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Relations between economic wealth, ecological footprint, and environmental protection depend on climatic demands

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It is an incomplete story that richer societies have larger ecological footprints and are more inclined toward environmental protection. Our 116-nation study shows that all countries, but especially richer countries, have larger ecological footprints under more demanding thermal climates. Further, business executives' ratings of the prevalence of environmental regulations and practices in their country are lowest in poor countries with demanding thermal climates (Armenia, Mongolia), moderate in poor and rich countries with undemanding climates (Mauritius, Nigeria), and highest in rich countries with demanding thermal climates (Canada, Finland). The same holds for efforts to respond to 'green' consumer demands. Explanations are sought in livability appraisals and behavioural adaptations to climato-economic environments. Some speculation is offered about the future management of national ecosystems.

Keywords: Ecological footprint; Protection; Climate; Wealth

1. Introduction

The Millennium Ecosystem Assessment [1] revealed that 'human activities have changed ecosystems rapidly and extensively over the past 50 years to meet growing demands for food, fresh water, timber, fibre, and fuel' [2, p. 120]. These growing demands can be traced back largely to growing population and growing consumption [3]. Canada, Denmark and Singapore, for example, are among the populations with the largest ecological footprints [4]. They are also among the countries having the strictest environmental regulations [5–7].

In this paper we investigate the idea that climatic demands on everyday life co-determine the relations of economic wealth with ecological footprint (EF) and environmental protection. Specifically, we test the hypothesis that the link between wealth resources and EF is stronger under a demanding thermal climate, and that the link between wealth resources and environmental protection is rather different under a demanding vs. undemanding temperature climate. To understand these relationships we propose that the utility or use-value of wealth resources is higher under colder-than-temperate and hotter-than-temperate climatic conditions, if only for buying or producing goods and services to cope with extreme temperatures. There is empirical evidence for this proposition [8–11].

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Before investigating these wide-ranging ideas, we introduce climato-economic theorizing [12,13], paying special attention to basic human needs, livability appraisals, and behavioural adaptations that transform wealth resources and climatic conditions into psychosocial realities. The methodology section then describes the country-level measures for assessing ecological footprint, environmental protection, climatic demands, wealth resources, and control variables. The results section reports multiple regression analyses to estimate the extent to which climato-economic conditions are predictive of how ecosystems in 116 nations are treated and perceived to be treated. The concluding section discusses the strengths, weaknesses, and implications of the observed pattern of environmental degradation and protection, in relation to economic wealth and climatic demands.

2. Climato-economic theorizing

2.1. Basic human needs

Deep evolutionary processes guide all species on earth along the narrow path between being frozen and being charred to death. Temperate climates offer optimal thermoneutral comfort, abundant nutritional ecosystems of flora and fauna, and healthy living conditions [9–15]. Colder winters and hotter summers require more and better clothing, shelter structures, increasing investments of time and effort in the pursuit of scarcer food and water, and more measures to safeguard family health [12]. As a consequence, the Arctic region and Antarctica and the deserts of the world are virtually empty.

2.2. Livability appraisals

Climato-economic theorizing states that human beings appraise their environment in relation to their well-being. *Primary appraisals* concern the extent to which winters and summers are comforting or stressful because satisfaction of basic needs for thermal comfort, nutrition, and health is potentially in danger; *secondary appraisals* deal with the extent to which wealth resources are sufficient to cope with stressful atmospheric cold and heat [12,13]. The core of the livability appraisals is that the utility of wealth resources increases in areas with colder-than-temperate winters or hotter-than-temperate summers [8–11]. This is so for the simple reason that liquid cash and other capital (e.g. real property, consumer durables, and livestock) can provide for clothing, housing, warming and cooling systems, meals, medical cure and care, and numerous other goods and services to cope with extreme climatic temperatures.

Inhabitants of a given area continually discuss their winters, summers, and standard of living, thus gradually pushing and pulling one another toward a shared idea of local livability. Poor populations in harsh climates are expected to appraise livability as stressful because demands are high, and their wealth resources to cope with the high stress are invaluable but insufficient; they live in *threatening environments*. Alternatively, stress is expected to be relatively low in places with undemanding winters and summers. These conditions render wealth resources less valuable for how well basic needs are satisfied in those temperate climates; people live in *comforting environments*. Furthermore, rich populations in harsh climates are expected to appraise livability as stressful because demands are high, and they appraise wealth resources to cope with the high stress as invaluable and sufficient; they live in *challenging environments*.

2.3. Behavioural adaptations

Basic needs and livability appraisals influence the extent to which money is spent on either short-term necessities or luxury goods. Poor populations spend up to 90% of their household incomes on goods and services that satisfy immediate needs for thermal comfort, nutrition, and health [9]; thus, their consumption patterns tend to reduce their ecological footprints. Rich populations, by contrast, spend most money on luxurious goods and services that satisfy cultural needs (e.g. fashions, sports, parties, holidays, education, life projects [16]), so that their consumption patterns tend to enlarge their ecological footprints. These socio-economic roots of the EF have been well-documented [3,4,17,18].

It is more interesting to explore the influence of environmental temperatures on the use of cash and capital for ecosystem treatment. Accordingly, we expected that more demanding climatic temperatures would have a smaller impact on the association between economic wealth and EF than on the association between economic wealth and environmental protection. *First*, the EF is a rough estimate of past CO₂ emissions, infrastructural land use conversion, and similar aspects of resource consumption and waste production [4,18], all of which proxy for economic production rather than climatic impacts. By comparison, environmental protection is more difficult to imagine without local people's appraisals of thermal demands and useful monetary resources to create ecosystem services in order to secure future access to climate-related goods and services.

Second, the transformation of greater economic wealth into a larger EF is driven by numerous factors, and atmospheric temperature is only one of them. In contrast, as global warming shows, the transformation of greater wealth into better care for the environment seems to be significantly driven by the utility of wealth resources for mitigating ecosystem degradation.

