SHD: Foundations, Drivers, and Essential Components

Final Project Report

The Advanced Consortium on Cooperation, Conflict, and Complexity (AC^4)
The Earth Institute, Columbia University

November 2016

Cover photo:

View from San Juan de Gaztelugatxe, Bizkaia province (Basque Country), overlooking the Bay of Biscay. October 2015.

Photo by Kristen Rucki.

About the Authors

The Advanced Consortium on Cooperation, Conflict, and Complexity (AC^4) is housed at the Earth Institute, Columbia University. AC^4 strives to foster sustainable peace through innovation and integration. AC^4 works to enable and support integrative research and practice on sustainable peace, constructive conflict engagement, and sustainable development. This is built on an understanding that creating peaceful and sustainable societies requires a systemic approach, leveraging the expertise and knowledge of scientists and practitioners from across disciplines and areas of practice. By connecting thought leaders at Columbia University and around the world, AC^4 works to build opportunities to apply leading-edge science to generate solutions for some of our most pressing social and environmental challenges.

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Executive Summary

The concept of 'sustainability' has come to permeate many aspects of political, economic, environmental, and corporate governance. It is generally understood that sustainability refers to the pursuit of individual and social development such that human welfare is maintained or increased over time. Beyond this general conceptualization, however, there is little consensus on the nature and properties of a sustainable system, and even less consensus on the appropriate social, political, environmental, and economic structures required to build or achieve sustainability. The lack of coherence regarding the conceptualizations of sustainability and the various experiments seeking to construct it have ramifications for the ways in which we define the concept and set the corresponding personal, national, global, and corporate agendas.

SHD: Foundations, Drivers and Essential Components, a three-year research program undertaken by the Advanced Consortium on Cooperation, Conflict, and Complexity (AC^4) at Columbia University, in collaboration with the Agirre Lehendakaria Center for Social and Political Studies (ALC) at the University of the Basque Country, has aimed to unify the concepts of sustainability and human development under a theoretical and operational framework of sustainable human development (SHD), while designing and verifying theoretical and empirical models of SHD.

This project is part of a larger collaborative research initiative titled *Sustainable Human Development (SHD): The Basque Case*. Together with AC^4 and the Agirre Lehendakaria Center, researchers from Seton Hall University, George Washington University, and Scensei LLC have engaged in a multidisciplinary investigation of the Basque model of SHD, conceptualized by Lehendakari Dr. Juan Jose Ibarretxe. The purpose of the initiative was to understand what social, economic, and political factors contributed to SHD in the Basque Country, with each partner institution studying different aspects of the Basque model. In this initiative, AC^4's broad and overarching theoretical and empirical work provides a framework that can be used to contextualize the case-specific learning.

In order to construct a theoretical framework of SHD, AC^4 undertook the 3-phase approach, depicted on the following page, with each phase building on the findings of previous phases.

Phase 1: Interdisciplinary Synthesis

Activities:

- Review of indices of sustainable development; sub-grants for discipline-based empirical reviews
- Synthesis of theoretical framework

Outputs:

- 1 peer-reviewed publication
- 3 internal white papers
- 1 publication pending peer review

→

Phase 2: Model design and indicator identification

Activities:

- Model design
- Hypothesis formation
- Indicator selection
- ANOVA modeling

Outputs:

- Data set constructed
- Preliminary indicators tested & refined
- 1 peer-reviewed publication

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Phase 3: Hypothesis testing & model refinement

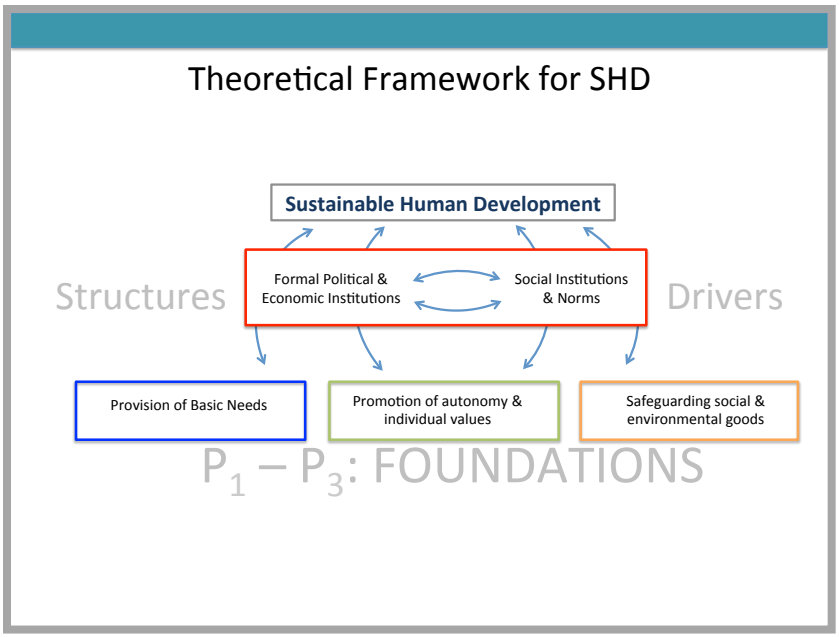
Activities:

