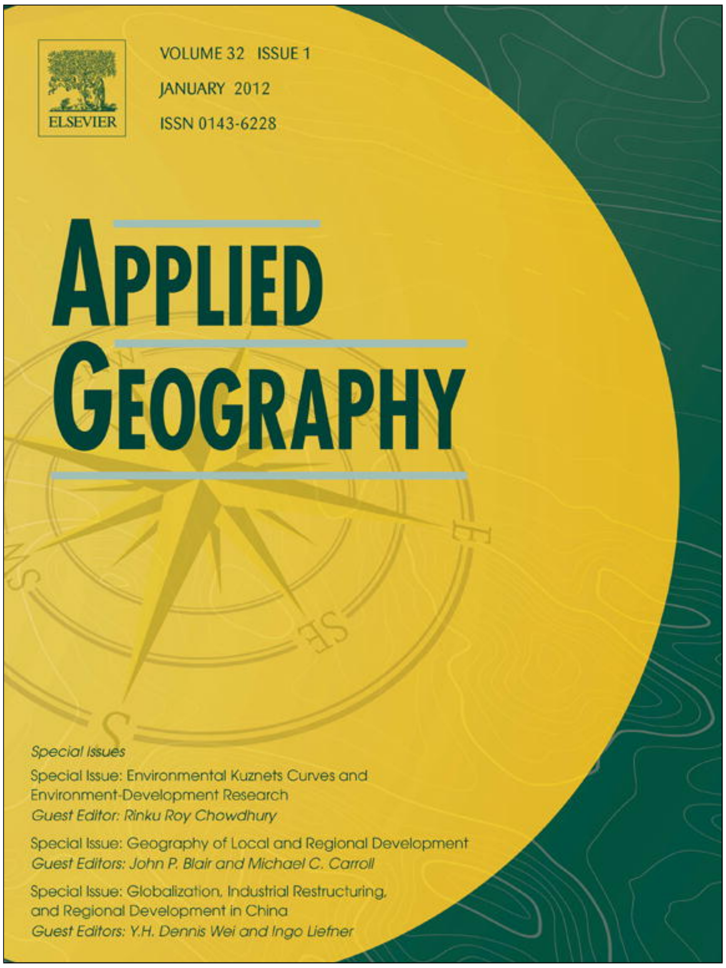
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Environmentally efficient well-being: Is there a Kuznets curve?

Thomas Dietz [a,*], Eugene A. Rosa [b], Richard York [c]

[a] Sociology and Environmental Science and Policy, Michigan State University, East Lansing, MI 48864, USA
[b] Department of Sociology, Washington State University, Pullman, WA 99164-4020, USA
[c] Department of Sociology, University of Oregon, Eugene, OR 97403-1291, USA

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A B S T R A C T

The environmental Kuznets curve (EKC) posits an inverted "U" shaped relationship between the affluence of a nation and the stress it places on the biophysical environment, with increases in affluence from low to moderate levels producing increased environmental stress but further increases eventually leading to a tipping point after which further affluence reduces environmental stress. We hypothesized that the same pattern might obtain for the relationship between affluence and the efficiency with which a nation produces human well-being compared to the stress it places on the environment. The environmental intensity of human well-being (EIWB) was represented as the ratio of a nation's per capita ecological footprint to its average life expectancy at birth. Using panel data on 58 nations, we find that, on average, the relationship between gross domestic product per capita and EIWB is a U shape, the inverse of the Kuznets curve.

Introduction

The environmental Kuznets curve (EKC) is a theoretical proposition to explain why nations differ from each other in the stress they place on the environment and why nations may change over time in generating environmental stress. The basic logic of the EKC builds on analyses made by Simon Kuznets regarding economic growth and income inequality (Kuznets, 1955). His argument was that as an economy grows from low income or gross domestic product per capita (GDPPC) to higher incomes or GDPPC, income inequality first increases, then reaches a turning point and declines thereafter. One implication is that a nation can "grow its way out" of inequality.[1] In the mid-1990s, several economists (Grossman & Krueger, 1995; Selden & Song, 1994; Shafik, 1994; Stern, Common, & Babbier, 1996, for a review see Stern, 2004) suggested that the logic of the EKC applies to environmental impacts.[2] Specifically, they argued that as national economies grow the stress they place on the environment increases at first but eventually reaches a turning point where from that point on further growth decreases environmental stress. The change is variously attributed to shifts in preferences as basic needs are met, shifts in the structure of industry away from the most environmentally degrading activities and changes in political institutions that lead to more environmental protection. In parallel, but with little cross-referencing (but see Mol, 2001), Ecological Modernization Theory (EMT) has posited that the process of modernization leads to a broadening of the scope of rationality, from an exaggerated emphasis on economic rationality to an emphasis on a broader "sustainability" rationality that encompasses environmental externalities. The result is reduced environmental impacts. EMT emphasizes changes in values, institutions, policies and practices (Mol & Sonnenfeld, 2000; Spaargaren & Mol, 1992, for a critical assessment of EMT see York & Rosa, 2003; York, Rosa, & Dietz, 2010). Early on concerns were raised that the EKC oversimplified complex relationships by focusing exclusively on economic development (Roberts & Grimes, 1997) but today the literature on the EKC is vast and growing, is detailed, is replete with controversy, and is increasingly sophisticated in analytic approaches (Carson, 2010; Cavlovic, Baker, Berrens, & Gawande, 2000; Rothman, 1998; Stern, 2004).

