Implications of Changing Environmental Concerns and Carrying Capacity for Humankind Survival*

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Abstract

This paper argues that environmental concerns are intensified (diminished) as the quality of the environment falls below (rises above) a threshold and that Earth's carrying capacity is affected by the quality of the environment. The paper subsequently argues that, with no further technological, social, and international progress and with a non-optimally diminishing complacency, the global environment and its human population embark on a clockwise oscillating course leading to a unique interior steady state. This steady state's population is similar to the present one, but its environmental quality is slightly lower.

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1. Introduction

Studies of wildlife population's survival and management typically employ growth functions embodying fixed, exogenously determined carrying capacity (cf., Clark, 1976; Berck, 1979; Berck and Perloff, 1984; Horan and Bulte, 2004). Unlike wildlife, the aggregate footprint of humans on Earth's environment is large and widespread. Excessive exploitation decreases Earth's carrying capacity, but also evokes concerns for the state of the environment and survival of the humankind. Whether the conflict between the environmentally damaging utilitarian desires and the concerns for the environment is resolved in survival, or extinction, of humans is the subject of this paper.

In their *Limits to Growth*, Meadows, Meadows, Randers and Behrens (1972) come to the conclusion that output-growth would likely not be impeded by lack of resources before it was impeded by severe pollution. Missing in their simulation model of the world is a link between pollution and pollution prevention. The rationale for such a link is growing concerns. Indeed, analyses of the Health of the Planet Survey, the World Values Survey and the International Social Survey Program indicate that during the last twenty years concerns for the environment have not only risen in rich countries as advocated by the affluence hypothesis (Diekmann and Franzen, 1999; Franzen, 2003), but also in poor ones (Inglehart, 1995, 1997; Dunlap, Gallup and Gallup, 1993; Dunlap and Mertig, 1997). Supporting arguments and evidence of rising environmental concerns are also given by studies of the Environmental Kuznets Curve including Shafik and Bandyopadhyay (1992), Selden and Song (1994), Grossman and Krueger (1995), Arrow et al. (1995), Chaudhuri and Pfaff (1998), Andreoni and Levinson (2001) and Chavas (2004).

In his *A Question of Balance,* Nordhaus (2008) provides an integrated assessment model for global warming by elaborately incorporating cost-benefit aspects of abatement of greenhouse gas emissions into Ramsey's (1928) prototype model of optimal economic growth. Unlike Meadows et al.'s *Limits to Growth* (1972), his DICE model has a feedback loop between the atmospheric carbon dioxide and abatement activities. With optimal aggregate feedback being assumed and, in view of the modest abatement costs estimated in the Intergovernmental Panel on Climate Change's Assessment Reports, environmental catastrophe is not predicted. However, as also admitted by Nordhaus' (1992) use of expressions such as "*idealized competitive markets*" and "*major leap of faith*" (p. 7, second paragraph), optimal aggregate emission abatement is neither a market realization nor the likely outcome of international negotiations.

The Earth's atmosphere and much of the contents of the Earth's surface and crust do not have the property of exclusivity: they belong to everyone and no one. Even nationally and privately held areas are subjected to trans-boundary pollution. Lack of exclusivity encourages free riding in sharing the costs of abatement activities. The larger the costs of abatement activities the stronger the inclination to free ride. Recalling Mendelsohn's (2008) arguments, the full costs of abatement activities are not modest. In which case, the real system of the environment and human population is likely to have a suboptimal feedback.

In the following sections we conduct a theoretical and empirical investigation of the possible joint course of the environment and human population and its implications for survival within a deterministic environment and population (E-P) model. Shocks (solar plasma bursts, volcanic eruptions, meteor collision and nuclear accidents) are ignored. We treat the whole biosphere as an open access resource and consider a Lotka (1925)-Volterra (1931) type of *ad hoc* feedback mechanism. In our E-P model, Earth's carrying capacity declines as the environment deteriorates and the intensity of the feedback is associated with the human population's aggregate level of environmental concerns. Exposure to environment that is different from a complacency threshold state changes awareness of the looming environmental-population mutual destruction and, consequently, the aggregate level of environmental concerns. Our investigation reveals that convergence to extinction is an unlikely scenario for the human race.

