7. Frameworks and systems thinking for measuring and achieving sustainable wellbeing

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INTRODUCTION

Ecological economics emerged and persists as a transdisciplinary field with a focus on addressing the challenges embodied in the ambition of achieving a sustainable future for humanity on Earth (World Commission on Environment and Development 1987; Costanza et al. 1991). Chief among the goals for the future are ensuring the wellbeing of humans and the natural environment in which they are embedded. How, and if, these goals are achieved will in turn depend on what is meant by wellbeing (Costanza et al. 2007), and the quality and applicability of the knowledge that continues to emerge from the scientific investigation of the Earth system and its dynamics (Schellnhuber 1999).

The preferred perspective of ecological economics considers humans as embedded in and inseparable from nature (Costanza et al. 1991). However, Planet Earth has not always been, nor will it necessarily always be, hospitable to hosting human life. In describing his "theater world," Schellnhuber (1999) articulates this hospitable window for humanity by defining two critical boundaries. At one end is a Martian regime attained through extreme planetary cooling, at the other, a Venusian regime achieved through extreme warming. While hypothetical in the "theater world," real examples of these boundaries exist. Prior to the Great Oxidation event some 2.2 to 2.0 billion years ago, for example, the Earth did not have an atmosphere capable of supporting what would eventually become human life (Lenton et al. 2004). Life did exist, and similar life forms continue to exist in anoxic environments, but the balance of nature has shifted dramatically. Recognizing Schellnhuber's critical boundaries, even if they are not fully understood, allows for the definition of a baseline operational space for humans on Earth (Rockstrom et al. 2009). But even this baseline space holds the possibility that humans and nature can exist in an infinite set of heterogeneous states, not all of them desirable.

Frameworks that go beyond the Earth system framing proposed by Schellnhuber (1999) have emerged to aid in the definition of coherent social-ecological systems, their parts, and connections. Each framework uniquely seeks to characterize and enable understanding of the heterogeneous states of humans and the nature in which they are

embedded. They further aim to provide comparability across studies and sites so that universal truths or laws might more readily emerge.

While positive scientific approaches remain the domain of describing how the world works, the ambition for a sustainable future goes further, requiring that humanity and nature not only exist, but exist in a state of wellbeing. Human wellbeing, however, defies easy definition. Most people would agree that wellbeing is an idea of what human flourishing should be (Diener 2000). For framing and measuring purposes we might characterize wellbeing as both a state, as in our current wellbeing, and as an aspiration, or well-becoming. This latter aspiration is often defined as the cluster of factors that allows us to develop future wellbeing and encompasses dimensions that are both physical and psychosocial in nature. Because these dimensions are not always easily identifiable or measured, wellbeing, variously measured, is also considered an indicator of the state of these other dimensions.

Fundamentally a cultural conception, human wellbeing has no single objective reality, making its incorporation into the scientific and international policy discourse all the more challenging (Dodge et al. 2012). That being said, wellbeing clearly allows individuals and society to achieve nominally good outcomes in an important range of objectives including health, education, and collective action that go beyond the provision of basic material needs. Similar considerations exist for the definition of the wellbeing of nature with an added complication, namely the lack of subjective assessment.

Informing the decisions required to assess and navigate the tradeoffs required to achieve a sustainable future for the Earth requires bridging the positive science of the Earth system with the normative components conceptions of wellbeing can inform. Importantly, each social-ecological system conceptualization can imply a different approach to framing and measuring wellbeing and the internal dynamics within the systems of interest. Consideration of such differences in approach is important in so far as it shapes new knowledge, expresses values, and subsequently informs various actionable and emergent governance processes (Dietz 2013). One prominent example of such emergent governance includes the development of the United Nations' Sustainable Development Goals (SDGs) through a deliberative and stakeholder-driven process (UN 2015). That process demonstrates that even after a framework has been adopted, agreement must then follow on specific measures, or indicators, such that progress or change in each system, component, and connection can be rendered quantifiable. Only then can the effectiveness and value of actions taken to achieve future goals be assessed. This process invariably simplifies the complex nature of the subsystems and their embeddedness.

This raises the following questions: *What are the dominant frameworks and indicators currently shaping knowledge to inform action for a sustainable future? How have these been successful, and what new pathways for research might they offer?* And, *what alternative frameworks exist that could be more widely adopted to complement the dominant modes of thinking?*

To address these questions within this chapter, we explore the frameworks and prominent indicators that have emerged within the field of ecological economics and within adjacent transdisciplinary fields. Several recent reviews identify a core set of frameworks that feature prominently in the literature both within ecological economics and across the broader socio-ecological literature (Binder et al. 2013; Dietz 2017). These frameworks represent potentially complementary perspectives that have developed to capture

emerging understandings and challenges of overlapping but still rather distinct research communities. Thus, coupled with our own bibliometric analysis, we suggest this core set renders other frameworks less frequently used, but no less useful. In particular, evolutionary frameworks, that consider the structural dynamics of the human and nature subsystems, may prove particularly useful to the field going forward.

In addition, we review several frameworks that have emerged seeking to incorporate conceptions of human and planetary wellness including the doughnut and the Genuine Progress Indicator (GPI). We also discuss the ways in which the UN Sustainable Development Goals (SDGs), a driver in shaping the international agenda, incorporate these ideas.

To lay the groundwork for a research agenda for ecological economics, we introduce useful systems concepts that should provide coherence to the growing body of knowledge around the connections and feedbacks between and among humans and their environments on Earth. In doing so, we assess the future of the field of ecological economics specifically, and also address the transition of knowledge to action (Guerry et al. 2015; Doran et al. 2017). We argue that any important future direction of the field must focus on the translation of the growing body of knowledge developed primarily for an audience of other scholars to the arenas of decision making and action (Doran et al. 2017).

FRAMEWORKS IN SOCIAL-ECOLOGICAL SYSTEMS RESEARCH

Frameworks help to organize thinking, conceptualize systems, articulate components and interactions, and provide tractable and comparable modes of analysis across studies. Simplifying and bounding a system and its interactions allows one to understand and describe that system in a certain way, while a different framework with different abstractions and system boundaries allows for different understanding of the same underlying system. It is important to emphasize that the frameworks we will consider are not theories in the sense that they provide specific hypotheses to be tested or parameters estimated. Rather, each provides general guidance to remind researchers of factors and interactions between factors that need consideration in developing spatially and temporally specific theories. A deeper understanding of the ways in which these tools shape knowledge creation and determine what is of value is therefore foundational to the discipline.

