ORIGINAL ARTICLE

Technology improvements and value changes for sustainable happiness: a cross-development analytical model

Fabio Zagonari[1]

Abstract This paper develops an analytical model to calculate the amount by which individuals are expected to modify their values (the relationship between lifestyle and happiness, as measured by subjective well-being, SWB) and to adopt innovative technologies (to increase the sustainability of production and consumption, measured by the ecological footprint, EF) to allow current and future generations to achieve sustainable happiness (the pursuit of happiness that does not exploit other people, the environment, or future generations). The paper also examines the dependence of these changes on an individual's concern for future generations and on their country's current state of economic development. It is shown that individuals in better-off developed countries and individuals in worse-off developing countries can achieve sustainability with a reasonable level of value change (0–30 %) and a feasible degree of technological innovation (10–40 %), respectively. In contrast, individuals in better-off developing countries and individuals in worse-off developed countries must rely to an impractical degree of technological innovation (50–70 %) and to an unreasonable level of value change (40–70 %), respectively. Finally, individuals in developing countries differ from individuals in developed countries in terms of their potential to achieve sustainable happiness, by achieving sustainability at a low SWB (about 10 % of its maximum) and a high SWB (about 80 % of its maximum), respectively.

Keywords Sustainability · Happiness · Values · Sustainable technologies · Model · Well-being · Ecological footprint

Introduction

Concerns about the trajectory of development and its harmful impacts on all life on the planet, including life that is yet to be born, have been outlined for many years (e.g. WCED 1987). These concerns have led many to advocate a shift from a materialistically oriented to a less materialistic worldview (see Ziolkowska and Ziolkowski 2011) or to a new welfare economics of sustainability (i.e. approaches to measure well-being that provide an alternative to equating per capita consumption with welfare; see Gowdy 2005). Others have advocated technological progress (e.g. IPCC 2007) or post-normal technologies, which involve stakeholder engagement and interaction with those who possess more traditional forms of expertise in order to co-produce knowledge about sustainability (see Frame and Brown 2008).

The concept of sustainable happiness (i.e. the pursuit of happiness that does not exploit other people, the environment, or future generations) was developed to draw attention to the consequences, both positive and negative, of how individuals, communities and nations pursue happiness (O'Brien 2008). In other words, the goal is to achieve happiness (as an end), but constrained by the (subjective) happiness or (objective) resources of others.

✉ Fabio Zagonari
  fabio.zagonari@unibo.it

[1] University of Bologna, Bologna, Italy

Moreover, de Vires and Petersen (2009) advocated a shift from welfare to capabilities and functions or to human-scale development in order to achieve a constructive resolution of the tension between objective and subjective notions of the sustainability and quality of life, by combining individual values and cognitive maps in worldviews translated into model-based narratives or scenarios. In other words, this means seeking sustainability based on values and beliefs: the tension between ends and means remains, but the distinction between objective and subjective disappears.

Finally, Sabau (2010) suggested sustainability as a principle of social continuity on Earth (i.e. to understand our rights and duties in light of the solidarity chain that links our fate to those of nature and of our fellow humans). In other words, this means aiming at sustainability regardless of happiness: the tension between ends and means also disappears in this approach.

The purpose of the present paper is to develop an analytical model to address the following questions: To what extent should we change our values (in particular, the relationship between lifestyle and happiness, as measured by subjective well-being, SWB) or introduce new technologies (in particular, those that promote sustainable production and consumption, as measured by their ecological footprint, EF) to allow people in current and future generations to achieve sustainable happiness? To what extent do these changes in values (materialistic vs. non-materialistic) and technologies (sustainable vs. non-sustainable) depend on the current state of economic development of a country and on concerns for future generations?

To better grasp the relationship between lifestyle and happiness, consider the possibility of different values that are capable of producing the same happiness level from different consumption patterns. For example, in order to reach their workplace on the other side of the city, an Italian worker who uses a 1500 cc gasoline-powered car could achieve the same level of utility as another worker who uses a 1000 cc car if the latter is more concerned about the use of the car while the former is more concerned about the social status revealed by the car. Similarly, different values can produce different happiness levels from similar consumption patterns. For example, if the Italian worker uses a 1500 cc car in the United States, they would achieve a smaller happiness level than in Italy because American cars are larger, on average, than in Italy.

To better capture the relationship between production and sustainability, think of different technologies that lead to different sustainability levels for similar consumption patterns. For example, the CO_2 emissions by a 47-kW electric car (i.e. one equivalent to a 1000 cc gasoline engine) are smaller than those of a 1000 cc gasoline-powered car if the electric car can be recharged using a

sufficiently high proportion of clean energy. Similarly, different technologies can lead to the same sustainability levels from different consumption patterns: for example, the electric car's CO_2 emissions would be similar to those from a 50 cc gasoline-powered motorcycle (i.e. equivalent to 2.3 kW) if the proportion of clean energy used to recharge the electric car is sufficiently large.

To better grasp the meaning of changes in values, think of a consumer who receives the same level of utility from the 1500 and 1000 cc gasoline-powered cars after adopting a less materialistic worldview. To better capture the impact of technological changes, think of a consumer who would move from a 1000 cc gasoline-powered car to an equivalent 47-kW electric car if technological innovation made this feasible.

In other words, I will assume based on these examples that science and technology can make significant potential contributions to help implement sustainability policies (see Huesemann and Huesemann 2008). To do so, I will quantify to what extent a fundamental change in values can replace scientific research and technological innovation in order to achieve sustainability (see Helliwell 2014), and to what extent changes in societal values and policies depend on a fair distribution of income between current generations and on just treatment of future generations and the environment that will sustain them.

Note that it is beyond the scope of this paper to address the following additional questions: Can individuals be educated or trained (see Solomon 2010) to make better choices about sustainable happiness? Which policies could contribute (see Hellstrand et al. 2009) to sustainable happiness?

Moreover, two main groups of actions can favour individual sustainability (which is only *partially* depicted by EF). First, consumers can directly choose consumption patterns based on less pollution emissions and resource use and can indirectly choose production technologies through their product choice. Second, producers can directly implement less manufacturing and more service industries and technologies that emit less pollution or use less resources. For the sake of simplicity, the abovementioned examples and the examples in the following sections will refer to "consumers" rather than "individuals" based on the assumption that consumers can choose economic structures, production technologies and consumption patterns. The distribution of global sustainability among countries (i.e. sustainability of human activities in a world that is seen as a system composed of interdependent economic, social and environmental sub-systems), linked to import decisions by consumers, will be disregarded (Kissinger and Rees 2010).

Finally, although several factors can affect individual happiness (which is only *partially* represented by SWB),

for the sake of simplicity, the abovementioned examples and the examples in the following sections will refer to "utility" instead of "happiness", based on the assumption that happiness linked to income arises from consumption and related freedoms rather than from social structures or ethical principles. The utility that arises from objective *uses* of goods or services will be distinguished from utility arising from subjective sources such as social *status* by disregarding global sustainability, which characterises goods or services.

The recent literature on sustainable development, which is relevant for this study, can be summarised in two main questions: What is sustainable development? How can it be achieved?