- Model refinement via OLS regression
- Model specification set via GLS regression

Outputs:

- Final statistics analyzed
- Project report and presentations conducted
- Manuscript prepared for submission for peer review

The first phase of this project was dedicated to reviewing existing theories, definitions, measures, and parameters of human development, environmental sustainability, and sustainable development. This review focused on macro-scale, international measures, applied to the national or state level of analysis. This review was then used to synthesize a unified theoretical model of sustainable human development (depicted below).



Phase II of the project applied the theoretical framework of SHD to generate four hypotheses that posit which institutional characteristics most effectively drive sustainable human development. The hypotheses are grounded in the empirical literature on human development, environmental sustainability, and institutional cooperation. In order to test the hypotheses, the research in Phase II consisted of identifying proxy measures and indicators of the institutional characteristics embedded in these hypotheses.

H_1: Democratic institutions will perform better on human development and environmental indicators.

H_2: The higher the level of institutionalized cooperation, the better a country will perform on human development indicators and on environmental indicators.

H_3: Countries with institutionalized processes for enabling and regulating competition will perform better on environmental and human development indicators.

H_4: The presence or onset of factionalism is correlated with worse performance on environmental and human development indicators.

Informed by the findings of Phases I and II, the Sustainable Human Development project culminated in the design and refinement of exploratory empirical models of SHD. These models were designed to test the hypotheses developed in Phase II of the project and to explore the impact of institutional characteristics on outcomes related to sustainable human development cross-nationally. Overall, the models demonstrate preliminary support for the overarching theory that SHD is made possible by greater degrees of cooperation in formal and informal institutions. Moreover, there is empirical support for three of our four hypotheses.

While the empirical evidence in the research is exploratory, several lessons for SHD appear to have preliminary statistical support that warrant further and deeper exploration. First, citizen participation in decision-making in both formal and informal institutions is important for SHD. This, however, requires that institutions function, are trusted, and remain responsive to citizen needs and will. According to our framework, human development depends on ecological integrity, and ecological integrity is more feasible to secure when well-being is advanced. Thus, this

interdependence becomes the mechanism by which progress can be made on both fronts. While the current modeling effort is insufficient to elucidate those pathways, there is at least preliminary evidence to suggest that further study into these processes and linkages is warranted.

Also, in line with much of the work of Elinor Ostrom and others, our findings suggest that both formal and informal institutions develop to prevent the so-called tragedy of the commons. While neo-liberal economics suggest that market competition should optimize societies and incentivize innovation for economic, environmental and social dilemmas, our findings hint that institutional constraints on competition are useful to guide competition toward more constructive avenues. Indeed, social cohesion institutionalized via cooperatively-oriented structures may be well-positioned to resolve or constructively manage the tensions and dilemmas inherent in our contemporary sustainability and development challenges.

Guggenheim Museum, Bilbao, Basque Country.
June 2016
Photo by Kristen Rucki

Introduction and Background

The concept of 'sustainability' has come to permeate many aspects of political, economic, environmental, and corporate governance. It is generally understood that sustainability refers to the pursuit of individual and social development such that human welfare is maintained or increased over time. Beyond this general conceptualization, however, there is little consensus on the nature and properties of a sustainable system, and even less consensus on the appropriate social, political, environmental, and economic structures required to build or achieve sustainability.

Historically, great distinctions have been made between the fields of environmental sustainability and human development, and the two ideas have largely been conceptualized, researched, and measured separately. The lack of coherence regarding the conceptualizations of sustainability and the various experiments seeking to construct it have ramifications for the ways in which we define the concept and set corresponding personal, national, global, and corporate agendas.