To illuminate the frameworks that have emerged, it is necessary that we consider both the ecological economics discipline and parallel interdisciplinary approaches such as human ecology and sustainability science. Each have become increasingly broad in their outlook and focus on understanding and addressing the systems, connections, and challenges of building a sustainable future for humanity (Costanza et al. 1991; Kates et al. 2001). Building linkages across these communities is further likely to prove useful for developing and building novel new approaches to existing and emerging challenges. We thus draw on reviews that have emerged across the literature and that seek to bring comparative coherence to the myriad approaches of understanding the fundamental links within and between social and environmental subsystems.

The selected frameworks are summarized in Table 7.1. The representation of the social (S) and ecological (E) subsystems and their interactions is of particular interest, as is the

Table 7.1 Emergent frameworks in the socio-ecological literature

Framework	Purpose	References (selection)	Interactions & Degree of Representation	Orientation	Social & Spatial Scale
Driver, Pressure, State, Impact, Response (DPSIR) ^+*	Develop an improved understanding of, indicators for, and appropriate responses to impacts of human activities on the environment along a causal chain.	Eurostat 1999; Carr et al. 2007; Svarstad et al. 2008	***Interaction:*** S → E ***Represented:*** Anthropocentric S > E	Action oriented	***Social:*** Decision makers ***Spatial:*** Applied at any scale
Earth Systems Analysis (ESA) ^	Understand the global interactions in and dynamics of the Earth system as well as its sustainable evolutions.	Schellnhuber 1998, 1999; Schellnhuber et al. 2005	***Interaction:*** S → E ***Represented:*** Ecocentric E > S	Analysis oriented	***Social:*** Society ***Spatial:*** Global
Ecosystem Services (ES) and Natural Capital ^+*	Analyze the integral, dynamic, and complex interactions of biotic and abiotic components of an ecosystem in relation to the supply of services this system provides to support life on Earth.	Costanza et al. 1997; Daily 1997; de Groot et al. 2002; Limburg et al. 2002	***Interaction:*** S → E ***Represented:*** Ecocentric E > S	Analysis oriented	***Social:*** Society ***Spatial:*** Applied at any scale
Human Environment Systems Framework (HES) ^	Provide a methodological guide for analyzing the structure of social-ecological systems and understanding the processes between the social and ecological systems within different scales of the social system.	Scholz and Binder 2004; Scholz et al. 2011a	***Interaction:*** S ↔ E ***Represented:*** Anthropocentric S > E	Analysis oriented	***Social:*** Includes all hierarchical levels ***Spatial:*** Applied at any scale
Material and Energy Flow Analysis (MEFA) ^*	Analyze the metabolic profiles of societies. Analyze the material and energy flows as representing the metabolism of a society, region, or nation.	Ayres 1978; Baccini and Bader 1996; Haberl et al. 2004; Brunner and Rechberger 2005	***Interaction:*** S → E ***Represented:*** Ecocentric E > S	Analysis oriented	***Social:*** Society ***Spatial:*** Applied at any scale
Management and Transition Framework (MTF) ^	Support the understanding of water systems, management regimes, and transition processes toward more adaptive management; enable comparative	Pahl-Wostl 2009; Knieper et al. 2010; Pahl-Wostl and Kranz 2010	***Interaction:*** S ↔ E ***Represented:*** Anthropocentric S > E	Analysis oriented	***Social:*** Includes all hierarchical levels ***Spatial:*** Applied at any scale

Table 7.1 (continued)

Framework	Purpose	References (selection)	Interactions & Degree of Representation	Orientation	Social & Spatial Scale
	analyses of a wide range of diverse case studies; and facilitate the development of simulation models based on empirical evidence.				
Social-Ecological Systems Framework (SES) ^+*	Provide a common language for case comparison for organizing the many variables relevant in the analysis of SES into a multitier hierarchy that can be unfolded when needed, and for selection of variables in a case study.	Ostrom 2007, 2009	***Interaction:*** S ↔ E ***Represented:*** Anthropocentric S ≈ E	Analysis oriented	***Social:*** Includes all hierarchical levels ***Spatial:*** Local and regional
Sustainable Livelihood Approach (SLA) ^*	Analyze which combination of livelihood assets enables the following of what combination of livelihood strategies with sustainable outcomes.	Ashley and Carney 1999; Scoones 1998	***Interaction:*** E → S ***Represented:*** Anthropocentric S > E	Action oriented	***Social:*** Local stakeholders ***Spatial:*** Local and regional
The Natural Step (TNS) ^	Provide a framework for planning toward sustainability based on: constitutional principles (how the system is constituted); outcome (principles for sustainability); and process to reach this outcome (principles for sustainable development).	Burns and Katz 1997; Robèrt 2000; Upham 2000; Missimer et al. 2010	***Interaction:*** S → E ***Represented:*** Ecocentric E > S	Action oriented	***Social:*** Business or regions ***Spatial:*** Businesses and regions
Vulnerability Framework (TVUL) ^	Analyzes who and what are vulnerable to multiple environmental and human changes, and what can be done to reduce these vulnerabilities.	Turner et al. 2003a, b	***Interaction:*** E → S ***Represented:*** Anthropocentric S > E	Action oriented	***Social:*** Local communities ***Spatial:*** Local
Coupled Human and Natural	Suggests seven key patterns emerge in local to regional	Liu et al. 2007a, b	***Interaction:*** S ↔ E	Analysis oriented	***Social:*** Local/ regional

Table 7.1 (continued)

Framework	Purpose	References (selection)	Interactions & Degree of Representation	Orientation	Social & Spatial Scale
Systems (CHANS) & Telecoupling+	human-nature coupling studies: context sensitivity, complex feedbacks, nonlinear response and thresholds, legacy effects and time lags, varied resilience, and heterogeneity.		***Represented:*** Ecocentric S ≈ E		***Spatial:*** Local/ regional with distant connections

Note: Emergent frameworks in the socio-ecological literature as summarized in literature reviews by (^) Binder et al. (2013) and (+) Dietz (2017). Additional analysis of frameworks denoted with an asterisk (*) appears in the text.

orientation toward fundamental or applied knowledge creation. The table also summarizes the temporal and spatial scale often associated with the framework as well as noting several foundational references. The characterizations reported are those of cited authors and we acknowledge that variation exists in studies leveraging these frameworks. On the whole, the identified frameworks balance with respect to the interaction directionality, representation of the subsystems, and orientation toward action. Further, there is a range of possible social and spatial connections represented within the frameworks that appear influential.