Third, there seems to be little evidence that the impact of economic wealth on the EF interacts with the climatic environment. Again in contrast, unmistakable indications exist of greater protection of the *psychosocial* environment in richer populations living in harsher climates, which may well be applicable to environmental protection more generally. Indeed, country-level research has shown that the protection of subjective well-being [19], social trust [20,21], and a variety of fundamental freedoms [13,22] is minimal in poor societies threatened by demanding thermal climates, intermediate in poor and rich societies comforted by undemanding climates, and maximal in rich societies challenged by demanding thermal climates.

Accordingly, we hypothesize that climatic temperature extremes have less of a role to play in determining wealth-based ecological footprints than in shaping wealth-based environmental protection.

Hypothesis 1: The ecological footprint is higher for richer countries, and even more so under a demanding thermal climate.

Hypothesis 2: Environmental protection is weakest in poor countries under demanding thermal climates (*'threatening environments'*), intermediate in poor and rich countries eased by undemanding climates (*'comforting environments'*), and strongest in rich countries under demanding thermal climates (*'challenging environments'*).

3. Methods and data

In an ideal experiment, one would randomly manipulate climatic demands and wealth resources in one hemisphere of the earth, use the other hemisphere as a control condition, and demonstrate that ecosystem treatments in the two hemispheres start to diverge as predicted. Obviously, this is impossible. But the above two hypotheses can still be tentatively tested by comparing countries' EF and tendency toward environmental protection under 2 (climate: undemanding vs. demanding) by 2 (wealth: poor vs. rich) environmental conditions.

Because analysis of variance has the disadvantage that median splits of continuous predictors throw away information and reduce statistical power, we used multiple regression analysis instead, with countries as units of analysis. Ecological footprint and environmental protection were regressed on standardized climatic demands, standardized wealth resources, and their interaction. Four additional regression models controlled for pairs of the most relevant confounding factors of geographic, climatic, parasitic, and demographic differences between countries. Inequality within nations and other socio-cultural differences among countries have not been controlled for because they frequently are significant covariations of climato-economic conditions [13,22]. To improve the communicability and validity of the results, the maximum number of predictor terms in each regression equation was set at 5% of the total number of 116 country cases.

3.1. Sample of nations

For a convenience sample of 116 nations listed in the Appendix (table A1), data on ecological footprint, perceived environmental protection (PEP) including reported environmental marketing, climatic demands and wealth resources were available from various sources mentioned below. Although there was a worldwide overrepresentation of countries with demanding climates (range 20–129; $M = 54.912$ for climatic demands across all countries, whereas $M = 61.388$ for the present sample of countries; $t = 3.097$, $p < .01$), supplementary analyses weighted for biased sampling provided essentially the same results.

3.2. Dependent variables

3.2.1. Ecological footprint

The well-known EF is a crude estimate of the spatial area required to produce the resources and to accommodate the waste generated by a society (expressed in global hectares per capita). If hypothesis 1 holds true, this index of collective consumption primarily depends on wealth resources and secondarily on climatic demands. Ecological-footprint estimates for 116 countries are given in table A1 [source: 4].

3.2.2. Environmental protection

The World Economic Forum regularly draws stratified samples of a country's top executives to measure economic competitiveness. For the years 2005 ($N = 10,503$) and 2006 ($N = 10,605$), Blanke & Loades [23] and Geiger & Loades [24] provide breakdowns of respondents by country, economic sector, and organization type. Only in these two years, participant observers responded to the following three questions about conservation

and preservation of the environment [sources: 5, p. 623; 6, p. 550). *How stringent are your country's environmental regulations?* (1 = lax compared to most countries, 7 = among the world's most stringent). *Environmental regulations in your country are ...* (1 = confusing and enforced erratically, 7 = stable and enforced consistently and fairly). *In your country, companies that harvest or process natural resources such as food, forest or fishery products ...* (1 = rarely concern themselves with the degradation of ecosystems, 7 = frequently take steps to preserve the ecosystems they depend on).

These questions can be criticized because they are single-item measures and do not refer to specific regulations or practices. Nonetheless, there is evidence that their omnibus nature may be capturing relevant aspects of the broader picture of interest. At country level, the test–retest reliabilities between the distinct samples in 2005 and 2006 were excellent ($r = .966$ for stringency; $r = .962$ for clarity and enforcement; $r = .961$ for business practices of ecosystem preservation), and the test–retest averages loaded reliably on a single factor (Cronbach's $\alpha = .980$; $\Delta R^2 = .970$). Table A1 gives the country scores for PEP – the average value of the stringency and enforcement of regulations, and the business practices.

3.2.3. Environmental marketing

The aggregate environmental-protection measure above was validated against reported environmental marketing (REM) as an independent criterion. In an earlier survey, the World Economic Forum [25, p. 617] had asked stratified samples of top executives: *In your country, environmental marketing, eco-labelling, and other efforts to respond to 'green' consumer demands are ...* (1 = unimportant, 7 = widespread and profitable). Environmental-marketing scores are available for 97 countries (see table A1).

3.3. Predictor variables

3.3.1. Climatic demands

The common use of annual mean temperature as a predictor of culture [e.g. 26–29] is inaccurate because seasonal variations in temperature are averaged out (small and large differences between winters and summers may have the same average; higher latitudes have both lower averages and larger variations). Advanced climate-culture research has therefore adopted 22 °C (~72°F) as a standard for measurements of social livability [30]. Accordingly, climatic demands were measured across each country's major cities, weighted for population size, as the sum of the absolute deviations from 22 °C for the average lowest and highest temperatures in the coldest month, and the average lowest and highest temperatures in the hottest month [source: 22, pp. 505–507]. The validity of the index seems to be apparent from its relations with life stress: populations are unhappier, report poorer health, and show higher levels of suicide to the extent that they have to cope with colder winters, hotter summers, or both [12].

