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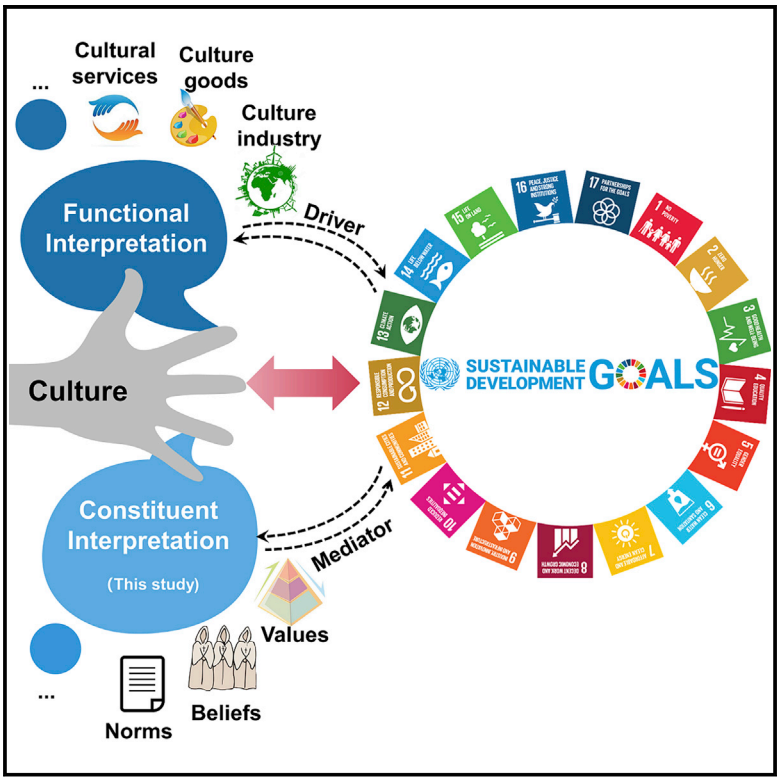
Consideration of culture is vital if we are to achieve the Sustainable Development Goals

Graphical abstract



Highlights

- We investigate the importance of culture in achieving the Sustainable Development Goals (SDGs)
- Culture mediates the attainment of 17 SDGs, represented by 79% of the SDG targets
- Cultural values explain as much as 26% of the variations in the achievement of the SDGs
- Sustainable policies can be tailored to, but not captive to, cultural context

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In brief

The role of culture in sustainable development has received increasing attention but remains undervalued. We bridge culture and the Sustainable Development Goals (SDGs) in both qualitative and quantitative manners and convert the vague understanding of culture-SDG links to concrete evidence. We show that culture is linked to the attainment of all 17 SDGs, represented by 79% of the SDG targets. Culture additionally explains as much as 26% of the variations in the achievement of SDGs.

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Consideration of culture is vital if we are to achieve the Sustainable Development Goals

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SCIENCE FOR SOCIETY For a long time, sustainability science and policy design have been rooted in environmental and economic perspectives, leaving the role of culture undervalued. Although a growing number of scholars and organizations, such as the United Nations Educational, Scientific and Cultural Organization (UNESCO), have realized the importance of culture in sustainable development and made substantial effort to integrate them, the debates against conventional sustainability discourses remain challenging. Our analysis contributes to the debate by providing both a conceptual framework and empirical evidence on the relations between cultural values and the achievement of the Sustainable Development Goals (SDGs). Our findings imply the necessity to consider more cultural context and nuances in sustainability science communication and policy design. In particular, sustainable development is suggested to be tailored to, but not be captive of, cultural context.

SUMMARY

Integrating the social and natural sciences to effectively tackle the intertwined challenges represented by the Sustainable Development Goals (SDGs) has been advocated for years. However, the practice is challenging, especially with respect to the beliefs, morals, and practices of individuals and groups or, more succinctly put, culture, which, despite attracting growing awareness, remains understated in sustainability. Here, we examine how and to what extent cultural values are linked to the achievement of the SDGs. Synthesizing knowledge from more than 300 publications, we show that cultural traits are linked to the achievement of all 17 SDGs and 79% of SDG targets. Further, empirical understanding obtained from a panel data analysis highlights that cultural values explain as much as 26% of the variations in the SDG achievements, yet the links are strikingly divergent across cultural traits and indicators. Our findings imply the need to consider more cultural contexts and nuances in sustainability science communications and policy design and to develop new cross-disciplinary solutions to sustainability challenges.

INTRODUCTION

With the aim of achieving a sustainable future of ''people, planet, and prosperity,'' 193 countries have committed to the United Nations (UN) 2030 Agenda, which outlined 17 Sustainable Development Goals (SDGs) and 169 associated targets.[1] Unlike conventional sustainability research and policies that focus on environmental challenges, the SDGs emphasize holistic

development in the economic, social, and environmental spheres, and many of their goals and targets potentially correlate with or diverge from one another.[2–4] To maximize synergies and minimize trade-offs within and among the SDGs, it is necessary, though challenging, to integrate advances in social sciences into the analysis and decision making of sustainability efforts.[5–8]

Culture as a mediator or driver of sustainable development has attracted growing attention in recent decades.[5,8–12] A key milestone that has raised attention to the role of culture in sustainable development is the adoption of the UN Educational, Scientific and Cultural Organization (UNESCO) 2005 Convention on Diversity of Cultural Expressions, in which Article 13 emphasizes integrating culture in sustainable development policies.[13] Since the appearance of the convention,[13] there has been wide-ranging academic and policy discussion concerning the relationship between culture and sustainable development[14,15] (see Table S1 for more examples). Particularly with the onset of the process for devising the SDGs beginning in 2012, international organizations that have competencies in the field of culture or related areas have put substantial interest and active efforts into the possible inclusion of one specific goal relating to culture in the SDGs.[16–18] The initiatives and advocacy have resulted in some positive feedback, including three UN General Assembly Resolutions on Culture and Sustainable Development,[19] but ultimately failed to secure an explicit cultural goal in the SDGs. Although culture has limited space in the final version of SDGs (i.e., it is only mentioned in 4 of the 169 targets as cultural diversity appreciation and cultural heritage protection), debates and efforts on the integration of culture into sustainable development continue.[20–23] For example, UNESCO developed a new framework, the Culture|2030 Indicators, to evaluate the progress of the contribution of culture to the 2030 Agenda and to encourage actions on the integration.[24]