To understand the potential opportunities and limitations for the identified frameworks to help inform future directions for research and action, we use a bibliometric approach to understand their influence in the field of ecological economics and within the broader literature (Barbieri 2017). Using Web of Science, we first searched the journal *Ecological Economics* to identify the frequency with which these frameworks appeared over time (Figure 7.1). From this analysis we narrowed the search down to the five most frequent frameworks and then conducted a second search of all journals to allow comparison with *Ecological Economics* (Figure 7.2). Reversing this procedure yielded similar results. While there are other ways to consider the discourse of a field as disciplinarily diverse as ecological economics (e.g. conference abstracts, publications in many other relevant journals) the journal *Ecological Economics* has been the main publication point for ecological economics research since 1989 and we thus use it as a proxy for the field overall. The journal's commitment to being "transdisciplinary in spirit and methodologically open" (*Ecological Economics* 2019) has been a stated goal since its inception indicating support for a wide variety of research. Its higher impact factor compared with other similar journals also likely makes it a desirable forum (Plumecocq 2014). The topic description search via Web of Science was refined from Barbieri (2017) to characterize the general trend of publications within the journal that explicitly contained one or more of the dominant frameworks within their description from the years 1982–2018 (Figure 7.1).

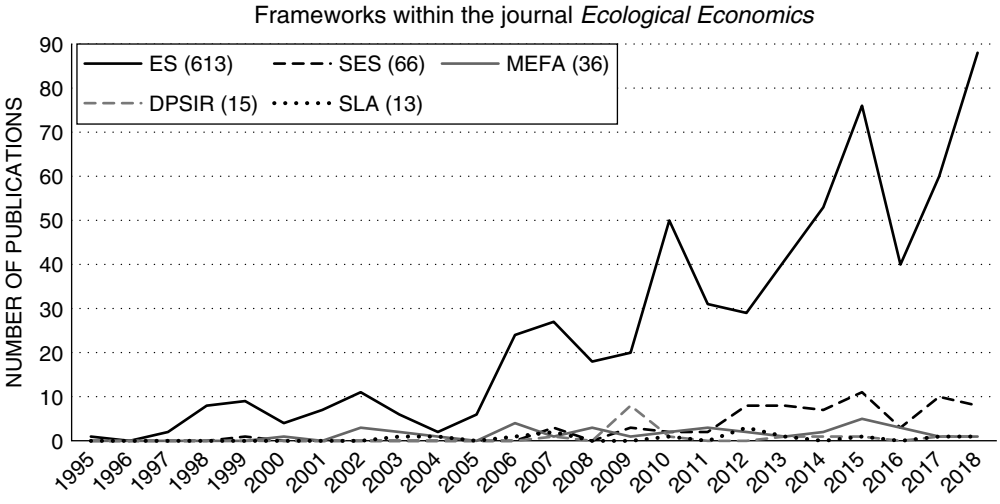
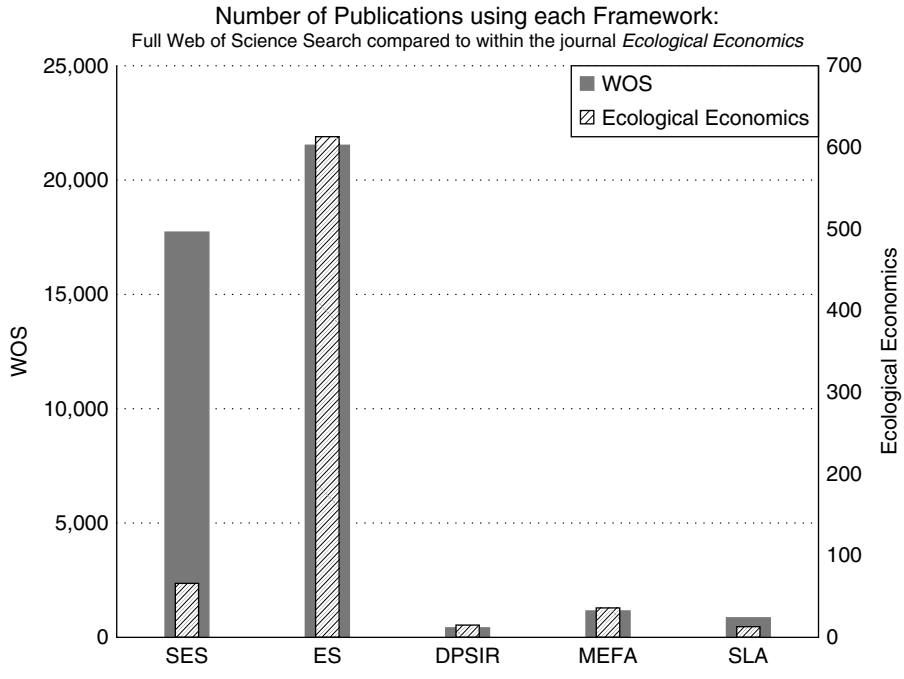


Figure 7.1 *The publication trend for the journal* Ecological Economics*, with the count of publications that include each framework within their description from a search within the journal through Web of Science*

The five frameworks that emerged from this analysis are indicated with an asterisk in Table 7.1. Other frameworks may have appeared in the journal but did not do so consistently across time. Within the set, a balance in the characteristics of interest is represented. This includes both ecocentric (ES, MEFA) and anthropocentric (DPSIR, SES, SLA) representations; both analysis (ES, MEFA, SES) and action (DPSIR, SLA) orientations; and a variety of spatial and social scales.

The results further suggest that within the journal *Ecological Economics*, Ecosystem Services (ES), and the attendant concept of Natural Capital, has been the dominant framing when a study adopted a specific, established, codified framework for conceptualizing and operationalizing a social-ecological system. ES' popularity has grown over time within the journal (Figure 7.1), particularly after 2005, the date of publication of the Synthesis Report of the Millennium Ecosystem Assessment that emphasized the link between human wellbeing and ecosystem services (Reid et al. 2005), despite the inception of the concept at least a decade prior (Costanza et al. 1997; Daily 1997). This analysis risks falsely concluding the dominance of ES based on its prevalence in the journal *Ecological Economics*, however, that humans derive real and quantifiable benefits from the existence and function of nature above and beyond the existing market-based valuation of natural resources has proved a popular idea across the literature since it was introduced (Figures 7.1 and 7.2). That these stocks (natural capital) and flows (ecosystem services) existed outside the real economic system as externalities in need of incorporation into value-based decision making has further found a wide audience, even as challenges in valuation and application in practice remain under study (Guerry et al. 2015). Independent analysis of the ES framework further suggests opportunities to expand the methodology itself, for example with respect to the inclusion of human and ecosystem health (Ford et al. 2015). The evidence we present here considers the perspective of the



Note: Scales are different.