Nevertheless, the international community's adoption of the 2030 Agenda for Sustainable Development in September 2015 confirms that, perhaps more so than ever, the concept of sustainability is at the forefront of global consciousness. In a departure from the Millennium Development Goals, which focused on eliminating extreme poverty, the new agenda includes 17 Sustainable Development Goals (SDGs), all aimed at meeting objectives for social, economic, and environmental dimensions of sustainable development by 2030. In order for this ambitious agenda to be realized, a unified theoretical framework, as well as an understanding of the complex system of mechanisms and processes by which it is advanced, is necessary.

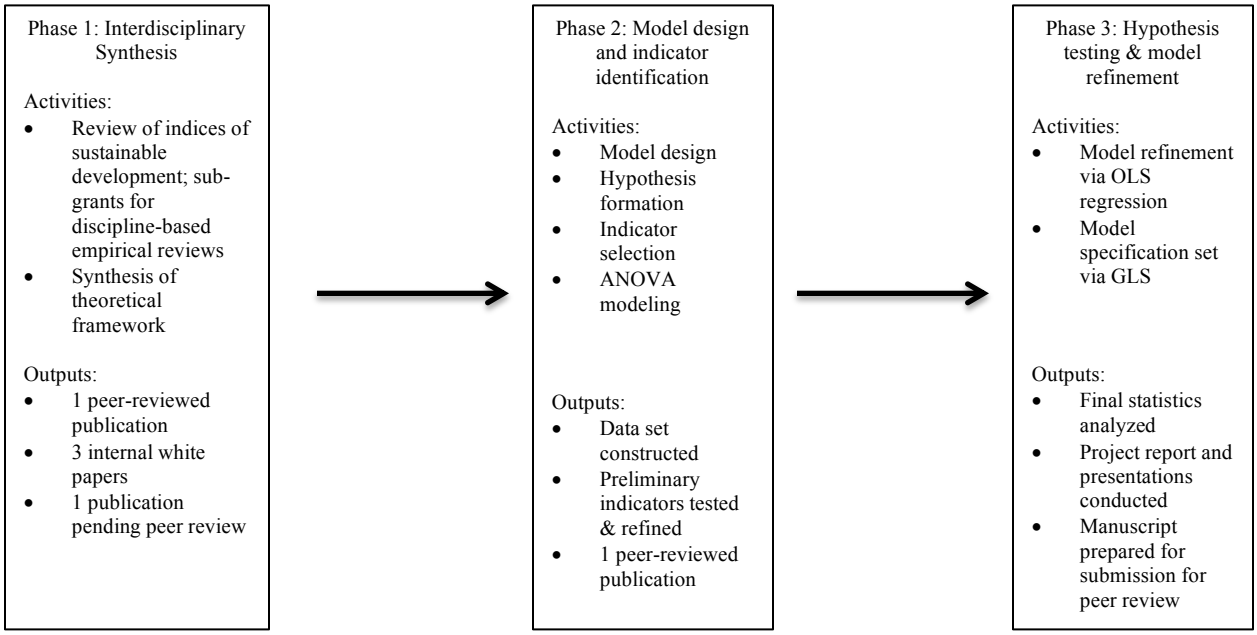
SHD: Foundations, Drivers and Essential Components, a three-year research program undertaken by the Advanced Consortium on Cooperation, Conflict, and Complexity (AC^4) at Columbia University, in collaboration with the Agirre Lehendakaria Center for Social and Political Studies (ALC) at the University of the Basque Country, aimed to unify the concepts of sustainability and human development under a theoretical and operational framework of sustainable human development (SHD), while designing and verifying theoretical and empirical models of SHD. Broadly, we define SHD as the synthesis of human development and environmental sustainability. Our conceptualization emphasizes equitable human and social development coupled with the maintenance of environmental integrity. Importantly, our theory incorporates linkages between the social and ecological components of SHD, understanding that they are interdependent.

This project is part of a larger collaborative research initiative titled *Sustainable Human Development (SHD): The Basque Case*. Together with AC^4 and the Agirre Lehendakaria Center, researchers from Seton Hall University, George Washington University, and Scensei LLC have engaged in a multidisciplinary investigation of the Basque model of SHD, conceptualized by Lehendakari Dr. Juan Jose Ibarretxe. The purpose of the initiative

was to understand what social, economic, and political factors contributed to SHD in the Basque Country, with each partner institution studying different aspects of the Basque model. In this initiative, AC^4's broad and overarching theoretical and empirical work provide a framework that can be used to contextualize the case-specific learning.