The role of culture in sustainable development varies with different interpretations of culture, from tangible and intangible human achievements to symbolic patterns, norms, and rules of human communities.[25,26] Despite the multi-interpretability of the concept of culture, attention to the linkages between culture and sustainable development can be generally classified into two sets according to the accepted definition of culture in terms of its constituent interpretation and its functional interpretation.[27] In the constituent interpretation, culture refers to a set of shared values, beliefs, and norms through which people perceive, interpret, or respond to actions and environments. Culture in this sense acts as a facilitator of or barrier to development by affecting human perceptions, actions, and achievements concerning sustainability.[28–30] The second interpretation has a more functional orientation and denotes the practice of culture through cultural production, consumption, and participation. In this definition, culture plays a role as a driver and enabler of development since the cultural and creative industries that produce cultural goods and services can generate growth, income, and employment.[31] In the international initiatives devoted to the integration of culture in sustainable development, culture is often mentioned in both senses.[13,24]

Despite the growing recognition and advocacy,[5,9] the way that culture, especially in the constituent definition, contributes to each SDG is unclear, and its role remains understated in sustainability research and governance. There are three main reasons for this understatement. First, existing scientific evidence of the influences of culture on sustainability is fragmented and scattered. Such knowledge is predominantly gathered from isolated studies that are dispersed across a vast range of disciplines due to the very broad conceptualization of sustainability and culture. Second, there are interdisciplinary barriers in methodology. Cultural analysis, in most cases, involves qualitative case study in the forms of ethnography and participant observation, while sustainability science usually relies on quantitative approaches.[10] Although the social science field has witnessed a conspicuous improvement in cultural measurement methods (i.e., indicators for elements of culture),[32–37] the concept remains abstract and obscure for many sustainability scientists whose backgrounds are in technology and engineering.[5] Third, scientists and policymakers tend to downplay cultural factors because of the complexity and low enforceability of cultural interventions. However, in a world with a wide diversity of cultural traditions, achieving the SDGs requires culturally sensitive approaches more than homogeneous technical measures.[25,38,39] A holistic understanding of how cultural values facilitate or hinder a nation's efforts toward sustainability is thus indispensable for elucidating cultural opportunities and the hurdles to address challenges to sustainability.[10,38,40]

In this study, we focus on the constituent definition of culture (mentioned as culture or cultural values below) and provide scientific evidence concerning the relationships between cultural values and SDG achievements using two complementary approaches. First, on the basis of the 169 targets of the 2030 Agenda, we synthesize scholarly knowledge from more than 300 publications. Moreover, given that scientific evidence obtained in diverse contexts (e.g., different research methods and spatial scales) is not always comparable, we use panel data regressions to obtain empirical evidence in a consistent framework. The synthesis of existing evidence shows that cultural traits are linked to the achievement of all 17 SDGs, represented by 133 of the 169 SDG targets (79%). The results of the statistical analysis further highlight that cultural values explain as much as 26% of the variations in the achievement of SDGs, yet the links are strikingly divergent across cultural traits and across SDGs. Our assessments enable a holistic understanding of the role of cultural values in the achievement of the 2030 Agenda, which can potentially catalyze cooperation between these two previously separate branches of sciences and contribute to the development of culturally sensitive solutions to sustainability challenges.

RESULTS

Cultural values influence the achievement of SDGs

Existing scientific evidence demonstrates that culture has vital implications across a diverse range of issues addressed by the SDGs (Figure 1). For 133 of the 169 SDG targets (79%), which cover each of the 17 SDGs and the three sustainability pillars to a great extent, there is evidence that culture influences their achievement (colored orange in Figure 1). For four SDGs, SDG 1 (No Poverty), 5 (Gender Equality), 6 (Clean Water and Sanitation), and 9 (Industrial Innovation and Infrastructure), the

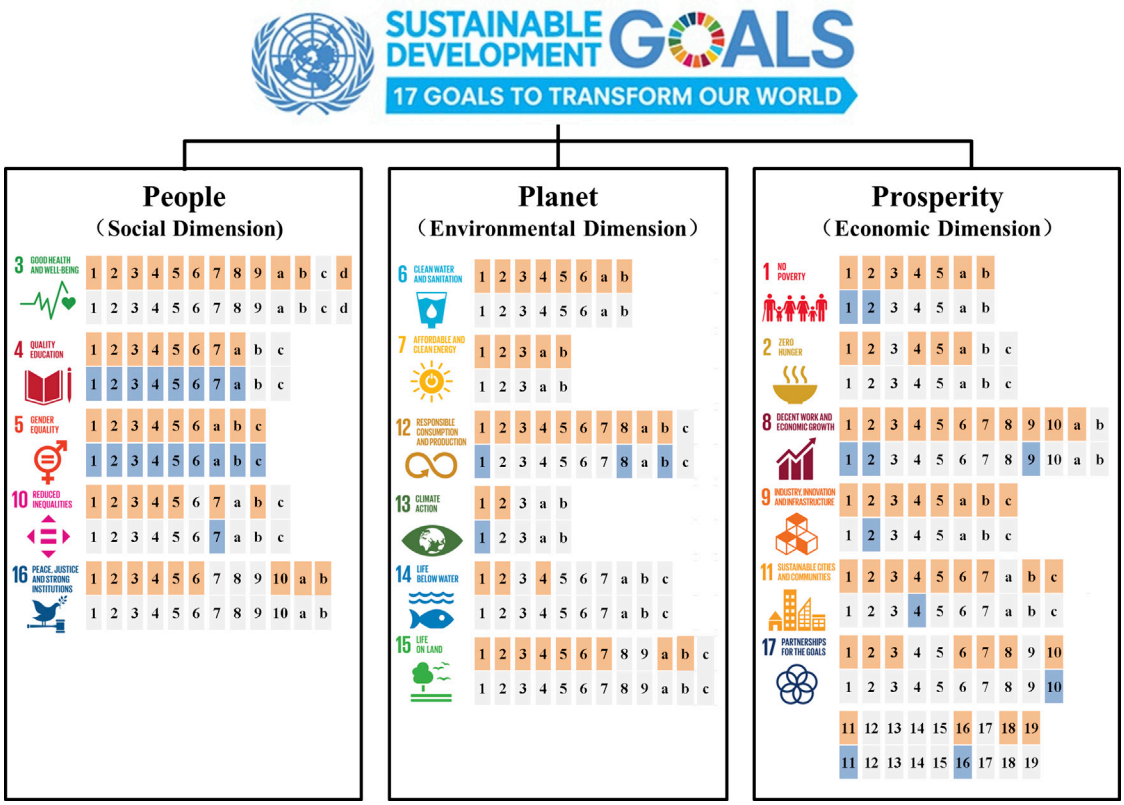

Figure 1. Linkages between culture and the SDGs demonstrated by existing scientific evidence

Rectangles to the right of each SDG correspond to the associated SDG targets. Orange indicates findings showing that culture affects the achievement of the SDG target, and blue shows evidence that culture evolves with the achievement of the target; boxes without highlighting indicate an absence of evidence in the existing literature. Note that the targets under each SDG are divided into number-designated outcome targets and letter-designated implementation targets. A detailed review of the literature is available in Table S2. This figure is adapted with permission from Fuso Nerini et al.[41] Copyright 2019 Springer Nature. The icon images are courtesy of the UN.[42]

evidence covers all underlying targets. The results of our analysis are highlighted below by the three broad dimensions of people, planet, and prosperity. A complete detailed literature review is available in Table S2.