3.3.2. Wealth resources

Economic wealth was measured as income per head, relative to a given basket of basic goods and services (purchasing power parity in 2002, three years before the dependent variable was measured). Wealth resources were log transformed to reduce their skewed cross-national distribution [source: 31, pp. 184–187].

3.4. Control variables

3.4.1. Geographic controls

Climatic, economic, and political similarities between adjacent countries may bias the results by violating the statistical assumption of independence [32]. This risk of spatial dependency and spillover effects has been examined assuming that a country is more similar historically to other countries if it is sharing more physical borders with them (1 = island; 2 = borders < coastlines; 3 = borders > coastlines; 4 = landlocked) [33]. On closer consideration, the *degree of landlockedness* usually controls for both spatial dependency and systemic differences between marine and terrestrial ecosystems.

Some changes in the EF or in ecosystem protection can be the result of *disasters*. This consideration made us pay attention to the average part of the country's population affected by 'droughts, earthquakes, epidemics, extreme temperatures, floods, insect infestation, storms, volcanoes and wildfires' during the first decade of this century (taking the natural logarithm to normalize its distribution) [34]. Note that this disaster risk index may be an overly destructive control variable because droughts, extreme temperatures, and wildfires have connections to thermoclimatic demands.

3.4.2. Climatic controls

In addition to average *precipitation* per year [35] *precipitation-squared* was also controlled for because both too little and too much rainfall or snowfall may destroy or endanger plants, animals and human beings, and influence consumer attitudes and concern with the environment.

3.4.3. Parasitic controls

Ecosystems also differ greatly in the extent to which they are home to parasites that transmit diseases among human and animal populations. Greater infectious disease burdens are confounded with atmospheric heat and collective poverty, which makes it fruitful to control for prevalence of nonzoonotic and zoonotic parasites [36].

3.4.4. Demographic controls

As a final consideration, more heterogeneous societies are more prone to economic and political failure, which may well translate into a smaller EF or failing environmental policy-making. We used increasing degrees of ethnic diversity and language diversity as proxies for increasing social heterogeneity [37].

4. Results

4.1. Preliminary descriptions

Country scores of the dependent variables and standardized scores of the predictor variables are provided in the Appendix (table A1), and zero-order correlations in table 1. Environmental protection perceived in 2005 and 2006, and environmental marketing reported by other respondents in 2004, attest to each other's measurement validity ($r = .863$, $p < .001$). Cash and capital appear to play a crucial role as the partial correlations between

EF and PEP ($r = .069$, $p = .467$), and between EF and REM ($r = .116$, $p = .262$) are greatly diminished and become insignificant when wealth resources are controlled for. The correlation coefficients in table 1 also reveal that climatic demands and wealth resources are only moderately correlated ($r = .375$, $p < .001$), so that problems of multicollinearity in regression analysis are negligible.

4.2. Test of hypothesis 1: ecological footprint

Table 2 first presents regression models that report the respective impacts of climatic demands, wealth resources, and their interaction on the EF (models 1–3). The other regression models test the robustness of the findings by controlling for degree of landlockedness and disaster-affectedness (models 4 and 5), precipitation and precipitation-squared (models 6 and 7), nonzoonotic and zoonotic disease burdens (models 8 and 9), and ethnic and language diversity (models 10 and 11).

The first three regression models show that the EF is larger in countries with more demanding climates ($R^2 = .177$, $p < .001$) and in richer countries ($\Delta R^2 = .452$, $p < .001$). The interaction term did not reach significance ($\Delta R^2 = .001$, $B = .092$, $p = .537$). When the geographic control variables were stepwise entered into the equation, it appeared that a much smaller EF in disaster-prone areas (model 4) served as a hidden suppressor of a climato-economic interaction effect (model 5). The visualization of model 5 in figure 1 provides the essence of this interaction. Typical countries represented are Greece, Japan, New Zealand (undemanding climate, richer), Burundi, Kenya, Nigeria (undemanding, poorer), Canada, Finland, Germany (demanding climate, richer), and Kyrgyzstan, Moldova, Mongolia (demanding, poorer). The upward slopes in figure 1 indicate that the EF is generally larger in harsher climates, but this increase is much stronger for richer societies (simple slope test at one standard deviation from the mean: $B = .728$, $p < .001$) than for poorer societies ($B = .293$, $p = .051$).

The EF is smaller in countries with lots of precipitation (model 6), an effect that even seems to overrule the impact of extreme climatic temperatures (model 7). If precipitation is added as a sixth predictor to model 5 (not shown in table 2), however, it does not reach significance, nor does it alter the observed climato-economic interaction effect. The non-zoonotic disease burden seems to be associated with a smaller EF (model 8), but this holds true only for the zoonotic disease burden (model 9). A final finding, reported in models 10 and 11, is that countries with greater ethnic diversity account for some additional variation in the EF when compared with model 3.

The overall conclusion, based on model 5 and portrayed in figure 1, is consistent with hypothesis 1: climatic demands reinforce the relationship between wealth resources and ecological footprint, but this reinforcement may be obscured by the smaller ecological footprints of disaster-prone, often poorer countries. The main effect of climatic demands means that the EF is generally larger for societies living under climates with more demanding winters, summers, or both.

4.3. Test of hypothesis 2: environmental protection

The first three regression models in table 3 show that climatic demands and wealth resources interact, together accounting for 66.9% of the cross-national variation in the rating of environmental protection. The interaction effect is plotted in figure 2a in such a way that it is easily comparable to figures 1 and 3. To do justice to the illuminating

Table 1. Intercorrelations of the study variables across 116 countries.

Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
(1) Ecological footprint	1.000											
(2) Environmental protection	.634***	1.000										
(3) Environmental marketing	.627***	.863***	1.000									
(4) Climatic demands	.420***	.299***	.495***	1.000								
(5) Wealth resources (ln)	.781***	.777***	.725***	.375***	1.000							
(6) Degree of landlockedness	-.336***	-.286**	-.166	.245**	-.418***	1.000						
(7) Disaster-affectedness (ln)	-.676***	-.585***	-.545***	-.392***	-.656***	.245**	1.000					
(8) Precipitation	-.278**	-.061	-.096	-.563***	-.080	-.272**	.237**	1.000				
(9) Precipitation-squared	-.010	-.083	-.108	-.327***	.024	-.217*	.075	.437***	1.000			
(10) Nonzoonotic parasites	-.620***	-.465***	-.519***	-.647***	-.668***	.157†	.510***	.283**	.144	1.000		
(11) Zoonotic parasites	-.270**	-.075	-.020	-.056	-.148	.052	.284**	.132	-.004	.477***	1.000	
(12) Ethnic diversity	-.251***	-.399***	-.453***	-.351***	-.537***	.149	.302***	.011	.058	.560***	.177	1.000
(13) Language diversity	-.207*	-.249**	-.234*	-.147	-.468***	.281**	.222*	-.148	-.088	.430***	.123	.690***

Note: Due to missing values, *N* varies from 97 to 116. Indicators of significance for two-tailed tests: †*p* < .10; **p* < .05; ***p* < .01; ****p* < .001.

Table 2. Climatic demands, wealth resources, and control variables predicting ecological footprint.

Regression models	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9	Model 10	Model 11
Number of countries	116	116	116	113	113	116	116	116	116	116	116
Unstandardized <i>B</i>	<i>B</i>	<i>B</i>	<i>B</i>	<i>B</i>	<i>B</i>	<i>B</i>	<i>B</i>	<i>B</i>	<i>B</i>	<i>B</i>	<i>B</i>
Degree of landlockedness				-.252	-.148						
Disaster-affectedness				-.421***	-.102*						
Precipitation						-.841***	-.607***				
Precipitation-squared						.307	.257				
Nonzoonotic parasites								-.727***			
Zoonotic parasites								.089	-.509**		
Ethnic diversity										.000	.001**
Language diversity										.000	.000
Climatic demands (CD)	.951***	.335*	.334*		.499***		.093		.415*		.425**
Wealth resources (WR)		1.650***	1.611***		1.061***		1.616***		1.632***		1.944***
CD × WR			.092		.222*		.175		.099		.063
ΔR^2	.177***	.452***	.001	.468***	.282***	.093**	.574***	.385***	.271***	.065*	.619***
Total R^2	.177***	.629***	.630***	.468***	.750***	.093**	.667***	.385***	.656***	.065*	.684***

Note: *B*s shown are unstandardized regression coefficients. There was little or no multicollinearity (variance inflation factors <4.596), and there were practically no outliers (Cook's D_k < .913). Indicators of significance for two-tailed tests: * p < .05; ** p < .01; *** p < .001.

Table 3. Climatic demands, wealth resources, and control variables predicting PEP.

Regression models	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9	Model 10	Model 11
Number of countries	116	116	116	113	113	116	116	116	116	116	116
Unstandardized <i>B</i>	<i>B</i>	<i>B</i>	<i>B</i>	<i>B</i>	<i>B</i>	<i>B</i>	<i>B</i>	<i>B</i>	<i>B</i>	<i>B</i>	<i>B</i>
Degree of landlockedness				-.192*	.015						
Disaster-affectedness				-.187***	-.019						
Precipitation						-.034	.030				
Precipitation-squared						-.071	-.027				
Nonzoonotic parasites								-.289***	.053		
Zoonotic parasites								.232*	-.016		
Ethnic diversity										.001***	.000
Language diversity										.000	.001*
Climatic demands (CD)	.308***	.009	.006		.021		.012		.054		-.014
Wealth resources (WR)		.803***	.676***		.677***		.681***		.732***		.724***
CD × WR			.289***		.271***		.288***		.286***		.279***
ΔR^2	.089***	.515***	.065***	.367***	.309***	.008	.661***	.244***	.427***	.161***	.520***
Total R^2	.089***	.604***	.669***	.367***	.676***	.008	.669***	.244***	.671***	.161***	.681***

Note: *B*s shown are unstandardized regression coefficients. There was little or no multicollinearity (variance inflation factors <4.596), and there were practically no outliers (Cook's *D*s < .212). Indicators of significance for two-tailed tests: **p* < .05; ***p* < .01; ****p* < .001.

Figure 1. Visualization of the interaction effect of climatic demands (± 1 SD) and wealth resources on the EF in 116 countries.

details, figure 2b illustrates the downward slope for poorer societies and the upward slope for richer societies with country labels. In support of hypothesis 2, PEP decreases in poorer societies with more demanding climates (simple slope test at one standard deviation

Figure 2a. Visualization of the interaction effect of climatic demands (± 1 SD) and wealth resources on PEP in 116 countries.

Figure 2b. Country details of the interaction effect of climatic demands and wealth resources on unstandardized scores of PEP in 116 countries (broken downward slope and bow ties represent poorer societies; solid upward slope and circles represent richer societies).

from the mean: $B = -.263$, $p < .002$), but increases in richer societies with more demanding climates ($B = .327$, $p < .001$). The left part of figure 2b also shows support for climato-economic theorizing in that environmental protection tends to be perceived as intermediately prevalent in poor and rich societies comforted by undemanding climates. Note that there is no main effect of climatic demands on environmental protection.

