Efficient Well-Being:

Rethinking the Relationship Between Human Benefits and Environmental Costs[1]

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## Abstract

Most theories of environmental impact assume that exploitation of the environment provides benefits to human well-being. However, this assumption has not been subject to much empirical discipline. We propose a model of Efficient Well-Being (EWEB) inspired by the Stochastic Frontier Production Models commonly used in economics. EWEB assesses a nation-state's efficiency in enhancing human well-being through the use of economic, natural and human resources. The approach suggests shifting analytic attention from the elusive question whether a nation is sustainable to the more tractable question of how efficient a nation is in producing human well-being while minimizing adverse environmental impacts. Drawing on sustainability theory, we conceptualize human well-being as a function of physical capital, natural capital and human capital. In a preliminary test of this approach we operationalized human well-being as life expectancy, flows of physical capital as gross domestic product per capita, flows of natural capital as the ecological footprint, and human capital as education. Using data from 135 nations, we find that controlling for physical and human capital, exploitation of the environment has no net effect on well-being. This suggests that improvements in well-being may be possible without adverse effects on the environment and that many nations could substantially improve their efficiency in using human and natural resources to generate well-being.

Keywords: Sustainability, human well-being, ecological footprint, Stochastic Frontier Production Models

## Introduction

In 1994 in this journal we reviewed the diverse assertions about the human sources or anthropogenic drivers of environmental change and argued they had not been much disciplined with empirical work (Dietz and Rosa 1994). We offered a simple model, subsequently labeled STIRPAT (www.stirpat.org), which would allow progress in systematic hypotheses testing about the anthropogenic drivers of environmental change. This approach consciously followed one of the distinguished ecologist's, Richard Levin's (Levins 1966) three strategies for model development: it is both *general* and *precise* though as a result it may lack *realism* in some applications. Our rationale for following this strategy is that it is always possible to elaborate a general and precise model to make it more realistic. At the same time, models that emphasize generality and precision allow for rigorous testing of hypotheses while that tack may not be possible if either of these attributes is sacrificed to the interests of realism. Indeed, a great deal can be learned by examining precisely what is needed to make a general and precise model more realistic for application in a particular context.

A slowly growing body of research examines the anthropogenic drivers of environmental change. In particular, a basic understanding of why nations differ in the amount of environmental impact they generate is available although more subtle questions, such as the specific behaviors impacting the environment and the decisions that produced them, remain to be addressed (Dietz, Rosa, and York In press). The application of the model produced initial findings that are perhaps not surprising—both population and affluence increase impacts (Dietz and Rosa 1997; Rosa, York, and Dietz 2004; York, Rosa, and Dietz 2003). In apparent contradiction to those findings there is some evidence that pollutants that have local impacts may be reduced after a threshold level of affluence is reached— a pattern called the "environmental Kuznets curve" (Dinda 2004; Grossman and Krueger 1995). But the evidence for that result is equivocal and for non-local effects, such as greenhouse gas emissions, there is literally no support for a strategy of "growing past" environmental impacts (Cavlovic et al. 2000).

Of course, there is far more to be done in examining the anthropogenic drivers of environmental change, and the papers in this special section address many of the open questions. But we note a great imbalance between the conceptual frameworks that organize international discussions of global change research and the portfolio of empirical work currently available to discipline those discussions. The variety of conceptual frameworks emphasize *both* the effects of humans on the environment (Human activities —>Environment) *and* the effects of the environment on humans (Environment—>Human Activities) (Alcalmo et al. 2003). While steady progress is being made in developing and testing theories of how human actions, anthropogenic forces drive environmental change; very little work has been done on how the environment affects the social world.[2]

[2] Human ecologists in the human-natural systems coupling tradition are exceptions (Diamond 1999, 2005; Lenski 2005; Moran 2006) as is the literature on vulnerability to environmental change, which for several decades has wrestled with the best way to