Figure 7.2 *A comparative count of publications that use each framework from across all journals within the Web of Science database compared to publications specifically within the journal of* Ecological Economics

entire field and suggests that the dominance of ES as a framework may be having the unintended consequence of overshadowing other useful perspectives and methodologies that may also be of benefit to ecological economics.

One such framework is the SES framework. With origins in natural resource management (Ostrom 2009), this framework places equal weight on the social and ecological subsystems and their resource-based interactions (Table 7.1). Based on data from publications within the journal *Ecological Economics*, the utilization of the framework does not indicate its widespread adoption within the field (Figure 7.1). While the SES framework appears to be rising in prevalence in studies published after 2005, we can contextualize this by looking at the broader literature (Figure 7.2). First it is useful to note that Ecosystem Services remains a dominant framework in understanding, describing, and managing social-environmental systems broadly across fields and journals. The SES framework, however, is highly represented in the broader literature, and comparatively under-represented within the journal *Ecological Economics*. While new to the stage relative to older frameworks (ES) this slow rise may simply indicate a maturing of the framing into the field. Alternatively, it may be an as yet underexplored framing from which ecological economics might benefit.

Our analysis of the additional core frameworks—DPSIR, MEFA, and SLA—suggests

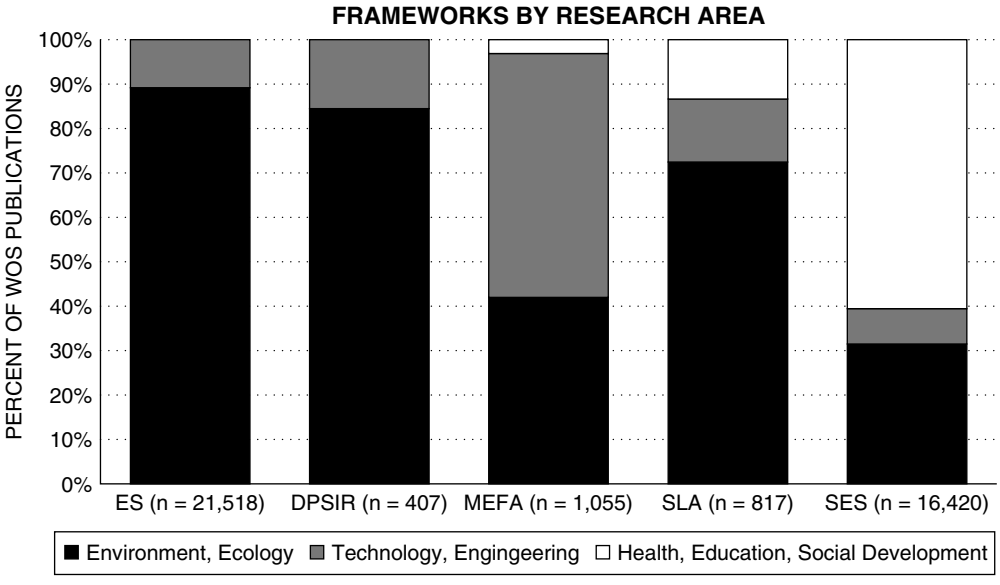


Figure 7.3 *The percentage of publications from across all journals for each framework with identified research areas from three broad categories: (1) environment and ecology; (2) technology and engineering; and (3) health, education, and social development*

that these are much less frequently used and remain proportionally similar over time both within *Ecological Economics* and broadly within peer-reviewed publications (with DPSIR slightly over-represented, and SLA slightly under-represented in *Ecological Economics* as compared to the rest of the literature). To understand possible disciplinary bias in these results we interrogate the Research Areas (as identified through Web of Science) most frequently used to categorize the peer-reviewed publications (Figure 7.3). While this characterization is not comprehensive, there are useful insights to be drawn from the underlying disciplinary, epistemological, and methodological differences implied by the use of each of the frameworks. We group the identified research areas into three categories: (1) environment and ecology; (2) technology and engineering; and (3) health, education, and social development and then show the ratio of occurrence for each category relative to each core framework (Figure 7.3).

The two frameworks that were most under-represented in the journal *Ecological Economics* (in comparison to the broader literature) were SLA (slightly) and SES (substantially). Both of those frameworks appear in publications with Research Areas more dominant in health, education, and social development—all particularly critical as the field strives to better address human wellbeing and more-than-human wellbeing across ecosystems and at the planetary scale.

Norgaard's call in the first volume of *Ecological Economics* that the field will "almost certainly fail if the methodological base is limited to the dominant strain of economics and any strain of ecology" (Norgaard 1989, p. 53) remains important. The evidence

presented here suggests that, while not limited, a strong bias for the neoclassical methodology of valuing nature under the framework of ecosystem services is present in the field. The emerging research agenda thus presents an opportunity to broaden the methodological base. The following two sections articulate two specific directions (consideration of evolutionary processes, and human and planetary wellness) that emerge from this analysis and that could be leveraged to that end. In addition, we suggest that ecological economics pursues the following research pathway and questions:

- *Framework Alignment and Integration*
  - Using critical alignment and integration of the dominant frameworks emerging across the transdisciplinary communities, how can ecological economics contribute to topics including: under what system conditions are each framework applicable; and how can different frameworks be best leveraged to inform action to enable a sustainable future for humanity?
  - Using rigorous typological framing of the systems, scales, and assumptions for particular studies, what findings emerge that are appropriate to cross boundaries and to become actionable?

ACCOUNTING FOR CHANGE

The frameworks that have been examined thus far seek to understand and make actionable the management of the interconnections between humans and nature. They describe the current system, but not necessarily how it is evolving over time. While small variation within the system's dynamics is generally well handled by each framework, the majority of these frameworks were developed to interrogate quasi-stable system states or their properties (e.g. vulnerability or resilience). These include current system states that can be parameterized from observable data, or alternative states that might emerge from small changes in parameterization. These frameworks are less frequently used to evaluate larger changes. This is due in part because the properties and dynamics that control such change and determine the structure of the next state are less well understood. Unraveling the evolution of social-environmental relationships over time and evolution of the structure of the systems in which those relationships are embedded requires a somewhat different approach, one that is rapidly maturing and which ecological economics has the opportunity to inform as well as benefit from.