Environmental protection tends to be weaker in landlocked states and in disaster-prone areas (model 4), but these are pseudo-effects that must be attributed to climato-economic conditions (model 5), particularly wealth. Unlike thermal climate, precipitational climate does not seem to play a part at all (models 6 and 7). Environmental protection is associated with the disease burdens and pathogenicity of nonzoonotic and zoonotic parasites (model 8) as yet another pair of confounded findings (model 9). Finally, models 10 and 11 reveal that neither ethnic diversity nor language diversity is able to affect the impact of climato-economic conditions. Time and again, we see that exogenous control variables have negligible effects, and that the climatic demands consistently strengthen the effect of national income per head. Perceived environmental protection largely is a function of countries' wealth resources, whereby the difference between poorer and richer countries is enlarged via climatic demands of cold and heat.

Table 4. Climatic demands, wealth resources, and control variables predicting reported environmental marketing.

Regression models	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9	Model 10	Model 11
Number of countries	97	97	97	95	95	97	97	97	97	97	97
Unstandardized <i>B</i>	<i>B</i>	<i>B</i>	<i>B</i>	<i>B</i>	<i>B</i>	<i>B</i>	<i>B</i>	<i>B</i>	<i>B</i>	<i>B</i>	<i>B</i>
Degree of landlockedness				-.192*	-.028						
Disaster-affectedness				-.187***	.001						
Precipitation						-.057	.089				
Precipitation-squared						-.071	.007				
Nonzoonotic parasites								-.348***	.020		
Zoonotic parasites								.401***	.129		
Ethnic diversity										.001***	.000
Language diversity										.000	.001*
Climatic demands (CD)	.512***	.181*	.001		.006		.067		.020		-.021
Wealth resources (WR)		.630***	.561***		.565***		.542***		.614***		.583***
CD × WR			.376***		.365***		.369***		.364***		.361***
ΔR^2	.245***	.303***	.062***	.304***	.310***	.014	.601***	.364***	.263***	.214***	.411***
Total R^2	.245***	.548***	.610***	.304***	.614***	.014	.615***	.364***	.627***	.214***	.625***

Note: *B*s shown are unstandardized regression coefficients. There was little or no multicollinearity (variance inflation factors <5.155), and there were practically no outliers (Cook's *D*s < .186). Indicators of significance for two-tailed tests: **p* < .05; ***p* < .01; ****p* < .001.

Supplementary analyses

There is an implicit corollary of hypothesis 2. The climato-economic results from the first three regression models in table 3 may be generalized from the prevalence of environmental protection to the prevalence of environmental marketing (introduced in the methodology section). An extra analysis demonstrated that this is indeed the case. Climatic demands, wealth resources, and their significant interaction effect accounted for 61% of the variation in reported environmental marketing, and the detailed results in table 4 mirror those for PEP in table 3. The interaction effect, plotted in figure 3, indicates that the reported prevalence of environmental marketing to meet consumers' green demands is minimal in poor populations threatened by demanding thermal climates, intermediate in poor and rich populations comforted by undemanding climates, and maximal in rich populations challenged by demanding thermal climates. And, similarly to environmental protection, there is no main effect of climatic demands on environmental marketing.

Climato-economic theorizing has been criticized for being misleading as a man-made economic condition is itself a cultural adaption in response to climatic demands rather than an ultimate cause of culture parallel to climatic demands [38]. Accordingly, we also estimated models in which wealth resources simultaneously mediate and moderate the ultimate impact of climatic demands [39]. The initial findings highlighted in table 2 (model 5) and in table 3 (model 3) withstood this test of conditional indirect effects of climatic demands through wealth resources on ecosystem treatment. The 95% confidence intervals of the mediating effect of wealth resources on EF and environmental protection did not include a single zero and were increasingly positive at the 10th, 25th, 50th, 75th, and 90th percentile values of climatic demands.

5. Discussion

5.1. Empirical conclusions

Building on climato-economic theorizing [12,13], we discovered that climatic temperatures have differential effects on the relation between economic wealth and ecological footprint, and between economic wealth and PEP. Controlled for disaster-affectedness, countries' ecological footprints appear to be larger in more demanding thermal climates, and this tendency is stronger for richer societies than for poorer societies. In addition, top executives from 116 countries perceived environmental protection in their country as least prevalent in poor populations under demanding thermal climates (e.g. Armenians and Mongolians), moderately prevalent in poor and rich populations in undemanding climates (e.g. Mauritians and Nigerians), and most prevalent in rich populations under demanding thermal climates (e.g. Canadians and Finns). The same holds for reported environmental marketing, including eco-labelling and other efforts to respond to *green* consumer demands.

Taken together, the findings portrayed in figures 1–3 seem to suggest that greater economic wealth has larger effects on ecosystem treatment in countries with more demanding winters, summers, or both. Compared to poorer populations in more demanding climates, richer populations in similar climates seem to consume more ecosystem resources and to also invest more in environmental protection including environmental marketing. Thus, the complementary trends of larger EF and greater environmental protection are predominantly limited to richer societies residing in harsher climates. In contrast, several

Figure 3. Visualization of the interaction effect of climatic demands (± 1 SD) and wealth resources on REM to meet consumers' green demands in 97 countries.

poorer populations (e.g. Kazakhstanis, Mongolians, Paraguayans and Ukrainians) seem to be lagging behind in environmental protection in response to a larger EF associated to a more demanding thermal climate (see table A1 under 'High footprint, low protection').

5.2. Theoretical implications

This pattern of results goes beyond the simpler conclusions that ecological footprints are larger for countries situated in colder climates [17] and that environmental concern and protection are driven by national wealth [40,41] and by country age [42]. Rather, the current results are in agreement with our climato-economic viewpoint of environmental protection as a behavioural adaptation to need-based appraisals of threatening, comforting, and challenging environments, respectively. This interpretation supplements world society theory [43–45], which argues that the extending international network of business ties to environmental organizations leads to greater institutionalization of environmental protection at the national level (e.g. environmental ministries, implementation of ecosystem treaties, and creation of national parks).

