# Only religious ethics can help achieve global environmental sustainability

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## Abstract

This paper develops a *theoretical* framework for comparing religious ethics (from Christianity, Judaism, Hinduism, Buddhism, and Islam) and secular ethics (based on duties vs. rights, current vs. future generations, humans vs. non-humans, intra- vs. inter-generational equity, teleological vs. deontological perspectives, anthropocentrism vs. biocentrism, cooperative vs. bargaining solutions, weak vs. strong sustainability, optimistic vs. current scenarios). I focused on the duties to nature (β) and future generations (γ), rights of future generations (δ), and aversion to intra- and inter-generational inequality (ε and ζ, respectively). To perform this analysis, I adopt an individual perspective to favor comparisons between religious and secular ethics. I also consider future scenarios for consumption preferences (α), population size (η), and improved technology (θ). I present *empirical* results for OECD and non-OECD countries, based on numerical simulations for current and maximum feasible parameter values and on statistical analyses for marginal reliable changes of parameters, within a single *graphical* framework. α, η, and θ are unessential for sustainability; β is beneficial but not feasible and unreliable in OECD countries; γ is detrimental in all countries; δ is beneficial, feasible and reliable in OECD countries, but inadequate; ε is detrimental and ζ is essential in all countries. The religious ethics were adequate, feasible and reliable for Hinduism or Buddhism, Islam, and Judaism.

## Keywords

Environmental ethics; equity; duties; rights; OECD countries; non-OECD countries

## DOI

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# 1.Introduction

Both developed countries (here, OECD) and less-developed countries (here, non-OECD) are currently environmentally unsustainable. The per capita ecological footprint in 2012 was 5.74 ha for OECD countries and 2.14 ha for non-OECD countries, versus a global sustainable value of 1.70 ha (http://www.footprintnetwork.org).

Trusting in future development of green technologies to create sustainability is uncertain and unrealistic: the technology of OECD countries would need to become 3.37 times more efficient, versus 1.25 times for non-OECD countries. Moreover, relying on future changes of consumption preferences is uncertain and questionable (e.g., happy de-growth may be unrealistic). Finally, trusting in future population decreases is uncertain and controversial: based on the abovementioned ecological footprint data, the population in developed nations would have to decrease to 30% of the current population, whereas the population in less-developed nations would need to decrease to 79% of the current population.

Unfortunately, the increasing damage caused by climate change suggests that global sustainability is *an urgent problem* (www.sdgindex.org/reports/2018). In other words, even if technology can be improved rapidly, consumption preferences can be changed, and populations begin to decrease, we cannot afford to wait for these processes.

The literature has recently begun to emphasize the role of ethics in achieving global environmental sustainability (Menning, 2016; Lenzi, 2017; Spahn, 2018). In particular, two main groups of environmental ethics can be identified: secular ethics and religious ethics (Zagonari, 2018a). *Secular* ethics focus on our responsibility to nature, responsibility to future generations, perceptions of the rights of human and non-humans, and beliefs in inter- and intra-generational equity. Note that responsibility to nature and non-humans can be direct (teleological biocentrism based on consequences rather than actions if non-humans are believed to have desires and hopes; deontological biocentrism based on actions rather than consequences if nature has an intrinsic value) (Coyne, 2017). It may instead be anthropocentric and indirect (teleological based on utilitarian or eudemonistic approaches; deontological based on freedom or virtue) (Svoboda, 2014; Gansmo Jakobsen, 2017). It may also be based on intrinsic and extrinsic views (Keitsch, 2018); on love, respect, honor, and cherished attitudes (James, 2016); on experiences with nature (Rush, 2015); on emotional responses to nature (Kasperbauer, 2015); on a basic belief in continuity between humans and other living things (Diehm, 2014); on a constitutive view (Altshuler, 2014); or on relational values (Arias-Arevalo et al., 2017). Here, I focus my analysis at an individual level, based on national-level statistics for a representative individual, and this approach does not require endorsement of a specific version of responsibility to nature; instead, my approach identifies the intrinsic value of nature using the perceived human responsibility to nature or the willingness to pay for its existence. Moreover, I will base responsibility to future generations on freedom or virtue under deontological anthropocentrism. This is consistent with the focus of this study, as ethics guides personal choices (i.e., actions). Finally, the rights of non-humans include the right of species (i.e., speciesism), the right of non-humans experiencing pain and suffering (i.e., sentientism), and the right of any life form (Saner and Bordt, 2016). By attaching value to each individual plant or animal (Campbell, 2018), to communities (Kortetmaki, 2017), or to biological diversity and ecological integrity (Mikkelson and Chapman, 2014), these rights can extend from small to large ecosystems.

However, the rights of non-humans are not universally accepted (e.g., secular legislation is required to protect them) and even when they are acknowledged, this may not contribute to nature conservation (i.e., it is unnecessary to consider the rights of individual organisms in conservation planning). I will therefore focus on perceptions of the rights of future generations (Brincat, 2015), although this might also require legislation to protect these generations and agents who are willing to enforce that legislation on their behalf. It may also require the specification of logically possible and realistically feasible ways to compensate future generations for damage to their rights; for example, restoration of an extinct species might be logically possible but realistically unfeasible,

even if the current generation has recorded its complete genome (Donoso, 2017). In particular, I will adopt an operational definition of rights by assigning an economic value to the missed enforcement of these rights (Almassi, 2017).

*Religious* ethics has a different focus in each religion. For example, we could say that Judaism focuses on stewardship (here, maximizing the use of resources to achieve the highest sustainable total welfare), Islam focuses on trusteeship and parsimony (here, minimizing the use of resources), Hinduism and Buddhism focus on maintaining equilibrium, and Christianity focuses on love of neighbors. Zagonari (2018b) provides a more nuanced description of these focuses and their ethical values based on a close reading of the sacred texts of these religions. Note that the moral standing of future generations derives from a divine figure or deity in all religions. Moreover, some ethical principles are shared by some religions (e.g., stewardship and trusteeship are similar). Finally, the moral standing of nature derives from a divine figure or deity in all religions, although to a different extent; this ranges from any life form in Hinduism or Buddhism, to species in Islam, Judaism, and Christianity.

However, the observed failures of international agreements on climate change suggest that the unsustainability of global society is *a practical problem* (i.e., one related to actual practice rather than to beliefs; www.sdgindex.org/overview). In other words, it is not enough for an ethical principle or precept to be consistent and to be intended to move the world away from unsustainable practices; the principle or precept must also provide feasible (i.e., effective and practical) and reliable (i.e., unfailing and trustworthy) incentives to achieve sustainability through the application of consistent ethical concepts to achieve realistic equilibrium conditions. This can potentially be achieved using empirical models that predict the consequences of applying these ethical concepts and incentives.

The purpose of this study is to identify which aspects of secular and religious ethics can help us to achieve global sustainability in the form of a realistic equilibrium. To do so, I use empirical models based on theoretical frameworks to quantify the effects of various secular and environmental ethics to determine which are feasible (i.e., could effectively guide behavior) and reliable (i.e., will unfailingly produce the expected result), under the current context and in an optimistic future perspectives. To perform this analysis, I focused on representative individuals in developed nations (for simplicity, represented by OECD countries) and less-developed nations (non-OECD countries). By evaluating ethical principles and precepts in terms of their feasibility and reliability, I will also seek consensus among religions and cultures to reduce conflicts among diverging worldviews by clarifying the impacts and definitions of the alternative ethics.

Note that Zagonari (2018a) and Zagonari (2018b) characterize the main secular and religious ethics, respectively, while a summary of the analytical frameworks for secular and religious ethics are presented in Appendix I and II, respectively.

# 2.Methods

Insights presented in this study are based on six concepts (Section 2.1), six parameters (Section 2.2), and six equilibria (Section 2.3).

## 2.1.Solutions, equilibria and paradigms

The analytical framework is based on six concepts that represent the main solutions and paradigms. I assume:

1. A Nash bargaining solution for welfare, in which OECD and non-OECD countries both exploit the potential gains from cooperation in terms of the current status or a future sustainable status.
2. A Kalai-Smorodinski bargaining solution for resources, in which OECD and non-OECD countries accept the same proportional losses to move towards a long-run equilibrium.
3. A Rawls equilibrium for resources, in which OECD and non-OECD countries aim to achieve a sustainable status that protects the poorest people).
4. Cooperative solutions for welfare and resources in which OECD and non-OECD countries pursue a common goal subject to common constraints.

5. Strong sustainability: future generations will have access to at least the same amount of resources available to the current generation. I will consider four versions: one with weighted population, one with maximum aversion to intra-generational inequality, one with minimum aversion to intra-generational inequality, and one with a cooperative weighted use of Earth's resources.
6. Weak sustainability: future generations will enjoy at least the same level of welfare enjoyed by the current generation, but under a sustainable equilibrium. I will consider four versions: one with weighted population, one with maximum aversion to intra-generational inequality, one with minimum aversion to intra-generational inequality, and one with a cooperative weighted level of world welfare.