Research Plan

In order to construct a theoretical framework of SHD, AC^4 undertook the 3-phase approach depicted below, with each phase building on the findings of previous phases. These phases and their results are briefly described below.



Phase I: Interdisciplinary Review

The first phase of this project was dedicated to reviewing existing theories, definitions, measures, and parameters of human development, environmental sustainability, and sustainable development. This review focused on macro-scale international measures applied to the national or state level of analysis. This review was then used to synthesize a unified conceptualization of sustainable human development.

Activities in the first phase of research included:

- Extensive review of existing literature related to environmental sustainability and sustainable human development, identifying the core components of each concept and

the points of convergence and interdependence.

- A comprehensive assessment of 14 indices measuring socio-economic and ecological components of sustainability and human development, assessing the metrics used to discover the key parameters of SHD.
- A review of the Basque model of sustainable human development, as theorized by Dr. Juan Jose Ibarretxe in 2010, in order to assess synergy with other models of human development and environmental sustainability, and to identify the novel contributions of this model.
- A grant competition for Earth Institute scholars from diverse fields of study to conduct in-depth discipline-specific reviews of the definitions, metrics, and scales of sustainable human development.
- Synthesis of knowledge to propose a unified theoretical framework of SHD.

The disciplinary reviews commissioned in the first phase of the SHD project contributed to a nuanced understanding of current perspectives on measuring SHD across differing academic fields of study. Across the disciplines explored, there exist multiple calls to better understand the institutional frameworks that can enable SHD or resolve the conflicts and tensions inherent in its pursuit. Additionally, these reviews demonstrate that modeling human behavior is fundamentally different from modeling physical or physics-based systems. These differences must be considered in order to effectively conceptualize and model the relationship between human well-being and environmental integrity. These reviews culminated in a series of white papers and peer- reviewed publications that are summarized below:

The Institutional Foundations of Sustainability: What Can We (Not) Learn from Political Economy?

by Marion Dumas and Johannes Urpelainen (see *Appendix A*).

This article reviews literature on political institutions from the perspective of sustainable human development and recommends a more robust analytical foundation for the design of institutions that can achieve long-term sustainability. Current institutions, even those that function effectively and promote conditions that encourage growth, are often still not conducive to achieving SHD in the long term. Moreover, SHD requires policies that are able to govern across multiple scales of decision-making and strategies that address a great deal of complexity, with which even the most advanced institutions currently struggle. The article offers the renewable energy sector in Denmark as an example of an institutional design that has successfully addressed the problem of scale and promoted cooperation, which enabled a sustainable transition to renewable energy in the country.

The Urban Sustainable Development Goal: Indicators, Complexity and the Politics of Measuring Cities

by Jacqueline M. Klopp and Danielle L. Petretta (see *Appendix B*).

This paper analyzes the goal of urban sustainable development as outlined in the post 2015 United Nations sustainable development agenda and addresses major challenges in sustainable city planning. It finds that the pursuit of the urban sustainability goal is complicated by the multitude of existing indices, the need to apply indicators to local contexts, the complex relationships that exist between cities and states, and poor data availability at the city level. It advocates for the creative and strategic use of the urban sustainability goal and its activities to provide coherence and global support to local urban problem-solving. This article has been submitted to the peer-reviewed journal *Cities*.

Sustainable Water Management in Urban, Agricultural and Natural Systems

by Tess Russo, Katherine Alfredo, and Joshua Fisher (see *Appendix C*).

This paper analyzes sustainable water management, particularly considering methods of evaluation, challenges, and recommendations for improvement. It finds there is a strong need for improved evaluation of sustainable management practices, particularly focusing on the interconnectedness of social and physical systems using quantitative metrics,. It also finds that long-term economic development is linked to ecological integrity such that social and economic development goals can use the estimated value of services to set thresholds for environmental degradation. This paper was published in the peer-reviewed journal *Water* in 2014.