2. E-P model with changing carrying capacity and environmental concerns

Our E-P model comprises the motion equations of the physical environment and human population. While the size of Earth's physical environment is roughly fixed, the quality of Earth's environment (defined as the suitability of Earth's environment for human life) may vary over time. We denote Earth's quality adjusted physical environment by $E \in \mathbb{R}_+$ and the population of human beings by $P \in \mathbb{R}_+$.

We assume that the physical environment is naturally improved at any instance t in a manner that can be approximated by the following regeneration logistic function:

$$G_e(t) = g_e E(t)\left(1 - \frac{E(t)}{E_{\max}}\right) \quad (1)$$

where g_e and $E_{\max}$ are positive scalars representing the environment's intrinsic improvement (recovery) rate and the maximal quality adjusted physical environment, respectively.

We further assume that the weaker the humans' concerns for the physical environment, *ceteris paribus*, the larger their production and consumption footprints on the physical environment. We consider humans to be quality responsive: as the environment deteriorates, awareness of, and, in turn, concerns for, the state of the environment are intensified. These assumptions are displayed by the incorporation of a complacency threshold: a quality adjusted physical environment, E_{comp} ($E_{comp} < E_{\max}$), above (below) which the individual footprint (IFP) on the environment is larger (smaller) than a positive scalar β. We refer to β as the footprint-complacency coefficient. This feedback is represented by the following *ad hoc* behavioral rule:

$$IFP(t) = \beta \frac{E(t)}{E_{comp}}. \tag{2}$$

Since there are P people (identical, for tractability), each detracting IFP from the environmental stock, the change in the quality adjusted physical environment is:

$$\dot{E}(t) = G_e(t) - IFP(t)P(t) = g_e E(t)\left(1 - \frac{E(t)}{E_{\max}}\right) - \beta \frac{E(t)}{E_{comp}} P(t). \tag{3}$$

Due to the fixed size of Earth's physical environment, a carrying capacity is incorporated into the formalization of the human population growth. We assume that humans cannot prevail in a quality adjusted physical environment lower than E_{ext}. We refer to E_{ext} as the extinction threshold. We further assume that at any point in time the physical environment's carrying capacity of human population ($\hat{P}(t)$) rises with the current deviation of the quality adjusted physical environment from the extinction threshold, and that the rise is amplified by improvements in technology, healthcare, social interaction and international relations. For instance, higher environmental quality in the form of lower greenhouse-gas concentrations results in higher potential food production, which is further increased by improvements in cultivation methods, in farmers' information, cooperation, healthcare and property rights, and in national and international security and marketing opportunities. Consequently, we specify the physical environment's capacity to carry humans as:

$$\hat{P}(t) = (\alpha + \gamma t)[E(t) - E_{ext}] \quad (4)$$

where $\alpha > 0$ and $\gamma \geq 0$ are scalars. The term $(\alpha + \gamma t) > 0$ is the inverse of the stock of the extra (beyond the extinction threshold) quality adjusted environmental resources required for sustaining a human being. We assume that improvements in technology, healthcare, social capital and international cooperation reduce this per capita environmental stock. Hence, a continuous overall technological, healthcare, social and international cooperation progress is depicted by $\gamma > 0$, whereas stagnation is represented by $\gamma = 0$. Though not consider in this paper, $\gamma < 0$ is possible. In particular, international relations might deteriorate to a destructive conflict that more than offset the carrying-capacity gains from improvements in production and healthcare technologies. The positive scalar α can be interpreted as the inverse of the stock of the quality adjusted extra environmental resources required for sustaining a human being under a perpetual stagnation. By setting $t = 0$ in equation (4), $\alpha = \hat{P}_0 / (E_0 - E_{ext})$. The multiplicative specification reflects that, even in the presence of a continuous combined technological, healthcare, social and international relation progress, the carrying capacity of Earth might decline as the physical environment deteriorates and vanishes when the extinction threshold is reached.

By incorporating the said specification of the carrying capacity into a logistic growth function, $g_p P(t)[1 - P(t) / \hat{P}(t)]$, the motion-equation of the human population is:

$$\dot{P}(t) = g_p P(t)\left(1 - \frac{P(t)}{(\alpha + \gamma t)[E(t) - E_{ext}]}\right) \quad (5)$$

where g_p is a positive scalar indicating the human population's intrinsic growth rate.