People: the social dimension

The literature suggests that culture plays a role in addressing issues from all five social sustainability dimensions (SDGs 3 [Good Health and Well-Being], 4 [Quality Education], 5 [Gender Equality], 10 [Reduced Inequality], and 16 [Peace, Justice, and Strong Institutions]), influencing 45 of the 54 underlying targets (83%).

Specifically, culture influences the achievement of goals related to physical health and psychological well-being.[7] Culture affects physical health (SDG targets 3.1–3.6, 3.9, and 3.a) by facilitating or hindering the prevention, detection, and treatment of diseases.[7,40] Risk factors that increase the burden of non-communicable (e.g., obesity, hypertension, diabetes addressed in target 3.4) and communicable diseases (e.g., HIV/AIDS addressed in target 3.5), including unhealthy dietary patterns, alcohol abuse, and nondisclosure of HIV status, are mediated by culture.[43,44] For example, cultural expectations of reproduction explain why people in Nigeria would marry a potentially HIV-positive person to avoid the stigma of not having a child.[45] Moreover, culture can help to explain diverse perceptions and acceptance of health interventions, such as medical treatment (3.1–3.2),[46] family planning (3.7),[47] and vaccination uptake (3.8).[48] When women and their families follow the cultural traditions of home births and fear maltreatment in hospitals, they are less likely to utilize skilled and formal healthcare services even when these services are accessible.[49] With regard to psychological well-being (3.4), culture influences people's perception of the world, interpretations and responses to emotions, ways of dealing with affective disorder, and availability of social support.[50] Examples can be found in cases in which Western cultures put high value on positive emotions and look down on negative emotions, leading to higher levels of happiness but, paradoxically, more affective disorder due to the discomfort and difficulty in dealing with unwanted negative emotions.[51] By contrast, Eastern cultures deal better with negative emotions (e.g., frustration) as they believe that negative emotions can bring positive outcomes (e.g., self-improvement), whereas excessive happiness may lead to negative consequences.[52]

The role of culture in justice and equality has been widely studied in a variety of disciplines, including education, gender sociology, economics, politics, and criminology.[53–56] The ever-

expanding body of evidence reveals three types of influences. First, culture has an impact on the resources to which women, the poor, and the vulnerable have access.[53,57,58] In cultures that value women less than men or associate women with passivity, nurturing, and subordination, women's opportunities to pursue education (4.1–4.a),[53] leadership roles (5.5),[57] and economic and technical resources (5.a and 5.b)[58] can be severely compromised. Gender inequality can be exacerbated in a collectivistic culture that emphasizes the norms and duties of the community and subordinates women's personal goals to their social obligations.[36,54] By contrast, such inequality is reduced in an individualistic culture that upholds impartial institutions and universal norms.[36,54] Second, acceptance of some harmful acts to children and women is culturally engrained, including forced and early marriage (SDG 5.3)[59] and violence against and torture of women and children (SDGs 5.2, 16.1, and 16.2).[60] For example, female genital cutting (FGC) has been a common cultural practice in sub-Saharan Africa, with more than 100 million girls and women already undergoing FGC and more than 3 million at risk for this procedure annually. This tradition is rooted in the widespread belief that FGC enhances fertility, purity, and marriage opportunities and prevents stillbirths, albeit without any scientific basis.[61] Third, culture influences society's responses to reduce the inequality and discrimination faced by disadvantaged and marginalized populations (SDGs 5.c, 10.1–10.4, and 16.3).[55] In European countries, there is often a wide range of pro-poor and gender-sensitive practices (e.g., wealth redistribution, social protection, anti-discrimination legislation, and maternity benefits). One explanation for this phenomenon is that these countries culturally perceive success as a matter of luck, connection, birth, and corruption rather than effort.[62] By contrast, such measures are much less popular in the United States, which believes that individual effort determines income, while poverty is a result of laziness.[62]

Planet: the environmental dimension

The published evidence indicates that culture can affect the achievements of all six SDGs related to environmental sustainability, influencing 37 of the 51 underlying targets (73%). The six SDGs are 6 (Clean Water and Sanitation], 7 (Affordable and Clean Energy), 12 (Responsible Consumption and Production), 13 (Climate Action), 14 (Life below Water), and 15 (Life on Land). Culture explains the anthropogenic causes and affects interpretations and risk perceptions of, as well as human responses to, the environmental issues targeted by these SDGs.

First, unsustainable production practices and consumption behaviors (12.1–12.b), which may lead to resource scarcity (6.1–6.a and 7.1–7.b), ecological degradation (14.1–14.2, 14.4, and 15.1–15.5), and climate change (13.1–13.2), are culturally engrained.[63] For instance, in countries with a culture of hospitality, such as China, a lack of leftovers by guests is considered a shameful sign that the hosts did not provide the guests with sufficient offerings or treat them well. Therefore, people are prone to cook much more food for banquets and events than is needed, resulting in a large amount of food waste,[64] which directly conflicts with SDG 12 (12.3) and indirectly affects the other five planet-related SDGs. In another example, cultures that consider the consumption of exotic animals for clothing, ornaments, and traditional medicine to be symbols of wealth and social status drive illegal wildlife trade and threaten biodiversity (15.4 and 15.7).[65] Moreover, cultural values that favor a carbon-intensive lifestyle embedded in mobility habits, consumer choice, and residential preferences might lead to a behavioral lock-in in carbon emissions.[66]

More notably, people's awareness of ecosystem values and their views of human-nature relations affect how they perceive the risks and consequences of environmental challenges.[29,67–69] A survey of 1,540 United States citizens demonstrates that individualists who follow a hierarchical system are more skeptical of climate change than collectivists who advocate equality.[67] Beyond perceptions, the design, implementation, and acceptance of sustainable policies are engaged with and influenced by stakeholders' values.[10,30,70,71] A policy that overlooks local culture might be unworkable or, at least, unable to generate results with its original intentions.[39,72,73] For example, in Europe, a throwaway culture has been identified as a key barrier to a circular economy, which aims to prolong the life span of products by repair, reuse, and refurbishment.[39] In rural India, public toilets and household latrines that are constructed by large sanitation programs and accessible to people are found to be seldom used, leading to exposure to feces, urine, and potential disease risks.[72] This is partly because the local culture perceives open defecation as more natural, convenient, and hygienic than using latrines in or around houses.[72] In the United States, energy efficiency technologies and low-carbon energy transition may encounter cultural impediments if climate-friendly alternatives interfere with people's freedom and diminish their control over their personal environment.[73] As such, culture influences the achievements of SDG targets with regard to sanitation and resource conservation (6.1–6.a and 7.1–7.b), sustainable production and consumption (12.1–12.b), climate change mitigation and adaptation (13.1–13.2), and ecological protection (14.1–14.2, 14.4, and 15.1–15.7).