The EKC is an extension of the conventional view—long unchallenged—that economic growth is desirable. But a formidable

* Corresponding author. Tel.: +1 517 353 8763.
E-mail addresses: tdietz@msu.edu (T. Dietz), rosa@wsu.edu (E.A. Rosa), rfyork@uoregon.edu (R. York).

[1] Kuznets discusses in some detail the structural differences between developing countries and historical development of the United States, Germany and the United Kingdom which provide his main empirical evidence. He notes that "There is danger in simple analogies…" (1955: 25); a point that applies both to generalizing across national histories and, presumably, to generalizing from income inequality to environmental stress.

[2] A parallel literature has examined the effects of economic growth on various measures of human well-being. Several prominent analyses in the 1990s seemed to affirm the positive effect of economic growth on well-being and health (Firebaugh & Beck, 1994; Pritchett & Summers, 1996). However a more extensive recent analysis by Brady et al. (2007) suggest that the relationship is more nuanced, with affluence having a positive effect on some but not all measures of well-being. In particular, they find a positive effect of affluence on life expectancy but not on infant and child mortality.

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counter-argument emerged in the 1970s. As Carson (2010) notes, a line of research that began in a debate between Barry Commoner (Commoner, 1972a, 1972b; Commoner, Corr, & Stamler, 1971) on the one hand and Paul Ehrlich and John Holdren (Ehrlich & Holdren, 1971; Holdren & Ehrlich, 1974) on the other crystallized the argument that economic growth may be bad for the environment. In a sense the EKC is a rejoinder to that view.[3] If economic growth is harmful to the environment, then society is faced with a tradeoff between environmental damage and the presumed benefits of economic growth. However, a growing literature questions exclusive or even primary reliance on income or economic activity as measured by gross domestic product per capita as a measure of human well-being. Many argue that it may be both feasible and preferable to use more direct measures of well-being or satisfaction than income or economic activity (Ayers & Martinás, 2005; Cobb, Halstead, & Rowe, 1995; Easterlin, 1974; European Commission, 2009; Frey, 2008; Hirsch, 1995[1977]; Huppert et al., 2009; Jackson, 2009; Knight & Rosa, 2009, in press; Waring, 1988). This line of reasoning notes that at the core of economic theory is the exercise of individual choice to maximize utility. Then preferences revealed in consumption practices are a reflection of consumer utility. Since one direction for computing national accounts is bottom to top, GDPPC is the typical surrogate for consumption utility at the aggregate level. But national accounts can also be computed from the top, via measures of production or changes in manufactured capital (Hecht, 2005). Hence, another approach to the aggregate utility or well-being of a society is to emphasize its various forms of capital. Thus, instead of equating income or consumption with utility it may be more appropriate to treat them as factors in the production of well-being. That recognition leads to the "four capitals" approach to aggregate well-being. The four capitals consist of manufactured capital (infrastructure), natural capital (nature's capital and services), human capital (education and productive potential of individuals), and social capital (trust and social networks) all of which contribute to the production of well-being (Dietz, Rosa, & York, 2009; Ekins, 2000; Ekins & Medhurst, 2006; Mulder, Costanza, & Erickson, 2005; Vemuri & Costanza, 2006).