Note that I could have applied a Nash solution for resources and a Kalai-Smorodinski solution for welfare, but it is more realistic that countries bargain on potential gains in welfare and accept relative losses in resources. However, since both OECD and non-OECD countries know that achieving global sustainability implies losses on both sides, these two bargaining equilibria, together with the Rawls equilibrium, within an individualist contractualism approach, are the most appropriate options in the present context, which is assumed to be static because the focus is on feasibility of long-run equilibria rather than short-run processes.

## 2.2.Ethical changes

The analytical framework is also based on six parameters that represent the main ethical changes:

1. $\alpha$ represents the proportion (values from 0 to 1) of income spent on consumption, and measures the relative effect of consumption on welfare.
2. $\beta$ represents the proportion (values from 0 to 1) of income spent on nature conservation and preservation, and measures the perceived responsibility to nature.
3. $\gamma$ represents the proportion (values from 0 to 1) of income spent on green R&D, and measures the perceived responsibility for future generations.
4. $\delta$ represents the proportion (values from 0 to 1) of income charged for environmentally unsustainable activities, and measures the opportunity cost of the current global unsustainability; it reflects the "polluter pays" principle.
5. $\varepsilon$ (a dimensionless value between 0 and 1) represents the aversion to intra-generational inequality, and depicts the perception of inequality in the distribution of Earth's resources
6. $\zeta$ (a dimensionless value between 0 and 1) represents the aversion to inter-generational inequality, and depicts a philosophical approach to human dignity.

Note that I will look for numerical solutions with the parameters fixed at current levels (i.e., $\alpha_0$, $\beta_0$, $\gamma_0$, and $\delta_0$) and at the maximum levels for both OECD and non-OECD countries. Moreover, changing the relative importance attached to consumption could take long time; thus, I will simulate a change in $\alpha$ only for future generations. Finally, I will assume that intra-generational equity has instrumental value (i.e., equality reduces social conflicts or improves social cohesion), whereas inter-generational equity has intrinsic value (i.e., future generations are perceived as being as important as current generations). In particular, I have depicted the maximum $\beta$ and $\gamma$ as 1 minus the proportions of income currently spent on the other two parameters (i.e., max $\beta = 1 - \alpha_0 - \gamma_0$ and max $\gamma = 1 - \alpha_0 - \beta_0$). Moreover, the maximum $\delta$ represents the payment to be charged to an individual in future generations at a sustainable level of activity if the current level of unsustainability is achieved. Finally, I will couple the maximum value of $\zeta$ (i.e., $\zeta = 1$), which represents a constant level of human dignity over time and the precautionary principle, with $\varepsilon$ at both its minimum level (i.e., $\varepsilon = 0$) and its maximum level (i.e., $\varepsilon = 1$), where the latter value depicts a reduction of the use of Earth's resources to protect the least privileged people.

## 2.3.Equilibrium environmental solutions

I defined the following six equilibrium conditions for the main environmental solutions:

1. Judaism, which corresponds to the maximum current welfare consistent with future sustainability
2. Islam, which corresponds to the minimum use of resources consistent with current welfare

3. Buddhism or Hinduism, which correspond to the Rawls equilibrium
4. Nash equilibrium in terms of the current use of resources, which corresponds to the most realistic equilibrium, since countries are likely to bargain today in terms of current welfare
5. Cooperative equilibrium in terms of resources, although this is a speculative equilibrium, since countries are unlikely to achieve an agreement that maximizes efficiency in world resources, regardless of resource distributions: I will retain to show what countries are renouncing to
6. Cooperative equilibrium in terms of welfare, although this is an unlikely equilibrium, since countries are unlikely to achieve an agreement that maximizes welfare from world resources, regardless of welfare distributions: I will retain to show what countries are renouncing to

Note that I did not refer to Christian equilibria, since these appear not to be supported by either theoretical or empirical insights. Moreover, for simplicity, I will depict only the most likely Kalai-Smorodinsky equilibria (e.g., to move from the current status to the Rawls equilibrium), and I will not represent Nash equilibria in terms of the strong sustainability status with maximum aversion to intra-generational inequality, since they always coincide with the Rawls equilibrium. Finally, I did not use intermediate values for changes in the ethical parameters (i.e., $\beta$, $\gamma$, and $\delta$), since the maximum changes reveal the potential outcome more clearly. Indeed, the solutions of the model are continuous so this approach does not omit any important intermediate equilibria.

Uncertainty about the future is depicted by optimistic scenarios, where "optimistic" means a 20% reduction in population so that the per capita ecological footprint in equilibrium ($\eta$) increases, a 20% improvement in technology ($\theta$) so that a smaller amount of resources is used to produce the same amount of consumption goods, and a 20% reduction in the relative importance of consumption ($\alpha$) so the same level of welfare can be achieved by relying on sources other than consumption (e.g., enjoying spare time in wild landscapes).

Note that larger changes seem unrealistic, since the global environmental sustainability problem must be solved in the near future.

# 3.The dataset

Some parameters of the models on ethics can be directly estimated. In particular, the proportions of the world's current population in OECD and non-OECD countries based on World Bank world development indicators (http://data.worldbank.org) for 2012 are 0.18 and 0.82 for OECD and non-OECD countries, respectively. If the per capita use of the global environment is measured by the ecological footprint (i.e., the biologically productive area needed to provide everything an individual uses), the sustainability of a representative individual for the world at the current population level requires the ecological footprint to be at $\eta = 1.70$ ha (http://www.footprintnetwork.org), whereas the values for actual use of the environment in OECD and non-OECD countries, based on data for 2012, are 5.74 and 2.14 ha, respectively.

The actual individual consumption as a percentage of GDP ($\alpha$) is available for each OECD country (55.3% on average) and each non-OECD country (69.0% on average) (http://www.oecd-ilibrary.org). Similarly, the actual revenues to the government from environmental taxes, fees, or charges as a percentage of GDP ($\delta$), which accounts for the rights of future generations, are available for each OECD country (2.4% on average) and each non-OECD country (1.7% on average) (http://www.oecd-ilibrary.org).

The degree of concern about the use of the environment ($\beta$) is based on the observed average government expenditure on environmental protection as a percentage of GDP (i.e., 1.8% on average in OECD countries and 2.6% on average in non-OECD countries) (http://www.oecd-ilibrary.org). Similarly, the current generation's concern for future generations ($\gamma$) is based on the observed expenditures on environmental R&D and patents as a percentage of GDP (i.e., 2.0% on average in OECD countries; 0.4% on average in non-OECD countries) (http://www.oecd-ilibrary.org).

Some parameters of the ethics models require additional assumptions or manipulations. In particular, the future population was normalized to 1. In other words, I compare representative individuals for the current and future world, with a change in the future population depicted by a

change in the sustainable per-capita ecological footprint. Future consumption preferences are assumed to be an average of the preferences of the current OECD and non-OECD generations.
The future generations can rely on the environmental technology currently being applied by the OECD countries. In other words, complete technology transfer between developed and less-developed nations is optimistically assumed to be implemented in the future. Indeed, some technological convergence is likely to occur, although it is impossible to quantify the degree of this convergence. Moreover, a future technology that represents an average of the capabilities of current technologies seems to be more plausible in the case of a specified group of countries at similar levels of development. Finally, this assumption does not affect the solutions for the strong sustainability paradigm, but makes the solutions for the weak sustainability paradigm less feasible.
Without significant loss of generality, I will assume that the per capita consumption can be measured by the per capita income (i.e., GDP in USD, based on purchasing power parity [PPP]). Indeed, postponed consumption (as a saving or investment) affects the welfare of future generations, but this welfare increase contributes to the current generation's utility (i.e., both developed and less-developed countries' utility depend on the future utility). Moreover, the consumption of imported goods (typically, in OECD countries) increases welfare where they are consumed, but their production might increase the use of the environment and thus reduce welfare where they are produced and then exported (typically, in non-OECD countries). Finally, net exports equal net imports at the world level. Thus, the per capita consumption levels in OECD and non-OECD countries, based on world development indicators data for 2012, are US$36 727 GDP PPP and US$8216 GDP PPP, respectively.
The parameters of the religion models can be directly estimated. I identified all countries where a given religion accounted for more than 50% of the total population in 2010 based on the CIA World FactBook (www.cia.gov). This approach identified 40 Muslim countries (i.e., Afghanistan, Albania, Algeria, Azerbaijan, Bangladesh, Bosnia-Herzegovina, Burkina Faso, Chad, Comoros, Egypt, Eritrea, Gambia, Ghana, Guinea, Guinea Bissau, Indonesia, Iran, Iraq, Jordan, Kyrgyzstan, Lebanon, Libya, Macedonia, Malaysia, Mali, Mauritania, Morocco, Niger, Nigeria, Oman, Pakistan, Senegal, Sierra Leone, Syria, Tajikistan, Tunisia, Turkey, Turkmenistan, Uzbekistan, Yemen), 8 Hindu or Buddhist countries (i.e., Bhutan, Cambodia, China, India, Japan, Laos, Sri Lanka, Thailand); 1 Jewish country (i.e., Israel); 83 Christian countries (i.e., Argentina, Armenia, Australia, Austria, Belarus, Belgium, Bolivia, Botswana, Brazil, Bulgaria, Burundi, Cameroon, Canada, Central African Republic, Chile, Colombia, Congo, Democratic Republic of the Congo, Costa Rica, Croatia, Cuba, Cyprus, Denmark, Dominican Republic, Ecuador, El Salvador, Ethiopia, Fiji, Finland, France, Georgia, Germany, Ghana, Greece, Guatemala, Guyana, Haiti, Honduras, Hungary, Ireland, Italy, Jamaica, Kenya, Latvia, Lesotho, Liberia, Lithuania, Luxembourg, Macedonia, Malawi, Mexico, Moldova, Montenegro, Mozambique, Nicaragua, Norway, Panama, Papua New Guinea, Paraguay, Peru, the Philippines, Poland, Portugal, Romania, Russian Federation, Rwanda, Serbia, Slovak Republic, Slovenia, South Africa, Spain, Sweden, Switzerland, Tanzania, Trinidad and Tobago, Uganda, Ukraine, United Kingdom, United States, Uruguay, Venezuela, Zambia, Zimbabwe).