The motion equations (3) and (5) constitute our E-P model. A continuous combined process of technological, healthcare, social and international relation improvements ($\gamma > 0$) renders this differential equation-system non-autonomous and hence precludes interior steady states in the E-P model. We ask whether such a multi-facet progress also prevents the E-P model from having a corner steady state – inhabitable planet. We claim that coupled with diminishing complacency it does. We support this claim by demonstrating that even in the absence of future technological, healthcare, social and international cooperation changes ($\gamma = 0$), the quality adjusted physical environment does not converge to E_{ext} and the human population is not driven to extinction, but rather converges to an interior steady state.

3. Unique, interior steady state in the absence of further progress

Recalling equations (3) and (5) and assuming that $\gamma = 0$, the isocline $\dot{E} = 0$ is given by $E = E_{\max} - [(\beta E_{\max})/(g_e E_{comp})]P$ and the isocline $\dot{P} = 0$ by $E = E_{ext} + (1/\alpha)P$. Since the intercept of the negatively sloped isocline $\dot{E} = 0$ is larger than the intercept of the positively sloped isocline $\dot{P} = 0$ these linear isoclines intersect one another once, and their intersection point is in the positive orthant of the $P - E$ plane. That is, in the absence of further technological, healthcare, social and international progress, or regression, there exists a unique, interior steady state.

The distance between the stationary quality adjusted physical environment and the extinction threshold is:

$$E^* - E_{ext} = \frac{1}{\alpha}\left(\frac{E_{\max} - E_{ext}}{\frac{1}{\alpha} + \frac{\beta / E_{comp}}{g_e / E_{\max}}} \right). \quad (6)$$

The stationary human population is:

$$P^* = \frac{E_{\max} - E_{ext}}{\frac{1}{\alpha} + \frac{\beta / E_{comp}}{g_e / E_{\max}}}. \quad (7)$$

Equations (6) and (7) suggest that as long as the lack of progress is not accompanied by absolute complacency ($E_{comp} = 0$) the stationary quality adjusted physical environment is better than the extinction threshold (E_{ext}) and, consequently, the stationary human population is not nil. The higher the population's complacency threshold (E_{comp}), the more distant the stationary quality of the physical environment from the extinction threshold and, due to a greater carrying capacity, the larger the stationary population of human beings. These equations also suggest that the stationary population and the stationary quality adjusted physical environment increase with the environment's intrinsic recovery rate (g_e) and the maximal quality adjusted physical environment ($E_{\max}$), and decrease with the footprint-complacency coefficient (β). The stationary population also decreases with the extinction threshold

(E_{ext}). The stationary population further decreases with the stock of the quality adjusted extra environmental resources required for sustaining a human being under perpetual stagnation ($1/\alpha$). As the subsequent positive effect of the population decline on the stationary quality of the environment can be dominated by the larger per capita requirement of environmental stock, $\partial(E^* - E_{ext})/\partial(1/\alpha) = \{1 - 1/[1/\alpha + \beta E_{\max}/g_e E_{comp}]\}P^*$ is not necessarily positive.

4. Is there convergence to the steady state?

In order to answer this question we evaluate the Jacobian of the E-P model's motion equations (3) and (5) with $\gamma = 0$ in the steady state indicated by (6) and (7):[1]

$$J = \begin{bmatrix} \partial\dot{E}(*)/\partial E & \partial\dot{E}(*)/\partial P \\ \partial\dot{P}(*)/\partial E & \partial\dot{P}(*)/\partial P \end{bmatrix} = \begin{bmatrix} [g_e - 2\frac{g_e}{E_{\max}}E^* - \frac{\beta}{E_{comp}}P^*] & -\frac{\beta}{E_{comp}}E^* \\ \alpha g_p & -g_p \end{bmatrix}. \quad (8)$$

The characteristic roots of this Jacobian are:

$$\lambda_{1,2} = 0.5\{g_e - [g_p + 2\frac{g_e}{E_{\max}}E^* + \beta\frac{P^*}{E_{comp}}] \pm \sqrt{\{g_e - [g_p + 2\frac{g_e}{E_{\max}}E^* + \frac{\beta}{E_{comp}}P^*]\}^2 + 4g_p[g_e - 2\frac{g_e}{E_{\max}}E^* - \frac{\beta}{E_{comp}}P^*] - 4\frac{\beta}{E_{comp}}E^*\alpha g_p} \quad .(9)$$