Here we present a test of the Kuznets proposition. The test is, by the symmetry of their common predictions, also a test of EM theory. We first define a measure of "environmental efficiency of human well-being" and then ask if there is an EKC for such a measure. Since the EKC is an extension of conventional economic theory, we adopt a conventional economic technique: benefit–cost analysis. We define the efficiency of well-being simply as the ratio of a measure of human well-being (benefits) to a measure of anthropogenic environmental stressors (costs). Our approach asks how much human well-being is being generated per unit of environmental stress. More efficient nations will have large ratios while less efficient nations will have smaller ratios. However, to be consistent with the EKC tradition, where the object of explanation is a measure whose increase is undesirable, we invert the efficiency ratio of well-being to produce a measure of environmental intensity—the amount of environmental stressors generated per unit of well-being. We ask if there is an environmental Kuznets curve, not for overall environmental impact but rather for the environmental intensity of well-being production. That is, does economic growth lead initially to an increase in intensity (a decline in efficiency) followed eventually by a decline in intensity (an increase in efficiency)? If economic growth is beneficial, then societies should become more environmentally efficient at producing well-being at higher levels of affluence, and thus the relationship between environmental intensity and GDPPC should follow an EKC or EM pattern.

Ecologically efficient well-being and ecological intensity of well-being (EIWB)

The energy or carbon intensity of nations is frequently deployed in both policy discussions and in research and thus serves as a familiar illustration of the logic of intensity and efficiency measures. Energy intensity is usually defined as a ratio; the total energy consumption of a country divided by its gross domestic product (GDP) (Energy/GDP) indicating the amount of energy used per unit of economic output. Similarly, carbon intensity is defined as a ratio; greenhouse gas emissions (a stressor) in carbon equivalents divided by GDP (Carbon/GDP). Of course, such ratios aggregate over details of the production processes that lead to both GDP and stresses on the environment. That is their purpose—to provide a broad picture of an economy that complements detailed sector by sector and actor by actor analyses that are hard to interpret in the aggregate.[4] The idea of the ecological intensity of human well-being (EIWB) uses a similar logic but instead of assessing how much energy is consumed or how much greenhouse gas is emitted per unit of gross domestic product, the EIWB examines how much stress is placed on the environment per unit of human well-being (Stress/Well-being). If we were using carbon emissions as the sole measure of environmental stress, then the shift from carbon intensity to EIWB would simply involve substituting a measure of human well-being for GDP (Carbon/Well-being). However, while greenhouse gas emissions are certainly a critical stressor of the environment, they are by no means the only important stressor, so the choice of both a measure of human well-being and environmental stressors is a critical consideration for our analysis.

Several criteria must underpin the choices of measures of environmental stress and human well-being. First, the measures must have strong face validity; that is, they must appear reasonable and be consistent with conventional meanings of anthropogenic stresses on the environment and with human well-being. We note that in the case of a measure of human well-being face validity has a substantial normative component in that we are, in some sense, trying to develop a measure of that which is "beneficial" or "good."[5] It is thus understandable that reasonable people may differ in their assessments of what measures of well-being are appropriate. As a result, any analysis such as ours, that deploys a single measure of well-being, must be seen as tentative. Second, the data underpinning the measure and the calculations aggregating that data into the final measure should be reliable and valid. Third, for comparative analysis the data must be available for many nations for many points in time.

[3] Indeed, in their classic study of the connection between GNP and welfare, Nordhaus and Tobin (1972: 1) quote Ehrlich in the opening paragraph: "We must acquire a life-style which has as its goal maximum freedom and happiness of the individual, not a maximum Gross National Product." Nordhaus and Tobin developed a Measure of Economic Welfare (MEW) that adjusted GNP by adding in the dollar value of non-market activities and leisure time, by reclassifying government expenditures and consumer durables, by subtracting instrumental expenditures such as the cost of commuting to work and by subtracting the disamenities of urbanization. They found that in the U.S. from 1929 to 1965 the MEW closely tracked GNP and concluded that GNP was, therefore, an acceptable indicator of national welfare, a conclusion now seriously challenged by recent studies with a larger sample of countries (Ayers & Martinás, 2005; Daly & Cobb 1989; Jackson & Marks, 1994).

[4] For example, one of the most common criticisms of ecological modernization scholarship is that it has focused on case studies of single industries. While these are valuable, they cannot answer the larger question of whether or not a nation is moving towards sustainability since improvements in one industry might be countered by adverse changes in another industry or simply overall growth in environmental impacts (York et al., 2010).

[5] A measure of environmental stress also has a normative component, although perhaps that is less obvious. The effects of human actions on the environment can be assessed scientifically but whether these effects are judged to be desirable or undesirable is invariably based on social values as are any weights used to commensurate across types of impact.