The reviews conducted in Phase I yielded two important results. First, they demonstrated that the commonalities and novel contributions of various models of environmental sustainability, sustainable development, and human development are sufficiently complementary to enable synthesis of the concept of SHD. More importantly, however, the reviews illuminated an important gap in our understanding of SHD. While a vast corpus of theoretical and empirical frameworks focuses on observing and measuring the components of SHD, relatively few identify the processes that enable SHD. In other words, we know more or less what SHD would look like, but virtually nothing about how to actually achieve it. Important questions arise from this: What are the institutional structures and configurations that enable a country to move closer to achieving SHD? What social and political processes promote sustainable versus non-sustainable development? How do states effectively navigate the tensions between economic growth, sovereignty, and environmental integrity? How can societies adapt to changes in the social and natural systems that comprise them?

Through the process of exploring the academic answers to those questions, a theoretical framework of SHD was synthesized that attempted to unify the empirical parameters of SHD with the institutional characteristics that engender it. This unified framework attempts to bridge the ideas of SHD as a system state to attain and sustain and SHD as a process of adapting to new and changing social and ecological dynamics. It is based upon the proposal that the pursuit of SHD involves four necessary components. The first three

components are meant to encapsulate the foundations of sustainable human development, while the fourth is a mechanism by which these three foundations are pursued. The following components condense many of the operational definitions of human development, well-being, and sustainability that exist in academic and policy literature.

Component One: *SHD involves preventing the deprivation of basic human needs.*

Component Two: *SHD involves the promotion of individual agency, equity, and opportunity to define and pursue subjective values.*

Component Three: *SHD involves the safeguarding of public, social, and environmental goods across temporally and spatially nested social-ecological systems.*

Component Four: *SHD involves the process of resolving the tensions between human development and ecological integrity via the creation and maintenance of cooperative social, political, and economic institutions.*

The initial review of indices found that existing metrics sufficiently measure the ability of systems to provide for basic human needs and the ability of systems to secure and expand individual capacity and opportunity (Components 1 & 2). However, it also found that current measures are not suited to record impacts across spatially-nested systems or the cumulative impact of policies or actions over time and the externalities associated with taking action (Components 3 & 4). The lack of metrics taking into account Components 3 and 4 is a result of the fact that existing metrics were designed in case or context-specific situations, often employing particular theoretical perspectives or with specific mandates to fulfill. Thus, they were not designed to be holistic measures of SHD.

In the theoretical framework developed in Phase I (see Figure 1), institutional cooperation (within both formal and informal institutions) is theorized as essential to navigating the dilemmas inherent in the sustainability debates. Thus, the framework assumes that institutions that rely on cooperation will enable countries to constructively resolve conflicts between the seemingly incompatible goals and needs of various actors and organizations operating in our social-ecological systems. The call to situate SHD as a dynamic process within a complex system and to reimagine the concept of sustainability to include peace and cooperative conflict resolution was advanced in the paper "Re-conceptualizing the science of sustainability: A dynamical systems approach to understanding the nexus of conflict, development, and the environment" (Fisher & Rucki, 2016).

This article explores academic conceptions of sustainability and finds that current understandings, focused on ecological and socio-economic sustainability, insufficiently incorporate findings from the fields of peace studies and conflict resolution. It posits that environmental quality, ecosystem functioning, economic development, and peace and conflict