# 4.Results

Table 1 summarizes the scenarios that I examined and where the corresponding results are shown.

**Table 1. Summary of scenarios and locations of the numerical results.**

| | | Duty to nature Max $\beta$ | | Duty to future generations Max $\gamma$ | | Rights of future generations Max $\delta$ |
|---|---|---|---|---|---|---|
| | | Without rights $\delta = \delta_0$ | With rights Max $\delta$ | Without rights $\delta = \delta_0$ | With rights Max $\delta$ | |
| Current scenario | Figure 1 | Figure 3 | Figure A1 | Figure 4 | Figure A2 | Figure 5 |
| Future scenario | Figure 2 | Figure A3 | | Figure A4 | | Figure 6 |

Note that Table 1 represents all meaningful scenarios, since β and γ are complementary to 1 for a given α (i.e., α, β and γ sum up to 1), and both β and γ may or may not be coupled with a change in δ.

## 4.1.Scenarios without ethical changes

Without ethical changes (i.e., with constant duty to nature and future generations and constant rights of future generations), Figure 1 represents the solutions for the current status and Figure 2 represents a scenario with changes in the technology, population, and consumption preferences.

**Figure 1. Solutions for combinations of the ecological footprint (ha/person) for less-developed (Eldc) and developed countries (Edc) with no change in the perceived duty to nature (β), and in the perceived duty to future generations (γ), in the perceived rights of future generations (δ), in the current scenario with no change in future technology (θ), in future population (η), and in future consumption preferences (α).**

The Hindu and Buddhist solution (grey point) is at (1.70, 1.70); the Islamic solution (green point) is at (0.28, 8.13); the Jewish solution (blue point) is at (1.79, 1.24); the Nash solution (magenta point) is at (2.14, 5.74); the strong sustainability cooperative solution (purple point) is at (1.90, 0.78); the decreasing (green) straight line represents the weighted global sustainability; the decreasing (blue) curve represents equal welfare for the current and future generations under weak sustainability equilibrium; the increasing (blue) straight line represents Kalai-Smorodinsky equilibrium; the horizontal pink line depicts equal welfare for OECD current and future generations; the vertical grey line depicts equal welfare for non-OECD current and future generations.

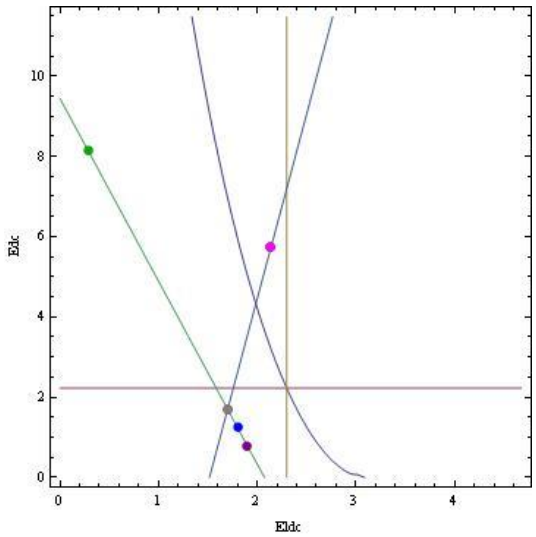



Figure 1 suggests that the current status is weak sustainability if ε = 0, but not if ε = 1. In other words, aversion to intra-generational inequality provides incentives towards global sustainability. Moreover, the Jewish solution, based on maximizing the use of resources to achieve the highest sustainable total welfare, is more egalitarian than the Islamic solution, based on minimizing the sustainable use of resources to achieve the given current welfare levels. In practice, the Islamic solution is easier to implement (i.e., each individual is expected to reduce their use of resources), but is harder to support theoretically (i.e., the current unequal distribution of welfare between developed and less-developed countries is taken as given). Finally, cooperative strong sustainability is achieved by allocating a larger proportion of resources to less-developed countries, whereas the weak sustainability cooperative solution is not feasible.

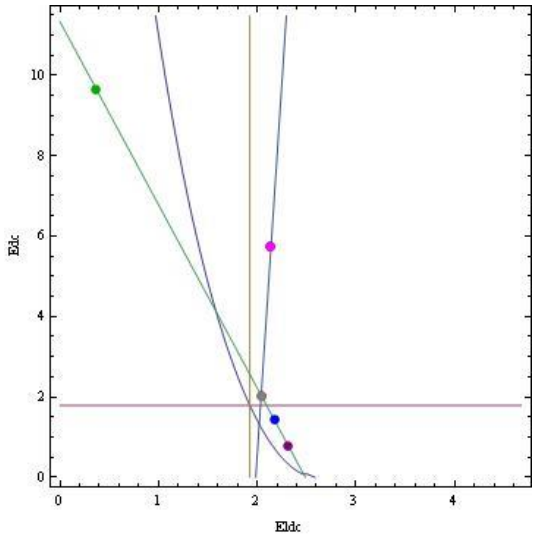
Statistical analysis (Section 4.3) based on the marginal impacts (i.e., the marginal change in the ecological footprint due to the prevailing majority religion) supports the feasibility and reliability of the depicted religious ethics: they are all feasible (i.e., all regression coefficients have negative signs), although they are characterized by different reliability: for Hinduism or Buddhism, $P > 0.314$; for Islam, $P > 0.362$; for Judaism, $P > 0.481$.

Comparing Figure 2 with Figure 1 suggests that the optimistic future scenario reduces incentives to change the current unsustainable status. Indeed, the current use of resources turns out to be weakly sustainable to a larger extent and at all aversions to intra-generational inequality (i.e., at both ε = 0

and ε = 1). Moreover, cooperative strong sustainability suggests that only less-developed countries should use more resources (i.e., the ecological footprint should increase from 1.90 to 2.31 ha/person). Finally, an optimistic future scenario makes both cooperative strong sustainability and Rawls solutions weakly sustainable.

**Figure 2. Solutions for combinations of the ecological footprint (ha/person) for less-developed (Eldc) and developed countries (Edc) with no change in the perceived duty to nature (β), in the perceived duty to future generations (γ), and in the perceived rights of future generations (δ), in the optimistic scenario with a 20% improvement in future technology (θ), a 20% reduction in future population (η), and a 20% decrease in future consumption preferences (α).**

The Hindu and Buddhist solution (grey point) is at (2.04, 2.04); the Islamic solution (green point) is at (9.64, 0.37); the Jewish solution (blue point) is at (1.42, 2.17); the Nash solution (magenta point) is at (2.14, 5.74); the strong sustainability cooperative solution (purple point) is at (2.31, 0.78); the decreasing (green) straight line represents the weighted global sustainability; the decreasing (blue) curve represents equal welfare for the current and future generations under weak sustainability equilibrium; the increasing (blue) straight line represents Kalai-Smorodinsky equilibrium; the horizontal pink line depicts equal welfare for OECD current and future generations; the vertical grey line depicts equal welfare for non-OECD current and future generations.




In summary, an optimistic future scenario provides additional support for maintaining the current unsustainable status.

