Disappearance of Species*. Stork noted that not knowing precisely the total number of animal and plant species at any given time makes conservation and accountability difficult, especially in light of the Ehrlichs’ spectacular short-term extinction claims (Stork, 1993).

Using the IUCN Red List data, we have shown that approximately 1.5 percent of species known to science have become extinct in the 20 years since IUCN started keeping records. Extinctions are not increasing in an unbounded fashion, however, as seen in Figure 1, where we have included the 2016 and 2020 IUCN data for context.

The cumulative extinction of approximately 1.4 percent of all IUCN characterized species in 2015 is on the order of magnitude of estimates listed by Stork (2010).

Extinction rates reported by Ceballos et al. (2015) confirm the estimates we have provided: A conservative number for mammal extinctions is 1.4 percent of IUCN evaluated species (Ceballos et al., 2015:e1400253) for the time period of 1900–2014, and a conservative number for other vertebrates is 0.5 percent of IUCN evaluated species (Ceballos et al., 2015:e1400253) for the same time period. Interestingly, Ehrlich, a co-author of the Ceballos et al. (2015) study, did not study extinctions over short time spans such as the decade stipulated in the counterwager (1994–2004). Instead, the Ceballos et al. (2015) authors plotted extinction rates in increments of whole centuries. Clearly, comparing extinction rates over a short time scale and with so little knowledge of actual species numbers is, and was in 1994, a poorly posed problem.

While it appears that Ehrlich's (1981) predictions of a 25–50 percent reduction in species by 2011 have been exaggerated, others are now raising similar warnings (Barnosky et al., 2011; Ceballos et al., 2015; Pimm et al., 2014). Current alarm is over group extinction rates compared to background extinction rates. Pimm et al. (2014:1246752-1) explained that “given the uncertainties in species numbers and that only a few percent of species are assessed for their extinction risk, we express extinction rates as fractions of species going extinct over time—extinctions per million species-years (E/MSY) — rather than as absolute numbers.” A current extinction rate, once calculated, is then compared to a background extinction rate based on the fossil record (Pimm et al., 2014).

Barnosky et al. (2011:52) defined the concept of the extinction rate as: “[...] essentially the number of extinctions divided by the time over which the extinctions occurred.” Background rates of between 0.1 and 2 E/MSY have been reported (Barnosky et al., 2011; Pimm et al., 2014; Ceballos et al., 2015.), yet they were computed over thousands if not millions of years for species, or more often genera, that had left intelligible fossil traces (Barnosky et al., 2011). Their use as valid background rates for all species has been discussed and challenged even by Barnosky et al. (2011). In fact, Barnosky et al. (2011:52) listed a number of issues concerning extinction rate calculations under the heading “Severe data comparison problems.” These issues included the uneven geographic distribution of the fossil record; limited selection of taxa, both fossil and extant, available for comparative study; time spans available for comparisons, extending from millions or hundreds of millions of years for the fossil record, but not more than 500 years for extant species; and species-level versus taxon-level extinction assessments (Barnosky et al., 2011). Barnosky et al. (2011) have thus hinted at the fact that too often rate comparisons may end up comparing apples (genera-based rates over very long periods) to oranges (species-based rates over geologically negligible time periods).

The species versus taxon or genus level assessment is a particularly important problem: “Analyses of fossils are often done at the level of genus rather than species. [...] This can result in lumping species together that are distinct” (Barnosky et al., 2011:52). What, thus, would be the comparable genus-level extinction rates from the fossil record? Pimm et al. (2014:1246752-2) have noted that “For mammals, the rate is ~100 extinctions of genera per million genera years (13) and ~60 extinctions for birds.” Current extinction rates of various taxonomic groups such as mammals or birds have been reported as varying from 107 E/MSY for amphibians to 243 E/MSY for mammals (Barnosky et al., 2011:53; Pimm et al., 2014:1246752-2). Modern species or taxon level extinction rates are thus of the same order of magnitude as fossil record genera level extinction rates. Alarm over these high numbers has prompted article titles such as “Entering the sixth mass extinction” (Ceballos et al., 2015) and “Has the Earth's sixth mass extinction already arrived?” (Barnosky et al., 2011). However, the extinction rates presented in these articles are the projected current species-level extinction rates based on endangered, not extinct, species numbers. Only such

extrapolated rates exceed the “normal (non-anthropogenic) range of variance in extinction rate” (Barnosky et al., 2011:54).