While there are many candidate measures for both human well-being and for anthropogenic environmental stressors, in this initial study of the ecological intensity of well-being we choose two that we believe adequately meet our three criteria. For well-being we choose life expectancy at birth. Life expectancy has a number of technical advantages as a measure of well-being. It is well measured in most countries. It is widely accepted as an indicator of societal "good".[6] Along with gross domestic product per capita and education, it is one of the three components of the Human Development Index and thus has achieved broad international consensus as a key component of perhaps the most widely accepted measure of well-being. The HDI is calculated annually for most countries of the world by the United Nations Development Programme (2009). We do not use the HDI per se because the other two components—education and affluence—are better thought of as resources that generate well-being. Education is perhaps the most widely used measure of human capital while affluence can be seen as a measure of the flow of manufactured capital. We have noted the move away from conflating affluence with well-being and in any event, the purpose of our analysis is to see if affluence is linked to intensity of well-being via an EKC relationship. So using the HDI as our measure of well-being would conflate our dependent and independent variables. These considerations led to life expectancy as our well-being measure. It has been the subject of substantial demographic research, and because much effort has been given to developing high quality demographic data systems in most nations, data on life expectancy are of good quality, certainly comparable to any other data used in cross-national analyses. Finally, data are available for most nations of the world for a substantial span of years.

Life expectancy has several features that recommend it as a metric for capturing the more general notion of well-being.[7] It is a direct indicator of health and longevity. It captures the overall health conditions of society since it directly reflects longer lifespans and reductions in infant mortality, and indirectly reflects pre-natal education, life-long medical services, and levels of literacy and education. Life expectancy also captures some aspects of equity. Poverty and inequality tend to affect infant and child mortality more than adult mortality, and infant and child mortality weigh more heavily than adult mortality in the calculation of life expectancy (because more potential years of life are lost by an early death than by a later one). Brady, Kaya, and Beckfield (2007) identify some differences between the factors that influence cross-national differentials in child and infant mortality and those that influence differentials in life expectancy (but do not include inequality in their analysis). This is likely because life expectancy captures death from chronic disease and from accidents at ages past childhood. For all these reasons, life expectancy seems a reasonable starting point in our exploration of well-being. To be perfectly clear, we are not arguing that life expectancy is the only appropriate measure of human well-being and certainly subsequent work should explore other measures.

Our choice for an initial measure of environmental stressors is the ecological footprint (Wackernagel & Rees, 1996; Wackernagel et al., 2002). The ecological footprint is a measure of stress to the environment that results from human consumption of resources. It consists of energy consumption, consumption of forest products, consumption of products of grazing and agriculture, consumption of seafood and the amount of land used for living space and infrastructure. The amount of land or sea area that would be required to support each form of consumption is estimated based on global average productivities. This area estimate is used to aggregate across categories to produce the overall footprint for a nation. The footprint thus has the advantage of covering a wide range of environmental stressors. Because it is a measure of consumption, the ecological footprint attributes environmental stress to the nation where consumption occurs, rather than to the place where the stress actually occurs. The footprint has been widely used and is supported by a substantial methodological literature (Kitzes, Peller, Goldfinger, & Wackernagel, 2007; Wackernagel et al., 2002, 2004; Wiedmann, Minx, Barrett, & Wackernagel, 2006). The ratio of the ecological footprint to the "biocapacity" (the productive land area) of a nation or the globe is sometimes used as a measure of the sustainability of a nation or of global society (Wackernagel & Rees, 1996; Wackernagel et al., 2002). That approach has been criticized largely because of concerns with the definition and measurement of biocapacity (Fiala, 2008 and references therein). There has been relatively little criticism of the ecological footprint as an aggregate measure of how consumption stresses the environment and that is the basis of our use of it. Kitzes et al. (2009) offer an extensive examination of methodological issues with the ecological footprint.

We emphasize that the ratio of the ecological footprint to life expectancy at birth is only a tentative specification of the ecological intensity of human well-being. Other specifications will have a set of advantages and disadvantages different from this one, and deserve examination. However, we believe this approach to ecological intensity has reasonable validity, and it can be deployed for a larger number of nations for more years than other plausible alternatives, so we consider it appropriate for this exploratory analysis.

We proceed by describing in Section 2 the data and the methods we use in the analysis. In Section 3 we provide descriptive information on the ecological intensity of well-being and estimate panel models to determine whether or not there is a Kuznets curve for ecological intensity.