## 4.2.Scenarios with ethical changes

Figure 3 shows the solutions with maximum perceived duty to nature, but with current perceived duty to future generations and rights of future generations. Comparing Figure 3 with Figure 1 suggests that achieving the maximum responsibility to nature (i.e., the maximum perception of the intrinsic value of nature) makes the current use of Earth's resources weakly unsustainable to a larger extent and for all aversions to intra-generational inequality (i.e., at both ε = 0 and ε = 1). However, these value changes do not affect the position of the Nash bargaining equilibrium. In other words, individuals in developed and less-developed countries are unlikely to change their environmental behavior. Note that the Islamic solution is not feasible. Figure A1 shows the results of maximizing both the duty to nature and the rights of future generations. Statistical analysis (Section 4.4) based on marginal impacts (i.e., the marginal change in the ecological footprint due to changes in responsibilities) supports these insights based on the maximum changes; that is, an increase in the duty to nature is beneficial, but insufficient to achieve strong sustainability. Indeed, β is beneficial but unfeasible and unreliable ($P > 0.871$) in OECD countries, but detrimental, unfeasible, and reliable ($P > 0.334$) in non-OECD countries. In other words, nature conservation functions as a luxury good (i.e., β is only beneficial in the developed countries).

Comparing Figure A1 with Figure 3 suggests that coupling a greater value for the rights of future generations (here, the maximum value) with a greater responsibility to nature (here, the maximum value) does not affect the positions of the equilibria.

**Figure 3. Solutions for combinations of the ecological footprint (ha/person) for less-developed (Eldc) and developed countries (Edc) with the maximum change in the perceived duty to nature (β), no change in the perceived duty to future generations (γ) and in the perceived rights of future generations (δ), in the current scenario with no change in future technology (θ), in future population (η), and in future consumption preferences (α).**

The Hindu and Buddhist solution (grey point) is at (1.70, 1.70); the Jewish solution (blue point) is at (1.95, 0.51); the Nash solution (magenta point) is at (2.14, 5.74); the strong sustainability cooperative solution (purple point) is at (1.90, 0.78); the decreasing (green) straight line represents the weighted global sustainability; the increasing (blue) straight line represents Kalai-Smorodinsky equilibrium; the vertical grey line depicts equal welfare for non-OECD current and future generations..

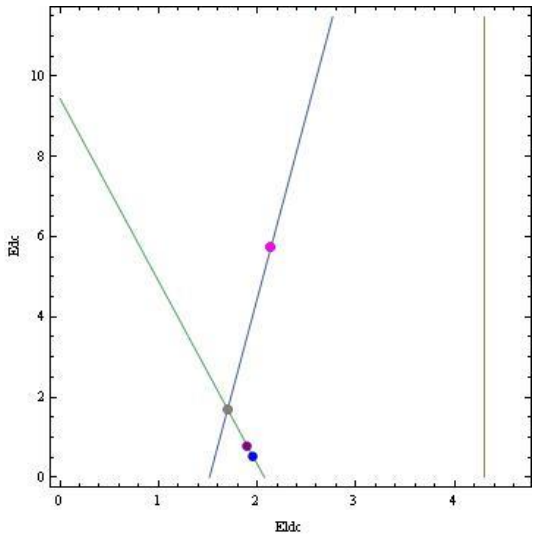
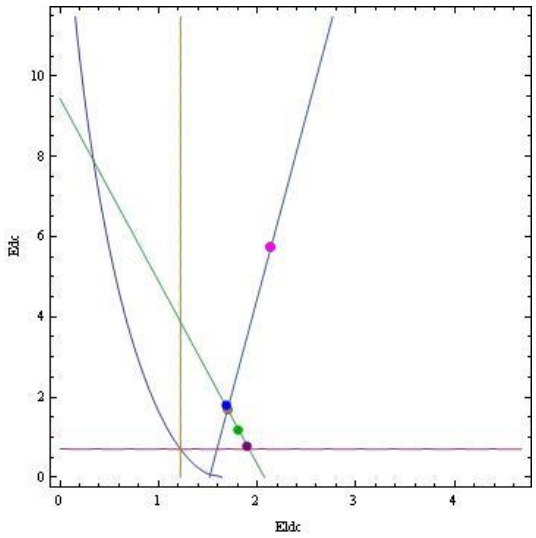



Figure 4 shows the solutions with current perceived duty to nature and rights of future generations, but with maximum perceived duty to future generations. Comparing Figure 4 with Figure 1 suggests that a greater responsibility to future generations (here, the maximum value) makes the current use of Earth's resources weakly sustainable to a larger extent at all aversions to intra-generational inequality (i.e., at both $\varepsilon = 0$ and $\varepsilon = 1$). Indeed, the static model developed in this paper, together with the assumption that future generations will be sustainable, implies that a larger amount of resources can be used by the current generation. An alternative dynamic model might highlight a positive relationship between $\gamma$ at time $t$ and $\theta$ at time $t$+1. However, these value changes do not affect the position of the Nash bargaining equilibrium. In other words, individuals in developed and less-developed countries are unlikely to change their environmental behavior.

**Figure 4. Solutions for combinations of the ecological footprint (ha/person) for less-developed (Eldc) and developed countries (Edc) with no change in the perceived duty to nature (β), the maximum change in the perceived duty to future generations (γ), no change in the perceived rights of future generations (δ), in the current scenario with no change in future technology (θ), in future population (η), and in future consumption preferences (α).**

The Hindu and Buddhist solution (grey point) is at (1.70, 1.70); the Islamic solution (green point) is at (1.81, 1.19); the Jewish solution (blue point) is at (1.79, 1.67); the Nash solution (magenta point) is at (2.14, 5.74); the strong sustainability cooperative solution (purple point) is at (1.90, 0.78); the decreasing (green) straight line represents the weighted global sustainability; the decreasing (blue) curve represents equal welfare of the current and future generations under weak sustainability equilibrium; the increasing (blue) straight line represents Kalai-Smorodinsky equilibrium; the horizontal pink line depicts equal welfare for OECD current and future generations; the vertical grey line depicts equal welfare for non-OECD current and future generations.




Note that the Islamic solution becomes more egalitarian, with larger resources available for the less-developed countries, whereas the Jewish solution becomes almost identical to the Buddhist and Hindus solution.

Figure A2 shows the solutions with the current perceived duty to nature, and the maximum perceived duty to future generations and rights of future generations. Comparing Figure A2 with Figure 4 suggests that coupling a greater perception of the rights of future generations (here, the maximum) with a greater perceived responsibility to future generations (here, the maximum) does not affect the position of the Nash bargaining equilibrium. However, the weak sustainability cooperative solution is now feasible, and the Jewish solution is now more egalitarian than the Islamic solution. Statistical analysis (Section 4.4) based on marginal impacts (i.e., the marginal change in the ecological footprint due to changes in responsibilities) supports these insights based on the maximum changes; that is, an increase in responsibility to future generations is detrimental. Indeed, $\gamma$ is detrimental but feasible and reliable ($P > 0.581$ and $P > 0.170$) in both developed and less-developed countries (i.e., $\gamma$ is detrimental in all countries).

Figure 5 shows the solutions for a scenario with current perceived duty to nature and perception of a duty to future generations, but with the maximum perception of the rights of future generations. Comparing Figure 5 with Figure 1 suggests that a greater perception of the rights of future generations (here, the maximum) moves the bargaining Nash equilibrium in a beneficial direction. Note that only developed countries will accept decreased availability of natural resources. Moreover, the new bargaining Nash equilibrium is not weakly sustainable at all levels of aversion to intra-generational inequality. Finally, the Islamic solution becomes less egalitarian. Statistical analysis (Section 4.4) based on marginal impacts (i.e., the marginal change in the ecological footprint due to changes in rights) supports these insights based on the maximum changes; that is, an increase in the rights of future generations is beneficial. Indeed, $\delta$ is beneficial and both feasible and reliable ($P > 0.629$) in OECD countries, although inadequate, and is beneficial but unfeasible and unreliable ($P > 0.996$) in non-OECD countries.

**Figure 5. Solutions for combinations of the ecological footprint (ha/person) for less-developed (Eldc) and developed countries (Edc) with no change in the perceived duty to nature ($\beta$) and in the perceived duty to future generations ($\gamma$), the maximum change in the perceived rights of future generations ($\delta$), in the current scenario with no change in future technology ($\theta$), in future population ($\eta$), and in future consumption preferences ($\alpha$).**

The Hindu and Buddhist solution (grey point) is at (1.70, 1.70); the Islamic solution (green point) is at (1.56, 2.33); the Jewish solution (blue point) is at (1.95, 0.53); the Nash solution (magenta point) is at (2.14, 4.44); the strong sustainability cooperative solution (purple point) is at (1.90, 0.78); the decreasing (green) straight line represents the weighted global sustainability; the decreasing (blue) curve represents equal welfare of the current and future generations under weak sustainability equilibrium; the increasing (blue) straight line represents Kalai-Smorodinsky equilibrium; the horizontal pink line depicts equal welfare for OECD current and future generations; the vertical grey line depicts equal welfare for non-OECD current and future generations.