As regards the first question, it is possible to envision a shift from a definition of sustainability to an epistemological foundation for the theoretical framework of sustainable development based on different categories and independent concepts (i.e. ethical paradox, natural capital stock, equity, eco-form, integrative management, utopianism, political global agenda). This shift highlights sustainability as an unresolved and fluid paradox, which can simultaneously inhabit different and contradictory environmental ideologies and practices (Jabereen 2008). Next, it is possible to envision a shift from a definition of sustainability to scientific sustainability principles (i.e. biophysical limits, societal welfare and development, irreducible minimum needs, system complexity). This shift leads to sustainability as an attempt to bring together scholars from different backgrounds and disciplines in order to create an integrated thesis (Quental et al. 2011).

As regards the second question, Hellstrand et al. (2009) emphasised that politicians must address the distributional issues within and between nations by stressing the drawbacks for nature and society that result from the pressure that society puts on nature. Thus, economic and ecological policies must address the restrictions on ecological sources and sinks that underlie sustainable development. Solomon (2010) stressed that environmental law and environmental education will not succeed in poor countries, where the government's overwhelming priority is placed on economic development; however, environmental ethics must be the force that drives the adoption of environmental priorities by other disciplines.

In this study, I will adopt a familiar definition of sustainable development (i.e. social and economic development defined in terms of happiness within ecological sustainability limits defined in terms of ecological footprints), and will explore this definition within a normative approach (see Baumgartner and Quaas 2010). My goal is to assess the potential substitutions between economic and ecological policies (here, represented by technological innovation) and environmental ethics (here, represented by

value changes) and the role of these substitutions in achieving sustainable development (see Konchak and Pascual 2006). In so doing, I will distinguish between developed countries and developing countries because of the different constraints they face.

Methodology

The constraints with current values and technologies

In this paper, I measured sustainability using EF values, which represent the relationship between the use of natural resources by individuals, organisations, or nations and the carrying capacity of the biosphere that sustains this use. Other indicators of the sustainability of current consumption could have theoretically been chosen (see Brand 2009), but I chose EF because of the high data availability. I referred to EF values for 141 countries provided by Bagliani et al. (2008). The originality of the present study does not rest on the use of original data; using other indicators would not change the approach and the insights it provides. Next, I measured happiness using SWB values, which represent an index that combines each person's responses to questions about happiness and life satisfaction. Again, although other definitions of happiness would be theoretically consistent with the model developed in this paper (see Deci and Ryan 2008), I chose SWB because of its high data availability, being aware that this measure of happiness does not cover all dimensions of happiness. I considered SWB values for 88 countries provided by Inglehart et al. (2008). The originality of the present study does not rest on the use of original data; using other indicators would not alter the approach and the insights it provides.

To simplify the model development, I assumed that each individual is expected to produce the same sustainable EF per year. This is set at the current value (the value in or around 2008 based on the available data), although this EF might not be the future equilibrium value with a larger world population that has a longer life expectancy.

Finally, each individual is assumed to theoretically refer to the same world "achievement function" that defines the ability to transform EF into SWB. This is obtained as a stochastic production function based on average data per country, with variability observed both in SWB and in EF among individuals and among countries. In this analysis, EF and SWB for each individual were normalised with respect to their current (in or around 2008) values by setting those values to 1, and expressing all changes as a proportion of that baseline value. Thus, EF and SWB are normalised with respect to their current values. However, I differentiated between individuals in developed and developing countries with respect to the part of the developed

"achievement function" that is feasible for them to implement in practice. In particular, by combining the world relationship between EF and income developed by Bagliani et al. (2008) (i.e. $0.9585 + 0.4y - 0.00757y^2$) with the global relationship between SWB and income developed by Inglehart et al. (2008) (i.e. $-0.276 + 0.2y - 0.0025y^2$), where y stands for per capita income in thousand USD, the global constraint that represents the relationship between EF and SWB can be derived as EF $\geq$ EF(SWB) (Fig. 1). This represents the smallest EF value that each individual can technologically produce, on average, for alternative values of SWB.

To better understand why individuals in developing countries, in practice, implement the lowest part of the same theoretical "achievement function" (based on world empirical data), think of an Indian consumer who cannot afford a 1500 cc gasoline-powered car, and who can only afford a 150 cc gasoline-powered motorcycle. Even if the consumer is more concerned about the uses obtained from the vehicle than about the social status provided by the means of transportation, they will never reach the utility level achieved by the Italian consumer who uses a 1500 cc gasoline-powered car; for example, the Indian faces difficulties carrying his/her spouse and two children on the motorcycle, let alone the family's luggage. However, it would be possible to shift to a 100 cc motorcycle if uses similar to those provided by the 150 cc motorcycle could be obtained from it, and to obtain a 4.7-kW electric motorcycle (i.e. equivalent to a 100 cc gasoline motorcycle), if this becomes feasible.

Note that EF $\geq$ EF(SWB) is a constraint that each individual faces, but it does not equal the macro-level
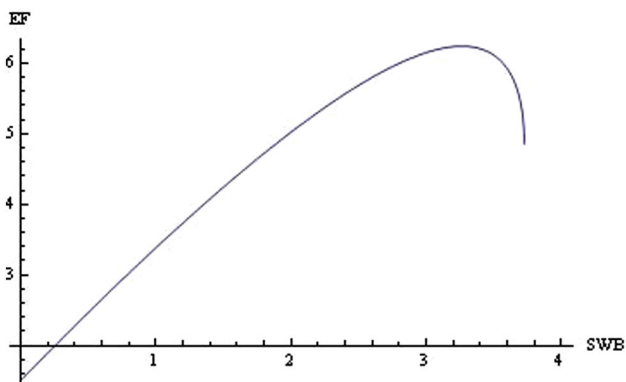

Fig. 1 Ecological footprint (EF) as a function of subjective well-being (SWB). The SWB is measured by combining a life satisfaction index (on a 10-point scale) with a happiness index (on a 4-point scale), with equal weight given to each variable (i.e. SWB = life satisfaction—2.5 happiness) so that SWB can range from the maximum score of 7.5 to negative scores (Inglehart et al. 2008). The EF is measured in global hectares, with country values from around 2008 ranging from 0.52 for Bangladesh to 11.87 for the United Arab Emirates (White 2007)

relationship between happiness and sustainability, unlike in the country rankings by NEF (2012), the linear regressions by Zidansek (2007), or the ranked data correlations by Moffat (2008). Also see Engelbrecht (2009) for macro-level relationships between happiness and natural capital, Bonini (2008) for macro-level relationships between life satisfaction and environmental conditions and Welsch (2007) for macro-level relationships between SWB and pollution. This constraint does not represent a causal link between greater happiness and greater sustainability; too many variables other than per capita national sustainability might affect per capita national happiness, including the states of economic development (Veenhoven 2005), democracy (Welsch 2003), social tolerance (Haller and Hadler 2006) or ethics (Zagonari 2011), for it to be possible to identify relationships or causal links between happiness and sustainability.

Moreover, the application of a single theoretical global stochastic constraint (Lothgren 1997), calculated by fitting average values per country properly weighted by population size, cannot account for the variability of EF(SWB) among individuals in different countries even if the constraint is split into separate parts for developed and developing countries. For example, compare a happy and sustainable person in a low-income country with an unhappy and unsustainable person in a high-income country. To obtain specific quantitative results, one should apply a different "achievement function" for each individual, or at least a different constraint for all individuals in a given country or a different "achievement function" for all individuals in the same group of countries. In practice, the reference to a global constraint is sufficient to provide qualitative insights.