Prosperity: the economic dimension

Culture influences all six prosperity-focused SDGs (1 [No Poverty], 2 [Zero Hunger], 8 [Decent Work and Economic Growth], 9 [Industrial Innovation and Infrastructure], 11 [Sustainable Cities and Communities], and 17 [Partnerships for the Goals]), affecting 51 of the 64 associated targets (80%).

Under few circumstances can an agent in the economic system get rid of the impacts of the cultural environment.[27] Culture partially explains why some individuals and nations succeed in economic prosperity while others fail to achieve it.[74,75] According to the "culture of poverty" theory,[75] the poor develop a subculture of poverty (e.g., a strong present-time orientation) to adapt to their feelings of marginality, helplessness, and inferiority in a capitalist society. Such a culture can sustain, reinforce, and transfer intra- and inter-generational poverty by influencing people's ability to produce wealth and catch up with economic opportunities.[75] Although the theory is controversial and has attracted intense criticism,[76] it inspired a series of theoretical and empirical analyses on the relations between culture and poverty (1.1–1.2) as well as other economic outcomes, including industrialization (9.1–9.2), urbanization (11.1–11.3), and development (8.1–8.3).[77–79] For example, individualistic culture, which accepts deviation from in-group expectations and encourages the setting of personal goals, is found to stimulate innovation

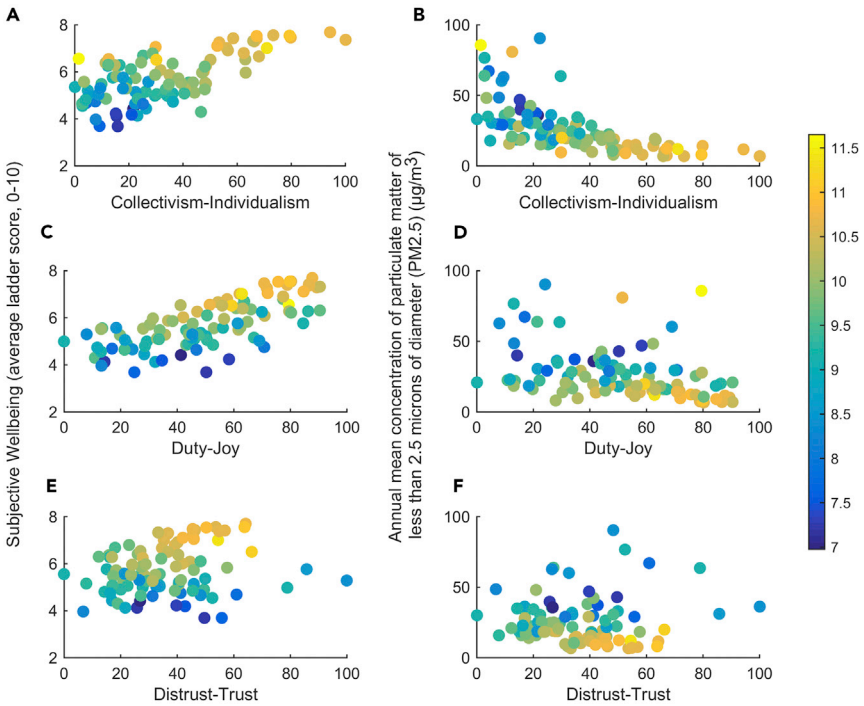

Figure 2. Indices of cultural traits and the selected SDIs

Beugelsdijk and Welzel's indices[36] of cultural traits are on the horizontal axis. In (A), (C), and (E), SWB (average ladder score, 0–10) is on the vertical axis. In (B), (D), and (F), annual mean concentration of particulate matter of less than PM2.5 ($\mu g/m^3$) is on the vertical axis. The full size of (A)–(F) corresponds to Figures S1–S6, respectively. The selected cultural index and the SDI are presented as examples. For the full list of the cross-national cultural indices and the SDIs, please refer to Table S3. The color bar denotes the logarithmic form of per capita GDP at purchasing power parity.

and to subsequently have a positive impact on long-run economic growth.[80]

Culture also plays a crucial role in the acceptance and effectiveness of economic stimulus plans, such as poverty alleviation strategies (1.b), financial aid programs (8.a and 17.1–17.3), technology transfer and alliance (17.6–17.8), and trade openness elevation (17.10–17.11).[81,82] Specifically, foreign financial aid may contribute negatively rather than positively to economic development in receiving countries due to the local inertial and bureaucratic culture.[81] Technology transfer may meet with low acceptance and limited application in host countries when they have a sizable cultural distance (i.e., the extent of cultural differences) from home countries.[82] Thus, considering cultural factors is central to the design of these plans to increase the chance of success in implementation.

The achievement of SDGs drives cultural evolution

In addition to influencing the achievements of SDGs, culture can adapt to progress in sustainable development. The achievement of 30 SDG targets (colored blue in Figure 1), most of which are in the social domains (i.e., 4 [Education] and 5 [Gender Equality]) and the economic domains (i.e., 1 [No Poverty], 8 [Economic Growth], and 17 [Partnerships]), drives cultural evolution. Understandings of the prosperity dimension dominated by the modernization theory, which predicts socioeconomic development, including urbanization, industrialization, technology innovation, and economic globalization, accompany changes in norms and values.[34] With respect to the people dimension, progress in the promotion of education, equality, and well-being, especially enhanced education accessibility for girls, can contribute to changes in social norms and cultural practices, such as the perception of gender roles, FGC, and maternal health.[83] For the planet dimension, it is also found that societies exhibit positive feedback loops in the adoption of pro-environmental behaviors and cultural traits, leading to the cultural evolution of sustainable behaviors.[63]

Although existing analyses and evidence concerning the relations between culture and sustainable development are fruitful, they fail to provide an in-depth understanding of how the links between culture and sustainability vary across the SDGs and cultural traits as a result of two barriers. First, most of the literature considers isolated contexts with various approaches (e.g., case study, theoretical analysis, and statistical analysis), multiple scales (e.g., from the individual level to the national level), and even different interpretations of the "same" cultural trait. Comparing the influence of specific cultural traits across the SDG targets is thus difficult. Second, existing evidence leans toward several prominent cultural traits, such as individualism versus collectivism,[84] which inevitably results in an uneven distribution of research resources among cultural traits and leaves unsolved the question of how culture-SDG relations vary across cultural traits. To fill these gaps, we synthesize these analyses in the consistent framework of SDGs and consider these relations in panel data to compare the influence across both the SDGs and cultural traits.