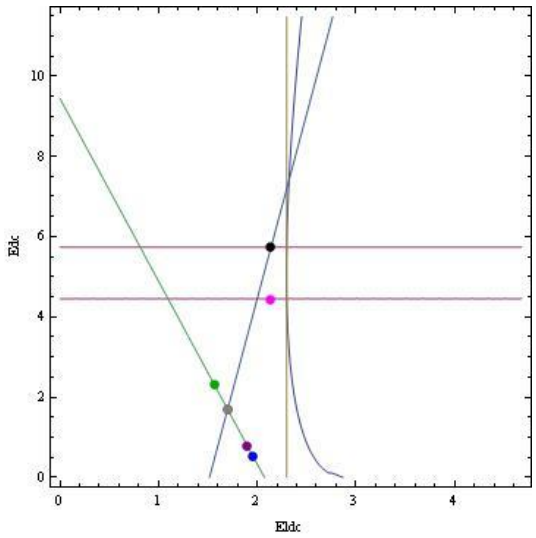



Figure A3 shows the solutions with the maximum perceived duty to nature, but the current perceived duty to nature and rights of future generations in a future optimistic scenario. Comparing Figure A3 with Figure 3 suggests that responsibility to nature is less effective with a future optimistic scenario, since the current use of Earth's resources is weakly sustainable to a larger extent in this scenario. Figure A4 shows the solutions with no perceived duty to nature and no rights of future generations, but with the maximum perceived duty to future generations in a future optimistic scenario. Comparing Figure A4 with Figure 4 suggests that responsibility to future generations in a future optimistic scenario is more detrimental with a future optimistic scenario, since all future equilibria become weakly sustainable to a larger extent.

**Figure 6. Solutions for combinations of the ecological footprint (ha/person) for less-developed (Eldc) and developed countries (Edc) with no change in the perceived duty to nature (β) and in the perceived duty to future generations (γ), the maximum change in the perceived rights of future generations (δ), in the optimistic scenario with a 20% improvement in future technology (θ), a 20% reduction in future population (η), and a 20% decrease in future consumption preferences (α).**

The Hindu and Buddhist solution (grey point) is at (2.04, 2.04); the Islamic solution (green point) is at (1.09, 6.33); the Jewish solution (blue point) is at (0.32, 9.84); the Nash solution (magenta point) is at (2.14, 1.81); the weak sustainability cooperative solutions (pink point) is at (4.65, 3.04); the strong sustainability cooperative solution (purple point) is at (2.31, 0.78); the decreasing (green) straight line represents the weighted global sustainability; the increasing and decreasing (blue) curve represents equal welfare of the current and future generations under weak sustainability equilibrium; the increasing (blue) straight line represents Kalai-Smorodinsky equilibrium; the horizontal pink line depicts equal welfare for OECD current and future generations; the vertical grey line depicts equal welfare for non-OECD current and future generations.

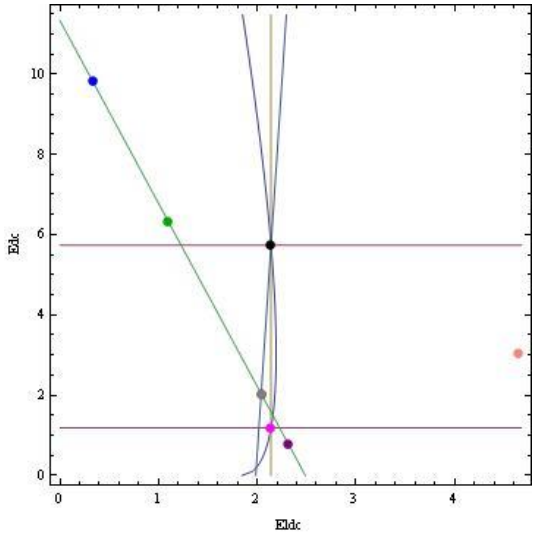


Figure 6 shows the solutions with no changes in the perceived duty to nature or future generations but the maximum perceived rights of future generations in a future optimistic scenario. Comparing Figure 6 with Figure 5 suggests that maximizing the rights of future generations in a future optimistic scenario is more effective than in the current scenario. Indeed, the Nash bargaining solution becomes strongly sustainable, and the weak sustainability cooperative solution is now feasible. Note that only developed countries will have decreased availability of natural resources, whereas the Jewish solution becomes less egalitarian than the Islamic solution.

In summary, apart from corroboration of the rights of future generations by the maximum charge for environmentally unsustainable activities in an optimistic future scenario, secular ethics turn out to be inadequate for achieving global sustainability, unless individuals and governments become aware that the outcomes of disagreement (i.e., the welfare obtained if one decides not to bargain with the other participants) is not the current status, but rather more equal per capita use of the Earth's resources. In particular, weak sustainability cooperative solutions are a small proportion of all feasible equilibria. Moreover, secular ethics might affect inequality of the Jewish and Islamic solutions, although not their sustainability. Finally, accounting for the rights of future generations will make the developed countries bear most of the costs of sustainability.

## 4.3.Statistical analysis for religious ethics

In this analysis, I performed linear regression using estimated the following equation:

$$\ln EF = \ln GDP + BUD/HIN + ISL + JUD + CHR + \xi$$

Where ξ represents the residuals. Note that there were 13 countries where no religion accounted for more than 50% of the total population. Table 2 presents the results of this analysis.

**Table 2. Statistical results.**

| Source | SS | df | MS | Number of obs = | 145 |
|---|---|---|---|---|---|
| | | | | F( 5, 139) = | 97.20 |
| Model | 10.7474035 | 5 | 2.14948071 | Prob > F = | 0.0000 |
| Residual | 3.07382149 | 139 | .022113824 | R-squared = | 0.7776 |
| | | | | Adj R-squared = | 0.7696 |
| Total | 13.821225 | 144 | .095980729 | Root MSE = | .14871 |

| lnef | Coef. | Std. Err. | t | P>\|t\| | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| lngdp | .4991936 | .0241188 | 20.70 | 0.000 | .4515065 | .5468807 |
| budhin | -.0644674 | .0638445 | -1.01 | 0.314 | -.1906993 | .0617645 |
| isl | -.0384913 | .0420894 | -0.91 | 0.362 | -.1217096 | .044727 |
| jud | .1084827 | .1536622 | 0.71 | 0.481 | -.1953348 | .4123002 |
| chr | -.000919 | .0390526 | -0.02 | 0.981 | -.0781329 | .0762949 |
| _cons | -1.557305 | .1013284 | -15.37 | 0.000 | -1.757649 | -1.356961 |

In summary, in terms of the sign of the result and its statistical significance, Buddhism or Hinduism (bud/hin) > Islam (isl) > Judaism (jud) > Christianity (chr). The positive sign of the dummy variable for Judaism is theoretically justified by Zagonari (2018b).

## 4.4.Statistical analysis for secular ethics

In this analysis, I performed linear regression using the following equation separately for OECD and non-OECD countries:

$$\ln EF = \ln GDP + \beta + \gamma + \delta + \xi$$

Where ξ represents the residuals. Note that there are 33 OECD countries, since Iceland was excluded from the 34 OECD countries in 2012 due to a lack of data., Moreover, in this analysis, endogenous problems can be excluded, since the dependent variable (i.e., the ecological footprint, *EF*) is expressed in area units (i.e., ha), whereas the independent variables (i.e., β, γ, and δ) are expressed in percentages (i.e., values between 0 and 1), and represent endogenous political decisions (e.g., the environmental tax rate could either increase or decrease the pollution level).

Finally, the analytical approximation of the logarithmic expressions presented above affects the magnitude of the estimation of δ, but not its sign and significance. Table 3 presents the results of this analysis for the OECD countries. For simplicity, and with full recognition that this approach ignores some exceptions, I have used the subscript N (northern hemisphere) to label parameters for OECD countries and the subscript S (southern hemisphere) for non-OECD countries.

**Table 3. Statistical results for the developed countries.**

| Source | SS | df | MS | | |
|---|---|---|---|---|---|
| Model | 2.05375339 | 4 | .513438347 | Number of obs = | 33 |
| Residual | 1.56979583 | 28 | .056064137 | F( 4, 28) = | 9.16 |
| | | | | Prob > F = | 0.0001 |
| Total | 3.62354922 | 32 | .113235913 | R-squared = | 0.5668 |
| | | | | Adj R-squared = | 0.5049 |
| | | | | Root MSE = | .23678 |

| lnefn | Coef. | Std. Err. | t | P>\|t\| | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| lngdpn | .6691525 | .1232108 | 5.43 | 0.000 | .4167666 | .9215384 |
| ben | -.0063982 | .0390049 | -0.16 | 0.871 | -.0862961 | .0734997 |
| gan | .0251808 | .0451371 | 0.56 | 0.581 | -.0672782 | .1176399 |
| den | -.0199112 | .0407201 | -0.49 | 0.629 | -.1033226 | .0635001 |
| _cons | -5.299215 | 1.272448 | -4.16 | 0.000 | -7.905707 | -2.692723 |

In summary, together with a negative and significant constant and a positive and significant coefficient for GDP, similar to estimations for religious ethics, the sign and significance of the results was $\gamma_N$ (detrimental and significant) > $\beta_N \approx 0$ (beneficial but non-significant) > $\delta_N$ (beneficial and significant). Table 4 presents the results of this analysis for the non-OECD countries.