Finally, EF $\geq$ EF(SWB) (i.e. the technologically feasible EF values that each individual can produce, on average, for alternative values of SWB) is a theoretical constraint faced by each individual, not a representative individual, with people in developed and developing countries differentiated in terms of the practical implementation; this avoids issues related to the relationship between representative individuals and the environment (Dasgupta 1998).

The constrained maximisation problem

The benefits of material progress are accompanied by psychological costs related to the sense of purpose, autonomy, identity, belonging and hope (Eckersley 2007); and materialism or consumerism breed dissatisfaction, depression, anxiety, anger, isolation and alienation rather than happiness (Kasser 2002). In the present analysis, I will introduce a parameter (α) to depict the magnitude of the shift towards non-materialistic values. Think, for example,

of a consumer who comes to attach the same utility to 1500 and 1000 cc gasoline-powered cars as a result of the adoption of a less materialistic worldview. This parameter represents a shifting of the constraint EF(SWB) to the right along the SWB axis.

Next, it is important to create enough pressure from public opinion that the environmental standards will be raised regularly in order to ensure sustainability (Moran et al. 2008). To account for this phenomenon, a parameter (β) is introduced to depict the magnitude of the introduction of environmentally sustainable technologies. Think, for example, of a consumer who moves from a 1000 cc gasoline-powered car to an equivalent 47-kW electric car if technological innovation makes this feasible. This parameter represents a shifting of the constraint EF(SWB) downwards along the EF axis.

Let us assume that each individual tries to

$\text{Maximise}_{\text{SWB,EF}} \; \text{IUF} =$

$$\left[\alpha^{(1-\varepsilon)} \text{SWB}^{(1-\varepsilon)} + (\alpha/\beta)^{(1-\varepsilon)} \text{EF}^{(1-\varepsilon)} \right]^{1/(1-\varepsilon)}$$

subject to the following constraints

$\text{EF} \geq \text{EF(SWB)}$

$\text{SWB} \geq 0, \; \text{EF} \leq \zeta, \; \text{EF} \geq 0$

with

$0 < \alpha \leq 1, \; 0 < \beta \leq 1, \; 0 \leq \varepsilon \leq 1,$

where ε (i.e. the inequality aversion of Atkinson's inequality index; Cowel 1995) depicts the aversion of the current individual to unequal welfare distribution between generations ($\varepsilon = 0$ means no aversion, $\varepsilon = 1$ means absolute aversion); IUF stands for the intergenerational utility function: it depends on consumption of both current (i.e. $C = \alpha$ SWB) and future (i.e. (α/β) EF) generations, under the assumption that each individual considers future generations in taking his decisions, to a smaller or greater extent according to his intergenerational inequality aversion; α is the relationship between the level of consumption and SWB ($\alpha < 1$ means that individuals achieve a greater SWB for a given consumption than is feasible today): it is applied to both current and future generations, under the assumption that a change in values can be individually instantaneous, although socially gradual; β is the relationship between consumption and EF ($\beta < 1$ means that individuals obtain a greater level of consumption per unit of EF than is possible today): it is applied to future generations only, under the assumption that an improvement of technologies cannot be socially instantaneous; and ζ depicts the sustainable EF for the current individual.

Note that each individual is fully rational (i.e. he maximises), but he is not selfish (i.e. he considers future generation SWB) (Gsottbauer and van den Berg 2011).

Moreover, he maximises the undiscounted sum of generational SWB, and a sustainabilitarian (Rawlsian) objective function is depicted by an extreme intergenerational inequity aversion (Romer 2011). Finally, the IUF includes EF as a measure of sustainability, where weak sustainability is considered by referring to the future generation SWB (Kratena and Streicher 2012).

To better understand the meaning of the intergenerational inequity aversion, observe that IUF is a constant elasticity of substitution utility function, where SWB of current generations is combined with SWB of future generations, which in turn depends on EF. If ε is close to 0, then it can be assumed that perfect substitution exists between current SWB and future SWB. In contrast, if ε is close to 1, then it can be assumed that there is no acceptable substitution between current SWB and future SWB: in order to achieve sustainability, one must rely solely on technological innovation. Analytical examples in the Supplementary Materials will refer to minimum ($\varepsilon = 0$), moderate ($\varepsilon = 0.5$) and maximum inequality aversion ($\varepsilon = 1$), while numerical simulations in Sects. No solutions with current values and technologies and Solutions with changed values and technologies will refer to small ($\varepsilon = 0.2$), moderate ($\varepsilon = 0.5$) and large inequality aversion ($\varepsilon = 0.8$).

Note that the model is normalised with respect to the current individual ($\alpha \leq 1, \; \beta \leq 1$) to obtain general qualitative conclusions for different individuals living in sustainable/unsustainable developed/developing countries, although large variability is observed in α, β and ε, with each individual potentially moving from one class to another: a worsening in current sustainability conditions is represented in terms of a possible decrease in ζ (that is, each individual should require at most ζ global hectares (gha) of productive land to sustain their level of consumption).

Moreover, $\text{EF} \geq \text{EF(SWB)}$ is a static constraint and $\text{EF} \leq \zeta$ is a dynamic constraint, although changes in α and β could be used to describe the dynamics of the achievement function. Only long-run equilibria are considered in this analysis.

Finally, since indifference curves in the plane (SWB, EF) (i.e. combinations of SWB and EF that provide the same level of IUF) are decreasing (i.e. a decrease in EF must be compensated for by an increase in SWB), both interior and corner solutions are feasible, as dependent on parameters α and β.

No solutions with current values and technologies

The graphical representation of constraints for the maximisation problem depicted in Sect. The constrained maximisation problem, at current values ($\alpha = 1$) and using

current technologies ($\beta = 1$), and at the current average per capita world sustainability ($\zeta = 1.8$; WWF 2010), leads to the conclusion that the only solution is at EF = 1.8 and SWB = 0.15 (Fig. 2 for $\varepsilon = 0.5$); however, this is an unacceptable solution because of the small SWB value (IUF = 2.99 if $\varepsilon = 0.5$).

Note that changing ε would modify the slope of the indifference curve as well as the achieved level of IUF and that imposing stricter sustainability conditions by decreasing ζ would decrease the SWB at the solution, but neither change would alter the results qualitatively.

The graphical representation of the constraints for the maximisation problem depicted in Sect. The constrained maximisation problem, together with the values of EF and SWB that characterised 33 countries in or around 2008 (White 2007; Inglehart et al. 2008), leads to the conclusion that only the Republic of Moldova has a feasible combination of EF and SWB, but with SWB < 0 (Fig. 3). This is not surprising, since a traditional agricultural society still prevails in the Republic of Moldova, as depicted by the lack of car production and the use of 82 cars per thousand people.