Empirical evidence on culture-SDG links

To obtain a consistent and holistic understanding of the relations between culture and sustainable development, we perform a panel data analysis at the national scale by using macro-cultural indices and country-level scores of the sustainable development indicators (SDIs) (examples of the data sample are shown in Figure 2; see more details of the variables in Table S3). Our approach to quantitatively integrate cultural and sustainability aspects is in line with a specific tradition of cultural analysis: the societal culture value dimension (SCVD), which reduces multidimensional culture to scores on a limited number of variables that distinguish the social characteristics of population groups. Although critiques on the development of macro-cultural indices remain,[85] SCVD is a unique tool to effectively represent the societal context in multilevel research and complement qualitative analyses.[86]

In sociology and psychology, there is a growing body of SCVD models[32–37] that are derived from different and debated empirical

Table 1. The three influential SCVD models underlying the panel data analysis

Framework	Cultural dimensions	Empirical basis
Hofstede et al.[32]	• power distance • individualism versus collectivism • masculinity versus femininity • uncertainty avoidance • long-term versus short-term orientation • indulgence versus restraint	the former four dimensions based on attitudinal surveys of IBM employees in the 1970s
Beugelsdijk and Welzel[36]	• collectivism versus individualism • duty versus joy • distrust versus trust	World Values Survey and European Values Studies, 1981–2014
Schwartz's[35] Personal Values Inventory	• affective autonomy • intellectual autonomy • harmony • embeddedness • hierarchy • mastery • egalitarianism	samples of elementary school teachers and college students, 1988–2000

bases and interpretations. We use three of the most widely cited SCVD models (Table 1) to obtain findings from multi-model consensus rather than leaning toward any one of them. Hofstede et al.'s cultural dimension model[32] presents one of the first dimensional descriptions of national culture and has inspired a variety of empirical studies on the influence of culture.[87] However, Hofstede et al.'s model received as many critiques as compliments as a result of the interpretations of the cultural dimensions, the design of the survey, and the possible outdatedness of the country scores.[88] Schwartz's[35] Personal Values Inventory represents an alternative cultural framework and one that is most widely used in psychology. More recently, Beugelsdijk and Welzel[36] analytically integrated Hofstede et al.'s cultural framework with Inglehart and Welzel's dynamic theory of cultural change,[34] which specifies the generational shift of cultural traits, to rectify their respective weaknesses. The cultural dimensions in the three SCVD models overlap with each other. For example, they all include a dimension describing the relations between individuals and groups, and the measurements of the dimension in the three models correlate positively.[36]

The links vary across cultural models and traits

Our empirical results reveal that, for all three cultural models, several dimensions explain additional variations (as much as 26%) in the achievement of SDGs, albeit in strikingly divergent ways (Figure 3 and more detailed results in Tables S4, S5, and S6). Beugelsdijk and Welzel's cultural measures[36] show better explanatory power of the cross-country variances in sustainable development by significantly correlating with 21 of the 53 SDIs we tested (95% confidence level), covering 13 of the 17 SDGs. Hofstede et al.'s cultural dimensions[32] are correlated with 13 SDIs, most of which address the economic aspects of sustainable development. In contrast, Schwartz's cultural measures[35] correlate with nine SDIs, most of which address the social and environmental aspects. The differences in the empirical results are related to the way these three frameworks measure culture. The significant correlations between Hofstede's et al.'s cultural dimensions and economic SDIs are explainable because Hofstede's et al.'s framework[32] is based on surveys with IBM employees, and the questions in the survey place more emphasis on people's job preferences. The significant correlations between the Schwartz Value Inventory[35] and the social and environmental SDIs are in line with the focus of his work, which is about the social interactions of human beings. By contrast, the measures by Beugelsdijk and Welzel[36] are obtained from a broader range of questions about people's values and attitudes toward religion, family, and tradition.

Because of the differences in the method, sample, and conceptualized explanation, the three models have few empirical convergences on the correlations between the cultural traits and the 53 SDIs we tested. Even for cultural dimensions with the same label or with similar concepts, their explanatory power for the variances in SDIs differs. If we take the dimension of individualism-collectivism as an example, Beugelsdijk and Welzel's individualism[36] predicts the SDIs with regard to gender equality, whereas such a correlation is not significant when Hofstede et al.'s[32] or Schwartz's[35] model is used. A possible reason is that these models capture different subdimensions of the cultural trait. In contrast to Beugelsdijk and Welzel's measurements,[36] which describe a broad orientation toward relations between individuals and groups, Hofstede et al.'s measurement[32] of individualism mainly focuses on the extent to which people value a job that allows personal life and freedom to adapt their own approach to the job, and this measurement of collectivism is about training opportunities, desirable working conditions, and using skills at work, which is criticized as being less relevant to collectivism.[89] Schwartz's embeddedness-autonomy dimension[35] (similar to the collectivism-individualism dimension) addresses personal values and distinguishes autonomy (similar to individualism) into two subcategories, intellectual autonomy and affective autonomy, to reflect the pursuit of intellectual interests and hedonic interests, respectively.