Materials and methods

Data

Our units of analyses are nation-states. Because of limitations in data availability, we use data on 58 nations for the period 1961–2003 for panel analyses. Missing data for some years for some nations results in an unbalanced panel with a working sample size of 1221. Life expectancy data and gross domestic product per capita are from the World Bank World Development Indicators database (World Bank, 2007). Data on gross domestic product per capita are based on exchange rates[8] as these are considered most appropriate for making analyses of environmental threats or impacts, consumption and quality of life because they better reflect a country's control over economic activity in the world-system (Nordhaus, 2007; Roberts & Grimes, 1997). The values are in

[6] Countries with longer life expectancy tend to score higher on subjective well-being (SWB) scales (Barber, 2009, Veenhoven, 1996, but see Deaton, 2008). Subjective well-being is of increasing interest to the research community but is not available for enough nations at enough points in time to be used here.

[7] One concern often raised about life expectancy as a measure of well-being is that heroic extensions of the end of life do not necessarily improve well-being. While this may well be true at the individual level, in the contemporary world such extensions have little impact on life expectancy, which is much more sensitive to deaths early in the life course. By the same logic, life expectancy is very sensitive to inequality, since the most affluent cannot extend their life long enough to compensate for the downward pull caused by the death of the impoverished young.

[8] The alternative method for valuing GDP is the Purchasing Power Parity (PPP) procedure, which adjusts currencies to reflect the purchasing power for a given market basket of goods in each home country. PPP, by taking into account the relative cost of living and inflation rates between countries, is especially suited to comparing standards of living but not to the buying power of national currencies in the international system. The two measures are highly correlated (Pearson's $r = 0.96$ in our dataset) so the choice of one measure of GDPPC over the other is unlikely to have much influence on our results.

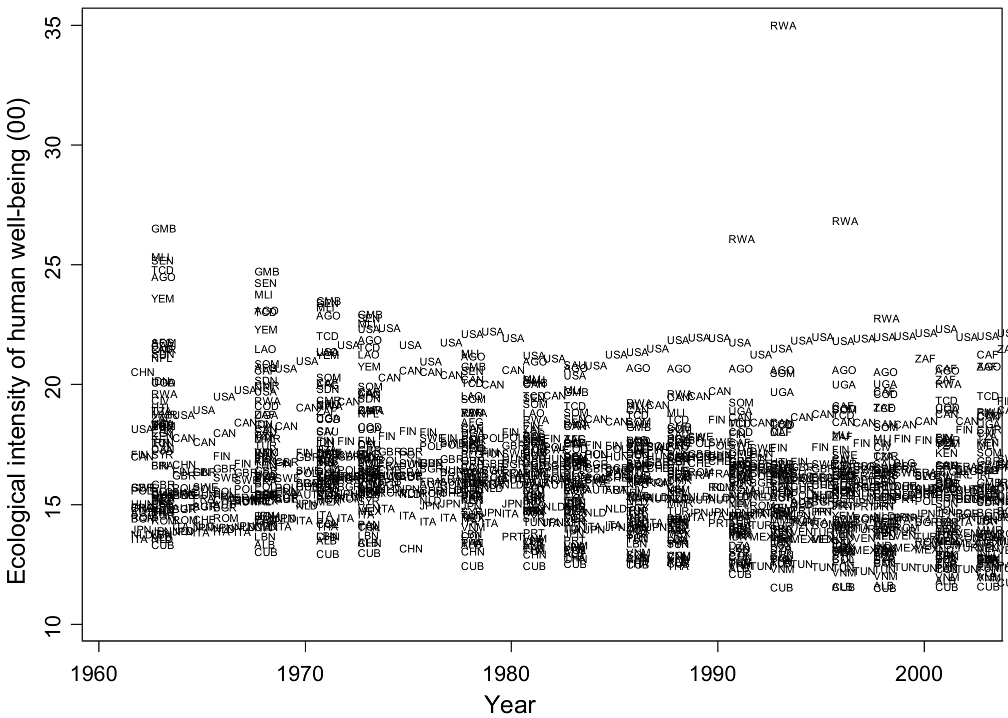

Fig. 1. Ecological intensity of human well-being by year.

constant 2000 U.S. dollars. Ecological footprint data were developed by the Global Footprint Network (www.footprintnetwork.org) and were provided to us by them.

Methods of analysis

As noted above, in order to maintain consistency with the EKC literature, where the object of explanation is always an undesirable outcome, we invert the well-being per unit of environmental stress measure (Well-being/Stress) into an intensity of well-being measure (EIWB = Stress/Well-being).

The specific hypothesis we test is:
There is a Kuznets curve relationship between GDPPC and ecological intensity of well-being (EIWB).