**Table 4. Statistical results for the less-developed countries.**

| Source | SS | df | MS | | |
|---|---|---|---|---|---|
| Model | 28.3351872 | 4 | 7.0837968 | Number of obs = | 112 |
| Residual | 14.0215074 | 107 | .131042125 | F( 4, 107) = | 54.06 |
| | | | | Prob > F = | 0.0000 |
| Total | 42.3566946 | 111 | .381591843 | R-squared = | 0.6690 |
| | | | | Adj R-squared = | 0.6566 |
| | | | | Root MSE = | .362 |

| lnefs | Coef. | Std. Err. | t | P>\|t\| | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| lngdps | .4395853 | .0361459 | 12.16 | 0.000 | .3679303 | .5112403 |
| bes | .0569742 | .0586674 | 0.97 | 0.334 | -.0593272 | .1732755 |
| gas | .1478731 | .1070159 | 1.38 | 0.170 | -.0642736 | .3600197 |
| des | -.0001254 | .0277826 | -0.00 | 0.996 | -.0552013 | .0549504 |
| _cons | -3.175824 | .3003074 | -10.58 | 0.000 | -3.771148 | -2.580499 |

In summary, in terms of sign and significance $\gamma_S$ (detrimental and significant) > $\beta_S \approx 0$ (detrimental and non-significant) > $\delta_S$ (beneficial and non-significant). Note that $\beta_N < 0$ whereas $\beta_S > 0$: that is, the environment can be considered to function as a luxury good. Moreover, $\delta_S$ is non-significant whereas $\delta_N$ is significant: that is, the rights of future generations are effective only in the developed countries. Finally, both $\gamma_N$ and $\gamma_S$ are detrimental and significant: that is, a greater investment in R&D implies greater use of resources, and the opposite implication (i.e., from large use of resources to large R&D) is excluded, since R&D decisions are taken years before R&D expenditures. In other words, within a static model, a greener technology that is available today allows the current generation to increase its use of resources, based on the belief that future generations are more likely to be sustainable tomorrow.

# 5.Discussion

Results obtained above support the statement that ethical principles and precepts must be accounted for by empirical models, the assumption that the suggested equilibria must be realistic, and the statement that the advocated ethical principles and precepts must be feasible and reliable. Indeed, almost all ethical principles and precepts can favor sustainability solutions, but many caveats will appear if real data are used. For example, the current status turns out to be weakly sustainable if inequality among countries is disregarded (i.e., $\varepsilon = 0$): under these conditions, some people might say that we do not need to do anything to improve the current situation. Similarly, if optimistic future scenarios apply (i.e., $\alpha$ decreases by 20%, $\eta$ increases by 20%, and $\theta$ increases by 20%), the strong sustainable equilibrium is also weakly sustainable: under these circumstances, some people might say that there is no point in sacrificing our use of resources or our welfare today to change our future from one sustainable equilibrium to another. Due to the many arguable issues involved in defining the equilibrium conditions (e.g., inter-generational equity focused on past and present generations), the political discussion should focus on realistic goals. For example, a cooperative solution to achieve global strong sustainability is not currently feasible, since the perception that we face a common problem is still lacking. Similarly, a bargaining Nash equilibrium in terms of the strong sustainability status is not currently feasible, since the perception that we face a dramatic problem is still lacking. By contrast, the focus on a bargaining Nash equilibrium (i.e., the maximum exploitation of potential bargaining outcomes) in terms of the current status or on a bargaining Kalai-Smorodinsky equilibrium (i.e., equally proportional losses by all parties) are realistic goals.

Note that the set of paired values for the ecological footprints of OECD and non-OECD countries that supports weak sustainability increases in size with increasing $\gamma$, decreases with increasing $\beta$, $\delta$, and $\varepsilon$, and increases with an optimistic future scenario.

The present study has the following methodological weaknesses:

- I depicted a dynamic problem using a static framework in which sustainability might not be achieved in some years, provided it is achieved in many or most subsequent years. However, the only acceptable time discount rate for nature conservation in the long-run is 0 (Heath, 2017), so that the sustainability problem consists of an infinite number of static problems.
- I presented both numerical solutions and statistical analyses in scenarios with extreme parameter values (i.e., the maximum and minimum aversions to intra- and inter-generational inequality). However, continuity and monotonicity of all the applied functions (Zagonari, 2018a) suggest that solutions for intermediate parameter values exist and lie between the presented solutions.

The present study has the following methodological strengths:

- I formalized all of the essential concepts involved in global sustainability in a single framework. This makes it possible to confirm the reliability and feasibility of potential solutions, and to avoid discussion of unrealistic concepts.
- I calculated both the feasibility (i.e., numerical results for the maximum values) and the reliability (i.e., statistical results for the marginal impacts) of the solutions, and these calculations turned out to be mutually supportive. This suggests that the methodologies are adequate and can provide realistic solutions.

The present study has the following political weaknesses:

- The analysis is based on national-level statistics for a representative individual. However, a downscaling of the analysis to focus on ecosystems, as has recently been accomplished (Erickson, 2016), is a promising development.
- I adopted an individual-level approach. However, an extension of the analysis to community approaches (Drahos and Downie, 2017) seems likely to be useful.

The present study has the following political strengths:

- Relying on different religious precepts for each religion does not require coordination of environmental policies at an international level (Welsch and Kuhling, 2017), and these prescriptions can be applied immediately (Castiglione et al., 2014).

- The global problem of sustainability must be tackled by involving the vast majority of the world's population (Riley and Bauman, 2017), and some 85% of the world's people claim to believe in some religion and its principles (www.adherents.com).

Note that this study compares secular and religious ethics, with the former based on ethical principles that could solve a perceived social problem such as global sustainability, whereas the latter checks whether individual religious precepts can achieve an equilibrium to improve a situation that is not perceived as a social problem.

# 6.Conclusion

The application of an empirical model to achieve realistic equilibria by relying on feasible and reliable ethical changes suggests that secular ethics is inadequate to achieve global sustainability. In particular, I empirically highlighted that α, η, and θ are not essential for achieving sustainability; β is beneficial but unfeasible and unreliable in OECD countries, but is detrimental, unfeasible, and unreliable in non-OECD countries; γ is detrimental but feasible and reliable in all countries; δ is beneficial, feasible, and reliable in OECD countries, but is inadequate, but is beneficial, unfeasible and unreliable in non-OECD countries; ε is detrimental; and ζ is essential.

Therefore, religious ethics (Hinduism or Buddhism, Islam, and Judaism) must be supported as feasible and reliable incentives to achieve sustainability, although they may be characterized by different levels of intra-generational inequality. This is important because of the huge numbers of individuals in all countries who claim to follow the tenets of some religion, and achieving sustainability requires a change in behaviors of the vast majority of the world population. Moreover, the present results agree with previous suggestions that secular ethics have counterintuitive effects on sustainability (Baumard and Boyer, 2013) and that they cannot support prescriptions (Snyder, 2017). Finally, many religions propose an infinite after-life penalty for unethical behavior and reward for ethical behavior that could strongly motivate individual choices, which I implicitly accounted for in the present model.

The application of an empirical model to achieve realistic equilibria by relying on feasible and reliable ethical changes can also favor consensus by clarifying often-misinterpreted concepts (e.g., ε), by eliminating divisive concepts (e.g., α, η, θ), and by clarifying often-overlooked concepts (e.g., γ).

In particular, the figures in this paper clarify some concepts that are theoretically problematic. It turns out that a higher concern for intra-generational inequality (ε) makes environmental sustainability harder to achieve. Similarly, changes in consumption preferences (α) and population reduction (η) were insufficient to achieve strong sustainability, even when they are combined in a potential solution. The figures also clarify a concept that might be theoretically and practically problematic. Specifically, a higher concern for future generations (γ) could lead to two unintended outcomes. If the current generation thinks that future generations will achieve long-run sustainability in some way (e.g., reduced consumption, technological improvements, population reduction), then an increase in γ could increase their current use of natural resources because they feel no need to change. Similarly, if an increase in γ leads the current generation to invest in green technologies, the current status could be perceived as more sustainable, and the current use of natural resources could increase due to the belief that technology can solve the problem.