This is rather surprising since both core theory and major international assessment efforts suggest that human impact on the environment is not driven by ignorance or carelessness but by the advantages derived from exploiting the environment. The idea is very old and very new. It is old in the unforgettable dictum—"Knowledge is Power"—uttered in 1597 by Francis Bacon, where he was referring to human power over nature for the betterment of the human condition. It is new in such examples as the Millennium Assessment of Ecosystems and Human Well-being (MEA) which had as a major goal "to assess the consequences of ecosystem change for human well-being and to establish the scientific basis for actions needed to enhance the conservation and sustainable use of ecosystems and their contributions to human well-being."(Reid et al. 2005) The goal reflects a longstanding concern in discussions of sustainability: how does human well-being relate to ecosystems? From the earliest documents calling for consideration of sustainability (International Union for the Conservation of Nature 1980; World Commission on Environment and Development 1987) to the idea of the "triple bottom line" of economic, environmental and social goals (Elkington 1999) the link between human well-being and use of the environment has been at the forefront of consideration. To date much of the analytical effort accompanying the interest in sustainability focuses on finding "win-win" solutions where preserving ecosystem structure and function also enhances human well-being, or in identifying the costs to human well-being associated with ecosystem degradation.

Thus one of the MEA's major conclusions is "The degradation of ecosystem services could grow significantly worse during the first half of this century and is a barrier to achieving the Millennium Development Goals." (Reid et al. 2005)1) However, as the MEA also notes, "The changes that have been made to ecosystems have contributed to substantial net gains in human well-being and economic development, but these gains have been achieved at growing costs in the form of degradation of many ecosystem services, increased risk of nonlinear changes, and the exacerbation of poverty for some groups of people."(Reid et al. 2005) (p. 1). These findings suggest that we have, indeed, purchased some well-being at the cost of environmental degradation. However, we may be reaching a tipping point beyond which the returns in human well-being from environmental degradation will decline sharply.

The sociological literature also has acknowledged instrumental reasons to degrade the environment. This idea is at the heart of Schnaiberg's "treadmill of production" (Schnaiberg 1980, 1994). The politics that drive extraction of raw materials from the environment and the dumping of wastes into the environment are grounded in the quest for minimizing costs of production to maximize profits for producers. Schnaiberg, neo-Marxists (Foster 1999, 2000) and neo-classical economists are in agreement on this point

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incorporate environmental influences into social theory (Kasperson et al. In preparation; McLaughlin and Dietz 2007). However the human ecological tradition emphasizes how the environment constrains and shapes societal evolution, while the vulnerability tradition typically focuses on untoward events (floods, droughts, famines, etc.). We are applying a much different lens, as we hope will be clear below.

though they view the political dynamics of environmental use much differently. For example, Schnaiberg's special insight was that the escalating exploitation of the environment was in large part driven by the need to overcome the social costs of technological improvements in production, such as unemployment. Class conflict is displaced into "conflict" between humans and the environment. His argument in this regard was presaged by Anderson (Anderson 1976) on whom Schnaiberg draws extensively. While Schnaiberg and other scholars in political economy emphasize the negative social and ecological aspects of this dynamic, the idea that some activities that degrade the environment can improve human well-being is wholly consistent with these arguments. This is not to ignore the short-sighted and inequitable nature of decisions to exploit the environment but only to say that some short term benefits to some humans may be derived from them.

Combining these arguments with the question "Why do nations differ in the amount of environmental impact they generate?" we might investigate the reason why nations differ in the amount of well-being they create for each unit of environmental stress they produce. That is, it may be appropriate to move from looking just at environmental "bads" to looking at what nations manage to produce from stressing the environment. This would allow a search for the nations that are most and least efficient at producing well-being. It moves attention from the powerful but overly general concern with how sustainable the practices and structures of a nation are to a more limited but more sharply focused concern with the relationship between environmental inputs and human well-being outputs. This, in turn, requires an operational definition of efficiency to measure how efficient a nation is at producing human well-being. The challenge is to provide an efficiency measure that weighs well-being benefits against environmental costs in the context of coupled human-ecological systems. We develop such a measure below which we call the Efficiency of Well-Being Index, or EWEB. Such a measure would facilitate assessing the sustainability of alternative political economies, institutional arrangements and cultural patterns. In turn it might identify strategies that enhance human well-being while minimizing environmental impact.