Over the last several decades, frameworks have emerged that account for, if not fully describe, the causes and consequences of small- to moderate-scale changes in social-environmental interactions. Adaptive governance, for instance, mirrors the DPSIR framework in structure but places particular emphasis on the sources of resilience and evolution within the social system that are activated and enable a response to change (e.g. Folke et al. 2005). Another framework that emerges from the resilience literature is Panarchy (Gunderson and Holling 2009), which theorizes that systems exist in four sequential states (exploitation, conservation, release, reorganization) that presage structural changes between cycles. While accounting for structural change within a dynamic system, the mechanism of that change is underdeveloped in the Panarchy framework.

Multilevel selection (Waring et al. 2015) seeks to address this shortcoming and provide

an evolution-based theory for cultural change. Emerging from the biological systems perspective, multilevel selection theory extends evolutionary principles of natural selection to higher levels of organization including groups and populations to explain the interactions between self-interest, cultural transmission, cooperation, and the role of groups (Waring et al. 2015, 2017). Similar to natural systems, the theory posits that selective pressure can emerge in the economic system, for example, and exert pressure at multiple levels of social organization (e.g. individuals, state, planet). Recognizing that humans are highly adaptive, cultural evolution adds guided variation, in which behavior is modified by new learning or research, to the previously theorized pay-off-based and conformity-based trait transmission principles of evolutionary theory (Brooks et al. 2018).

As these cultural evolution studies mature, researchers are increasingly turning their attention toward sustainability making for a natural bridge to ecological economics (Waring et al. 2015; Brooks et al. 2018). Within economics, the application of high discount rates to the future has perhaps discouraged further attention in this area, however, analysis of paleo records and system state transitions suggests this to be a powerful framing that is deserving of additional attention. In particular, ecological economics, and work within the ecosystem services and SES frameworks, could provide guidance in the construction of links within evolutionary systems and serve as a grounded expression of the dynamics. Much theoretical development is also called for (Waring et al. 2015) to which a transdisciplinary field such as ecological economics would be ideally suited to address.

With this in mind we suggest a second research pathway for ecological economics:

- *Consider Evolutionary Processes*
  - Can an evolutionary perspective, particularly with respect to the evolution of norms and values, provide a pathway toward understanding and informing social change?
  - Can an evolutionary approach account for and build understanding around not just the temporal dynamics but also the structural evolution of the systems under consideration?
  - How can ecological economics contribute to the management of transitions between structural states for spatial and intergenerational equity?

FRAMING AND MEASURING HUMAN WELLBEING

The second pathway for potential methodological expansion within ecological economics stems from the articulation of human and natural wellbeing as it relates to a sustainable future. A broad articulation of future wellbeing using the frameworks discussed above is often omitted in favor of one collectively defined through stakeholder engagement around the particular resources or challenges under investigation (Kates et al. 2001; Wallerstein and Duran 2010). While non-trivial to perform such research (Newig and Fritsch 2009), other, broader perspectives on human wellbeing warrant particular attention as well and it is toward these perspectives that we now turn our attention.

To synthesize this research and make it actionable, several frameworks have emerged to shape our understanding of the multiple dimensions of wellness and how they comport

with the planetary boundaries and health of the ecosystems in which social systems are embedded. We briefly explore a small sample of approaches that have emerged with particular force in recent years and suggest their possible connections to the pathways forward within ecological economics.

One dimension for consideration includes the extent to which individual health, and more broadly wellness, can be tied to the natural environment. On an individual level, nature has been shown to significantly influence mental health and overall wellbeing and satisfaction with life (Mayer and Frantz 2004; Howell et al. 2011). This has been demonstrated using data at both the national and state scales (Gyourko and Tracy 1991; Abdallah et al. 2008; Russell et al. 2013; McMahan 2018), however open questions remain (Frumkin et al. 2017). How society might value this connection as a conception of whole system, or planetary, wellness is an open, active, and rapidly maturing area of study (Myers et al. 2013; Whitmee et al. 2015). Extensive literature exists around the measures and determinants of human health as it relates to specific pathologies. In moving beyond these specific toxic exposure and risk models, literature is now emerging that links larger-scale changes in environmental systems to quantifiable impacts on public health. Examples of this connection include the variable impacts of large-scale land cover change like deforestation and an increase in communicable disease vector pathways (Myers et al. 2013), as well as non-communicable disease incidence including cardiovascular and lower-respiratory-tract illness (Donovan et al. 2013).

As concern about global-scale challenges like climate change has risen within scientific and governance bodies, bottom-up processes of understanding and shaping the response to these challenges have similarly developed. In particular, the United Nations has been the leading international, stakeholder-driven, deliberative entity seeking to define a future vision and an agenda by which to achieve that vision. From this decade's long, bottom-up process 17 goals—the UN Sustainable Development Goals (SDGs) (UN 2015)—have emerged to shape the work necessary to achieve the ambition of sustainable development first articulated in the Brundtland Commission report of 1987 (World Commission on Environment and Development 1987). What has been clear since that first articulation more than three decades ago is that in order for action to take place across environmental systems, conceptions of human wellness must also be taken into account. The SDG's 17 goals and 244 indicators and objectives therefore span social objectives including poverty alleviation, access to food, water, education, health, sanitation, sustainable energy, and spatial and temporal inequality and justice. This, in addition to the natural systems objectives that include addressing climate change, ocean health, and terrestrial ecosystems. One recent analysis, however, suggests that the SDGs and their sub-goals are not only tightly linked, but addressing one goal may be to the unintended detriment of other goals within the agenda (Lim et al. 2018). Reconciling the output of this stakeholder-driven, bottom-up process with the scientific and policy frameworks intended to inform analysis and action is an important challenge, one that will have to be addressed via processes that link public deliberation of values and tradeoffs with scientific analysis (National Research Council 2008).