Calculations of current extinction rates take into account the ratio of extinct species to known species multiplied by the number of years the species have been known. It is sufficient to use conservative counts of known species of a taxon or grouping, and a short timespan over which the individual species have been known (a common average, in Pimm et al., 2014) is only 80 years, despite the fact that most species have been known much longer) to see how sensitive these extinction rate calculations are to the exact numbers used. Let us illustrate these sensitivities using an example of avian extinctions developed by Pimm et al., (2014:1246752-1): 1,230 known bird species, each of which has been known, on average, for 80 years, give 98,334 species-years. With 13 species extinctions for this group, the extinction rate is  $13/98,334 \times 1,000,000 = 132$  E/MSY, the same order of magnitude as genera-level fossil extinctions. If we knew 1,500 species (only 270, or 20 percent, more than we do) and if we knew them, on average, for just 100 years instead of 80, but we had lost 15, not 13, species, we would have an extinction rate of only  $15/(1,500 \times 100) \times 1,000,000 = 10$  E/MSY.

This new rate arrived at by increasing the number of species by 20 percent and the knowledge interval by 20 percent, while also increasing the extinction number by 15 percent, is an order of magnitude smaller than the currently reported extinction rate. What this exercise does show is that the measure adopted by many in the current extinction literature is easy to manipulate and exceedingly sensitive to the exact numerical values used. Moreover, reported without error bars, the E/MSY number projects a false sense of security.

Thus, upon closer scrutiny and cross-correlation between sources, current E/MSY extinction rates are on the same order of magnitude as fossil record genera-level rates reported by Pimm et al. (2014). They are also very sensitive to changes in the numerical values used to derive the E/MSY rates, values that, as in the human knowledge of the species interval, could be arbitrarily defined. For species correlated with human activity through the archaeological record, using knowledge intervals on the order of tens of years would be, in fact, misleading.

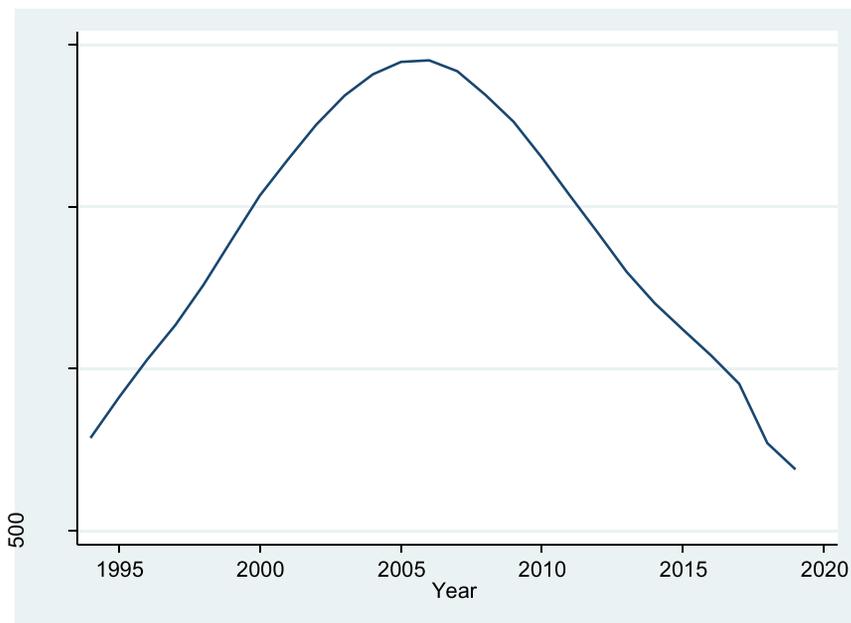
With species loss, the long-term outcome for claim 12 may even be in Simon's favor, as world species estimates are now reaching 8.7 million (Mora et al., 2011), with up to 86–91 percent of the insect and microorganism species still unknown to science, and the current extinction numbers increasing at rates still comparable to the non-anthropogenic rates established for fossil record genera.

### ***Outcome 13: AIDS***

Ehrlich and Schneider's choice of AIDS mortality statistics is one of the few counterwager claims not subject to interpretation. Since the peak of deaths in 2005, the annual number of deaths from AIDS shows a downward trend (Figure 2). By 2018, the number of world deaths due to HIV/AIDS returned below the level observed in 1994 (770,000 vs. 790,000) (UNAIDS, 2019) and further declined significantly the following year (690,000) (UNAIDS, 2020).