Despite these clarifications, secular ethics is not a straightforward concept, as it depends on many debatable and uncertain factors, and can therefore be modified by politicians to achieve a political advantage. For example, they include:

- Discussion of the sustainability concepts to be pursued (e.g., why should I sacrifice my opportunities if my activities are already weakly sustainable?) or political perspectives to be adopted (e.g., why should I be concerned about intra-generational equity?)
- Uncertainty about future generations (e.g., why should I sacrifice my opportunities if future generations will rely on greener technologies?). Moreover, "what if future generations are less concerned with consumption?" Finally, "why should I sacrifice my opportunities if future generations will realize that a reduction in population is required?"

- Debate about past responsibilities at a national level (e.g., why should my country adopt measures that reduce my opportunities if your country polluted much more than we are doing in the past) and current strategies at a national level (e.g., why should my country adopt measures that reduce my opportunities if you have no incentive to meet your commitments in the future?).

To respond to these problems, religious ethics must be supported, as the religious ethics defined in this study are based on a few clear precepts grounded in standardized sacred texts.

Therefore, even if the concern for future generations is maximized, the recognition that environmental conservation has opportunity costs suggests that many cooperative or non-cooperative *theoretically* feasible sustainable agreements, based on the political and social institutions that currently exist, will be difficult to achieve *in practice* unless individual environmental behavior can be changed to promote such agreements. Thus, the environmental precepts of each religion should be emphasized for residents of countries dominated by a given religion. Because the present results show different results for different religions, supporting inter-religious dialogue to combine the benefits of the different precepts seems likely to be more promising than fostering international agreements based solely on secular ethics.

# Appendix I: the analytical framework for secular ethics

Zagonari (2018a) justifies the mathematical description of environmental ethical principles. Here, I will refer to the following equilibria (again, for simplicity, I have used the subscript N (northern hemisphere) to label parameters for OECD countries and the subscript S (southern hemisphere) for non-OECD countries; the subscripts C and F refer to current and future generations, respectively):

For weak sustainability, if $\varepsilon = 0$ and $\zeta = 1$ (pink points in the Figures):

$$Max\ U_{\mathrm{C}} = p_{\mathrm{N}}U_{\mathrm{N}} + p_{\mathrm{S}}U_{\mathrm{S}}\ s.t.\ U_{\mathrm{C}} \geq U_{\mathrm{F}}$$

Where

$$U_{\mathrm{N}} = {X_{\mathrm{N}}}^{\alpha \mathrm{N}} {E_{\mathrm{N}}}^{-\beta \mathrm{N}} {U_{\mathrm{F}}}^{\gamma \mathrm{N}} - \delta_{\mathrm{N}}(E_{\mathrm{N}} - \eta)$$
$$U_{\mathrm{S}} = {X_{\mathrm{S}}}^{\alpha \mathrm{S}} {E_{\mathrm{S}}}^{-\beta \mathrm{S}} {U_{\mathrm{F}}}^{\gamma \mathrm{S}} - \delta_{\mathrm{S}}(E_{\mathrm{S}} - \eta)$$
$$U_{\mathrm{F}} = {X_{\mathrm{F}}}^{\alpha \mathrm{F}}$$
$$X_{\mathrm{N}} = \theta_{\mathrm{N}} E_{\mathrm{N}}$$
$$X_{\mathrm{S}} = \theta_{\mathrm{S}} E_{\mathrm{S}}$$
$$X_{\mathrm{F}} = \theta_{\mathrm{F}}\, \eta$$

Note that welfare levels (here, expressed as the utility) are weighted according to the relative population sizes (i.e., $p_{\mathrm{N}}$ and $p_{\mathrm{S}}$ in the OECD and non-OECD countries, respectively). Moreover, $\alpha$, $\beta$, and $\gamma$ are expressed as real numbers in [0, 1], since these parameters represent the proportion of income spent on the related items (i.e., consumption, nature conservation, and green R&D, respectively). Finally, $\delta$ represents the opportunity cost in welfare terms per unit of unmet rights of future generations; because this parameter is multiplied by the difference between the current status and the sustainability status, it is then added to a welfare measure.

If $\varepsilon = \zeta = 1$ (the horizontal pink line and vertical grey line, respectively, in the Figures):

$$U_{\mathrm{N}} = U_{\mathrm{F}} \text{ and } U_{\mathrm{S}} = U_{\mathrm{F}}$$

If $\varepsilon = 0$ and $\zeta = 1$ (the decreasing blue curve in the Figures):

$$p_{\mathrm{N}}U_{\mathrm{N}} + p_{\mathrm{S}}U_{\mathrm{S}} = U_{\mathrm{F}}$$

For strong sustainability, if $\varepsilon = 0$ and $\zeta = 1$ (purple points in the Figures):

$$Max\ E_{\mathrm{N}} + E_{\mathrm{S}}\ s.t.\ p_{\mathrm{N}}E_{\mathrm{N}} + p_{\mathrm{S}}E_{\mathrm{S}} \leq E_{\mathrm{F}} = \eta$$

Note that the use of resources is not weighted.

If $\varepsilon = \zeta = 1$ (grey points in the Figures):

$$E_{\mathrm{N}} = \eta \text{ and } E_{\mathrm{S}} = \eta$$

If $\varepsilon = 0$ and $\zeta = 1$ (decreasing green straight line in the Figures):

$$p_{\mathrm{N}}E_{\mathrm{N}} + p_{\mathrm{S}}E_{\mathrm{S}} = E_{\mathrm{F}} = \eta$$

The Nash bargaining solution in terms of the current status is based on:

$$Max\ [U_{\mathrm{N}} + U_{\mathrm{N}}(5.74)]\ [U_{\mathrm{S}} + U_{\mathrm{S}}(2.14)]$$

The Nash bargaining solution in terms of the strong sustainability status with maximum aversion to intra-generational inequality is based on:

$$Max\ [U_{\mathrm{N}} + U_{\mathrm{N}}(\eta)]\ [U_{\mathrm{S}} + U_{\mathrm{S}}(\eta)]$$

The Kalai-Smorodinsky solution is based on:

$$(5.74 - E_{\mathrm{N}})/(5.74 - \eta) = (2.14 - E_{\mathrm{S}})/(2.14 - \eta)$$

Note that I distinguished responsibilities (here, represented by percentages as parameters of a Cobb-Douglas utility function) from rights (here, represented by a linear penalty function) to solve for the maximum estimated rights in terms of opportunity costs that depend on the variables and parameters.

# Appendix II: the analytical framework for religious ethics

Zagonari (2018b) justifies the mathematical description of the environmental religious precepts. Here, I will refer to the following equilibria (again, for simplicity, I have used the subscript N (northern hemisphere) to label parameters for OECD countries and the subscript S (southern hemisphere) for non-OECD countries; the subscripts C and F refer to current and future generations, respectively):

For Judaism:

$$Max\ U\ s.t.\ E_{\mathrm{C}} \leq \eta \text{ with } \zeta = 1 \text{ and } \varepsilon = 0$$

where:

$$U = \left\{[(p_{\mathrm{N}}U_{\mathrm{N}})^{1-\varepsilon} + (p_{\mathrm{S}}U_{\mathrm{S}})^{1-\varepsilon}]^{(1-\zeta)/(1-\varepsilon)} + {U_{\mathrm{F}}}^{1-\zeta}\right\}^{1/(1-\zeta)}$$

Thus (blue points in the Figures):

$$Max\ p_{\mathrm{N}}U_{\mathrm{N}} + p_{\mathrm{S}}U_{\mathrm{S}}\ s.t.\ E_{\mathrm{C}} = p_{\mathrm{N}}E_{\mathrm{N}} + p_{\mathrm{S}}E_{\mathrm{S}} \leq \eta$$

Note that welfare levels are weighted by the relative population.