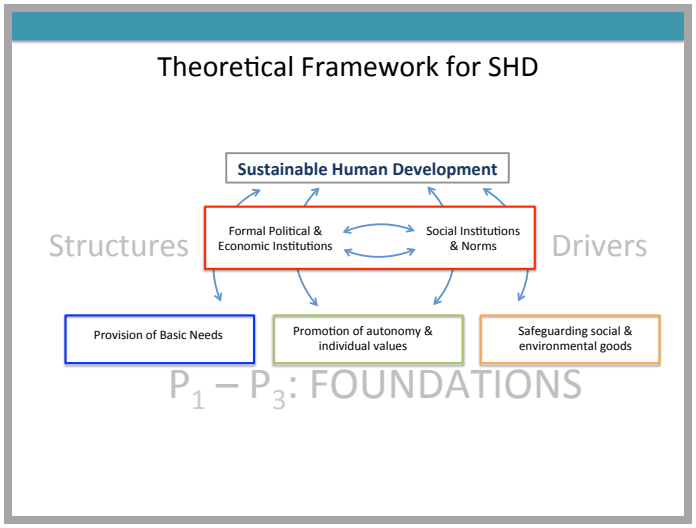


Figure 1: Theoretical framework for SHD produced in Phase I research

management are critical components of sustainability. The article proposes that, due to the lack of understanding of the drivers of and relationships between these components, new research and practice paradigms are necessary. It recommends the application of complex systems approaches, specifically Coupled Systems Theory and Dynamical Systems Theory, in order to understand sustainability at the nexus of conflict, environment, and development. Coupled Systems theory focuses on the natural world and social impacts upon it, while Dynamical Systems Theory currently focuses almost entirely on the social world. The article proposes that an amalgamation of the two theories would fill the gaps in the current practice and understanding of sustainability science, particularly in the area of human decision-making and perceptions. The two key lessons from this article are 1) It is necessary to study sustainable human development through a framework that can be applied to a dynamic rather than stable system, and 2) Incorporating conflict resolution approaches is beneficial to understanding interactions between social and natural systems (See *Appendix D*).

Phase II: Hypothesis Generation and Empirical Model Design

Phase I brought to the forefront the importance of cooperative institutions and processes of conflict resolution as essential mechanisms for pursuing SHD, as well as the gaps in knowledge regarding the institutional characteristics that best enable the promotion of well-being and environmental integrity. Phase II of the project applied the theoretical framework of SHD to generate four hypotheses that posit which institutional characteristics most effectively drive SHD. The hypotheses are grounded in the empirical literature on human development, environmental sustainability, and institutional cooperation. In order to test the hypotheses, the research in Phase II likewise consisted of identifying proxy measures and indicators of the institutional characteristics embedded in these hypotheses.

H_1: *Democratic institutions will perform better on human development and environmental indicators.*

H_2: *The higher the level of institutionalized cooperation, the better a country will perform on human development and environmental indicators.*

H_3: *Countries with institutionalized processes for enabling and regulating competition will perform better on environmental and human development indicators.*

H_4: *The presence or onset of factionalism is correlated with worse performance on environmental and human development indicators.*

This phase culminated in the construction of an empirical modeling framework that utilized the Human Development Index and the Environmental Performance Index as proxies for SHD. Because the theoretical framework assumes that both human well-being and ecological integrity are essential and interdependent components of SHD, it was necessary to find a way to measure these components. Several metrics have been constructed which attempt to integrate them into a single measurement. However, based on our review of these in earlier phases, it appeared that multi-dimensional indicators were too coarse in their resolution to enable a granular exploration of the institutional characteristics that drive specific environmental or human development gains. As such, we elected to separate SHD out into its constituent components in our preliminary models.

In a cross-sectional, time series framework, the model analyzes data from 138 countries (in total) between 2002 and 2011. More data proved to available for larger, higher income countries. In addition to the test variables, a series of variables were identified to control for the influence of wealth, intrastate income disparity, and corruption on development and environmental outcomes. The basic modeling approach consists of two sets of regression models, described as:

$$y_1 = Bx_{i...j} + e$$

&

$$y_2 = Bx_{i...j} + e$$

In the equations above, where y_1 & y_2 represent the Human Development Index and Environmental Performance Index respectively, B represents the intercept used in linear regression, and $x_{i...j}$ represent the variables identified as proxies for the institutional characteristics described above. Finally, e is an error term.

Phase III: Model Testing and Refinement

Informed by the findings of Phases I and II, the Sustainable Human Development project culminated in the design and refinement of exploratory empirical models. These models were designed to test the hypotheses developed in Phase II of the project and to explore the impact of institutional characteristics on outcomes related to sustainable human development cross-nationally. Initial tests included analysis of variance (ANOVA) and ordinary least squares (OLS) regression, but after testing multiple model specifications, the team employed Generalized Least Squares (GLS) regression to test the hypotheses.

Results from the statistical models are pending peer review, and thus are only summarized coarsely here. Overall, the models demonstrate preliminary support for the overarching theory that SHD is made possible by greater degrees of cooperation in formal and informal institutions. Moreover, there is empirical support for three of our four hypotheses.

In simple terms, the more democratic a state, the better it performs. While the results tended to support H_1 , the models demonstrated sensitivity to different specifications.

For H_2, states in which the rule of law and civil liberties are upheld perform better on both environmental and human development outcomes, thus offering support for our hypothesis.