A priori, the signs of these characteristic roots are not clear. Yet insight about the possibility of convergence to steady state can be gained from the off-diagonal elements of the Jacobian. As $\partial\dot{E}(*)/\partial P = -\beta E^*/E_{comp} < 0$, the vertical arrows in the phases above (below) the isocline $\dot{E} = 0$ point downward (upward). As $\partial\dot{P}(*)/\partial E = \alpha g_p > 0$, the horizontal arrows point rightward (leftward) in the phases above (below) the isocline $\dot{P} = 0$. The directions of the horizontal and vertical arrows imply convergence to the steady state from any initial combination of population and quality adjusted physical environment along a clockwise spiraling trajectory, as displayed in Figure 1. To further investigate the possibility of such convergence, note that the discriminant in equation (9) can be expressed as:

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[1]Recalling that $E^* = E_{ext} + (1/\alpha)P^*$, $\partial\dot{P}/\partial E = \alpha g_p P^{*2}/[\alpha(E^* - E_{ext})]^2 = \alpha g_p$ and $\partial\dot{P}/\partial P = g_p - 2g_p P^*/[\alpha(E^* - E_{ext})] = -g_p$.

$$\Delta = (trJ)^2 + 4g_p(trJ + g_p) - 4\alpha\beta g_p(E^* / E_{comp})$$
$$= (trJ + 2g_p)^2 - 4\alpha\beta g_p(E^* / E_{comp}). \tag{10}$$

A converging spiral trajectory exists when $\Delta < 0$ and $trJ < 0$. From equation (10), $\Delta < 0$ as long as:

$$\frac{E^*}{E_{comp}} > \frac{(trJ + 2g_p)^2}{4\alpha\beta g_p}. \tag{11}$$

Recalling that

$$trJ = g_e - \left[g_p + 2g_e \frac{E^*}{E_{\max}} + \beta \frac{P^*}{E_{comp}} \right] \tag{12}$$

$trJ < 0$ as long as the ratio of the human population's intrinsic growth rate to the environment's intrinsic recovery rate satisfies the following inequality:

$$\frac{g_p}{g_e} > 1 - \left[2\frac{E^*}{E_{\max}} + (\beta / g_e)\frac{P^*}{E_{comp}} \right]. \tag{13}$$