To test for an EKC we follow standard practices in the literature. The specification of our model includes both a linear and a quadratic term, a second order polynomial, in log (base 10) GDPPC. The basic environmental Kuznets curve conceptualization underpinning this hypothesis argues for a total effect of GDPPC, so we exclude control variables. However, in panel analysis it is conventional to allow for time and cross-section specific effects. We will follow common practice by using a fixed effects (within) model with robust standard errors based on treating countries as clusters. The robust cluster approach provides consistent estimates even in the presence of serial correlation or cross-sectional heterogeneity in errors (Wooldridge, 2009). Fixed effects estimates effectively control for all country specific effects that are constant over time, such as climate zones. We also include time as years since 1960 and the square and cube of time to correct for time trend effects. This fixed effects estimator with time polynomial and robust standard errors will be the starting point for our analysis. However, researchers beginning with Roberts and Grimes have argued that assuming a uniform Kuznets curve for all nations may be unrealistic (Roberts & Grimes, 1997; Vollebergh, Melenberg, & Dijkgraaf, 2009). Vollebergh et al. (2009) have noted that a priori restrictions of equality of coefficients across some nations must be imposed on model parameters for an EKC model to be identified. Wagner (2008) shows that most approaches to non-stationarity that have been used by EKC researchers can lead to misleading results. In response to these concerns Stern (2010) has suggested that the “between” panel estimator (based on across time averages within each cross-sectional unit) is a robust specification that captures large scale dynamics. We will report results from the between estimator as well as from our fixed effects models.

One complication with using a ratio as an indicator must be noted. Because the variability and the range of the numerator and denominator can differ substantially, a ratio can be dominated by one or the other. In our dataset, the coefficient of variation for the ecological footprint per capita (EFPC) is 0.798 and the range is 0.13–9.69. For life expectancy (LE) the coefficient of variation is 0.182 and the range is 23.68–81.76. The coefficients of variation are telling us that the relative variation in EFPC, the numerator, is much larger than variation in LE, the denominator. Thus variation in EFPC will drive variation in the ratio. There are several methods for standardizing indicators (Organization for Economic Cooperation and Development, 2008). However, most of these do not solve the problem of numerator or denominator dominance. Here we use a method developed by the New Economics Foundation (New Economics Foundation, 2009, Saamah Abdallah personal communication) that constrains the coefficient of variation of the numerator and denominator to be equal by adding a constant to one of them. Adding a constant to one variable, a straightforward linear transformation, shifts its mean without changing the variance and thus allows us to equalize the coefficient of variation of our numerator and denominator. For our analysis the coefficient of variation of life expectancy and ecological footprint per capita can be made equal by adding 7.508

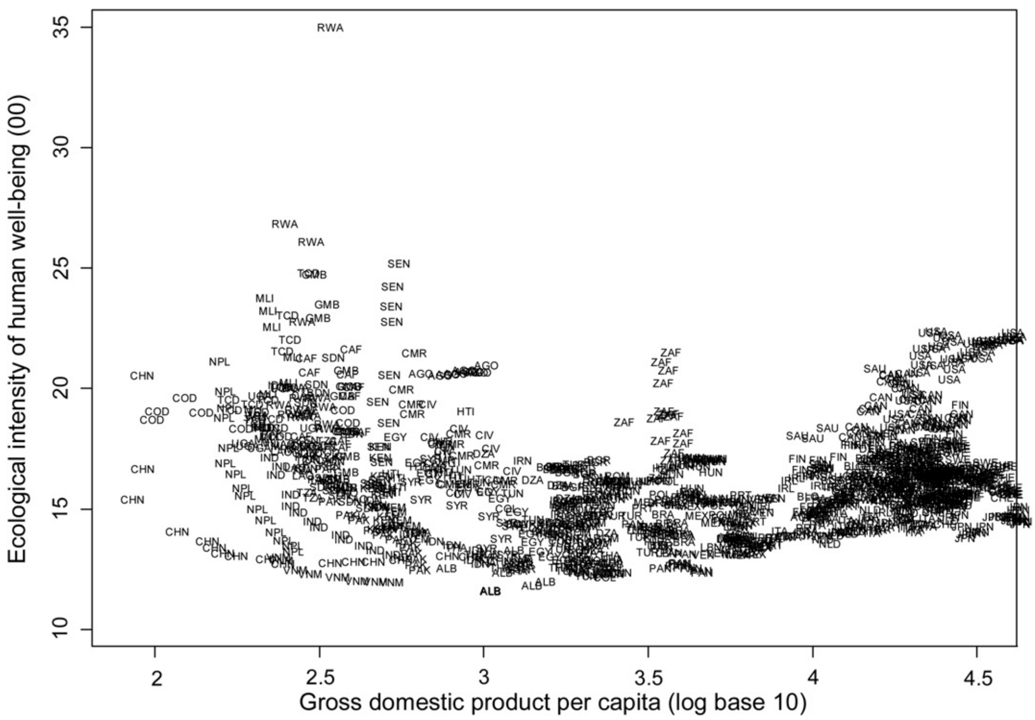

Fig. 2. Ecological intensity of human well-being by gross domestic product per capita.