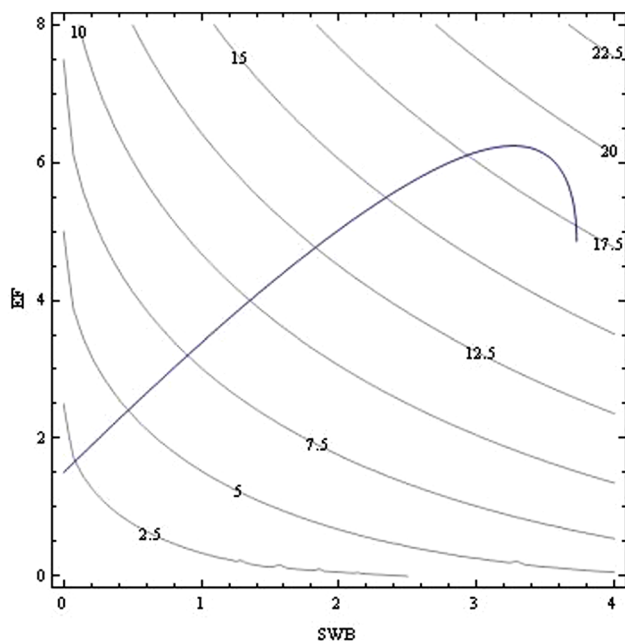Next, the graphical representation of the theoretical indifference curves (i.e. IUF levels related to couples of EF and SWB) together with the empirically observed values of EF and SWB for 33 countries (i.e. points in the plane EF and SWB) (Fig. 3) allows us to depict physical, human and social capital constraints, by differentiating countries in terms of the current IUF(0) into *worse-off and better-off developing countries* (i.e. IUF(0) < 5 and IUF(0) in [5, 10], respectively) and *worse-off and better-off developed countries* (i.e. IUF(0) in [10, 15] and IUF(0) > 15, respectively).

Note that replacing data on SWB (for which negative values might exist) with data on life satisfaction (for which only positive values are possible) would not alter the insights qualitatively; this is because the inverted-U shape of the relationship between EF and income has a stronger influence on the outcome than the concave-down relationships between SWB or life satisfaction and income.

Moreover, the depicted constraint is obtained by combining the fitting curves presented by Bagliani et al. (2008) for EF versus income and by Inglehart et al. (2008) for SWB versus income in order to use the largest coverage of countries, while the points presented in Fig. 3 refer to only the 33 countries for which I could obtain consistent data (in or around 2008) for both EF and SWB.

Finally, Fig. 3 reveals the expected groups of countries, with former members of the Soviet Union on the lower left, Latin American countries on the lower right (together with Turkey and South Africa), Catholic Western countries in
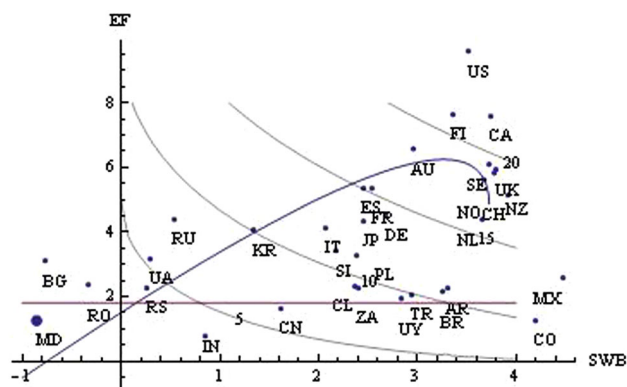

Fig. 2 The constraint EF ≥ EF(SWB) (*dark diagonal line*), the constraint EF ≤ 1.8 (*unshown horizontal line*) and indifference curves (*pale lines*) for $\alpha = 1$, $\beta = 1$ and $\varepsilon = 0.5$. *EF* ecological footprint, *SWB* subjective well-being, *IUF* intergenerational utility function, α the relationship between consumption and SWB, β the relationship between consumption and EF, ε the aversion of the current individual to intergenerational inequity. The numerical solution to the constrained maximisation is at EF = 1.8, SWB = 0.15, with IUF = 2.99

Fig. 3 The constraint EF ≥ EF(SWB) (*dark curved line*), the constraint EF ≤ 1.8 (*horizontal line*) and the indifference curves (*pale lines*) shown for IUF = 5 (*left*) to IUF = 20 (*right*) at intervals of 5, for $\alpha = 1$, $\beta = 1$ and $\varepsilon = 0.5$. Points representing 33 countries in terms of their EF and SWB values in or around 2008 were obtained from White (2007) and Inglehart et al. (2008). The Republic of Moldova (MD) is highlighted by a larger point. *EF* ecological footprint, *SWB* subjective well-being, *IUF* intergenerational utility function, α the relationship between consumption and SWB, β the relationship between consumption and EF, ε the aversion of the current individual to intergenerational inequity. Country names are defined using the ISO 2-letter country codes (www.iso.org/iso/country_codes)

the middle, Protestant Western countries on the upper right and China and India in the lower middle.

Solutions with changed values and technologies

The lack of acceptable solutions to the constrained maximisation problem depicted in Sect. The constrained maximisation problem and described in Sect. No solutions with current values and technologies leads to the following inequality problems:

Find α and β such that

$$\left[\alpha^{(1-\varepsilon)}\, \mathrm{SWB}^{(1-\varepsilon)} + (\alpha/\beta)^{(1-\varepsilon)}\mathrm{EF}^{(1-\varepsilon)}\right]^{1/(1-\varepsilon)} = \mathrm{IUF}(0)$$

$$\mathrm{EF} = \mathrm{EF}(\mathrm{SWB})$$

$$\mathrm{EF} = \zeta = 1.8.$$

Alternative values for ε (e.g. $\varepsilon = 0.2$, $\varepsilon = 0.5$ and $\varepsilon = 0.8$) will characterise alternative scenarios for each numerical solution, while referring to different current levels of IUF(0) will distinguish developed and developing countries in the analysis presented in Sect. Discussion.

To better understand the meaning of these conditions, note that the first condition represents indifference curves, in which current happiness and sustainability are combined; the second condition depicts the feasible relationship (due to values and technologies) between EF and SWB; and the third condition measures the current sustainability level.

Note that depicting β as a decision variable amounts to implicitly assuming that production processes are driven by consumers. Moreover, the "achievement function" is met with equality (i.e. EF = EF(SWB)), since I have referred to a global average constraint: countries below the EF(SWB) curve do not completely exploit the environmental capacity that is available to them, which is consistent with their achieved happiness level. Finally, the sustainability condition is met with equality (i.e. EF = 1.8), since I have disregarded the distribution of the sustainability burden among the world's countries: each country is expected to achieve sustainability.

Figure 4 displays the solutions for α and β to the inequality problems depicted above at $\varepsilon = 0.5$ for IUF within [0,20]. Figure 5 presents a solution to the constrained maximisation problem depicted in Sect. The constrained maximisation problem at the specified values of $\alpha = 1$, $\beta = 0.3$, $\varepsilon = 0.5$ for a developed country, while Fig. 6 at the specified values of $\alpha = 1$, $\beta = 0.7$, $\varepsilon = 0.5$ for a developing country.