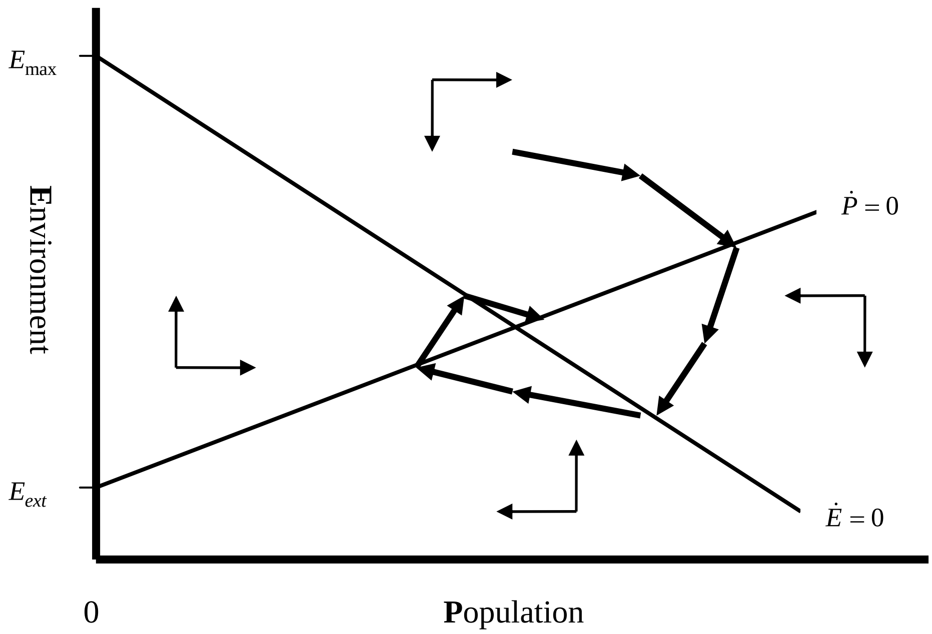

Figure 1. The E-P phase-plane diagram in the absence of progress

For quantifying the steady state of the E-P model without progress and examining its aforementioned asymptotic properties of convergence an estimation of the parameters of equations (3) and (5) is attempted. The estimation requires time-series observations on the world's population and state of environment. In the absence of data on the latter variable, we firstly construct an index of the state of the global environment with available observations on annual harmful emissions. Due to the prominence of the global warming problem our construction of the index of the state of the global environment is based on the principal greenhouse gas stock.

5. Carbon-dioxide based index of the state of the global environment

Approximately eighty percent of the total warming potential of the major greenhouse gases is due to Carbon Dioxide (Nordhaus, 1992). The World Development Indicators (WDI, The World Bank Group, 2007) include forty-six observations on the world's annual emissions of carbon dioxide (q) between 1960 and 2005. Complete time-series on the other greenhouse gases are not available. Consequently, our index of the state of the global environment is based on the concentration of carbon dioxide in the atmosphere.

In assessing the undocumented global stock of atmospheric carbon dioxide (Q) in each of the aforementioned years, the following law of motion is assumed:

$$Q_t - (1-\delta)Q_{t-1} = q_t \qquad (14)$$

for every $t = 1, 2, 3, ..., 46$ with $\delta > 0$ denoting a time-invariant annual rate of natural depletion of atmospheric carbon dioxide. By induction,

$$Q_t = (1-\delta)^t Q_0 + \sum_{j=0}^{t-1} (1-\delta)^j q_{t-j} \qquad (15)$$

where, Q_0 is the 1959 global stock of atmospheric carbon dioxide. Taking this initial stock as a benchmark,

$$\hat{E}_t = \frac{Q_0}{Q_t} = \frac{Q_0}{(1-\delta)^t Q_0 + \sum_{j=1}^{t} (1-\delta)^j q_{t-j}} \qquad (16)$$

is proposed as an indicator of the state of the global environment. As can be seen from the second column in Table 1, the aggregate emissions of carbon dioxide have strongly risen since 1962. It can be expected that they have dominated the natural annual depletion and rendered $0 < \hat{E} < 1$ over the period 1962 to 2005.

The 1959 global stock of atmospheric carbon dioxide is unknown. Recalling equation (14), $Q_2 - Q_1 = -\delta(1-\delta)Q_0 - \delta q_1 + q_2$. Let $Q_2 - Q_1 = \theta q_2$, then

$Q_0 = [(1-\theta)q_2 - \delta q_1]/[\delta(1-\delta)]$, where $\theta < 1$ is an unknown scalar. The substitution of this expression into (16) renders the proposed index as:

$$\hat{E}_t = \frac{\dfrac{(1-\theta)q_2 - \delta q_1}{\delta(1-\delta)}}{(1-\delta)^{t-1}[(1-\theta)q_2/\delta - q_1] + \sum_{j=1}^{t}(1-\delta)^j q_{t-j}} \qquad (17)$$

where 1960 is year 1 and 1961 is year 2. The computation of this index of the state of the environment with annual carbon-dioxide emission figures depends on the values of δ and θ.

Our choice of δ is based on Forster et al. (2007):

> "Since 1750, it is estimated that about 2/3rds of anthropogenic CO_2 emissions have come from fossil fuel burning and about 1/3rd from land use change. About 45% of this CO_2 has remained in the atmosphere, while about 30% has been taken up by the oceans and the remainder has been taken up by the terrestrial biosphere. About half of a CO_2 pulse to the atmosphere is removed over a time scale of 30 years; a further 30% is removed within a few centuries; and the remaining 20% will typically stay in the atmosphere for many thousands of years."