to EFPC.[9] Our measure of the environmental intensity of human well-being (EIWB) is then:

$$\text{EIWB} = ((\text{EFPC} + 7.508)/\text{LE}) \times 100$$

where EFPC is ecological footprint per capita and LE is life expectancy. We multiple by 100 to scale the ratio.

Thus the model we test is:

$$\text{EIWB}_i = f(\text{GDP}, e) = a + b^*(\ln \text{GDP}) + c^*(\ln \text{GDP})^2 + f(t) + e$$

where $f(t)$ represents the time polynomial and a, b, c and e (the error term) are to be estimated.

Trajectories of the ecological intensity of human well-being

Fig. 1 plots EIWB by year, using UN 3 letter country codes as plotting symbols. Fig. 2 plots EIWB against the base 10 logarithm of gross domestic product per capita. The overall pattern seems to approximate a U shape, embarrassing the predicted *inverted*-U of environmental Kuznets and EM theories.

Table 1 provides estimates of the fixed effects model with robust standard errors using countries as clusters and of the "between" estimator that averages within countries over time. Both estimators give quite similar results. In both cases the environmental Kuznets hypothesis is not sustained as an overall description of the relationship between EIWB and affluence. Rather, the estimates yield a negative coefficient for the linear term in the log of gross domestic product per capita and a positive coefficient for the square of logged gross domestic product per capita—resulting in a U-shaped pattern. This pattern is the inverse of the inverted-U predicted by the Kuznets proposition. It appears that increases in affluence from the lowest levels to a mid-range tend to reduce the ecological stresses of producing well-being. But past a turning point of about $2558 dollars per capita (based on between estimates), ecological stresses per unit well-being increase.

In an analysis not reported in detail here, we have also estimated the environmental Kuznets curve separately for each of the 45 countries for which there are least 15 data points. Because of the strong time trend in GDPPC, the small sample size and the colinearity between the linear and quadratic terms in GDPPC, we do not explore these results in detail as we cannot be confident they are robust. However, we note that 23 of the 45 seem to be on a Kuznets trajectory while 22 have a U-shaped trajectory. This suggests that there may be substantial heterogeneity across countries in their paths towards or away from sustainability.

Table 1
Estimates of the effects of gross domestic product per capita on ecological intensity of human well-being.

	Fixed effects model	Between estimator
Gross domestic product (logged)	−18.878**	−16.992**
Square of logged gross domestic product	3.246**	2.493**
Time in years since 1960	−0.023	–
Time in years since 1960 squared	−0.003	–
Time in years since 1960 cubed	0.000	–
Intercept	42.330***	43.700***
Overall R^2	0.056**	0.174***
Number of observations (number of countries)	1221 (58)	1221 (58)

Note: standard errors in parentheses. For fixed effects model, standard errors are robust estimates treating countries as clusters. *$P < 0.05$; **$P < 0.01$.

[9] Since the coefficient of variation is the standard deviation (s) divided by the mean (m) then, using subscripts f and l to indicate ecological footprint and life expectancy, respectively, the correction factor $d = ((s_f \times m_l)/s_l) - m_f$. For our data this yields $d = 7.508$.