Moreover, different cultural dimensions are not equally predictive across the contexts of sustainable issues. Some cultural dimensions, including those that have previously received less attention, are better at explaining specific sustainable

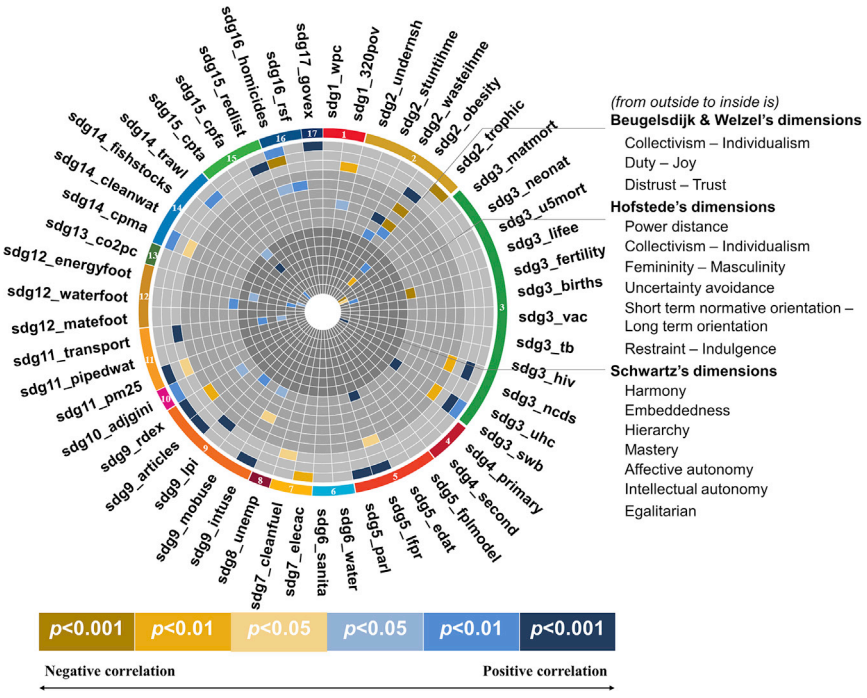

Figure 3. Empirical evidence for the correlations between cultural dimensions and SDIs

Each fan that extends from the center to the relevant SDG (indicated by the number, e.g., 17 denotes SDG 17) represents an indicator we tested (see a detailed explanation of the indicators in Table S3). Each circular ring represents a cultural dimension. The crossed sectors colored in brown or blue indicate that cultural features are negatively or positively, respectively, associated with the achievement of sustainable development on that indicator. Darker brown or blue represents higher confidence in the significance (represented by the p values). For sectors colored in gray, we did not find significant or robust evidence for linear correlations on the basis of our sample; however, this does not necessarily indicate the absence of interlinkages.

development phenomena than those that are dominant in cross-cultural studies (e.g., the individualism-collectivism cultural trait).[87] For example, Beugelsdijk and Welzel's distrust-trust dimension[36] is a significant predictor in the context of poverty eradication (addressed in SDG 1), whereas the other two dimensions in the model are not. The distrust-trust dimension describes the extent to which members of a society are comfortable with unstructured situations and anxiety. A lower score on this dimension (i.e., distrust) is associated with higher uncertainty avoidance, which implies that people have less trust in others and are cautious in dealing with people. By contrast, a higher score on this dimension (i.e., trust) represents more uncertainty acceptance and confidence in society and government. The empirical results illustrate that countries with less trust (more uncertainty avoidance) have lower poverty rates. A possible explanation for the relation is that people with less trust are conservative in investment and have a higher precautionary demand for saving,[90] which reduces the possibility of falling into poverty in case of significant disease or failed investment. Another explanation for the correlation is that a higher poverty rate facilitates more emphasis on a present-time orientation and less anxiety about the unknown future, implying more uncertainty acceptance (i.e., trust).[75] The finding that cultural traits that are not prominent in the literature show better predictive ability for specific sustainable development phenomena supports the idea that cross-cultural analysis should consider more cultural dimensions instead of exclusively focusing on one.

Synergies and trade-offs between culture and SDIs

Although the specific correlations between cultural traits and SDIs are unique to various cultural models, a phenomenon holds for all three cultural models: a cultural trait can positively correlate with the attainment of some SDIs while negatively relating to others. The synergy and trade-off correlations between a specific cultural trait and different dimensions of sustainable development are visualized in Figure 3.

For example, countries that score higher on Beugelsdijk and Welzel's individualism dimension[36] have better performance in subjective well-being (SWB), gender equality, high-tech development, income equality, environmental protection, and social well-being but worse performance in electricity accessibility. Some of these findings are in line with the previous literature.[54,80,91,92] Specifically, the positive correlation between individualism and SWB (denoted by sdg3_swb in Figure 3) is probably because individualism implies more freedom of choice and emphasis on the pursuit of individual positive feelings, which relate to higher happiness levels.[91] The positive correlation between individualism and gender equality (denoted by sdg5_lfpr and sdg5_parl) is in accordance with expectations as an individualistic culture places more emphasis on impartial institutions and universal norms than on group expectations, allowing women to pursue their personal goals in work and leadership positions.[36,54] For a similar reason, individualism positively correlates with personal achievements and innovation and is linked to a higher level of high-tech development (indicated by sdg9_intuse, sdg9_articles, and sdg9_rdex). Higher levels of social welfare in individualist societies, represented by higher levels of income equality (sdg10_adjgini) and government health and education spending (sdg17_govex), are different from the conventional wisdom that a belief in individualism undermines support for redistribution and welfare assistance,[93,94] but in line with Binder's findings.[92]

The relationship between individualism and environmental protection is much debated. A stream of literature demonstrates that individualistic culture "places a priority on personal goals over the goals of collectives" and hence tends to encourage environmental sacrifices for personal reasons.[95] However, others argue that individualism is not the same as selfishness; an individualistic orientation enables like-minded people to form interest groups that play vital roles in environmental protection.[96] Using the annual mean concentration of particulate matter of less than 2.5 μm in diameter (PM2.5) (sdg11_pm25) and the

mean area that is protected in marine sites important to biodiversity (sdg14_cpma) as indicators, our empirical analysis supports the latter viewpoint. In contrast to these positive correlations, individualism is found to correlate negatively with electricity accessibility (sdg7_elecac). One possible explanation for this phenomenon is that decision-making independence in individualistic societies may hinder the process of approving collective projects,[38] such as large-scale grid investments and constructions.

We did not find significant correlations of the indicators with the cultural variables, which does not necessarily indicate the absence of relationships. Several reasons might account for the lack of significance. First, the regression model we tested is linear and fails to reveal nonlinear relations between culture and the SDGs. Second, the measurement of sustainable development depends on the indicators formulated in the SDG framework, which have been critiqued as value laden, incomplete, and failing to represent the reality well.[97] Although the SDG framework is a joint effort and has been widely accepted, its formulation of the frame, choice of specific indicators, and reliability of reported data could still be influenced by the cultural values of the framework designers, relevant researchers, and primary data collectors. Moreover, despite enabling quantifiable cross-cultural analysis, the SCVD models may inevitably cause a mass loss of cultural information, which may include cultural features that are correlated with the achievement of these targets but not captured by the cultural dimension measurements.