At an average value of intergenerational inequality aversion (i.e. at $\varepsilon = 0.5$), developing and developed countries will achieve sustainability at low and high SWB levels, respectively: the marginal rate of substitution between α and β is smaller in developed countries (i.e. at larger IUF).
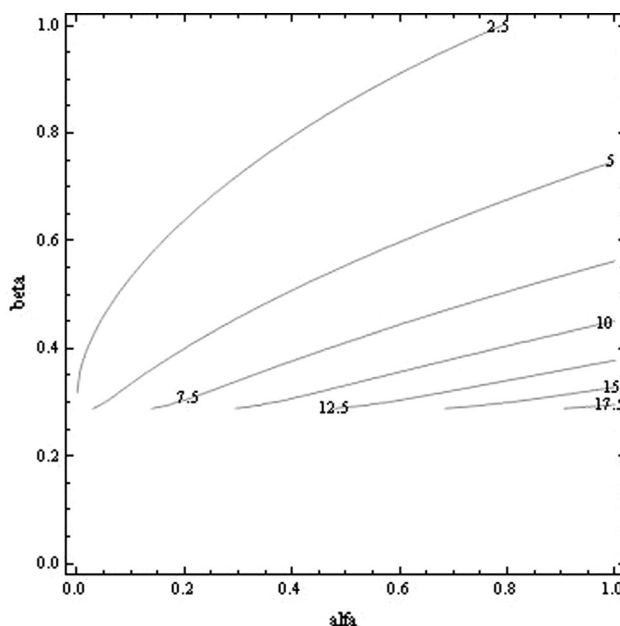

Fig. 4 Solutions at $\varepsilon = 0.5$ for EF = max EF = 1.8 and SWB = max SWB from EF(SWB) = 1.8, with IUF in [0,20]. *EF* ecological footprint, *SWB* subjective well-being, *IUF* intergenerational utility function, α the relationship between consumption and SWB, β the relationship between consumption and EF, ε the aversion of the current individual to intergenerational inequity

Figures 7 and 8 present the solutions for α and β to the three inequality problems depicted above for IUF within [0,20] at $\varepsilon = 0.2$ and $\varepsilon = 0.8$, for developing and developed countries, respectively. Worse-off developing countries (e.g. India, Moldova, Bulgaria, Romania, Serbia) with IUF < 5 are sustainable provided feasible technology improvements are implemented (i.e. a reduction of β by 10 to 40 %). Better-off developing countries (e.g. South Africa, Uruguay, Turkey, Poland, Chile, Colombia, Russia, Ukraine, China) with IUF in [5,10] can achieve sustainability by improving technologies to an implausible extent (i.e. a reduction of β by 50 to 70 %). Worse-off developed countries (e.g. Italy, Spain, Germany, Japan, France, Slovenia, South Korea) with IUF in [10, 15] can achieve sustainability by changing values to an implausible extent (i.e. a reduction of α by 40 to 70 %). Better-off developed countries (e.g. Australia, Sweden, Norway, Finland, Canada, Nederland, USA, UK, Switzerland, New Zealand) with IUF > 15 are sustainable provided feasible value changes are implemented (i.e. a reduction of α by 0 to 30 %).

Note that each country could increase its IUF by improving its technologies and changing its values (i.e. by reducing both β and α) at any value of intergenerational inequality aversion (i.e. for each ε), although economic costs and psychological efforts related to technology

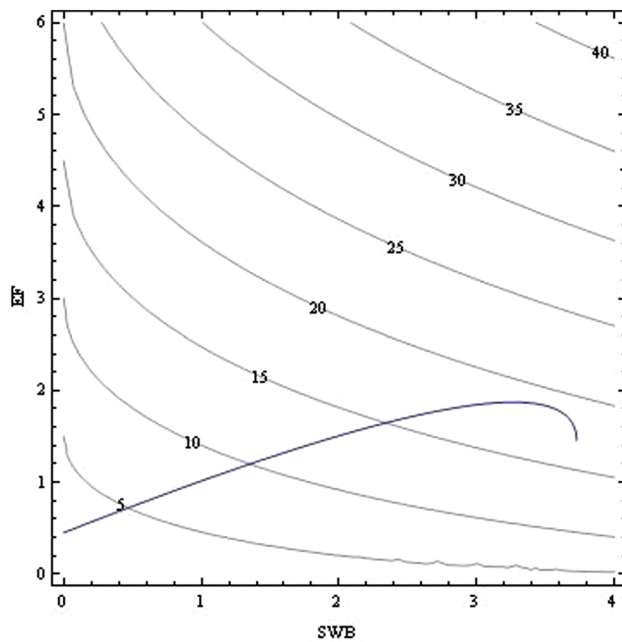**Fig. 5** The constraint EF ≥ EF(SWB) (*dark curved line*), the constraint EF ≤ 1.8 (*unshown horizontal line*) and the indifference curves (*pale lines*) for α = 1, β = 0.3 (i.e. feasible values for *developed countries*) and ε = 0.5. *EF* ecological footprint, *SWB* subjective well-being, *IUF* intergenerational utility function, α the relationship between consumption and SWB, β the relationship between consumption and EF, ε the aversion of the current individual to intergenerational inequity. The numerical solution to the constrained maximisation is at EF = 1.76, SWB = 3.52, with IUF = 18.52

Fig. 6 The constraint EF ≥ EF(SWB) (*dark curved line*), the constraint EF ≤ 1.8 (*unshown horizontal line*) and the indifference curves (*pale lines*) for α = 1, β = 0.7 (i.e. feasible values for *developing countries*) and ε = 0.5. *EF* ecological footprint, *SWB* subjective well-being, *IUF* intergenerational utility function, α the relationship between consumption and SWB, β the relationship between consumption and EF, ε the aversion of the current individual to intergenerational inequity. The numerical solution to the constrained maximisation is at EF = 1.80, SWB = 0.55, with IUF = 5.51

improvements and value changes should be taken into account.

Discussion

The main logics of the analysis presented in this paper can be summarised as follows. Data show that very few countries are sustainable (here measured by EF), although large differences in happiness (here measured by SWB) are observed. Many critiques have been raised against EF and SWB concepts (see Welsch 2009; Malghan 2011): however, the qualitative results obtained here are not affected by the use of these indexes in quantifying sustainability and happiness. Note that I adopted a "representative consumer" approach, and this does not account for heterogeneity within each country. This approach is empirically consistent with the SWB index that I applied, although it theoretically fails to represent the subjective costs that result from having different values (e.g. my satisfaction from driving a fashionable electric car could partially arise from the car's ability to impress the people around me) or from using different technologies (e.g. my satisfaction from
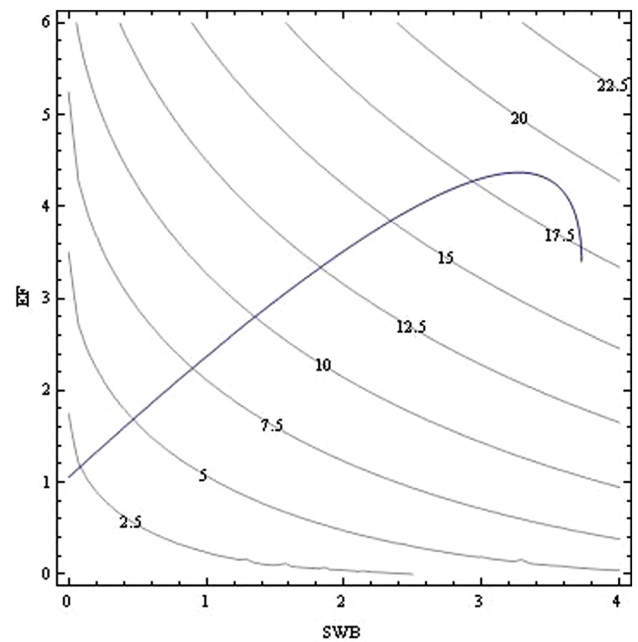
driving an electric car could arise partially from the fuel choices of others due to their influence on the spread of power suppliers). However, these effects are not relevant in depicting sustainable happiness.