H_3 is complex, as there are few good proxies for institutionalized competition that have sufficient nuance to adequately capture this phenomenon. Given that limitation, we focused our efforts on the ways in which competition plays out politically and institutionally in terms of representation of a range of views in political processes and institutional controls on that inclusion. Two key phenomena provided preliminary data to support the hypothesis: the degree of voice and accountability in institutional processes and the challenges that ethnic heterogeneity may pose to the common pursuit of SHD. Meanwhile, further research and clarification is needed regarding the potential impact of the degree to which multiple political parties are represented at the institutional level.

H_4 has perhaps the most surprising result. Contrary to our hypothesis, factionalism by itself does not appear to impact environmental or human development outcomes.

While none of the models or variables themselves are sufficient to fully explain SHD outcomes, our empirical results do provide evidence to support the proposition that cooperative institutions with mechanisms for inspiring confidence and productively channeling competition perform better in terms of development outcomes.

Summary and Synthesis

The research initiative into sustainable human development produced a series of working papers and peer-reviewed publications that enabled the construction of a theoretical model of SHD, which seeks to describe the processes by which SHD can be achieved and maintained. The framework provides significant utility to the understanding and practice of

sustainable human development in several ways. First, it simultaneously captures the 'system state' and 'development process' aspects of SHD. Next, by focusing on both the state and the process, the framework enables measurement of institutional effectiveness via incompatible needs and goals such as economic growth and ecological integrity. Finally, it operates on theoretically and empirically grounded assumptions from multiple disciplines, and is thus an evidence-based approach.

This approach is novel in that it begins to explore the ways in which both formal institutions (political mechanisms, civil society, etc.) and informal institutions (customs, norms, cultural dynamics) impact SHD. In so doing, it enables a new lens through which to view development, and also provides a framework that can enable future initiatives to more accurately uncover the mechanisms underlying institutional characteristics and SHD outcomes.

While the empirical evidence in the research is exploratory, several lessons for SHD appear to have preliminary statistical support that warrant further and deeper exploration. First, citizen participation in decision-making in both formal and informal institutions is important for SHD. This requires that institutions function and are trusted, and that institutions remain responsive to citizen needs and will.

Given that electoral cycles and environmental time frames are not necessarily identical, it is not immediately clear that the short-term calculus of democratic processes should be responsive to longer-term problems like environmental sustainability. Indeed, even the recent climate debate and token commitments by most governments seem to indicate that at the national scale, short-term economic calculus (which admittedly is necessary for economic development and thus well-being) may outweigh longer-term sustainability concerns. However, our theoretical framework posits that institutions geared at cooperation and constructive competition should perform better on both environmental and human development indicators. According to our framework, both aspects are components of SHD, and are thus interdependent. In this way, human development depends on ecological integrity, and ecological integrity is more feasible to secure when well-being is being advanced.

Also, and in line with much of the work of Elinor Ostrom and others, our findings suggest that both formal and informal institutions develop to prevent the so-called tragedy of the commons. While neoliberal economics suggest that market competition should optimize societies and incentivize innovation for economic, environmental, and social dilemmas, our findings hint that institutionalized constraints on competition are useful to guide competition down more constructive avenues. Indeed, social cohesion that is institutionalized via cooperatively-oriented structures may be well-positioned to resolve or constructively manage the tensions and dilemmas inherent in our contemporary sustainability and development challenges.

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Klopp, J. M., & Petretta, D. L. (Under Revision). The urban sustainable development goal: Indicators, complexity and the politics of measuring cities. Submitted to *Cities*.

Russo, T., Alfredo, K., & Fisher, J. (2014). Sustainable water management in urban, agricultural, and natural systems. *Water*, 6(12), 3934-3956.

Appendix A

The Institutional Foundations of Sustainability: What Can We (Not) Learn from Political Economy?

Marion Dumas and Johannes Urpelainen
Columbia University

Abstract

This article offers a critical, systematic review of the literature on political institutions from the perspective of sustainable human development (SHD). We consider a socio-economic system sustainable if it is capable of renewing itself over extended periods of time. Many political institutions that are deemed elective at solving a host of societal problems do not promote long-run sustainability. Institutions that maintain order, reduce conflict, and allow collective decisions to be made lay the foundation for economic development. However, such development is often unsustainable in the long run without levels of cooperation and foresight that today's political institutions usually do not achieve. SHD requires policies that do not corrode natural capital over centuries and millennia, governance across multiple scales of decision-making, and strategies to deal with exceptionally high levels of complexity. Even the most advanced and successful political institutions do not meet these challenges.