DISCUSSION

More consideration of culture in sustainability science

Acknowledging the importance of culture is the prerequisite for integrating culture into the framework of sustainable development. Despite the substantial pioneering efforts of UNESCO and other organizations[13–15] (see more details in Table S1), the role of culture continues to be undervalued in both research and policy concerning sustainable development. The qualitative and quantitative analysis of our study contributes to the debate by enriching the evidence on the indivisibility of culture and SDG achievement from the perspective of cultural values. Three aspects of our analysis require further elaboration to provide research implications for future efforts to integrate culture and sustainable development.

The first issue is the comparison and validation of cultural models we performed in the context of sustainability science. By comparing the three cultural models by correlating all dimensions to the same SDI data, we find that Beugelsdijk and Welzel's framework[36] is a better predictor in the context of sustainable development than Hofstede et al.'s[32] and Schwartz's[35] frameworks. Hofstede et al.'s framework[32] is more closely linked to the economic performance of sustainable development, while Schwartz's framework[35] is linked to environmental and societal performance. The differences in the empirical evidence are related to the variations in the ways the cultural models are developed (i.e., focusing on different aspects of social values), which are worth noting in future quantitative studies. An investigation of the theoretical background of the cultural models, as well as the empirical relationships between the cultural dimensions and the variables studied, would assist researchers in selecting specific cultural models or dimensions that apply best to their research questions.

The second issue that requires further elaboration is that neither culture nor sustainable development is static; they are dynamic processes,[27,98] and the two processes co-evolve with mutual effects on each other.[9] For example, it has been observed that, driven by socioeconomic development, the generational culture is shifting from collectivism to individualism;[36] in turn, this can favor both high-tech economic growth and environmental protection according to the empirical findings.[80,96] The correlations further imply that the collectivism-to-individualism cultural shift is a driving force of the possible transformation of trade-offs between economic development and environmental protection into synergies. As such, future studies would benefit from collecting data to identify the trends of generational cultural shifts and predict changes in sustainable development as well as changes in the strength of the synergies and trade-offs between SDGs.[99] A promising avenue would be to equip existing quantitative models in the sustainable development field with a dynamic simulation of culture-SDG co-evolution, such as endogenizing generational cultural shifts in the functions depicting sustainable progress.

Third, the correlations between culture and sustainable development can be attributed to multiple influencing channels, including direct and indirect channels. On the one hand, a cultural trait may directly influence or be influenced by the achievement of some SDGs. On the other hand, it may be indirectly related to the SDGs through interactions within and among the SDGs (i.e., the achievement of one SDG may affect the achievements of another positively or negatively). For instance, the positive correlation between individualism and better environmental performance can be attributed to either the direct influence of individualistic culture in enabling like-minded people to get together to protest for the environment[38] or the indirect mechanism by which a more individualistic orientation promotes innovation-driven economic development,[80] which enables more advanced technologies and financial support to environmental protection (indirect influence through the relations between SDGs).[100] As such, the synergies and trade-offs observed in the culture-SDG relations are, in fact, the compounded effects of multiple influencing channels. Although causal inference is challenging and goes beyond the scope of our analysis, the compounded effects warrant further research.

More consideration of culture in policy design

Our analysis supports the pioneering argument that the integration of culture and sustainable development provides not only theoretical substance but also potential application in real policy decisions.[12,31] One approach to convert recognition into practice is to construct a standard indicator framework that helps to evaluate the cultural fitness of potential policies and measures, similar to those being developed for social, environmental, and economic impact assessment. Such work, focusing on the pre-evaluation of policies from the perspective of cultural values, could be a complement to the Culture|2030 Agenda developed by UNESCO,[24] a set of cultural indicators that provide post-evaluation monitoring of the contribution of culture to the 2030 Agenda. Merging cultural assessment in the pre-evaluation of sustainable policies will provide more comprehensive guidance

in decision making and eliminate the risks of failure in policy implementation and public acceptance resulting from cultural mismatch.

Beyond the evaluation, it is necessary to select localized policies, which means tailoring our endeavors to achieve the SDGs to distinct cultural contexts. For instance, environmental solutions led by government regulations and officially recognized groups may work better in collectivistic societies, while individual initiatives and voluntary associations where like-minded people get together to protest for the environment may be more suitable for individualistic societies.[38] In this sense, solutions to sustainability problems are not universal. As one person's medicine may be less effective for another, policymakers need to fully consider cultural nuances when borrowing (or rejecting) policies and measures to promote sustainability. Networking management cultures and providing cooperative solutions across systems might be efficient pathways to address sustainability challenges.

Additionally, it is important to note that developing sustainable policies and practices aligned with the local culture does not mean being captive to the negative side of culture or using cultural settings to justify unsustainable practices. Instead, it is necessary to eliminate the adverse effects of culture that are universally agreed to be unacceptable for sustainable development. One strategy on this issue is to learn from different cultural contexts that help to remove unsustainable perceptions and acts that are not locally entrenched. For instance, a "throwaway" society with material culture may learn from a "saving society" about culturally constructing the boundaries between food surplus and food and feeling guilty about food waste.[101] Eastern cultures with a lower prevalence of affective disorder provide a foundation for learning better skills to manage negative emotions.[50] Furthermore, if properly employed, cultural heterogeneity within the nation can serve to promote overall sustainability, sometimes even more effectively than accentuating intercultural divisions. An experiment showed that using entertainment to dramatize discordant local views could help to change cultural attitudes toward FGC in Sudan.[60] As such, cultural approaches provide a promising pathway to a sustainable future.

Concluding remarks and limitations

We acknowledge that there are limitations to our analysis. One of the problems is that the observer is always part of a culture, and the cultural values the observer inherits or learns shape the interpretation of the findings. Although this work included a multi-national team of authors to reduce the limitations, it is still like quantum mechanics: we cannot isolate the observation from the act of observing. Second, this study does not escape the risk of reductionism since the cultural models categorized cultural traits on the basis of a limited number of value indicators that, to a sociologist, actually describe social cohesion and social identity. While the lines between the cultural and the social are inevitably blurring, there is still substantial distinction that allows these domains to be separated.[27,102] As none of the models can depict culture in its entirety, the exchange of insights among various cultural models may compensate for the information loss produced by dimension reductionism. Moreover, limitations also exist in predetermining cultural group memberships solely by geopolitical borders and thus fail to substantially account for the cultural diversity within a country or region.[103] Countries are not governed by monolithic values, and there is always a variety of contending values espoused by different segments of the population.[104,105] Future studies would benefit from deriving clusters of cultural group memberships (i.e., value tribes) on the basis of real social value consensus.[106] Doing so would substantially increase the accuracy of segments, better than using predetermined criteria such as geopolitical borders. The emergence of archetypes in the clustering allows for a more detailed analysis of the cultural features and the tracing of sustainable performance to cultural drivers. Furthermore, bridging archetypes and sustainable performance might provide a more accurate tool to predict behaviors with regard to SDGs and develop sustainable policies tailored to various values.