Another recent framework, the so-called "doughnut" (Raworth 2017), seeks to articulate social objectives as a second set of planetary boundaries that exist within the original planetary boundary framework proposed by Rockstrom et al. (2009). The original boundaries are largely ecological in nature, however influenced by human action. The

implication however, is that the largest challenges facing humanity are fundamentally environmental. These form the outer ring of the new doughnut framework proposed by Raworth (2017). For example, biodiversity loss must be kept well below its current rate, climate change must be addressed, and anthropogenic control of the phosphorus and nitrogen cycles must be contained. The inner ring of the framework proposed by Raworth (2017), allows that there are equally important social conditions, termed foundations, that must be met for the safe operating space for humanity to also be just. These foundations include access to water, food, energy, health, housing, social and gender equity, and justice, among others. This conceptualization returns us to the theater world of Schellnhuber (1999) with the specific articulation of the indicators that will define the preferred space in which the human and natural systems can or must achieve balance. The challenge, which Raworth (2017) further articulates in her book, is the shift in the economic system and economic thinking that will be required to actualize the ambition of achieving the ideal human condition as variously defined and self-articulated by peoples around the world.

These are just two of the frameworks emerging to mature the social-ecological frameworks to incorporate more complex conceptions of wellness, particularly in the human and social subsystem. Wellbeing, as is evidenced through this small sampling of emerging frameworks, is the outcome of a convergence of factors, ranging from good human relations, to greater equality, as well as a healthy social and natural environment (Wilkinson and Pickett 2009; Boarini et al. 2012). Actual measurement of these qualities, again, allows for iterative evaluation and adaptive progress toward desired outcomes, but is nontrivial. The act of measuring can further influence the objective itself, thus, the importance and weight taken on by the debate about what and how to measure its dimensions (Kates et al. 2001).

Indicators are the essential outcome of this deliberative process. For example, within the 17 SDGs are contained 244 measurable indicators, each with an associated target. The degree to which any one indicator is adopted across different swaths of a society will further determine its influence in driving policy and practice. For example, the wide consensus on increasing the gross domestic (or national) product (GDP/GNP) demonstrates the enormous influence a consensus indicator can have on policy, research and even conceptualization. The GDP is a measure of the productivity of an economy, that is a measure of the goods and services created and traded in an economy over a given period of time. It is comparable across space and can be adjusted for inflation to make comparisons across time. This particular indicator, however, has significant shortcomings when it is interpreted as a measure of the wellbeing of the society and environment, which it largely does not consider.

In recent years, much work has focused on developing alternative indicators to GDP that more comprehensively consolidate economic, environmental, and social elements into a common framework. While it is unclear that such complexity is necessary when simple, comprehensive indicators exist (see Box 7.1), a number of researchers have proposed alternatives to GDP that make one or more of these adjustments with varying components and metrics (Smith et al. 2013). These indicators can be divided into three broad groups: (1) measures that modify economic accounts to address equity and nonmarket environmental and social costs and benefits; (2) measures that use weighted indices of "subjective" indicators based on survey results (OECD 2013); and (3) measures

BOX 7.1 ONE OR TWO CANARIES IN THE COALMINE?

by Michael Abrams and Kate Pickett

Mortality is the critical event that characterizes the health of a population, and for humans like other animals, it is often most sensitive to environmental conditions in early infancy and late adulthood. This is why average life expectancy at birth and the infant mortality rate have become the most important measures of human population health. They are holistic measures that reflect multiple influences on wellbeing.

Life expectancy is a key indicator of the vitality of a population; its usefulness is that it necessarily incorporates all of the influences, whether known or unknown, that impact human longevity. It is heavily weighted toward the mortality of infants and children. Within the human evolutionary time frame, life expectancy declined when populations moved from the "original affluence" of hunting and gathering societies to domiciliary agriculture. Globally, over the twentieth century, human life expectancy roughly doubled, and health continues to improve in most countries—but those gains were mostly accompanied by the erosion of natural capital. Before 1980, *declines* in national life expectancies were almost always the result of war, famine, or population upheaval, as in industrializing Europe and the United States during 1830–1860 (McMichael et al. 2004). Modern declines, where they do exist, are now more likely to be the result of the failure of contemporary political and economic systems to provide the social foundations for human wellbeing within planetary boundaries. This is true in both developed and developing countries. By the early 2000s there had been declines in life expectancy at the national level in sub-Saharan Africa, Eastern Europe, and several other nations (Leon 2011). From this, it might seem that reversals have been confined to less-developed countries but a recent study reported that a majority of 18 of the highest-income nations had suffered declines in life expectancy over 2014–2015 (Ho and Hendi 2018; Jasilionis 2018). While most of those experienced "robust gains" the following year, two who did not were the United States and the United Kingdom (Ho and Hendi 2018). Clearly, life expectancy is a simple measure that can reflect both long-term and short-term influences.

Infant mortality rates (IMRs), defined as deaths in children under 1 year of age per 1000 live births in the same year, is another key indicator of the success of human populations. It is regarded as a very sensitive proxy for population health, due to the strong links between causes of infant mortality and factors that influence health over the life-course (Reidpath and Allotey 2003). These factors include socioeconomic, environmental, and cultural conditions, social and community networks, individual lifestyle factors and individual constitutions. It has been argued that proxy measures like IMR can be problematic because policies aimed to improve them might have relatively little impact on population health as a whole. This has led to consideration of more sophisticated indices, for example, Disability-Adjusted Life Expectancy (DALE), which is sensitive to changes in population health and takes into account both illness and deaths. However, research shows that IMR and DALE are highly correlated, with variation in one explaining more than 80 percent of the variation in the other (Reidpath and Allotey 2003).

Simple indicators, like life expectancy and IMR, that are measured and recorded universally and with high accuracy can give as good a picture of population health and wellbeing as more sophisticated measures that inevitably require more complex data and analysis. Their value in this regard is demonstrated in studies that use them as proxies to investigate the role of environmental stress as a driver of wellbeing (Jorgenson 2014; Dietz 2015; Jorgenson et al. 2018).

that use weighted indices of a number of "objective" indicators (Costanza et al. 2014). As post-GDP measurements are integrated into institutional processes, they will be followed by relative rewards and sanctions, as is the case with GDP at present.

One such indicator, which fits into the first category above, is the Genuine Progress Indicator (GPI). The GPI is a version of the Index of Sustainable Economic Welfare (ISEW), first proposed in 1989 by Herman Daly and John Cobb (Daly and Cobb 1989)

and later modified and renamed the Genuine Progress Indicator (Progress 1995). GPI adjusts personal consumption expenditures (a major component of GDP) using approximately 25 different components that range in influence from positive to negative. For example, these components subtract those aspects of an economy that are overall negative activities in society, such as the costs of environmental degradation, biodiversity loss, and ecosystem services loss, cost of family breakdown, cost of unemployment, and cost of crime and pollution. They also add positive components left out of GDP, including the benefits of volunteering and household work, among others. GPI, unlike GDP, is also adjusted for income distribution (Cobb et al. 1995; Lawn 2003; Bagstad and Shammin 2012). By separating activities that diminish welfare from those that enhance it, GPI better approximates sustainable economic welfare. It is not meant to be an indicator of sustainability, however. It is a measure of economic welfare that needs to be viewed alongside biophysical and other indicators.