In this strategy we are following in the footsteps of Mazur and Rosa (Krebill-Prather and Rosa 1995; Mazur and Rosa 1974; Rosa 1997), who examined the link between energy consumption and life style and carbon emissions and well-being, demonstrating that energy consumption had "decoupled" from human quality of life and that carbon emissions were decoupled from well-being for many nations. This approach embeds the question of how stressing the environment contributes to human well-being into a more general question of what factors overall contribute to well-being, a theme that is tacit in most work in political economy.

## A Borrowed Model

Our exploration of the anthropogenic drivers of environmental change started with an intuitively simple model upon which we could elaborate. We suggest the same strategy is appropriate here. The problem of understanding cross-national variation in efficiency of well-being immediately brings to mind the well-developed suite of methods developed by economists to examine efficiency in production.

In economics, Stochastic Frontier Production Models (SFPMs) provide rich machinery for modeling cross-national variation in the efficiency of each nation in producing the most economic output from the least inputs. (Aigner, Lovell, and Schmidt 1977; Kuhmbhakar and Knox 2003). The standard formulation for such a model is:

1) $$O_i=f(\mathbf{X}_i)*E_i$$

where $E_i$ is the efficiency of a nation in producing output, $O_i$, and $\mathbf{X}_i$ is the vector of inputs.

After the STIRPAT conceptualization, suppose we consider human well-being (W) within a similar formulation. In particular, suppose we assume well-being to be a function of, or dependent upon both affluence (A) and environmental impact (I). Then we could represent the well-being of W for a nation i as:

2) $$W_i=f(A_i,I_i)*E.$$

In this formulation $W_i$, is well-being and $E_i$ is the EWEB, or the Efficiency of Well-Being Measure, $E_{i,}$ which varies by nation. $E_i$ is assumed to have an upper bound of 1, so that nations are compared to a hypothetical most efficient nation. The larger the value of E the more efficient the nation is at producing well-being from economic activity and use of the environment. Finally we would assume that there is a stochastic term representing random shocks, measurement error in W, etc. so, adding the stochastic term D, the generic model (1) becomes:

3) $$W_i=f(\mathbf{X}_i)*E_i*D_i$$

What are the candidate components of **X**? Here sustainability theory suggests three inputs: physical capital—or capital in the traditional sense of political economy—natural capital and human capital. If we represent physical, natural and human capital by A (for affluence), I (for impact on the biophysical environment) and H (for human capital) we can operationalize the model. The model, then, becomes:

4) $$W_i=f(A_{i,}\ I_{i,}\ H_i)*E_i*D_i$$

If we assume that the production function is linear in the logs[3] we have

[3] Note STIRPAT applications we have used both base e, natural logarithms, and base 10 logarithms depending upon the objectives of the analysis. There is a longstanding tradition in econometrics of using natural logarithms on modeling stochastic frontier production functions, so we follow that tradition and here use natural logs. As with STIRPAT we begin with a form that is linear in the logs, but can easily expand to

5) $$\ln(Wi) = A_0 + B_1 * \ln(A_i) + B_2*\ln(I_i) + B_3*\ln(H_i) - \ln(E_i) + \ln(D_i)$$

Then in estimation $\ln(E_i)$ is constrained to be strictly negative.[4] There is a substantial literature in econometrics on how to estimate this function with the appropriate constraint on $\ln(E_i)$. The most common approach, which we will use here, is the half-normal distribution where values are restricted to one side of the normal distribution.

## An Approach Using the Model

What measures for A, I, H and W are reasonable? The standard measure of affluence, $A_i$, is gross domestic product per capita (GDPPC). This seems reasonable, for while we usually think of GDPPC as a measure of income it has its origins in tracing the economic activities in an economy, and so is a measure of the processes that produce goods and services (Hecht 2005).

The problem of a measure for $I_i$ is more difficult. Measures that pick a single environmental stressor, such as emissions of greenhouse gases are not useful for our purposes. They ignore tradeoffs and, therefore potentially underestimate environmental costs. For example, a nation might reduce greenhouse gas emissions by increased reliance on nuclear power, but nuclear power has its own environmental consequences. Here we use the ecological footprint (EF) as our measure of environmental impact. Specifically, the EF is calculated by taking basic forms of consumption—crops, meat, seafood, wood, fiber, energy, and living space—and converting them, at world average productivity, into six types of biologically productive land and sea space—crop land, forest land, grazing land, water area, land for infrastructure and land needed to absorb $CO_2$ emissions. Not without criticism, it is, nevertheless, the most comprehensive and most widely adopted overall measure of threats to environmental sustainability. Among its strengths are the capture of tradeoffs, for example, between fossil fuels and nuclear power or between consumption of fish and consumption of meat (Wackernagel et al. 2002). Its major limitation is that it does not account for local impacts such as biodiversity loss or pollution emissions (except for $CO_2$). However, cross-national data on local impacts are meager so at present they cannot be included in the footprint.