Conclusions

Our main conclusion views this effort as providing not definitive empirical results but an initial conceptual validation, opening a new realm of theoretical and analytical development. Despite their preliminary nature, our findings are encouraging of more refined analyses of environmental efficiency in producing human well-being. A very substantial literature on the anthropogenic drivers of environmental stressors using cross-national analyses (e.g. Dietz, Rosa, & York, 2007, 2010; Jorgenson, 2009; Jorgenson & Clark, 2009; Rosa, York, & Dietz, 2004; Shandra, Shor, & London, 2009; York, Rosa, & Dietz 2003) complements the environmental Kuznets curve literature cited above. But there has been relatively little exploration of what precisely nations gain from exploitation of the biophysical environment. We submit that examining the tradeoffs, the benefits versus costs, of alternative development strategies could contribute to fundamental understanding of the dynamics of human ecological relationships and political economy.[10] This approach was pioneered by examinations of the relationship between energy consumption and life-style during the 1970s (Buttel, 1978; Mazur & Rosa, 1974). It is consistent with early (Easterlin, 1974) and recent moves in economics away from seeing income or gross domestic product per capita as strongly equivalent to utility or well-being and toward exploring other measures, including subjective well-being (Brooks, 2008; Di Tella & MacCulloch, 2006; European Commission, 2009; Frey, 2008; Knight & Rosa, 2009, in press; Layard, 2005; New Economics Foundation, 2009).[11] Our foray into this reformulation of development applies the logic of the environmental Kuznets curve, one of the dominant theories linking economic growth and the environment, to an analysis of the relationship between one measure of human well-being (life expectancy) and one measure of anthropogenic environmental stress (the ecological footprint). We acknowledge that our analysis of the Kuznets proposition is preliminary. There are a variety of alternative measures of both human well-being and of environmental stressors that should be explored in parallel with considerations of human and social capital and institutional, cultural and environmental influences in shaping human well-being.

However, within the limits of the indicators and data available to us, we find the Kuznets argument inadequate as an overall explanation of national trajectories in well-being. The overall fit of our simple model demonstrates a U-shaped relationship, not the predicted inverted-U. These estimates constrain the effects of affluence to be equivalent across countries, and, as noted above, this may be an unrealistic assumption (Melenberg, Vollebergh, & Dijkgraaf, 2010; Roberts & Grimes, 1996; Vollebergh et al., 2009) although it reflects the general argument behind environmental Kuznets theory. There is a further methodological problem in that the factors that influence the numerator and denominator in a ratio may be different. At present, there is no well developed method for handling that problem—it remains an open challenge in the methodological literature.[12]

The Kuznets hypothesis is a simple one—increasing affluence, instantiated as GDPPC, leads to reduced stress on the environment. In this analysis we have transferred that hypothesis to a measure of sustainability and found it wanting. This will not be a surprise to most social scientists, despite the common assumption in the political and policy debates that economic growth will solve sustainability problems. Our results open the door for further exploration. It is plausible that institutional, cultural and environmental factors have far greater influence on a nation's path towards or away from sustainability than does affluence. Indeed, rather than assuming a link between a master variable of development, affluence, and various outcomes (i.e. environmental stressors, ecological intensity of well-being) we might pose a more general question of how nations deploy the resources at their disposal to produce well-being. This was a major theme of the Millennium Ecosystem Assessment (Reid et al., 2005). Several recent analyses have pursued this logic by examining the role of manufactured, human, social and natural capital in producing human well-being (Dietz et al., 2009; Engelbrecht, 2009; Mulder et al., 2005; Vemuri & Costanza, 2006). Such an approach may allow for a more nuanced account than emerges from environmental Kuznets models. One especially promising aspect of it is the potential to link work at the household and local level to macro-comparative work. Analyses in what has been called the "livelihood" tradition (Bebbington, 1999; de Sherbinin et al., 2008) emphasizes the active use of various forms of capital to produce livelihoods at the household level, demonstrating a logic parallel to the production of well-being approach being explored at the macro-comparative level here. We need an integration between these two approaches because macro-level analysis is adept at examining the influence of contextual factors and large scale structural changes but cannot readily unpack processes at the micro-level underlying such changes. Complementary micro-level studies, while rich in uncovering micro-level processes are typically limited by their time horizons and by their ability to make comparisons across large numbers of institutional, organizational and cultural contexts. To date these two rich traditions have been distinct and even somewhat antagonistic. However, a common theoretical framework is possible, and as larger number of place based analyses accumulate and as macro-comparative work develops tools for more detailed and nuanced analyses, the two traditions should be able to produce a richer and more complementary understanding of the link between human well-being and environmental stress. Our results here point towards the need to disaggregate one of the most commonly deployed theories in the macro-comparative framework—the environmental Kuznets curve—is a small step in that direction.

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[10] We use the term "development" advisedly. We intend it to describe the complex patterns of transformations occurring in nations around the globe over the last few centuries and do not imply that these are simple "unfoldings" as some theories of "development" imply (Dietz, Burns, & Buttel, 1990).

[11] One of the most visible examples of this trend is the Commission on Measurement of Economic Performance and Social Progress created by Nicolas Sarkozy, the President of France, and chaired by Nobel Laurates Joseph E. Stiglitz and Amartya Sen along with the distinguished French economist Jean-Paul Fitoussi. See their first report: <www.stiglitz-sen-fitoussi.fr>.

[12] We thank Prof. Kenneth Bollen for his advice on this matter.

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