To illustrate the utility of incorporating wellness components into value-based indicators that inform decision making let us consider a set of examples from about 20 countries worldwide comparing GPI and GDP (Lawn and Clark 2008; Kubiszewski et al. 2013). These studies have indicated that in many countries, beyond a certain point, the correlation between conventional GDP growth and the adjusted measures breaks down. The trend is similar in many countries; GPI tracks GDP pretty closely as a country develops, but at a certain point the two diverge. In the United States this happened in the late 1970s while in China in the mid-1990s. GDP keeps growing while GPI levels off or decreases.

Additionally, on the global level, evidence suggests that GPI per capita peaked in 1978 (Kubiszewski et al. 2013). Interestingly, 1978 is also around the time that the human ecological footprint, a biophysical indicator that measures humanity's demand on nature, exceeded the Earth's capacity to support humanity. Other global indicators, such as surveys of life satisfaction from around the world, also began to level off around this time. Disaggregation of the indicator allows for the identification of why these trends may be occurring and which factors, on which side of the balance are acting to increase or decrease economic welfare. This determination can then inform further use of other indicators better suited to guide deeper understanding of other aspects of wellbeing. For example, life satisfaction, determined by surveys, is a better measure of overall self-reported (i.e. subjective) wellbeing compared to GPI. By observing the change in individual benefit and cost components, GPI reveals which factors cause economic welfare to rise or fall even if it does not always indicate what the driving forces are behind this. It can account for the underlying patterns of resource consumption, for example, but may not pick up the self-reinforcing evolution of markets or political power that drives change.

Recently, two state governments in the United States have adopted GPI as an official indicator, the states of Maryland and Vermont, and others have begun calculating it (Berik and Gaddis 2011; McGuire et al. 2012; Ericson et al. 2013; Stiffler 2014; Kubiszewski et al. 2015). In addition, the data necessary to estimate GPI is becoming more available in many countries and regions. For example, remote sensing data allow better estimates of changes in natural capital and a growing number of national governments are experimenting with routine surveys of individuals regarding measures of their subjective wellbeing including use of their time and life satisfaction. New means of measuring inequality are being developed, and more detailed data are being collected on the costs of crime, family breakdown, underemployment, and other measures that might

be used in GPI in the future. The bottom line is that the costs of estimating GPI are not particularly high, the data limitations can be overcome, and it can be relatively easily estimated in most countries.

Emerging research suggests that a similar asymptotic relationship exists between stress on the environment and wellbeing (Dietz 2017). The approach taken to date follows from the observation that increased stress on the environment, like increased GDP per capita, does not appear to advance human wellbeing once a modest threshold is passed. Future research should continue to focus on understanding what then allows some societies to produce high levels of human wellbeing while keeping stress on the environment low, while others are quite inefficient in the sense that they generate substantial environmental stress in exchange for moderate wellbeing. The literature has thus far examined the influence of inequality and political and economic institutions on the environmental intensity of human wellbeing. These two examples indicate that attention within the future agenda of the field should thus focus on the interrelationships between subjective and objective measures of both human and environmental wellbeing.

To improve the incorporation of wellbeing into decision making, ecological economics should consider pursuit of the following research pathways and questions:

- *Comparative, temporal analysis of individual wellbeing*
  - How do subjective and objective indicators of human and environmental wellbeing relate to one another?
  - What does an appropriate measure of wellbeing look like; how is it constructed and what forms of subjective and objective variables should be used? What do alternative ethical theories imply about what should be measured?
  - What can we learn about causes and consequences of changes in wellbeing from comparative analysis of wellbeing in individuals as well as comparative analysis of wellbeing in the aggregate (e.g. of communities or nations), particularly when considering fluctuations over time?

- *Consider the value and distribution of wellbeing*
  - How do we collectively assign the value and appropriate distribution of resources and effort toward the achievement of wellbeing across the global population?
  - What is the relationship between natural capital and wellbeing?

- *Consider comparison of bottom-up and top-down approaches to achieving wellbeing*
  - What benefits, costs, and equity implications emerge from the definition and pursuit of wellbeing in bottom-up and top-down approaches?
  - What types of wellbeing emerge at different scales and how are these best valued and managed across space and time?

SYSTEMS THINKING FOR COHERENCE AND CHANGE

As the field of ecological economics undertakes the research necessary to inform the incorporation of normative conceptions of wellbeing with the positive science of the dis-

cussed frameworks, several themes have emerged that bear further mention. In particular, several fundamental systems concepts should prove useful to the discourse moving forward such that broader comparison and transferable knowledge can emerge from the academic discourse and processes of knowledge co-production to influence decision making at all levels.

Assumptions and Limitations

No model or framework is appropriate all of the time. Just as the findings derived in the course of using a particular framework or modeling technique are similarly not universal (Ostrom et al. 2007). While some academic pedagogies are more strongly disciplined in the practice of clearly stating assumptions and implied limitations, the adoption of this practice must be carried to all disciplines and practitioners. This is particularly true of those whose work and findings inform action, but also a relevant critique of those contributing directly to the academic discourse. Engineering disciplines for example hold a strong tradition in this regard in part because the abdication of such responsibility has, in the past, led to instances of clear and obvious harm to the public. While infrastructure, buildings, and products may hold an obvious physical connection with harm, the importance of this practice in less obvious discourses is equally if not more important. The challenge of doing so with clarity however is also greater and requires particular and careful attention.

Frame of Reference and System Boundaries

One of the most important assumptions for any study might be the adoption of a frame of reference and definition of the system boundaries under consideration. The possible level of complication of each of the social and ecological system components and their possible connections is infinite. To make any study tractable, some level of place-based detail is obviously necessary as is an appropriate level of abstraction or simplification.

The frame of reference selected for the study will necessarily dictate the structure of the relationships that are investigated. It will also likely suggest particular frameworks as being more or less relevant. Take for example the flow of nutrients in an ecosystem. One frame of reference might be to consider the physical transformation and flow of, say, phosphorus through a lake-watershed system. A material flow analysis would lend itself to such an investigation. An alternative frame might consider the problem of harmful algal blooms in that system, for which phosphorus might be a controlling nutrient but which suggests other important factors such as land change that would better be captured in a social-ecological framing.