The present research refines the finding that wealth resources, ecological footprints, and tendencies toward environmental protection and compensation are intertwined [3,41,46]. In line with Knight and Messer's [47] explanation of cross-national differences in environmental concern, this relationship suggests that inhabitants of countries with high levels of economic affluence have introduced environmental protection after realizing the risks of their high EF for future access to need-satisfying goods and services. This suggestion then raises the uneasy question whether eco-efficiency and environmental compensation [46] mostly function to provide an excuse for increasing natural resource use to continue economic growth. The cautionary message of this study is that climato-economic theorizing is

applicable to both environmental exploitation and environmental protection as its complement. At the same time, this study reveals that environmental protection should certainly not be considered to be the natural sequel of environmental exploitation.

A methodological point of interest is the use of participant observers. Top executives of large organizations have provided subjective bird's-eye views of the environmental regulations in their country and the corresponding practices in national business companies. Indeed, the observed global pattern of environmental conservation and preservation is unique, not only in its climato-economic orientation, but also in its experiential basis. In this research field, environmental degradation vs. preservation is almost always assessed in objective terms such as fertilizer consumption [48], air and water quality [49], deforestation [45], and risks of extinction to species [32]. The present study complements these approaches by investigating the mindset of daily decision-makers in relation to a healthy environment.

No evidence surfaced to suggest that geographic, climatic, parasitic, or demographic conditions, in and of themselves, can predict the objectively computed or subjectively observed national treatment of plants, animals and human beings. Although economic wealth (or ecological footprint, rather) is a stronger predictor, economic prosperity does not propel societies in the direction of ecosystem preservation as the UN Development Programme [31,34] and the World Values Surveys group [7,50,51] would have it. Populations in undemanding climates (e.g. Costa Ricans, Indonesians, and Ugandans) appear to be relatively insensitive to the level of economic wealth when experiencing environmental stresses and making decisions about environmental courses of action (for details see figure 2b and table A1).

5.3. Practical applications

It is difficult to avoid a causal interpretation of the findings in figures 2a, 2b and 3, especially of the consistent increases in PEP and reported environmental marketing, which are minimal in threatening environments (at the low right end of the downward slopes), intermediate in comforting environments (at the converging left ends of the slopes), and maximal in challenging environments (at the high right end of the upward slopes). Certainly, the longitudinal processes of adaptation of environmental policies to climato-economic environments have been examined here in a cross-sectional manner. But it is unlikely that the observed interaction effects of climatic demands and wealth resources are mere coincidence. If the present findings are valid, and reflect causality rather than simultaneity, policy makers should be aware of the basic fact that harsher-than-temperate climates tend to strengthen the impact of economic development on ecological footprint, environmental protection, and environmental marketing.

In its fifth assessment report, the Intergovernmental Panel on Climate Change [52, pp. 802–803] notes that ‘... climate change is an additional burden to people in poverty (...), and it will force poor people from transient into chronic poverty and create new poor (...) climate change, climate variability, and extreme events synergistically add on to and often reinforce other environmental, social, and political calamities.’ Actually, history is once again repeating itself. From the 10th to the 15th century the earth also experienced global warming that was most burdensome to people in poor areas [53]. Given the above study results, the IPCC observation seems to imply that the links between wealth and environmental protection could become more pronounced as climate change intensifies, making economic impulses in climate-stricken areas both more necessary and more effective.

Although the current investigation is restricted to 116 countries, the co-occurrence of climato-economic conditions and ecosystem treatment implies that the fate of living beings can be estimated for most of the world's terrestrial territories. Approximations of the EF can be based on the following equation from model 5 in table 2, accounting for no less than 75% of the variation:

$$EF = -.102 DA + .499 CD + 1.061 WR + .222 (CD \times WR),$$

where DA is disaster-affectedness, CD is climatic demands, and WR is wealth resources. Likewise, approximations of perceived environmental protection (PEP, model 3 in table 3) and reported environmental marketing (REM, model 3 in table 4) can be based on the following equations, both of which account for over 60% of the variation in business awareness of local ecosystem treatment:

$$PEP = .006 CD + .676 WR + .289 (CD \times WR).$$

$$REM = .001 CD + .561 WR + .376 (CD \times WR).$$

Given the present results, existing forecasts of global warming and economic change may perhaps even bring forecasts of EF, PEP and REM within reach. Of course, the accuracy of predictions of EF, PEP and REM necessarily depends on the quality of climatic and economic forecasts, with the consequence that predictions need to be made carefully and that results should not be over-interpreted. Nevertheless, it would be foolhardy not to use insights from research on the recent past to make predictions of the further future that might help locate, diagnose, and potentially mitigate environmental problems.

The IPCC [54] has simulated climatic temperatures and wealth resources for four world regions by late in this century. Building on this solid foundation, others have undertaken downscaling of forecast data to the national level for monthly temperatures [55], and for income per head [56,57]. Cline's temperature projections for 2070–2099, and Gaffin et al.'s or Van Vuuren et al.'s wealth projections for 2100 enable simulations of countries' climato-economic conditions at the end of this century. Given these forecasts of climatic demands and wealth resources, one can apply the above formulas to calculate the country's likely ecosystem treatment a century hence, and to predict the changes. This procedure has been applied to country changes in fundamental freedoms [13].

Such predictions of changes in ecosystem treatment may be only informed guesses. Ecosystem treatment – represented by EF, PEP and REM – is influenced by multiple factors outside the IPCC scenarios, including unforeseen discoveries, major disasters, mass violence, and public health emergencies [3]. What our descriptions and corresponding predictions suggest, however, is that creeping changes in climato-economic environments may shape creeping changes in how these environments are managed. As a consequence, scientific engineering of ecosystem treatment may soon become possible. In the end, we are not out to describe and predict ecological footprint, environmental protection and environmental marketing, but to shape and improve them.

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Appendix

Table A1. Ecological footprint, perceived environmental policies, climatic demands, and wealth resources for 116 countries. On the basis of median splits, the table is broken down for 36 countries with high footprint and high protection, 21 countries with high footprint and low protection, six countries with low footprint and high protection, and 53 countries with low footprint and low protection.