I suggest a potential improvement in technologies (i.e. producing the same goods with a smaller environmental impact) or a potential change in values (i.e. achieving a greater happiness with the same goods) or any combination of these improvements or changes in order to ensure a sustainable happiness (see Kallis et al. 2012). These potential substitutions are identified as feasible solutions (i.e. couples of α and β values, with 0 < α ≤ 1 and 0 < β ≤ 1) to a set of inequalities and depicted as level curves (i.e. points in the [α, β] plane at different IUF levels) in scenarios with a small (ε = 0.2), a medium (ε = 0.5) and a large (ε = 0.8) concern for future generations: lack of potential substitutions (i.e. no solutions to inequalities and no level curves for some IUF in one or both scenarios) means missed sustainable happiness, while alternative combinations of technology improvements or value changes to achieve sustainable happiness (i.e. α and β values as solutions to inequalities and level curves in the [α, β] plane for some IUF in one or both scenarios) are attached to
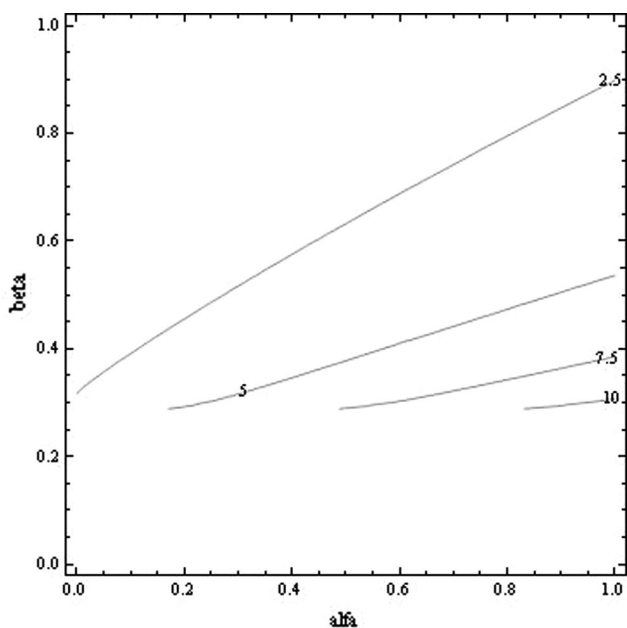
Fig. 7 Solutions at $\varepsilon = 0.2$ (i.e. plausible values for *developing countries*) for EF = max EF = 1.8 and SWB = max SWB from EF(SWB) = 1.8, with IUF in [0,20]. *EF* ecological footprint, *SWB* subjective well-being, *IUF* intergenerational utility function, α the relationship between consumption and SWB, β the relationship between consumption and EF, ε the aversion of the current individual to intergenerational inequity

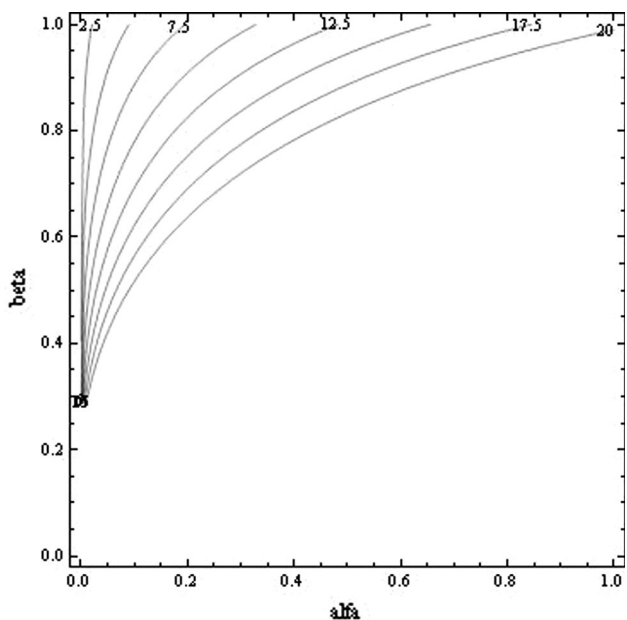**Fig. 8** Solutions at $\varepsilon = 0.8$ (i.e. plausible values for *developed countries*) for EF = max EF = 1.8 and SWB = max SWB from EF(SWB) = 1.8, with IUF in [0,20]. *EF* ecological footprint, *SWB* subjective well-being, *IUF* intergenerational utility function, α the relationship between consumption and SWB, β the relationship between consumption and EF, ε the aversion of the current individual to intergenerational inequity

developed and developing countries according to their current IUF levels.

The main questions can be summarised as follows: (1) are there feasible changes in values and improvements in technologies in order to achieve a sustainable happiness? (2) which countries (developed vs. developing countries) have which substitution opportunities (changes in values vs. improvements in technologies)? (3) which countries will bear the burden of the global sustainability?

The main insights from this analysis can be summarised as follows.

Individuals in developed countries (i.e. countries at IUF(0) > 10) can substitute changed values for new technologies at a plausible level of concern for future generations (e.g. $\varepsilon = 0.8$). Individuals in developed countries can achieve sustainability at a higher SWB when the constraint EF(SWB) is decreasing. Sustainable happiness seems to be achievable for individuals in better-off developed countries (i.e. countries at IUF(0) > 15) with a reasonable magnitude of change in values (e.g. an average $\alpha = 0.8$, which means 25 % more happiness from the same consumption pattern or the same happiness for a less-frequent consumption pattern, such as buying a new car every 2.5 years rather than every 2 years). By contrast, sustainable happiness seems to be unachievable for individuals in worse-off developed countries (i.e. countries at IUF(0) in [10, 15]) with an unfeasible magnitude of change in values (e.g. an average $\alpha = 0.5$, which means 200 % more happiness from the same consumption pattern or the same happiness for a less-frequent consumption pattern, such as buying a new car every 4 years rather than every 2 years).

Individuals in developing countries (i.e. countries at IUF(0) < 10) must rely to a greater extent on technological innovation at a plausible level of concern for future generations (e.g. $\varepsilon = 0.2$). Individuals in developing countries will achieve sustainability at a lower SWB when the EF(SWB) constraint is increasing. Sustainable happiness seems to be unachievable for individuals in better-off developing countries (i.e. countries at IUF(0) in [5, 10]) with an unfeasible level of technological innovation (e.g. an average $\beta = 0.4$, which means a 60 % reduction in use of resources or emission of pollutants for the same consumption bundle, such as the combination of 20 % of energy obtained from renewable sources, an 20 % gain in energy efficiency, and a 20 % reduction of CO_2 emissions). By contrast, sustainable happiness seems to be achievable for individuals in worse-off developing countries (i.e. countries at IUF(0) < 5) with a reasonable magnitude of change in technologies (e.g. an average $\beta = 0.7$, which means a 30 % reduction in use of resources or emission of pollutants for the same consumption bundle, such as the combination of 10 % of energy obtained from renewable sources, a 10 % gain in energy efficiency and a 10 %

reduction of CO_2 emissions). Therefore, better-off developing countries are expected to bear the burden of the global sustainability.