Dumas, M., & Urpelainen, J. (2014). The institutional foundations of sustainability: What can we (not) learn from political economy? Available at SSRN 2441677.

Appendix B

The Urban Sustainable Development Goal: Indicators, Complexity and the Politics of Measuring Cities

(Submitted to the journal *Cities*)

Jacqueline M. Klopp and Danielle L. Petretta
Columbia University

Abstract

As part of the post-2015 United Nations sustainable development agenda, the world has its first urban sustainable development goal (USDG), which is "to make cities and human settlements inclusive, safe, resilient and sustainable". This paper provides an overview of the USDG and explores some of the challenges around using this goal as a practical and tactical planning tool for improving cities. Challenges include 1) 'localization" or how to encourage the uptake of the goal and its targets by diverse actors in widely different cities that are in often complex relationship with national states that control statistics 2) "translation" of indicators so that they are relevant, acceptable and practicable and make sense within an environment with many existing indicators and 3) improvement of data and data collection systems and creative and compelling ways for data to be open and useful within the political and planning process. Currently, accessible, standardized and open data for key indicators at the city scale for many countries simply do not exist. At the same time a bewildering array of indices at different scales are proliferating. We argue that whether the USDG can help bring some coherence and focus to city problems within this context will depend on the skill with which the goal, its targets and indicators are used creatively and tactically within existing urban movements and planning processes at multiple scales.

Klopp, J. M., & Petretta, D. L. (Under Revision). The urban sustainable development goal: Indicators, complexity and the politics of measuring cities. Submitted to *Cities*.

Appendix C

Sustainable Water Management in Urban, Agricultural, and Natural Systems

(Published 12 December 2014 in *Water*)

Tess Russo, Katherine Alfredo, and Joshua Fisher
Columbia University

Abstract

Sustainable water management (SWM) requires allocating between competing water sector demands, and balancing the financial and social resources required to support necessary water systems. The objective of this review is to assess SWM in three sectors: urban, agricultural, and natural systems. This review explores the following questions:
(1) How is SWM defined and evaluated? (2) What are the challenges associated with sustainable development in each sector? (3) What are the areas of greatest potential improvement in urban and agricultural water management systems? And (4) What role does country development status have in SWM practices? The methods for evaluating water management practices range from relatively simple indicator methods to integration of multiple models, depending on the complexity of the problem and resources of the investigators. The two key findings and recommendations for meeting SWM objectives are: (1) all forms of water must be considered usable, and reusable, water resources; and (2) increasing agricultural crop water production represents the largest opportunity for reducing total water consumption, and will be required to meet global food security needs. The level of regional development should not dictate sustainability objectives, however local infrastructure conditions and financial capabilities should inform the details of water system design and evaluation.

Russo, T., Alfredo, K., & Fisher, J. (2014). Sustainable water management in urban, agricultural, and natural systems. *Water*, 6(12), 3934-3956.

Appendix D

Reconceptualizing the Science of Sustainability: A Dynamical Systems Approach to Understanding the Nexus of Conflict, Development and the Environment

(Published in 2016 in *Sustainable Development*)

Joshua Fisher and Kristen Rucki

Columbia University

Abstract

The concept of sustainability has come to permeate many spheres of governance, decision-making, and scientific inquiry. Although current academic conceptualizations of sustainability often acknowledge the conflicts inherent in the pursuit of sustainable development, the present discourse does not explicitly include the concepts of peace and conflict. This omission has been in error, as the pursuits of sustainable environmental governance and sustainable human development are themselves efforts to manage and resolve conflict. Thus, this article advocates for an expanded framework of sustainability that operates at the nexus of conflict, environment, and development by exploring current mainstream conceptualizations of sustainability and illustrating the direct connections between sustainability and the fields of peace studies and conflict resolution. It goes on to discuss the utility of applying a complex systems approach to the expanded conceptualization of sustainability, including aspects of both coupled systems and dynamical systems theory, in order to provide an analytical framework for studying mechanisms that enable sustainable development by dealing explicitly with conflicting needs and interests among actors in social-ecological systems.

Fisher, J., & Rucki, K. (2016). Reconceptualizing the science of sustainability: A dynamical systems approach to understanding the nexus of conflict, development and the environment. *Sustainable Development*. Advance online publication. http://onlinelibrary.wiley.com/doi/10.1002/sd.1656/epdf

Window in Getaria, Gipúzkoa (Basque Country). May 2015
Photo by Kristen Rucki