Countries	Ecological footprint	Perceived regulations		Perceived business practices	Perceived environmental protection	Reported environmental marketing	Climatic demands	Wealth resources
		Stringency	Enforcement					
High footprint, high protection								
Australia	6.84	5.80	5.35	5.35	5.500	4.7	0.649	1.404
Austria	5.30	6.55	5.70	5.70	5.983	5.3	0.960	1.433
Belgium	8.00	6.05	4.60	5.15	5.267	5.1	0.782	1.382
Brazil	2.91	5.05	3.90	4.15	4.367	4.3	-0.816	0.268
Canada	7.01	5.80	5.25	5.40	5.483	4.9	1.936	1.441
Chile	3.24	4.90	4.20	4.80	4.633	3.5	0.027	0.474
Czech Republic	5.73	5.35	4.50	4.65	4.833	4.3	1.315	0.891
Denmark	8.26	6.60	6.30	5.50	6.133	5.6	0.960	1.483
Estonia	7.88	4.80	4.65	4.50	4.650	4.3	1.626	0.669
Finland	6.16	6.30	5.75	6.05	6.033	5.5	1.626	1.337
France	5.01	5.80	5.30	5.20	5.433	4.9	0.604	1.361
Germany	5.08	6.70	5.90	5.90	6.167	5.7	1.004	1.367
Hungary	2.99	5.15	4.35	4.20	4.567	3.8	1.004	0.747
Ireland	6.29	5.30	4.90	5.10	5.100	4.7	0.338	1.625
Israel	4.82	4.75	4.55	4.55	4.617	3.8	-0.106	1.079
Italy	4.99	4.95	4.05	3.90	4.300	3.9	-0.106	1.345
Japan	4.73	5.95	5.65	5.30	5.633	5.7	-0.417	1.362
Latvia	5.64	4.20	4.15	4.00	4.117	3.9	1.626	0.418
Lithuania	4.67	4.60	4.05	4.15	4.267	3.9	1.626	0.518

(Continued)

Table A1. (Continued).

Countries	Ecological footprint	Perceived regulations		Perceived business practices	Perceived environmental protection	Reported environmental marketing	Climatic demands	Wealth resources
		Stringency	Enforcement					
Malaysia	4.86	5.10	4.85	4.95	4.967	4.1	-1.260	0.409
Netherlands	6.19	6.20	5.45	5.60	5.750	5.1	0.693	1.430
New Zealand	4.89	6.15	5.30	5.85	5.767	4.9	-0.372	1.173
Norway	5.56	6.30	5.90	5.65	5.950	5.0	1.226	1.631
Poland	4.35	4.15	3.90	3.95	4.000	3.4	1.270	0.538
Portugal	4.47	5.05	4.35	4.60	4.667	3.7	-0.461	1.021
Qatar	10.51	4.65	4.55	4.10	4.433		-0.372	1.093
Singapore	5.34	5.70	5.85	4.85	5.467	4.4	-1.438	1.262
Slovakia	4.06	4.95	4.50	4.55	4.667	4.3	1.537	0.710
Slovenia	5.30	5.25	4.90	4.65	4.933	4.2	0.960	1.033
South Korea	4.87	4.65	4.65	4.35	4.550	5.0	0.782	0.954
Spain	5.42	4.75	4.30	4.40	4.483	3.8	0.338	1.162
Sweden	5.88	6.35	5.70	5.75	5.933	5.6	1.226	1.332
Switzerland	5.02	6.40	6.00	5.85	6.083	5.7	0.960	1.457
United Arab Emirates	10.68	4.65	4.50	4.15	4.433	3.7	-0.372	1.200
United Kingdom	4.89	5.85	5.50	5.45	5.600	4.8	0.249	1.336
United States	8.00	5.45	5.05	5.20	5.233	4.3	0.782	1.611
<i>High footprint, low protection</i>								
Bahrain	10.04	3.35	3.30	3.30	3.317	3.4	-0.550	0.965
Bosnia-Herzegovina	2.75	2.45	2.90	2.85	2.733	2.5	0.826	0.036
Bulgaria	4.07	3.15	2.95	2.70	2.933	3.0	0.738	0.192
Croatia	3.75	4.10	3.70	3.70	3.833	3.5	0.960	0.511
Gambia	3.45	3.55	4.00	3.50	3.683	3.7	-0.683	-1.074
Greece	5.39	4.15	3.70	4.00	3.950	3.8	-0.239	1.042

Kazakhstan	4.54	3.25	3.65	3.40	3.433	1.892	0.021
Kuwait	6.32	3.30	3.25	3.55	3.367	-0.284	0.916
Macedonia	5.66	2.70	2.90	3.25	2.950	0.826	0.107
Mauritius	4.26	3.80	3.65	4.30	3.917	-1.216	0.558
Mexico	3.00	3.95	3.60	3.30	3.617	-0.550	0.394
Mongolia	5.53	2.35	2.70	2.15	2.400	3.002	-1.064
Nepal	3.56	2.90	3.00	3.20	3.033	-0.772	-1.259
Panama	2.87	3.55	3.25	3.30	3.367	-1.305	0.065
Paraguay	3.19	2.65	2.35	2.30	2.433	0.382	-0.191
Romania	2.71	3.40	3.25	3.30	3.317	1.404	0.119
Russia	4.41	3.05	3.05	2.70	2.933	1.759	0.319
Trinidad and Tobago	3.09	3.15	3.10	3.10	3.117	-0.683	0.438
Ukraine	2.90	3.10	3.20	3.00	3.100	1.137	-0.143
Uruguay	5.13	3.90	3.90	4.15	3.983	0.160	0.275
Venezuela	2.89	3.40	2.90	3.20	3.167	-0.861	-0.055
<i>Low footprint, high protection</i>							
Costa Rica	2.69	4.80	4.05	4.25	4.367	-0.994	0.382
Ghana	1.75	4.20	4.10	4.20	4.167	-1.216	-0.870
Namibia	2.15	3.85	4.10	4.45	4.133	-0.239	0.071
South Africa	2.32	4.80	4.45	4.85	4.700	0.072	0.496
Thailand	2.37	4.30	4.20	4.05	4.183	-0.728	0.177
Tunisia	1.90	4.90	4.85	4.90	4.883	0.072	0.146
<i>Low footprint, low protection</i>							
Albania	1.91	2.15	2.10	2.05	2.100	0.027	-0.150
Algeria	1.59	3.30	3.00	3.00	3.100	-0.284	0.005
Angola	1.00	2.40	2.70	2.70	2.600	-1.394	-0.870
Argentina	2.60	3.40	3.15	3.50	3.350	0.160	0.564
Armenia	1.75	2.95	2.95	2.60	2.833	1.226	-0.535