Note that a developing country moving from worse-off to better-off classes should improve its technologies; a better-off developing becoming a worse-off developed country should increase its concern for future generations and change its values; a developed country moving from worse-off to better-off classes could keep its technologies and values (see Motesharrei et al. 2014).

The main limitations of the analysis presented in this paper can be summarised as follows. Human rights and land degradation are neglected. As a result, the applied EF could be an inadequate measure of social and environmental sustainability (Fiala 2008). National boundaries are implicit in the model, but the applied EF should be improved to account for cross-border trades of goods (Kitzes et al. 2009). Using EF as a measure of sustainability, the model implicitly assumes that all greenhouse gases that mankind produces need to be sequestered or eliminated (Venetoulis and Talberth 2008), but by normalising the current EF to 1 for each individual, the model mitigates problems that result from this assumption by changing this to a calculation that estimates the reduction in current emissions. The model is implicitly static because it is based on EF, but the introduction of β makes it possible to depict the differences in technological progress among countries (Mulder 2007). Individuals with an intrinsic value orientation (i.e. personal growth, self-acceptance, relationships, physical fitness and community involvement) are less materialistic and more inclined to engage in environmentally friendly behaviour than individuals with an extrinsic value orientation (i.e. financial success, social recognition, image and popularity). A decrease in α could therefore imply a decrease in β (see also Brown and Kasser (2005) for a micro-level relationship between SWB and ecologically responsible behaviour due to intrinsic values and mindfulness). Individuals will never undertake sustainability behaviours as long as responsible behaviour is framed in terms of self-sacrifice, which is assumed to detract from happiness. Instead, a decrease in β should be thought to lead to a decrease in α (see also Ferrer-i-Carbonell and Gowdy (2007) for a micro-level relationship between SWB and environmental awareness about ozone depletion and biodiversity loss, with concern about positive environmental features having positive effects on SWB). The current limits on sustainable lifestyle choices and livelihoods are disregarded (see Lianos 2013). Consumers sometimes cannot affect β, which is chosen by stakeholders with vested interests in unsustainable policies and practices. Differences in the constraints that affect each individual are disregarded. Note that the adoption of a "representative consumer" approach means that implicit

path dependence and lock-in phenomena could be at work, since larger satisfaction might be achieved by sharing the majority preferences (i.e. the bandwagon effect) and larger satisfaction might be achieved from using a popular technology (i.e. the network effect), and this could imply greater dismay and dissatisfaction for an individual who changes values and technologies (e.g. from a 1500 cc gasoline-powered car to an equivalent 47-kW electric car). However, the same effects could be used to move society, as depicted by the representative consumer, from the current situation to a more sustainable equilibrium. For example, this could be achieved by increasing the social awareness of environmental issues in schools or by introducing national regulations requiring any fuel supplier for cars to also supply electric power.

The analysis could be improved by specifying a different achievement function for each country to achieve more specific quantitative results. The path to long-run equilibria in sustainable happiness as a result of the potential impacts of education (see Escobar-Tello and Bhamra 2013) or other social policies (see Ericson et al. 2014) is neglected. In future research, the simultaneous dynamics of α and β, with potentially multiple and different transition paths for developed and developing countries, could be analysed.

Conclusions

In this study, I adopted a familiar definition of sustainable development, in which social and economic development is defined in terms of happiness within ecological sustainability limits, which are in turn defined in terms of ecological footprints. The analysis was conducted within a normative approach (see Baumgartner and Quaas 2010) in order to assess the potential substitution between economic and ecological policies (here, represented by technological innovation) and environmental ethics (here, represented by changes in values), with the goal of achieving sustainable development. This was accomplished by distinguishing between developed and developing countries.

The main findings can be summarised as follows. Sustainable happiness seems to be achievable for individuals in better-off developed countries (e.g. Australia, Sweden, Norway, Finland, Canada, Nederland, USA, UK, Switzerland, New Zealand) with a reasonable level of value change, and for individuals in worse-off developing countries (e.g. India, Moldova, Bulgaria, Romania, Serbia) with a feasible degree of technological innovation, both at plausible levels of concern for future generations. In the example discussed in this paper, an Australian consumer can shift from a 1500 cc gasoline-powered car to a 1000 cc gasoline-powered car, with a large absolute increase in sustainability and at high level of happiness, whereas an

Indian consumer can shift from a 100 cc gasoline-powered motorcycle to an equivalent 4.7-kW electric motorcycle, with a small absolute increase in sustainability and at low level of happiness.

Moreover, sustainable happiness seems to be unachievable for individuals in worse-off developed countries (e.g. Italy, Spain, Germany, Japan, France, Slovenia, South Korea) because it requires an unreasonable level of value change, and for individuals in better-off developing countries (e.g. South Africa, Uruguay, Turkey, Poland, Chile, Colombia, Russia, Ukraine, China) because it requires an impractical degree of technological innovation, both at plausible levels of concern for future generations.

In the example discussed in this paper, an Italian consumer should shift from a 1500 cc gasoline-powered car to an equivalent 47-kW electric car, with a large absolute increase in sustainability and at high level of happiness, whereas a Chinese consumer should shift from a 150cc gasoline-powered motorcycle to an equivalent 4.7-kW electric motorcycle, with a small absolute increase in sustainability and at low level of happiness.

Finally, developing and developed countries differ in terms of their potential to achieve sustainable happiness. In the example discussed in this paper, both Italian and Chinese consumers should rely on similar degree of technological innovation to achieve a given level of sustainability, although the Italian consumer achieves it at higher level of happiness than the Chinese consumer.

The optimistic results for better-off developed countries (i.e. sustainable happiness is achievable with a reasonable level of value change at a plausible level of concern for future generations and at high level of happiness) and worse-off developing countries (i.e. sustainable happiness is achievable with a feasible degree of technological innovation at a plausible level of concern for future generations although at low level of happiness) are outweighed by the pessimistic results for better-off developing countries (i.e. sustainable happiness is achievable with an impractical degree of technological innovation at a plausible level of concern for future generations) and worse-off developed countries (i.e. sustainable happiness is achievable with an unreasonable level of value change at a plausible level of concern for future generations) for two main reasons: first, because of the inequity between these groups of countries, which places the burden of sustainability largely on better-off developing countries, and second, because of the global unsustainability, if the analysis is expanded to account for the distribution and dynamics of the world's population as well as life expectancy, which differ between developed and developing countries (see Diffenbaugh 2013).

Note that the equity would be smaller if technological changes were assumed to affect the population and per capita affluence (Huesemann and Huesemann 2008), since developing countries should rely on technological innovation to a greater extent. Next, global sustainability would be less likely if green consumption patterns were assumed to be not self-enforcing and not locked in permanently (Buenstorf and Cordes 2008), since eventual global sustainability would only be temporary.