With the latest data available for 2018 and 2019, Simon would have won this claim as HIV/AIDS mortality adopted a noticeable downward trend after 2017, giving Simon the victory with 2018 data.

FIGURE 2  
Deaths from HIV/AIDS, World, 1994–2019



SOURCE: UNAIDS (2019, 2020).

### ***Outcome 14: Sperm Count***

As discussed in Part 1 of this two article set, sperm count assessments are difficult to conduct ethically and reliably (Daniels, 2006; Cooper et al., 2010; Levine et al., 2017) and have been subject to selection bias (Deonandan and Jaleel, 2012). Moreover, sperm counts vary by temperature and geography, by ethnic group, and in conjunction with different kinds of physical and mental activity (Daniels, 2006; Swan, Elkin, and Fenster, 2000). Possibly the most rigorous early systematic reviews, and subsequent reanalyses, of male fertility studies have been conducted by Shanna Swan, Eric Elkin, and Laura Fenster (Swan, Elkin, and Fenster, 1997, 2000). Swan, Elkin, and Fenster (2000) reevaluated 54 of the 61 studies presented by Carlsen et al. (1992), then added 47 studies conducted between 1934 and 1996, each studying at least ten men using reliable and consistent procedures. Swan, Elkin, and Fenster (2000) offered a comprehensive discussion concluding that from 1934 to 1996, sperm counts declined by 1.5 percent in the United States, by 3 percent in both Europe and Australia, but remained unchanged in the so-called “non-Western” or “other” countries (Swan, Elkin, and Fenster, 2000:961, 963). Others concurred, noting that “[...] the undersampling of rural and less affluent men from low-income countries[,] calls into question researchers’ claims of universally declining semen norms” (Deonandan and Jaleel, 2012:303).

Since 2000, a number of European studies confirmed the decline in sperm density and quality in Western European countries such as France (Burton, 2013; Rolland et al., 2013, on a sample of more than 26,000 men). Swan, Elkin, and Fenster (2000) have noted that

more studies addressing geographic variation in sperm counts and quality are needed to learn about the changes in male fertility and their underlying causes.

According to the population by world region data (Roser, Ritchie, and Ortiz-Ospina, 2020), in 1994 European and North American populations constituted 17.97 percent of the world total; in 2004 their share of global population fell to 16.29 percent. Thus, sperm count declining trends apply to at most, 18 percent of the world while they remain unknown for the majority of world populations (Swan, Elkin, and Fenster, 2000; Deonandan and Jaleel, 2012). As such, the outcome of claim 12 (sperm count) remains uncertain.

It may be worth noting, too, that the decline in sperm density and quality in Western European countries reported by Burton (2013), among others, is still not catastrophic as “the average estimated sperm count is still well above the level deemed normal by the World Health Organization” (Burton, 2013:A46). Swan, Elkin, and Fenster (2000:965) also noted that while much is made of the decline of sperm density and quality as an indicator of environmental decline, more work is needed before these issues are connected. Ongoing research confirms that this claim still cannot be settled globally, merely, with provisos, for certain well-studied heavily developed geographic areas.

### ***Outcome 15: Inequality***

After 2000, estimates of global wealth inequality are far superior to those available pre-2000 even if there are important debates over measurement methodologies. The World Inequality Lab (part of the WID.world project) is arguably the research group that has exerted the greatest effort in measuring inequality. The *World Inequality Report* which the World Inequality Lab publishes (Alvaredo et al., 2019) includes nonfinancial assets, unlike the Oxfam Project, but still falls short of recognizing the full value of the property owned by the poor, at least if one accepts de Soto's (2000) estimates. Since 2000, the level of wealth inequality appears stable, a finding that is confirmed by other sources regardless of whether one looks at the top decile or the top centile (Davies, Lluberas, and Shorrocks, 2017). Simon thus wins claim 15 as the gap in wealth between the richest 10 percent of humanity and the poorest 10 percent is not significantly greater in recent years than it was in 1994.