Complementing the frame of reference is the boundary of the system under consideration. The selection and communication of this assumption is of importance because it determines the factors considered and places all else outside the system boundary. While external factors can influence what happens inside the system boundary, they are not the fundamental concern. To build upon the phosphorus example, one might consider the system boundary to be consistent with the watershed boundary and therefore the external dynamics of phosphorus coming into the system, from fertilizer or feed for instance, to be external to the system. Questions related to the prevention or remediation of harmful

algal blooms in the system will thus be limited to the internal dynamics and control of phosphorus within the system.

Scale

Scale, both temporal and spatial, is closely tied to the system boundaries previously discussed, however as a typological matter it must be clearly delineated. Scale, or the relative size of various system components will further suggest particular models, level of abstraction, and manner of analysis to enable tractability and relevant knowledge generation. The interaction of forces and processes across temporal and spatial scales is, of course, of great interest. Global challenges, like climate change in particular, which become apparent only at the global level, must nevertheless be solved at the local level with action points at each descending level of spatial and temporal disaggregation. That is to say, there are actions that must be taken globally, nationally, regionally, and hyperlocally to address the challenge and those actions must play out over days, weeks, months, years, and decades.

System Components

Several of the frameworks discussed in previous sections in part articulate the components, or parts, of each subsystem that might be under consideration in a particular study. The selection of relevant or measurable components to include must however be made, particularly if a question of interest relates to the relative importance of competing components, in which case all must be included to make any claim of relevant finding.

Indicators

Much effort has been made to determine what to measure, or the indicators and therefore the data that we will have to work with. The adage, "you measure what you care about and you care about what you measure" may seem circular, but it implies both the possible and the normative.

There are two main types of indicators: subjective and objective. It is difficult, if not impossible, to measure subjective indicators in nature. As it relates to human wellness, subjective indicators use people's own evaluation of their satisfaction with their lives—a cognitive evaluation of their entire lives (Myers and Diener 1995). Subjective life satisfaction, or quality of life, assumes that a person can actually assess how they feel about their life in the context of their own relative standards (Diener and Suh 1997). It implies that a person identifies what is significant in their lives and how important that aspect is to them. Measuring the degree of life satisfaction allows for a common variable to be established, allowing for comparison between regions and populations while incorporating diverse influences and objectives (Stiglitz et al. 2009).

However, the use of life satisfaction survey scores to measure overall wellbeing has its weaknesses (Kubiszewski et al. 2018). One problem is that scores vary based on factors such as daily mood, recent events remembered, cultural norms, personality, framing, priming, and a multitude of other factors that cannot be fully accounted for in a survey

(Schwarz and Strack 1991; Kahneman 2011). Individual life satisfaction may also vary based on relative improvement in conditions over time, regardless of current objective conditions. Humans also have a strong predilection to adapt to situations, where their satisfaction with life is relative to their past situation and the situation of those around them.

Objective indicators, in turn, are based on observable and quantitative factors. In the case of wellness again, these might include access to material goods, crime, inequality, and proximity to green spaces (D'Acci 2011). Strict standards around collection enable comparability between geographical regions and populations. While many of these indicators reflect normative ideas that a society holds, regardless of whether individuals perceive these, objective indicators represent the conditions and assets that allow people to meet their needs and experience subjective wellbeing (Costanza et al. 2007).

Objective indicators also have their limitations. Ensuring consistent boundaries and standards around measuring of these indicators is critical for comparison purposes (Dolan and Metcalfe 2012). Also, collecting such data becomes difficult in developing cultures where many aspects of the culture are informal and take place outside official institutions. For example, infant mortality when childbirth occurs at home or inequality when a large portion of the economy is informal (Diener and Tov 2012).

Evaluation and Analysis

Disciplinary pedagogies promote certain methods of evaluation and analysis. As interdisciplinary practices mature, these silos will invariably merge and disaggregate, however particular methods of evaluation and analysis will remain more or less appropriate given the circumstances of the aforementioned systems concepts. Careful attention to study design, assumptions, and statistical testing will further enable improved learning to take place that leverages the power of statistical methods in particular in understanding systems that exhibit high levels of variability and uncertainty.

Ecological economics has long sought disciplinary transcendence and methodological pluralism. By placing these bounds on the frameworks that have emerged in that ambition, the potential for actionable knowledge generation is greatly improved.

RESEARCH AND ACTION AGENDA

What follows is a summary of the future directions identified throughout the chapter that might serve to shape emerging research agenda in the field of ecological economics. These are further matters for all the transdisciplinary communities that seek to address the multitude of challenges that must be navigated to achieve a sustainable future for humanity on Earth.

Framework Alignment and Integration

1. Using critical alignment and integration of the dominant frameworks emerging across the transdisciplinary communities, how can ecological economics contribute

to topics including applicability and action motivation to inform a sustainable future for humanity?
2. By using a rigorous typological framing of the systems, scales, and assumptions for particular studies, what findings emerge that are appropriate to cross boundaries and to become actionable?

Consider Evolutionary Processes

1. Can an evolutionary perspective, particularly with respect to the evolution of social and cultural norms, provide a pathway toward understanding and informing social change?
2. Can an evolutionary approach account for and build understanding around not just the temporal dynamics but also the structural evolution of the systems under consideration?
3. How can ecological economics contribute to the management of transitions between structural states for spatial and intergenerational equity?

Comparative, Temporal Analysis of Individual Wellbeing

1. How do subjective and objective indicators relate to one another and to wellbeing?
2. What do appropriate measures of wellbeing look like; how are they constructed and what forms of subjective and objective variables should be used?
3. What can we learn about controlling factors and enabling systems from comparative analysis of wellbeing in individuals as well as comparative analysis of wellbeing in the aggregate (e.g. of communities or nations), particularly when considering fluctuations over time?

Consider the Value and Distribution of Wellbeing

1. How do we collectively assign the value and appropriate distribution of resources and effort toward the achievement of wellbeing across the global population?
2. What is the relationship between natural capital and wellbeing?

Consider Comparison of Bottom-up and Top-down Approaches to Achieving Wellbeing

1. What benefits, costs, and equity implications emerge from the definition and pursuit of wellbeing in distributed versus mandated approaches?
2. What types of wellbeing emerge at different scales and how are these best valued and managed across space and time?

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