Economics in the Anthropocene:

Species Extinction or Steady State Economics.

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Shortened version prepared for the First North-South Conference on Degrowth-Decrecimiento, Mexico City, September 3rd-7th, 2018

At the dawn of the Anthropocene, continued economic growth carries the risk of irreversibly damaging the global carrying capacity for human activity. Using IUCN Red List of Threatened Species data (2016), I calculate an expected extinction rate during the coming century for 538 regions. I show that these rates exceed the planetary boundary formulated by Rockström et al. (2009) virtually everywhere and increase with population density and GDP per capita. In doing so, this paper addresses an ongoing debate whether absolute or relative scarcity is relevant to economic thought. My findings suggest that the conservation of nature requires a transition to degrowth or steady state economics.

"*I cannot, therefore, regard the stationary state of capital and wealth with the unaffected aversion so generally manifested towards it by political economists of the old school. I am inclined to believe that it would be, on the whole, a very considerable improvement on our present condition.*"

John S. Mill (1848, Book 4, Chapter 6)

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1. Introduction

The Anthropocene refers to the geological epoch during which mankind has obtained an influence over global natural processes (Crutzen, 2002). In response, Rockström et al. (2009) formulate planetary boundaries for economic activity and assign parameter values to eight such ecological limits. Currently, we surpass three safe thresholds: Climate change, biodiversity loss, and our influence over the nitrogen cycle. Naturally, the idea that economic growth can only be a transitory stage is not new to economics (Malthus, 1798; Mill, 1848). Daly (1974) already reasoned for the desirability and necessity of steady state economics based on common sense and the second law of thermodynamics. The accumulated evidence that continued economic growth could seriously harm global carrying capacity makes a paradigm shift to steady state economics urgent as well.[1]

This paper concentrates on biodiversity loss. Reductions in biodiversity impair global carrying capacity through reduced ecosystem efficiency and resilience, increased risks of infectious diseases, and for many, lower immaterial value. Background extinction due to natural selection is thought to lie between 0.1 and 1 extinctions per million species years (E/MSY) (Pimm et al., 2014). Rockström et al. (2009) set the planetary boundary for biodiversity loss at 10 E/MSY and Steffen et al. (2015) add a zone of uncertainty up to 100 E/MSY. The current extinction rate is estimated to lie between 100 and 1000 E/MSY (Pimm et al., 2014).

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[1] This paper follows Daly (2013)'s recommendation to distinguish between economic growth and development. A steady state economy does not allow for quantitative growth of wealth, but does leave room for development, i.e., qualitative improvements obtained from this wealth.

2. Data and Analysis

The IUCN Redlist of Threatened Species contains assessments of extinction threat levels for both plant and animal species based on population size, habitat range and estimated extinction risk. This paper uses the 2016-2 version that contains 82,954 assessments, categorized as either least concern (39,053), data deficient (13,489), vulnerable (11,219), endangered (7,602), near threatened (5,323), critically endangered (5,107), extinct (855), lower risk/conservation dependent (238), or extinct in the wild (68). Most of the assessments are carried out by an IUCN Species Survival Commission, and all assessment are reviewed by a member of the Red List Authority on the relevant taxonomic group. Close to 70 percent has been (re-)assessed after 2010.

To construct my measure for expected species extinction, I assume that the sufficiency criterion about extinction risks is a valid estimate for the extinction risk for all assessments within the category. For critically endangered species, the extinction risk criterion specifies a probability of extinction of at least 50% during the coming 10 years, and for endangered and vulnerable species 20% and 10% within 20 and 100 years, respectively (IUCN, 2012).[2] I add the expected background extinctions by multiplying the number of non-extinct non-data deficient assessed species with the upper bound estimate for background extinction of 1 E/MSY.

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[2] I further assume that (critically) endangered species that managed to survive (ten) twenty years will continue to do so for the remainder of the century. Assuming that (critically) endangered species that survive (ten) twenty years face an unchanged extinction risk, would more than double the global extinction rate estimate and imply that less than one in thousand critically endangered species survives the century.

Finally, I express this estimate for expected extinctions relative to this background extinction to create my dependent variable, heightened *Extinction Rate*. Globally, the extinction rate is 759 times the background extinction rate.[3] To calculate the regional estimates, I only consider the assessments of species that were labelled as (once) native to the respective regions. I do so 538 regions, covering 98% of global land surface. Note that, although I refer to regional estimates, I still base my estimates on global extinction risk. For example, the Giant Panda which is assessed as vulnerable and regionally extinct in Hunan, still contributes to the extinction rate of Hunan, because it is labelled as once native to the region.

Figure 1 presents the distribution of *Extinction Rate* geographically. The 17 regions in the dark green color stay below the planetary boundary for biodiversity loss, representing 2.6 percent of assessed land area. The 192 regions in the zone of uncertainty are depicted in light green and yellow and make up 45.9 percent of assessed land. Due to the positive skew in the regional estimates, I chose different bin sizes for the different colors and use the logarithm of *Extinction Rate* in the regression analysis. For population density and GDP per capita, I used the most recent estimates

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[3] This estimate of 759 consists of the expected number extinctions due to heightened extinction risk, 5,195.8 (=0.5*5,107+0.2*7,602+0.1*11,219) plus 6.852 background extinctions (=1*(82,954–855–86–13,489)* 100/1,000,000) relative to the 6.852 background extinction. Using the lower bound for background extinction gives an expected rate of 7582 times the background rate. In the remainder of the paper, I discuss the estimates expressed relative to the upper bound estimate for background extinction.

from the World Bank for most countries, complemented with regional estimates from various sources. Both population density and GDP per capita exhibit a large positive skew as well, hence I use *Ln Population Density* and *Ln GDP per Capita* in the regression analysis. The number of observations for the population density variable drops to 528 (due to the omission 10 uninhabited islands after the log transformation). I found estimates of the *GDP per Capita* for 489 regions. In the regression analysis, I control for land surface and add 14 dummies to control for (sub)continental variation and whether regions are islands or landlocked.