References

Bagliani M et al (2008) A consumption-based approach to environmental Kuznets curves using the ecological footprint indicator. Ecol Econ 65:650–661

Baumgartner S, Quaas M (2010) Sustainability economics—general versus specific, and conceptual versus practical. Ecol Econ 69:2056–2059

Bonini A (2008) Cross-national variation in individual life satisfaction: effects of national wealth, human development, and environmental conditions. Soc Indic Res 87:223–236

Brand F (2009) Critical natural capital revisited: ecological resilience and sustainable development. Ecol Econ 68:605–612

Brown KW, Kasser T (2005) Are psychological and ecological well-being compatible? The role of values, mindfulness, and lifestyle. Soc Indic Res 74:349–368

Buenstorf G, Cordes C (2008) Can sustainable consumption be learned? A model of cultural evolution. Ecol Econ 67:646–657

Cowel FA (1995) Measuring inequality. Prentice Hall, London

Dasgupta P (1998) Population, consumption and resources: ethical issues. Ecol Econ 24:139–152

De Vires BJM, Petersen AC (2009) Conceptualising sustainable development: an assessment methodology connecting values, knowledge, worldviews and scenarios. Ecol Econ 68:1006–1019

Deci EL, Ryan RM (2008) Hedonia, eudaimonia, and well-being: an introduction. J Happiness Stud 9:1–11

Diffenbaugh NS (2013) Human well-being, the global emissions debt, and climate change commitment. Sustain Sci 8:135–141

Eckersley R (2007) Progress, sustainability and human well-being: is a new worldview emerging? Int J Innov Sustain Dev 1:304–317

Engelbrecht H-J (2009) Natural capital, subjective well-being, and the new welfare economics of sustainability: some evidence from cross-country regressions. Ecol Econ 69:380–388

Ericson T, Kjonstad BG, Barstad A (2014) Mindfulness and sustainability. Ecol Econ 104:73–79

Escobar-Tello MC, Bhamra T (2013) Happiness as a harmonising path for bringing higher education towards sustainability. Environ Dev Sustain 15:177–197

Ferrer-i-Carbonell A, Gowdy JM (2007) Environmental degradation and happiness. Ecol Econ 60:509–516

Fiala N (2008) Measuring sustainability: why the EF is bad economics and bad environmental science. Ecol Econ 67:519–525

Frame B, Brown J (2008) Developing post-normal technologies for sustainability. Ecol Econ 65:225–241

Gowdy J (2005) Toward a new welfare economics of sustainability. Ecol Econ 53:211–222

Gsottbauer E, van den Berg JCJM (2011) Environmental policy theory given bounded rationality and other-regarding preferences. Environ Resour Econ 49:263–304

Haller M, Hadler M (2006) How social relations and structures can produce happiness and unhappiness: an international comparative analysis. Soc Indic Res 75:169–216

Helliwell JF (2014) Social norms, happiness, and the environment: closing the circle. Sustain: Sci Pract Policy 10:78–84

Hellstrand S et al (2009) The relevance of ecological and economic policies for sustainable development. Environ Dev Sustain 11:853–870

Huesemann MH, Huesemann JA (2008) Will progress in science and technology aver or accelerate global collapse? A critical analysis and policy recommendations. Environ Dev Sustain 10:787–825

Inglehart R et al (2008) Development, freedom, and rising happiness. Perspect Psychol Sci 3:264–285

IPCC (2007) Guidelines for national greenhouse gas inventories

Jabereen Y (2008) A new conceptual framework for sustainable development. Environ Dev Sustain 10:179–192

Kallis G et al (2012) The economics of degrowth. Ecol Econ 84:172–180

Kasser T (2002) The high price of materialism. MIT Press, Cambridge

Kissinger M, Rees WE (2010) Exporting natural capital: the foreign eco-footprint on Costa Rica and implications for sustainability. Environ Dev Sustain 12:547–560

Kitzes J et al (2009) A research agenda for improving national EF accounts. Ecol Econ 68:1991–2007

Konchak W, Pascual U (2006) Converging economic paradigms for a constructive environmental policy discourse. Environ Sci Policy 9:10–21

Kratena K, Streicher G (2012) Spatial welfare economics vs. ecological footprint: a sensitivity analysis introducing strong sustainability. Environ Resour Econ 51:617–622

Lianos TP (2013) The world budget constraint. Environ Dev Sustain 15:1543–1553

Lothgren M (1997) Generalised stochastic frontier production models. Econ Lett 57:255–259

Malghan D (2011) A dimensionally consistent aggregation framework for biophysical metrics. Ecol Econ 70:900–909

Moffat I (2008) A preliminary analysis of composite indicators of sustainable development. Int J Sustain Dev World Ecol 15:81–87

Moran DD et al (2008) Measuring sustainable development—nation by nation. Ecol Econ 64:470–474

Motesharrei S, Riva J, Kalnay E (2014) Human and nature dynamics (HANDY): modeling inequality and use of resources in the collapse or sustainability of societies. Ecol Econ 101:90–102

Mulder KF (2007) Innovation for sustainable development: from environmental design to transition management. Sustain Sci 2:253–263

NEF (2012) The happy planet index 1.0. www.neweconomics.org

O'Brien C (2008) Sustainable happiness: how happiness studies can contribute to a more sustainable future. Can Psychol 49:289–295

Quental N et al (2011) Sustainability: characteristics and scientific roots. Environ Dev Sustain 13:257–276

Romer JE (2011) The ethics of inter-temporal distribution in a warning planet. Environ Resour Econ 48:363–390

Sabau GL (2010) Know, live and let live: towards a redefinition of the knowledge-based economy—sustainable development nexus. Ecol Econ 69:1193–1201

Solomon UU (2010) A detailed look at three disciplines, environmental ethics, law and education to determine which plays the most critical role in environmental enhancement and protection. Environ Dev Sustain 12:1069–1080

Veenhoven R (2005) Apparent quality-of-life in nations: how long and happy people live. Soc Indic Res 71:61–86

Venetoulis J, Talberth J (2008) Refining the ecological footprint. Environ Dev Sustain 10:441–469

WCED (1987) Our common future. Oxford University Press, Toronto

Welsch H (2003) Freedom and rationality as predictors of cross-national happiness patterns: the role of income as a mediating variable. J Happiness Stud 4:295–321

Welsch H (2007) Environmental welfare analysis: a life satisfaction approach. Ecol Econ 62:544–551

Welsch H (2009) Implication of happiness research for environmental economics. Ecol Econ 68:2735–2742

White N (2007) Sharing resources: the global distribution of the ecological footprint. Ecol Econ 64:402–410

WWF (2010) Living planet report, Avenue du Mont-Blanc CH-1196 Gland, Switzerland

Zagonari F (2011) Which ethics will make us individually and socially happier? And cross development analytical model. J Happiness Stud 1:77–103

Zidansek A (2007) Sustainable happiness and happiness in nations. Energy 32:891–897

Ziolkowska JR, Ziolkowski B (2011) Product generational dematerialization indicator: a case of crude oil in the global economy. Energy 36:5925–5934