Human capital, $H_i$, is even more difficult to assess, in part because it is more difficult to conceptualize and in part because comparable measures across nations are difficult to obtain. Nevertheless, there is general agreement that human capital implies the acquisition of knowledge and skills that permits an individual greater efficacy in navigating through life. For this initial effort, we will use the U.N. education index,

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examine functional forms that are non-linear in the logs when that seems theoretically appropriate.

[4] Note the constraint $0<E\leq 1$ because the upper bound of E is one. So the log of E, or EWEB, must be non-positive and finite. This is true because the log of a fraction must satisfy the equation $e^x = 0<E\leq 1$, which means that $x = <0$, and thus the sign of the efficiency term is negative.

which combines adult literacy and school enrollment (United Nations Development Programme 2001).[5]

There are many candidate measures of human well-being, $W_i$, but no universally accepted single one. We will restrict our attention to life expectancy at birth. Life expectancy has a number of advantages as a measure of well-being. It is well measured in most countries. It is widely accepted normatively as a measure of a societal "good." For example it is one of the three components of the U.N. Human Development Index (United Nations Development Programme 2001).[6] Once adjusted for the effects of ill-health or disability, life expectancy becomes either "healthy life expectancy" or "disability adjusted life expectancy" each of which is widely accepted in the public health community as a key measure of desirable outcomes from policy (http://www.who.int/healthinfo/boddaly/en/index.html).

Life expectancy also captures some aspects of equity. Poverty and inequality tend to increase 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). For all these reasons, life expectancy seems a reasonable starting point in our exploration of well-being.[7]

## Some initial results

We have assembled cross-sectional data on these four variables for 1999 to provide an initial test of the Stochastic Frontier Production Model (SFPM) applied to human well-being. Data on life expectancy and the education index are from the United Nations (United Nations Development Programme 2001). Data for the ecological footprint are from the Living Planet Report (World Wide Fund for Nature 2002). GDP is

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[5] Technically, the education index is a weighted average of the adult literacy rate (given 2/3 weight) and the school enrollment ratio (given 1//3 weight) scaled to range from 0-1.
[6] The other two are the education index and a standardized version of GDPPC. Thus we are treating education and affluence as causes of well-being rather than as well-being per se, so in a in a sense we are decomposing the Human Development Index to elucidate its causal structure while also taking account of the effects of environmental impact in generating well-being.
[7] In this discussion we do not address the issue of stocks versus flows. At a simple level one might argue that GDP per capita and the ecological footprint are annual flows, the education index is a weighted average of a stock (literacy) and a non-annual flow (enrollment rates) while life expectancy is largely a stock. However, the critical issues are which variables are subject to substantial short term changes and which ones move more slowly, and which causal effects are instantaneous when viewed from an annual perspective and which ones unfold more slowly (York, Rosa, and Dietz 2002). We expect that this will be an important issue for future work. Since we restrict our scope here to cross-sectional data, we believe it best to address these issues in a subsequent paper deploying panel data.

per capita in 1999 U.S. dollars at parity purchasing power is from the World Bank Data online site (devdata.worldbank.org/dataonline/SMRresult.asp; accessed 6/14/2004). We estimated a standard OLS regression model and a SFPM using a half-normal distribution for estimating the efficiency parameter[8]. Reported significance levels are based on maximum likelihood estimates (which are equivalent to ordinary least squares for the simple regression models). Robust estimates of standard errors via Jackknife procedures yielded identical results except that the significance level for A in the SFPM dropped from $p<0.001$ to $p<0.05$. The Variance Inflation Factors (VIFs) for A, I and H were 5.57, 4.77 and 2.10 respectively, within an acceptable range.[9] Niger has the highest leverage in the data set, but removing it does not change substantive conclusions.