This description of the carbon-dioxide's atmospheric residence time is more accurate than Nordhaus' (1992) assumption of 120 years. Solving equation (14) with hypothetically no further emissions ($q_t = 0$), $Q_t = c(1-\delta)^t, c > 0$. Substituting the approximated thirty-year period resident time for 50 percent of the stock, $(1-\delta_{highest})^{30} = 0.5$ (where 0.5 is the share of the remaining stock). Consequently, $\delta_{highest} \simeq 0.023$ for the depleted half of the stock. The annual depletion rate of the 30 percent of the stock that "is removed within a few centuries" (*ibid*) is smaller. As the number of centuries is not indicated, it is arbitrarily set to be slightly less than half of $\delta_{highest}$: namely, $\delta_{medium} = 0.010$. The annual depletion rate of the remaining 20 percent that "will typically stay in the atmosphere for many thousands of years" (*ibid*) is negligible: to wit, $\delta_{lowest} = 0$. Consequently, the weighted average annual depletion rate of the atmospheric carbon dioxide is: $\delta = 0.5\delta_{highest} + 0.3\delta_{medium} + 0.2\delta_{lowest} = 0.0145$.

Our choice of θ takes into account that $\theta q_2 = Q_2 - Q_1 = q_2 - \delta Q_1$ or, equivalently, that $\theta = 1 - \delta(Q_1/q_2)$. With $\delta = 0.0145$, $\lim \theta = 0$ when $(Q_1/q_2) \to 68.965$. In view of the low annual depletion rate and the thousands of years of deforestation and emission of carbon dioxide into the atmosphere, and in view of the small increase (0.659%) in the aggregate carbon-dioxide emissions in 1961, Q_1 / q_2 (the ratio of the 1960 stock to the 1961 emissions of carbon dioxide) should be sufficiently high for θ to be negligible.

The third and fourth columns of the table in the Appendix display the computed values of the atmospheric carbon-dioxide stock and the index of the state of the global environment with $\delta = 0.0145$ and $\theta = 0$.

6. Estimation of the E-P model

By rearranging the terms in equations (3) and (5), taking time to be discrete, and adding zero-mean and finite-variance random disturbances ε_t and υ_t the following regression-equations of the rates of change in the quality-adjusted physical environment and human population are obtained:

$$e_t \equiv \frac{E_t - E_{t-1}}{E_{t-1}} = g_e - \left(\frac{g_e}{E_{\max}}\right)E_t - \left(\frac{\beta}{E_{comp}}\right)P_t + \varepsilon_t \tag{18}$$

$$p_t \equiv \frac{P_t - P_{t-1}}{P_{t-1}} = g_p\left(1 - \frac{P_t}{(\alpha + \gamma t)[E_t - E_{ext}]}\right) + \upsilon_t\,. \tag{19}$$

Using Lee and Strazicich’s (2003) unit-root test with structural breaks it is found that *e*, *p*, *E* and *P* are I(0). The estimates of the parameters of equations (18) and (19) and their t-statistics are presented in Table 1. The least squares estimates of the parameters of equation (18) are obtained with Newey-West (1987, 1994) heteroskedasticity and autocorrelation consistent (HAC) adjustment. The estimates of the parameters of equation (19) are obtained with RATS’ Gauss-Newton algorithm for finding the minimum of sum of squares residuals of a non-linear regression equation. The estimates have the expected sign and are statistically significant. The estimation results of β / E_{comp} do not reject the hypothesis of an *ad hoc* environmental-concern mechanism with a complacency threshold. The estimation results of α, γ and E_{ext} do not reject the varying carrying-capacity hypothesis. The statistically significant, positive estimate of γ suggests an overall progressive trend.

Table 1. Estimated parameters of the E-P model

Ordinary least squares estimation results of equation (18)				Non-linear least squares estimation results of equation (19)			
Parameter	g_e	$\frac{g_e}{E_{\max}}$	$\frac{\beta}{E_{comp}}$	g_p	α	γ	E_{ext}
Estimate	0.264574	0.188557	2.37E-11	0.027960	14,109,821,229	154,806,111	0.129553
t-statistic	6.198403	5.971179	7.093538	43.15132	197.95749	3.19970	2.00838
Adjusted R-squared 0.834 F-statistic 111.14 Probability (F-statistic) 0.000 Estimation with Newey-West HAC adjustment				Centered R-squared 0.951 R-bar-squared 0.948 Estimation by Gauss-Newton algorithm Convergence obtained in 6 iterations			

The substitution of the estimates into equations (6) and (7) implies that the steady state figures of the environment and human population are $E^* = 0.588758261$ and $P^* = 6,479,304,144$. Recalling equation (8), the estimated Jacobian of the linearized E-P model evaluated with these steady-state figures is:

$$J = \begin{bmatrix} -0.111014491 & -1.395E-11 \\ 394510601.56 & -0.02796 \end{bmatrix}. \qquad (20)$$

In turn, $trJ = -0.13897449$ and $\Delta \equiv (trJ)^2 - 4\det J = -0.01511565$. As both the trace and discriminant are negative, the characteristic roots of the estimated Jacobian are conjugate-complex pair with a negative real part.