However, wealth inequality is a very problematic measure. Generous welfare states encourage lower savings rates as there are fewer incentives to accumulate wealth for a downturn (Feldstein, 1974; Kaymak and Poschke, 2016). Age composition of the population is quite crucial as older populations tend to have more accumulated wealth. Adjusting for age composition of the population leads to dramatically different levels *and* trends of inequality (Paglin, 1975; Almås and Mogstad, 2012; Almås, Havnes, and Mogstad, 2011, 2012). Inequality trends based on wealth are thus are subject to uncertainty.

What about other measures of inequality? There are two viable substitutes. The first is income inequality. On that front, there is a clear agreement amongst scholar that global income inequality has been falling (Sala-i-Martin, 2006; Liberati, 2015). The measures disagree on the extent of the decline, but they all trend downward; see Liberati (2015) for a review of existing measures of inequality. Sala-i-Martin (2006:384) points to changes in inequality between 1979 and 2000 that range between  $-2.6$  and  $-29.6$  percent. There is a key nuance to note here. There is rising inequality *within* numerous countries, especially western countries. However, there is falling inequality *between* countries, which dominates the effect of inequality within western countries.

The second measure is human development inequality, a number based on the human development index constructed by the United Nations. The index is created by weighting different components of well-being such as education, life expectancy, and income. Prados de la Escosura (2018) assembled historical data on these components for most countries going as far back as 1870 to create the index for countries. Using the populations of the different countries to weight each country, he created a distribution of human development inequality. With that index, he found that inequality has fallen by roughly a quarter between 1995 and 2015.

### ***The Tally of Outcomes After Extended Timeline and Analysis***

Table 3 provides the tally of the bet if the terms were extended to the most recent available data points. Simon would win three claims, with trends in two more clearly favoring his perspective, while Ehrlich and Schneider win nine. Three indicators remain uncertain. The word “problematic” refers to the use of proxy data when the concepts used by Ehrlich and Schneider did not have equivalents in the literature, or else when they can hardly be considered as supportive of the Ehrlich–Schneider worldview (e.g., land per capita).

### **Simon’s Rationale and Counterwager to the Second Bet Offer**

Simon offered three reasons for his rejection the second bet offer: the role of government policy; a personal version of the process more widely known as the environmental Kuznets curve; and the preference for direct measures of human welfare. The last of these reasons explains the indicators on which Simon proposed to wager a counterbet.

### ***Markets, Governments, and the Kuznets Curve***

The role of government policies and the environmental Kuznets curve are intimately tied to each other. In the 1980 bet, Simon insisted on betting on commodities that were not subjected to important government interventions (e.g., price control, quotas, trade, or production restrictions) to reflect his view that creative individuals in free markets are able to produce solutions to deal with environmental problems. Implicit in this outlook is the notion that government policies can hinder the ability of markets to provide environmental solutions. Thus environmental problems could be—as Simon often pointed out<sup>1</sup>—caused by governments meddling with markets or by governments failing to secure private property rights.<sup>2</sup> These interventions would further delay the inflexion point of the relationship between economic development and environmental quality, which

<sup>1</sup>For example, in discussing waste management in the *Ultimate Resource* Simon observed that governments had a role to play in the creation of “proper rules” that led to the internalization of externalities. However, he added that “crafting and legislating such rules is not easy” as the legislative process was bound to be subjected to intense pressure by interest groups who seek private gains from regulations whose costs is spread over large populations (1996:302).

<sup>2</sup>For example, Simon pointed out in *The Ultimate Resource* that the absence of property rights, not economic activity per se, was the greatest threat to fish stock preservation. Research on the role of property rights in allowing fisheries to recover confirms the plausibility of this view (Costello, Gaines and Lynham, 2008).

TABLE 3  
Outcome of the Ehrlich-Schneider 1995 Counterwager When Extended to the Most Recent Data

Ehrlich and Schneider's Indicators and Claims, 1994—Most Recent Year for Which Data Are Available	Can the Indicator Be Measured Satisfactorily?	Winner
1. Most recent years available will on average be warmer than 1992–1994	Yes	Ehrlich and Schneider
2. More carbon dioxide in atmosphere in most recent year available than in 1994	Yes	Ehrlich and Schneider
3. More nitrous oxide in atmosphere in most recent year available than in 1994	Yes	Ehrlich and Schneider
4. Concentration of ozone (troposphere) greater in most recent year available than 1994	No global data available	Uncertain (trend favors Simon)
5. Emissions of sulfur dioxide in Asia significantly greater in most recent year available than in 1994.	Yes	Ehrlich and Schneider (trend favors Simon)
6. Less fertile cropland per person in most recent year available than in 1994	Problematic, (proxy: farmland)	Ehrlich and Schneider
7. Less agricultural soil per person in most recent year available than in 1994	Problematic (proxy: farmland)	Ehrlich and Schneider
8. On average less rice and wheat grown per person in most recent year available than in 1992–1994	Yes/yes	Simon
9. In developing nations less firewood available per person in most recent year available than in 1994	Problematic (proxy: wood fuel harvest and production)	Ehrlich and Schneider