Table 1. Production Models of Human Well-Being

| | OLS Regression | Half normal stochastic frontier production model |
|---|---|---|
| A (Affluence) | 0.088*** | 0.064*** |
| I (Impacts) | -0.007 | -0.022 |
| H (Human Capital) | 0.243*** | 0.235*** |
| Intercept | 3.502*** | 3.836*** |
| $R^2$ | 0.696 | -- |
| N | 135 | 135 |

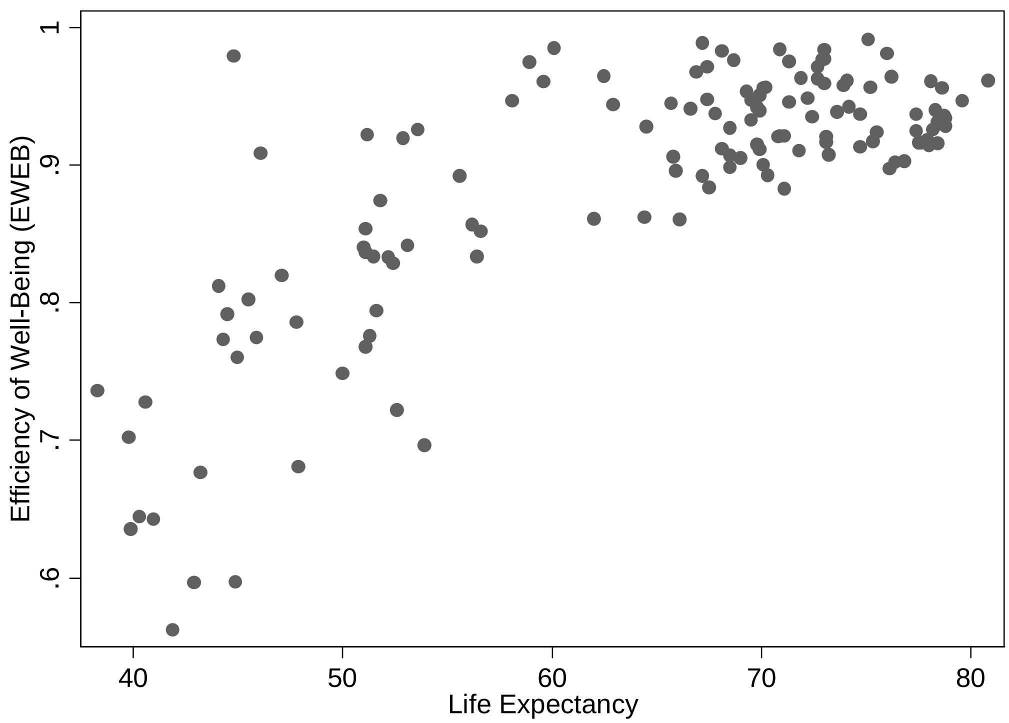
***--p<0.001

Table 1 displays the results of estimating a standard OLS regression in log-log form, where no special structure is imposed on the residuals and the SFPM using a half-normal distribution for estimating the efficiency parameter. The results for both approaches are quite consistent. Affluence has a significant positive effect, as does human capital. However, we find no evidence that adversely stressing the environment improves human well-being, net of affluence and human capital. The per capita ecological footprint has a negative effect but is not statistically significant via any method of estimation we have used. This suggests, that, in the tradition of Mazur and Rosa (Mazur and Rosa 1974), the link between human well-being and exploitation of the environment is being decoupled. We stress that this is a net effect. Impacts in and of themselves do not improve well-being once affluence is taken into account, but we acknowledge that to the extent impacts are converted to affluence they may have an indirect effect on well-being. We will return to this point below.

[8] Models were estimated with Intercooled Stata 9.2.

[9] There is no established standard for VIFs. Hamilton (Hamilton 1992 :134) suggests values above 5 (a tolerance of .20, the reciprocal of 5) or 10 (a tolerance of .10) may be a problem. Similarly, Chatterjee, Hadi and Price (Chatterjee, Hadi, and Price 2000:240) suggest that a VIF above 10 (which corresponds to a tolerance below .10) is a problem and Greene (Greene 2000:258) suggests a VIF above 20 is a problem (which corresponds to a tolerance of below .05).