Figure 1: Geographical distribution of *Extinction Rate*.

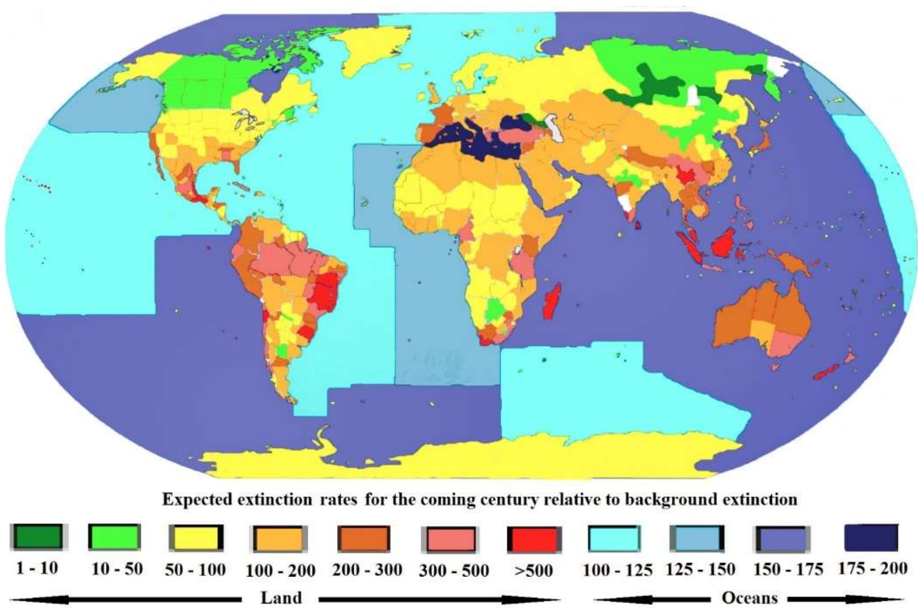

Table 1 presents the OLS regression results of regressing my extinction rate measure on population density in (1), and subsequently on population density and GDP per capita in (2) due to the different number of observations for both variables. Column (1) and (2) of Table 1 show that a doubling of population density is associated with an increase in the extinction rate of 11.2 percent, and of 15.6 percent after controlling for

GDP per capita in the smaller sample, respectively. These estimates are statistically significant at the 1 percent level. GDP per capita is also positively related to the extinction rate (*p-value* = 0.035), where a doubling is associated with an increase of 8.3 percent.[4]

Table 1: OLS regression results

	(1)	(2)
Ln Population Density	.112**	.156**
	(.025)	(.027)
Ln GDP per Capita		.083*
		(.039)
N	528	489
F-statistic[a]	20.86**	18.03**

**, * indicate coefficients significantly different from zero at the 1% and 5%, standard errors are shown in parentheses.

a. Comparison to a model that contains only the control variables.

Although partial correlations do not allow for causal inference of an effect of human activity on species extinction, to put these estimates in perspective, the expected global population increase from 7.3 billion to the UN estimate of 11.2 billion by the end of the century would raise the extinction rate with 8.3 percent (United Nations, 2015). For the current number of assessed species, this is equivalent to 432 additional expected extinctions, about half the number of recorded during the past millennium.[5]

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[4] The results are robust to clustering standard errors on the (sub)continental level, see Sol (2018). If anything, I expect my estimates to suffer from downward attenuation bias due regional spillovers.

[5] The global extinction rate would be raised from 759 to 822, or an additional 63 times the background extinction of 6.9 species. For some of

3. Discussion and Conclusions

While I do consider the regional variation in expected extinction rates that I illustrate in this paper informative, I caution the reader to base conservation priorities solely on these rates. In terms of the library metaphor in Weitzman (1998)'s Noah's Ark problem, the expected extinction rates could be considered the survival probability of a library, but not the number of books in the library (i.e., species richness) nor their distinctiveness (i.e., species' isolation on a phylogenetic tree). For maps of species richness and genetic diversity, see e.g. Jenkins, Pimm, and Joppa (2013) and Miraldo et al. (2014), respectively. To the best of my knowledge, this paper is first to map expected species extinction relative to expected background extinction.

According to the IUCN assessments, we may need to record more than five times the number of extinctions during the coming century than we did in the past millennium.[6] Continued growth of population and GDP per capita is likely to increase the number extinctions even further. Yet, economic growth oftentimes remains a celebrated means to reduce poverty and improve human welfare. We should realize, however, that continued growth comes at a collective cost, whereas reducing poverty through redistribution of income has less apparent ecological cost. Economic policy in the Anthropocene should aim to improve carrying capacity rather than zealously chase economic growth.

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the extinctions included in the IUCN data, the last observations date back from the 11th century (e.g., the Madagascan Dwarf Hippopotamus).

[6] The past millennium we have already experienced more extinctions than expected from background extinction only; based on the IUCN sample we would expect 83 extinctions during the last millennium instead of 855.

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