7. Conclusion

The empirical results support the conceptually generated depiction of the joint trajectory of the population and the environment as a clockwise converging spiral. With a non-optimally diminishing complacency and no further technological, social, and international progress, the global environment and the human race are on a course leading to an interior steady state with a population similar to the present and a slightly lower environmental quality. These findings do not support Meadows et al.'s (1972) pessimistic outlook. Despite the underlying non-optimal feedback, they are more in line with Nordhaus' (2008). Convergence to extinction is not a likely course for a species that, in addition to displaying diminishing complacency toward deteriorating environmental conditions, generates improvements in technology, in healthcare provision and in social and international affairs.

Appendix: Data

Table A.1: Carbon dioxide emissions and stock, environment index and population

Year	Carbon-Dioxide Emissions[2] (in kilotons)	Carbon-dioxide Atmospheric Stock (in kilotons)	World Environment Index (E)	World Population (P)[3]
1960	9442128	655476965.5	1.000096	3121477101
1961	9504416	655476965.5	1.000096	3186981140
1962	9892800	655865349.5	0.999504	3252585073
1963	10435072	656790373.9	0.998096	3319792342
1964	11021312	658288225.5	0.995825	3390053636
1965	11523280	660266326.3	0.992842	3459775928
1966	12109520	662801984.5	0.989044	3530674067
1967	12497904	665689259.8	0.984754	3605947470
1968	13146432	669183197.5	0.979612	3681596861
1969	13923200	673403241.1	0.973473	3760216598
1970	14934464	678573358.1	0.966056	3837305018
1971	15502384	684236428.4	0.958061	3913581553
1972	16117936	690432936.2	0.949462	3990363847
1973	16982640	697404298.6	0.939972	4065380485
1974	17015616	704307552.3	0.930758	4138250636
1975	16909360	711004452.8	0.921992	4210942357
1976	17891312	718586200.2	0.912264	4284497599
1977	18426256	726592956.3	0.902211	4359247244
1978	18704720	734762078.5	0.892180	4434466506
1979	19737968	743845996.3	0.881285	4511281324
1980	19536448	752596677.4	0.871038	4590035431
1981	18935552	760619577.6	0.861850	4668825873
1982	18785328	768375921.7	0.853150	4747053320
1983	18723040	775957510.8	0.844815	4826996384
1984	19382560	784088686.9	0.836054	4910665750
1985	19946816	792666217.0	0.827007	4996354042
1986	20555040	801727596.8	0.817659	5083156555
1987	21078992	811181538.7	0.808130	5170308311
1988	21852096	821271502.3	0.798202	5259139944
1989	22310096	831673161.6	0.788218	5344209637
1990	22584896	842198796.7	0.778367	5426373277
1991	22907328	852894242.2	0.768607	5509691674
1992	22522608	863049883.7	0.759562	5591798510
1993	22551920	873087580.3	0.750830	5674980207
1994	22984272	883412082.4	0.742055	5755872246
1995	23449600	894052207.2	0.733224	5836558560
1996	23907600	904996050.2	0.724357	5916098534
1997	24303312	916176919.5	0.715517	5995874180
1998	24149424	927041778.2	0.707131	6073279636
1999	24083472	937683144.4	0.699106	6150949153

[2] Source: The World Development Indicators (WDI, The World Bank Group, 2007)
[3] Source: The World Development Indicators (WDI, The World Bank Group, 2007)

2000	24713680	948800418.8	0.690915	6227969448
2001	25369536	960412348.7	0.682561	6305155602
2002	25541744	972028113.7	0.674405	6381200063
2003	26769184	984702890.0	0.665724	6457749643
2004	28183488	998608186.1	0.656454	6534293221
2005	29257040	1013385407.0	0.646881	6610256630

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