Figure 1. Life expectancy versus Efficiency of Well-Being (EWEB)




A likelihood ratio test rejects the hypothesis of the log of efficiency parameters ($E_i$) being simultaneously zero ($p<0.001$), thus there is evidence of some inefficiencies across nations. Figure 1 displays the efficiency multipliers (the $E_i$ in Equation (3)) for the nations in our sample plotted against life expectancy. Virtually all the cases with life expectancy under 60 years and EWEB less than 0.9 are in sub-Sahara Africa. It appears that many, but by no means all, African nations are relatively inefficient in their production of well-being. This suggests that the problems with improving well-being in Africa will require not only raising the levels of education and alleviating poverty but also changes in the factors that underpin this lack of efficiency. It also points to the importance of expanding on this analysis to better understand those factors. We also note that a number of moderate and low income nations—such as Jamaica, Morocco, Yemin, Syria, Nicaragua, Egypt—do quite well in generating well-being from their modest levels of affluence and human capital. Two key questions come to mind: Why are these nations relatively efficient in translating their inputs of affluence and human capital into well-being? Will those efficiencies hold as affluence and human capital increase? An answer to both questions will inform broad strategies for improving well-being without serious ecological deterioration. Of course, these results are illustrative and the details may change as this approach is explored further. We conclude by considering the logical next steps in such explorations.

## Conclusions and Directions for Further Work

We have pursued several goals in this paper. The first, and most general, is to point out that the effect of using the physical environment on human societies deserves much more extensive theorizing and empirical examination. The second is to suggest that looking at the relationship between environmental stresses visited on the environment and human well-being is one way to frame an examination of these links, and that the traditions of production function modeling in economics provides a useful machinery for empirical work within such a frame. Finally, we have offered some empirical results. These results, while we believe them sound, must be viewed as very preliminary. We have used a very simple model of the production function for human well-being, and that model certainly bears elaboration based on further theorizing and analyses. We have examined only one measure of human well-being, albeit one we consider quite defensible. Furthermore, we have looked at only a cross-section of nations. The moderate sample suggests caution regarding maximum likelihood results. And use of cross-sectional data precludes us from examining the dynamics, including cross-lagged and other effects, between the environment and society.

The results from this analysis need to be considered in the context of other findings from the STIRPAT program and other research to more fully understand their implications. First, one of the most consistent findings from previous STIRPAT research is that affluence, as measured by GDPPC, is closely linked to environmental impacts (Rosa, York, and Dietz 2004; York, Rosa, and Dietz 2003; York, Rosa, and Dietz 2002). Thus, although we find here that affluence improves human well-being, we should not lose sight of the fact that this typically comes at a high environmental cost. Second, it also appears likely that improvements in well-being from growing affluence are best characterized by a relationship of diminishing returns; i.e., growth in affluence for very low income countries can substantially improve well-being, but this benefit rapidly diminishes so that for affluent countries, further economic growth does little to improve human well-being. Here and in other analyses we have found a decoupling of environmental stressors and well-being, once the effects of affluence are controlled (Dietz, Rosa, and York 2007). The decoupling of environmental stressors from well-being but not from economic growth leads to a clear conclusion: human well-being can be improved without dramatic environmental degradation, but not through development strategies that focus on the expansion of economic production alone. A more explicit focus on improving human well-being directly, rather than indirectly by expanding wealth, may serve to both limit human impacts on the environment and improve the human condition.

Despite the empirical limits in our analysis, we believe this has been a useful exercise. Like the original STIRPAT formulation, it awaits elaboration. Nevertheless, like STIRPAT, it provides a framework for examining how societies make use of the biophysical environment. This allows construction of specific conjectures about how social structure, political economy, culture and other factors influence sustainability. This is a move from the admirable but perhaps overly general and operationally challenging idea of sustainability to a more specific formulation— measuring the well-being gain obtained from use of nature's capital and services. Instead of asking how "sustainable" various social formations and practices are, we ask how efficient are they in producing human well-being? This approach allows conjectures to be disciplined with data, with quantitative assessment of the performance of nations, and with promise for operational guidance for informed decision making. We believe that the process of elaborating and testing such models will provide useful information for the transition towards sustainability.

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