*Continued*

TABLE 3  
Continued

Ehrlich and Schneider's Indicators and Claims, 1994—Most Recent Year for Which Data Are Available	Can the Indicator Be Measured Satisfactorily?	Winner
10. Remaining area of <i>virgin</i> tropical moist forests <i>significantly</i> smaller in in most recent year available than in 1994	Problematic (proxies: humid tropical forest deforestation) Yes	Ehrlich and Schneider
11. Oceanic fisheries harvest per person will continue its downward trend and thus in most recent year available will be smaller than in 1994	Problematic (proxy: IUCN Red List; no reliable estimate of global species) Yes	Ehrlich and Schneider Uncertain
12. Fewer plant and animal species still extant in most recent year available than in 1994	No global data available	Simon (after 2018) Uncertain
13. More people will die of AIDS in most recent year available than did in 1994	No global data available	Simon
14. Between 1994 and most recent year available, sperm counts of human males will continue to decline	Problematic (incomplete data)	Simon: 3 Ehrlich and Schneider: 9 Uncertain: 3
15. The gap in wealth between the richest 10 percent of humanity and the poorest 10 percent will be greater in most recent year available than in 1994		
Tally		

means that indicators could deteriorate for a longer period of time until showing signs of improvement.

This viewpoint can be observed in claims 1 and 2 related to climate change. In this case, government subsidies to transport fuels will result in greater greenhouse gas emissions than would have otherwise been the case. Numerous studies have thus found that eliminating these subsidies would reduce worldwide greenhouse gases (GHG) emissions by somewhere between 5 and 36 percent (Larsen and Shah, 1992; Burniaux and Chateau, 2014; International Energy Agency and Organization of Economic Cooperation and Development, 2010; Stefanski, 2016). Thus, Simon's free-market arguments are not disproved by the bet's outcome.

Similarly, one can identify environmental Kuznets curve patterns with regard to ozone, sulfur dioxide, biodiversity and forest cover. For ozone and sulfur dioxide, the Kuznets-type curves suggest that the time period of the bet was ahead of the peak point. This means that if current developments continue, the ozone and sulfur dioxide outcomes will eventually favor Simon.

However, it is in the case of biodiversity that the interplay between government policies and the environmental Kuznets curve is most noticeable. Arrow et al. (1995) and Raymond (2004) pointed out that Kuznets-type relationships are rarer in situations where there are issues of national boundaries and costs spread out over multiple generations. The study of biodiversity is subject to such problems and often delivers mixed or contradictory results. Some studies thus fail to identify a statistically significant Environmental Kuznets Curve (EKC) inflexion point (Raymond, 2004; Asafu-Adjaye, 2003), while others do (McPherson and Nieswiadomy, 2005; Mills and Waite, 2009). What is particularly interesting about those papers is that their authors make the case that Kuznets-curve relationships need to be examined with a better understanding of the impact of existing institutional arrangements. When institutions are included and measured with Simon's preferred metric (the economic freedom index), the inflexion point is significant and occurs earlier (Pandit and Laband, 2009).<sup>3</sup> Simon was thus arguably correct to suggest that improvements would be forthcoming *conditional* on letting markets work and confining government actions to internalizing externalities.

Forest transition provides another illustration of this interplay between "good" institutions and the environmental Kuznets curve. Barbier (2019) thus points out that institutional quality, proxied by variables such as the enforcement of property rights, which are a key component of economic freedom indexes, can hasten forest recovery. In this, Barbier echoes other work suggesting the presence of a Kuznets curve with regard to forest cover (Cuaresma et al., 2017; Benedek and Fertő, 2020; Bhattarai and Hammig, 2001; Murtazashvili, Murtazashvili, and Salahodjaev, 2019). Also in line with Simon's worldview is that much evidence suggests that government ownership, mismanagement, and subsidies are major drivers of tropical deforestation while strengthening the land and resource rights of native populations typically results in both better stewardship and lower rates of deforestation (Stevens et al., 2014). The combination of these elements suggests that it is likely that, along with a better definition and strengthening of ownership rights, economic development will in time deliver a forest transition in which greater wealth and population numbers are correlated with an expansion of the forest cover in tropical regions.