Despite the limitations, our analysis contributes to the literature and policymaking in three aspects. First, it converts what is intuitively obvious and has been reflected in the arguments by UNESCO and many others regarding the role of culture within the SDGs to concrete and varied evidence. Substantiating this role via the literature survey and the empirical analyses linking SDIs and cultural traits yields a more comprehensive understanding of the relations between culture and SDGs. Second, the work on bridging cultural measures with the framework of SDGs in this paper is exploratory and lays the groundwork for further quantitative empirical research concerning the culture-SDG links. We reflect on the suitability of different cultural frameworks not only in light of our findings but also on the basis of their ability to reflect on relevant cultural traits, highlighting the need to improve cultural measurements or develop new approaches to integrate these two disciplines. Finally, given the inadequacy of cultural discourses in sustainability policymaking, we provide a new vision to incorporate more consideration of culture in sustainable modeling and developing culturally sensitive solutions to sustainability challenges. In particular, we suggest that science communications and policy decisions in sustainable development should be tailored to, but not captive to, cultural context.

EXPERIMENTAL PROCEDURES

Resource availability

Lead contact

Further information and requests for the datasets should be directed to and will be fulfilled by the lead contact, Can Wang (canwang@tsinghua.edu.cn).

Materials availability

This study did not generate new unique materials.

Data and code availability

The data and code for the statistical analysis, as well as copies of Tables S4, S5, and S6, are available in Mendeley Data: http://dx.doi.org/10.17632/x2nz352ffm.3.

Structured literature review

For each of the 169 SDG targets, we looked for theoretical or empirical evidence from the literature to address the following two questions: (1) whether culture has an impact on the attainment of any of the targets and (2) whether the attainment of the target influences culture. We obtained answers to the questions using the consensus-based expert elicitation method (among the co-authors).[41,107] It is worthwhile to note that, to be consistent with prior practices,[41,107] a literature review of each target is not a systematic review. Instead, a single item of the relevant published evidence was deemed sufficient to indicate the presence of an interrelationship between national culture and the SDG targets. We synthesized over 300 publications, including theoretical analysis,

empirical evidence, case studies, and reviews. The research scale of the literature varied from individual to community and from regional to global.

Panel data analysis

The empirical descriptions of sustainable development are obtained from quantitative estimates of the SDIs by country. Our panel analysis involves 53 SDIs covering all 17 SDGs (Table S3) whose correlations with culture are qualitatively supported by theory or evidence, and the available data can support quantitative statistical analysis. The indicators are selected according to the following criteria. (1) The indicators are comparable across countries. Compared with indicators that are strongly related to population and total gross domestic product (GDP) (e.g., SDG 2.3.2 and the average income of small-scale food producers), we prefer percentage indicators or standard index measures. (2) The available data for the indicator should cover at least 25 countries whose per capita GDP spans a broad range to ensure long-term representativeness of the sample. (3) Some indicators (e.g., SDGs 1.5.1 and 1.5.2 and loss attributed to disasters) are significantly influenced by other determinants (e.g., disaster frequency), for which reliable public data are elusive. Thus, we exclude them from our analysis. The indicators representing 16 goals of the SDGs are obtained from indicator screening, for which data are sourced from the UN's global SDG database[108] and compiled by Sachs et al.[109] For SDG 12 (Responsible Consumption and Production), the UN's global SDG database provides insufficient data to support convincing empirical tests. To fill this data gap, we use the data of per capita water footprint, energy footprint, and material footprint sourced from the Eora multi-regional input-output database.[110]

We regress each of the SDIs on Hofstede et al.'s,[32] Beugelsdijk and Welzel's,[36] and Schwartz's[35] cultural dimensions after controlling for economic development and other variables, including industrialization, urbanization, governance, and democracy (see more detailed descriptions of the variables in Table S3). The basic regression model is described by Equation 1:

$$SDI_{it} = \alpha + \beta culture_i + \eta controls_{it} + D_{year} + \varepsilon_{it}, \quad \text{(Equation 1)}$$

where SDI_{it} is an array of indicator variables that represent the sustainable performance for country i in year t. $Culture_i$ is an array of cultural dimension variables for country i. The cultural variable is time invariant for a given country. β is a vector of coefficients corresponding to the cultural variables. $Controls_{it}$ refers to control variables, including the natural logarithm of per capita GDP and other socioeconomic determinants. Since it is widely acknowledged that the affluence level is a significant determinant of sustainability, we control it for each SDG indicator. For robustness checks, we control for other variables that are unique to each SDG indicator according to previous literature (see details in Table S7). η is the coefficient corresponding to the control variables. D_{year} is the year dummy variable, which captures the time effects on sustainability. ε_{it} is the error term. As all regression models are tested to have a variance inflation factor (VIF) value smaller than 10, the level of multicollinearity in the model is low.

The model is estimated with the between estimator (BE) test. BE analysis first averages the data for each country over time and then performs a cross-sectional regression on the mean data for each country. Compared with other estimators, BE performs better in providing consistent estimates of long-term correlations,[111] which suits the circumstances here as cultural evolution is a prolonged process. Moreover, the hypotheses are tested on the basis of unbalanced panel datasets. For each SDI, the number of countries and the years with sufficient available data are heterogeneous. To maximize the sample size of each regression model, we include all available data for each variable. The heterogeneity of the sample data exerts little effect on the comparison across the SDG targets since the BEs predict long-term correlations. If the sample covers a broad range of countries representing different development statuses and cultural traits, the predictions are plausible and comparable.

SUPPLEMENTAL INFORMATION

Supplemental information can be found online at https://doi.org/10.1016/j.oneear.2021.01.012.

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AUTHOR CONTRIBUTIONS

X.Z. and C.W. led and designed the research. X.Z. and R.W. led the writing of the paper with substantial input from A.H., M.K., E.H., D.G., and C.W. Y.Z. and K.G. assisted with the literature review. A.H. and M.S. helped conceptualize the paper. Z.S., J. Zhu, and J. Zhang advised on the panel data analysis. A.L. and X.P. revised the manuscript. All authors contributed to the analysis and the interpretation of the results.

DECLARATION OF INTERESTS

The authors declare no competing interests.

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