For Islam:

$$Min\ E_{\mathrm{C}}\ s.t. U_{\mathrm{N}} \geq u_{\mathrm{N}} \text{ and } U_{\mathrm{S}} \geq u_{\mathrm{S}} \text{ and } E_{\mathrm{C}} \leq \eta \text{ with } \varepsilon = 0$$

Where:

$$E_{\mathrm{C}} = p_{\mathrm{N}}E_{\mathrm{N}} + p_{\mathrm{S}}E_{\mathrm{S}}$$

With $u_{\mathrm{N}}$ and $u_{\mathrm{S}}$ the welfare levels currently achieved by developed and less-developed countries, respectively. Thus (green points in the Figures):

$$Min\ p_{\mathrm{N}}E_{\mathrm{N}} + p_{\mathrm{S}}E_{\mathrm{S}}\ s.t. U_{\mathrm{N}} + U_{\mathrm{S}} \geq u_{\mathrm{N}} + u_{\mathrm{S}} \text{ and } E_{\mathrm{C}} \leq \eta$$

For Buddhism and Hinduism:

$$Max\ W\ s.t.\ E_{\mathrm{N}} \leq \eta \text{ and } E_{\mathrm{S}} \leq \eta \text{ with } \zeta = 1 \text{ and } \varepsilon = 1$$

Where:

$$W = \left\{\left[{E_{\mathrm{N}}}^{1-\varepsilon} + {E_{\mathrm{S}}}^{1-\varepsilon}\right]^{(1-\zeta)/(1-\varepsilon)} + {E_{\mathrm{F}}}^{1-\zeta}\right\}^{1/(1-\zeta)}$$

Thus (grey points in the Figures):

$$E_{\mathrm{N}} = \eta \text{ and } E_{\mathrm{S}} = \eta$$

# Appendix III: sensitivity analysis

**Figure A1. Solutions for combinations of the ecological footprint (ha/person) for less-developed (Eldc) and developed countries (Edc) with the maximum change in the perceived duty to nature (β), no change in the perceived duty to future generations (γ), with the maximum change in the perceived rights of future generations (δ), in the current scenario with no change in future technology (θ), in future population (η), and in future consumption preferences (α).**

The Hindu and Buddhist solution (grey point) is at (1.70, 1.70); Jewish solution (blue point) is at (1.95, 0.51); Nash solution (magenta point) is at (2.14, 5.74); strong sustainability cooperative solution (purple point) is at (1.90, 0.78); the decreasing (green) straight line represents the weighted global sustainability; the increasing (blue) straight line represents Kalai-Smorodinsky equilibrium; the vertical grey line depicts equal welfare for non-OECD current and future generations.

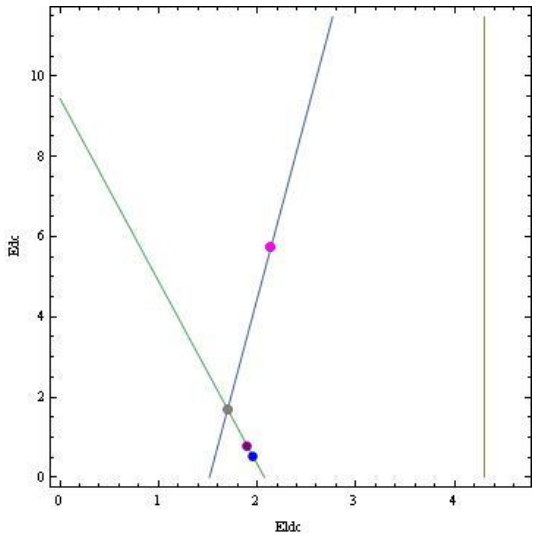



**Figure A2. Solutions for combinations of the ecological footprint (ha/person) for less-developed (Eldc) and developed countries (Edc) with no change in the perceived duty to nature (β), the maximum change in the perceived duty to future generations (γ), with the maximum change in the perceived rights of future generations (δ), in the current scenario with no change in future technology (θ), in future population (η), and in future consumption preferences (α).**

The Hindu and Buddhist solution (grey point) is at (1.70, 1.70); the Islamic solution (green point) is at (1.92, 0.68); the Jewish solution (blue point) is at (0.44, 7.43); the Nash solution (magenta point) is at (2.14, 5.74); the weak sustainability cooperative solution (pink point) is at (4.66, 1.65); the strong sustainability cooperative solution (purple point) is at (1.90, 0.78); the decreasing (green) straight line represents the weighted global sustainability; the decreasing (blue) curve represents equal welfare of the current and future generations under weak sustainability equilibrium; the increasing (blue) straight line represents Kalai-Smorodinsky equilibrium; the horizontal pink line depicts equal welfare for OECD current and future generations; the vertical grey line depicts equal welfare for non-OECD current and future generations.

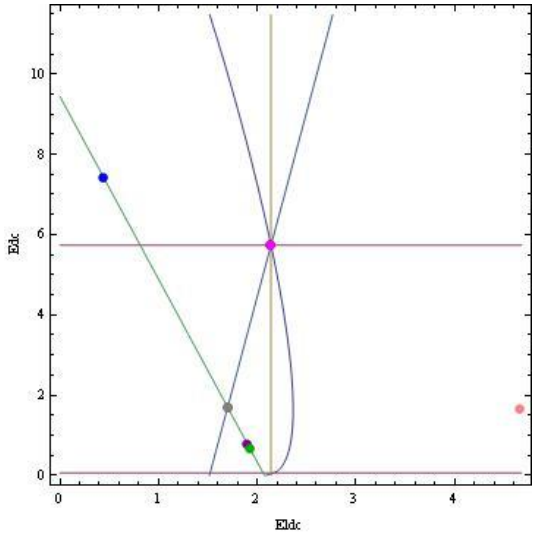



**Figure A3. Solutions for combinations of the ecological footprint (ha/person) for less-developed (Eldc) and developed countries (Edc) with the maximum change in the perceived duty to nature (β), no change in the perceived duty to future generations (γ) and in the perceived rights of future generations (δ), in the optimistic scenario with a 20% improvement in future technology (θ), a 20% reduction in future population (η), and a 20% decrease in future consumption preferences (α).**

The Hindu and Buddhist solution (grey point) is at (2.04, 2.04);the Jewish solution (blue point) is at (2.35, 0.58); the Nash solution (magenta point) is at (2.14, 5.74); the strong sustainability cooperative solution (purple point) is at (2.31, 0.78); the decreasing (green) straight line represents the weighted global sustainability; the decreasing (blue) curve represents equal welfare of the current and future generations under weak sustainability equilibrium; the increasing (blue) straight line represents Kalai-Smorodinsky equilibrium; the vertical grey line depicts equal welfare for non-OECD current and future generations.

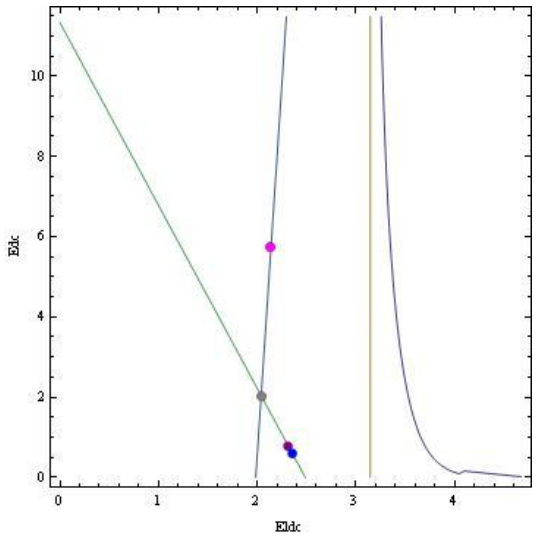
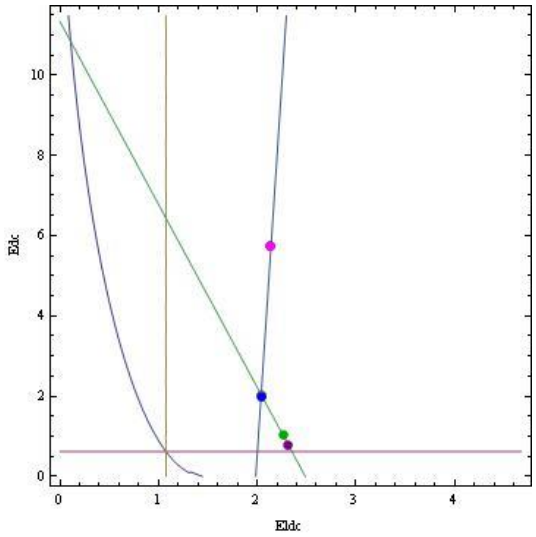



**Figure A4. Solutions for combinations of the ecological footprint (ha/person) for less-developed (Eldc) and developed countries (Edc) with no change in the perceived duty to nature (β), the maximum change in the perceived duty to future generations (γ), no change in the perceived rights of future generations (δ), in the optimistic scenario with a 20% improvement in future technology (θ), a 20% reduction in future population (η), and a 20% decrease in future consumption preferences (α).**

The Hindu and Buddhist solution (grey point) is at (2.04, 2.04); the Islamic solution (green point) is at (2.26, 1.02); the Jewish solution (blue point) is at (2.04, 1.99); the Nash solution (magenta point) is at (5.74, 2.14); the strong sustainability cooperative solution (purple point) is at (2.31, 0.78); the decreasing (green) straight line represents the weighted global sustainability; the decreasing (blue) curve represents equal welfare of the current and future generations under weak sustainability equilibrium; the increasing (blue) straight line represents Kalai-Smorodinsky equilibrium; the horizontal pink line depicts equal welfare for OECD current and future generations; the vertical grey line depicts equal welfare for non-OECD current and future generations.

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