<sup>3</sup>Using the IUCN's percentage of species in each country that were on the Red List of threatened species in 2004, Pandit and Laband (2009) found that initial increases in economic freedom led to greater proportions of species being lost. However, there was an early inflexion point, which suggested that, past that threshold, fewer and fewer species were threatened as economic freedom increased. The effect was statistically significant for mammals and vascular plants and income also had no statistically significant effects once economic freedom was controlled for.

### *Simon's Counterbet*

When he rejected Ehrlich and Schneider's offer, Simon stated he would rather use "measures of actual welfare, rather than intermediate conditions." Without formally proposing a new bet, Simon (n.d.) suggested some indicators on which he would be willing to wager: "mortality and morbidity," "life expectancy," "future calorie intake, food prices, or food output," "fish consumption which includes (...) fish farming" and "skin cancer death" (to reflect ozone-related problems).

Shifting to these indicators gives Simon's a clear win. For example, in Table 2 we already showed that the overall food supply (measured in calories per capita) has increased over the time window of the bet, which explains why global indicators of malnutrition have shown marked improvements in recent decades (Roser and Ritchie, 2013). Life expectancy at birth rose from 66.1 years in 1994 to 68.7 in 2004 and 72.6 in 2018 (World Bank, 2020). When wild catch and aquaculture fisheries are added to each other, fish consumption per capita increased 7 percent from 1994 to 2004 and a further 17 percent to 2015 (FAO, 2020b). Simon would only lose with regard to one of his proposed indicators: skin cancer rates which, when age-standardized, have increased mildly since 1995 (IHME, 2020).<sup>4</sup>

### **Reflective Conclusion**

Because of the nature of their original bet, the debate between Ehrlich and Simon is often mistakenly reduced to the nominal price and future availability of natural resources while the true object of the debate was human welfare and its relation to the environment. To Paul Ehrlich, any increase in population numbers and well-being were ultimately unsustainable because of the finite nature and limited carrying capacity of our environment. His counteroffer reflects this view. To Simon, markets and population growth provide solutions to environmental problems *conditional* on "good" institutions. In a certain way, even though it was never accepted, the second bet offers deeper insights into the complex views of both Ehrlich and Simon and those who follow in their footsteps.

On its own terms, the second bet is a victory for Ehrlich (and Schneider) in spite of numerous uncertainties regarding some indicators. Even when the time horizon is extended, Simon loses to Ehrlich and Schneider. Yet, Ehrlich and Schneider's claims on topics such as fertile cropland, agricultural soil, and fuelwood per capita, while correct, can arguably be interpreted as actual evidence of environmental improvement.

Simon's key priority and main contribution to the environmental debate was the assembling and communication of data. His critique of the proposed second bet, however, also highlighted another component of his worldview that was often downplayed or ignored by his critics, that is, the crucial role that institutions play in determining the relationship between the environment and economic development. As economist Mokyr (2003:60) pointed out: "what seem to be failures of technology are often the failures of institutions." Simon thus occasionally expressed the view that many real environmental problems were caused in large part by poorly secured property rights, high barriers to entrepreneurial activity, and government interventions that distort price signals. As such, they often had little if anything to do with anthropogenic pressures on a limited stock of resources and fragile ecosystems.

<sup>4</sup>In 1994, the age-standardized death rates for nonmelanoma skin cancer rose from 0.821 per 100,000 to 0.826 per 100,000 in 2004 to 0.849 in 2017 (IHME, 2020).

In the end, we do not doubt that both Simon and Ehrlich shared the same goals of improving human standards of living and reducing pressures on ecosystems. Their visions to achieve these outcomes, however, were almost completely opposite. The fact that Ehrlich and Schneider's own choice of indicators yielded mixed results in the long run, coupled with the fact that Simon's preferred indicators of direct human welfare yielded largely favorable outcomes is, in our opinion, sufficient to claim that Simon's optimistic perspective was once again largely validated.

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