(Continued)

Table A1. (Continued).

Countries	Ecological footprint	Perceived regulations		Perceived business practices	Perceived environmental protection	Reported environmental marketing	Climatic demands	Wealth resources
		Stringency	Enforcement					
Azerbaijan	1.87	2.90	3.15	3.35	3.133		1.226	-0.510
Bangladesh	0.62	2.95	2.80	2.65	2.800	2.5	-0.772	-1.069
Benin	1.23	3.35	3.05	3.30	3.233		-1.571	-1.476
Bolivia	2.57	3.00	2.90	2.70	2.867	2.5	-0.461	-0.744
Botswana	2.68	3.35	3.75	3.75	3.617	3.5	0.249	0.312
Burkina Faso	1.32	3.60	3.60	3.70	3.633		-0.150	-1.452
Burundi	0.90	2.70	2.70	2.60	2.667		-1.749	-1.942
Cambodia	1.03	2.70	3.05	2.85	2.867		-0.994	-0.900
Cameroon	1.04	2.90	2.85	2.95	2.900		-1.127	-0.926
Chad	1.73	2.35	2.05	2.55	2.317	2.0	-0.284	-1.518
China	2.21	3.05	3.40	3.35	3.267	4.9	0.915	-0.197
Colombia	1.87	4.30	3.75	3.75	3.933	3.3	-1.172	0.093
Dominican Republic	1.47	3.00	2.90	2.95	2.950	2.7	-1.172	0.130
Ecuador	1.89	2.85	2.70	2.90	2.817	2.7	-0.417	-0.414
Egypt	1.66	3.15	3.10	3.55	3.267	3.6	-0.062	-0.359
El Salvador	2.03	3.65	3.25	3.40	3.433	3.0	-0.284	-0.139
Ethiopia	1.10	2.45	2.70	2.55	2.567	2.5	-0.328	-1.754
Georgia	1.82	3.20	3.25	2.65	3.033	2.3	0.160	-0.818
Guatemala	1.77	3.00	2.80	3.25	3.017	2.6	-0.816	-0.299
Guyana	2.38	2.85	2.85	2.90	2.867		-1.704	-0.261
Honduras	1.91	3.40	2.90	3.20	3.167	2.4	-1.704	-0.695
India	0.91	4.25	3.80	3.75	3.933	3.2	-0.372	-0.672
Indonesia	1.21	3.15	3.40	3.15	3.233	4.1	-1.394	-0.504
Jamaica	1.93	3.40	3.20	3.80	3.467	3.0	-1.172	-0.320

Jordan	2.05	3.85	3.80	3.65	3.767	3.1	-0.062	-0.269
Kenya	1.11	3.55	3.50	3.65	3.567	3.5	-0.905	-1.518
Kyrgyzstan	1.25	2.45	3.00	2.85	2.767		0.116	-1.111
Lesotho	1.07	2.60	3.10	3.30	3.000		0.116	-0.758
Madagascar	1.79	3.55	3.25	3.50	3.433	2.5	-0.550	-1.800
Malawi	0.73	2.90	3.05	3.20	3.050	2.6	-0.506	-2.015
Mali	1.93	3.10	2.95	3.60	3.217	2.0	-0.239	-1.599
Mauritania	2.61	2.90	3.10	3.70	3.233		-0.372	-0.834
Moldova	1.39	3.15	3.30	3.00	3.150		1.137	-1.197
Morocco	1.22	3.10	2.95	3.05	3.033	3.7	0.072	-0.359
Mozambique	0.77	3.00	3.20	2.90	3.033	3.1	-0.239	-1.493
Nicaragua	1.56	2.85	2.90	2.80	2.850	2.6	-1.660	-0.740
Nigeria	1.44	3.35	3.45	3.70	3.500	3.5	-1.083	-1.668
Pakistan	0.77	3.20	3.20	2.90	3.100	2.6	-0.106	-0.953
Peru	1.54	3.55	3.35	3.45	3.450	2.9	-1.172	-0.118
Philippines	1.30	3.65	2.95	3.30	3.300	3.0	-1.127	-0.279
Sri Lanka	1.21	3.25	3.15	3.30	3.233	3.2	-1.394	-0.416
Tajikistan	1.00	2.80	3.25	3.40	3.150		1.048	-1.553
Tanzania	1.18	3.50	3.90	3.30	3.567	3.4	-0.816	-2.015
Turkey	2.70	3.70	3.45	3.50	3.550	3.3	1.048	0.096
Uganda	1.53	3.45	3.40	3.35	3.400	3.4	-1.038	-1.246
Vietnam	1.40	2.90	2.95	3.05	2.967	3.5	-0.594	-0.803
Zambia	0.91	2.50	2.20	1.90	2.200	3.4	-0.594	-1.689
Zimbabwe	1.25	3.45	3.50	4.05	3.667	2.5	-0.417	-0.776