Guided Cultural Evolution and Sustainable Development:

Proof of Concept and Exploratory Results

by

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A thesis

presented to the University of Waterloo

in fulfillment of the

thesis requirement for the degree of

Doctor of Philosophy

in

Social and Ecological Sustainability

Waterloo, Ontario, Canada, 2021

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Author's Declaration

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

I understand that my thesis may be made electronically available to the public.

Abstract

This dissertation innovatively uses Cross-Impact Balances (CIB) to study how societal cultures evolve, and how societies might steer the evolution of their cultures towards sustainability. Societal cultures have been conceptualized as interdependent sets of worldviews, institutions, and technologies (WITs), which co-evolve and interact with their environment (Beddoe et al. 2009). CIB is a judgment-based, computational method for identifying internally consistent scenarios (self-reinforcing system states) and pathways (sequences of contradictory system states between pairs of self-reinforcing system states) (Weimer-Jehle 2006). CIB uses categorical variables to represent state-specific effects, allowing it to represent system change as an evolutionary process of recombination (e.g., of types of worldviews, institutions, and technologies).

My dissertation develops a new analytical approach for studying socio-cultural evolution; elaborates the WITs framework of socio-cultural evolution; and presents a dynamic model of socio-cultural evolution, along with validation and a set of exploratory results. Validation shows that the model performs well in reproducing the recent evolutionary histories of a sample of contemporary societies. The exploratory results provide preliminary answers to the following research questions: which combinations of worldviews, institutions, and technologies (societal cultures, or WITs) are self-reinforcing, and under what environmental selective pressures; which self-reinforcing societal cultures appear to be most compatible with sustainable development, and why; and how might an unsustainable, self-reinforcing societal culture be transformed into a sustainable, self-reinforcing societal culture?

My exploratory results suggest that societies have been converging towards a small number of highly contrasting cultural types, and that this polarization may be expected to continue. My exploratory results also suggest that achieving sustainable development may require a transformation in the international system from competition to cooperation. Achieving such a transformation might require societies to foster an inclusive social identity, in order to overcome potential sources of conflict that can stem from sharp cultural differences.

My dissertation breaks new ground in the study of guided cultural evolution and sustainability transformations.

Acknowledgements

I would like to thank the funders and individuals who supported me throughout the writing of this dissertation.

Thank you to the Faculty of Environment (Deans Doctoral Initiative), the Balsillie School of International Affairs, a UW/SSHRC Institutional Grant, and the National Sciences and Engineering Research Council for funding my research.

Thank you, Dr. Vanessa J. Schweizer, for taking me under your wing. I have benefitted immensely from your expertise and guidance. Thank you for always challenging and supporting me throughout the entirety of my PhD studies.

Thank you, Dr. Thomas Homer-Dixon, for your course on complexity theory, for mentoring me in preparation for the comprehensive exam, for your input into the development of my research proposal, and for patiently pushing me to take my dissertation research to a higher level.

Thank you, Dr. Stephen Quilley, for introducing me to Terror Management Theory, for mentoring me in preparation for the comprehensive exam, for your input into the development of my research proposal, and for challenging my presuppositions.

Thank you, Dr. Dawn Parker, for pushing me to improve my model, to sharpen my analysis, and to write more clearly, and for serving as the internal-external examiner on my dissertation committee.

Thank you, Dr. Simon Dalby, for mentoring me in preparation for the comprehensive exam, and for interesting me in graduate studies at the University of Waterloo.

Thank you, Dr. Wolfgang Weimer-Jehle, for hosting me at the Centre for Interdisciplinary Risk and Innovation Studies (ZIRIUS) at the University of Stuttgart, where I received invaluable mentorship in Cross-Impact Balances and feedback on my dissertation research. Thank you also, Dr. Ricarda Scheele, for contributing to an enriching experience during my stay at ZIRIUS.

Thank you, Dr. Dirk Helbing, for arranging an opportunity for me to present an early version of my dissertation research and receive feedback at the Chair of Computational Sociology, ETH Zürich. Thank you also to Stefan Klauser for additional feedback on later iterations of my dissertation research.

Thank you, Dr. Christoph Oberlack and Dr. Cordula Ott, for arranging an opportunity for me to present an early version of my dissertation research and receive feedback at the Centre for Development and Environment, University of Bern.

Thank you, Dr. Bob Gibson and Marian Davies, for your kindness, humour, and support.

Thank you, Amanda Campbell and Jennifer Nicholson, for your constant kindness and support throughout my PhD studies.

Thank you to my colleagues in the Schweizer Research Group: Dr. Jude Kurniawan, Natalya Siddhantakar, Ajar Sharma, Anita Lazurko, Emily Nordemann, Crystal Drakes, Mark Brodrick, and Jonathan Hui.

Thank you to my family: Susan, Brian, Sean, and William. Most of all, thank you to my husband, Cristian, for your unwavering patience, encouragement, and support. Thank you to our puppy, Athena, for helping me get through the final few months of the PhD.

Thank you to my friends and fellow PhD candidates: Dr. Evan Andrews, Dr. Sondra Eger, Dr. Steph Barr, Barb Davy, and Amanda Joynt.

Special thanks to Norm Pase, Dr. Rominda Brignardello, Dr. Carmel Mothersill, Dr. Colin Seymour, Dr. Becky Seymour, and Denise Nistor.

Dedication

I dedicate this dissertation to Dr. Atif Kubursi, Dr. Nibaldo Galleguillos, and the late Dr. John Browning: teachers, mentors, and friends who inspired me to follow in their footsteps.

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Chapter 1: Introduction

1.1: Introduction

Today's societies face an historic challenge: to re-embed themselves in nature and learn to develop sustainably. "Sustainable development," popularized and defined (rather abstractly) by the United Nations in 1987, conventionally refers to "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (UN 1987, 15). Since 1987, sustainable development has appeared in more and more multilateral agreements. "Sustainable economic growth and development" was included as one of the objectives of the United Nations Framework Convention on Climate Change (UN 1992), and "environmental sustainability" was included as one of the eight Millennium Development Goals (UN 2000). But it was not until 2015, when the United Nations adopted the seventeen Sustainable Development Goals (SDGs), that the term "sustainable development" gained a concrete definition in the form of 169 targets for the year 2030 (UN 2015).

It has been argued that the SDGs, which emerged from a "long process of reiterated consultations and amendments," are in need of a theory that explains, among other things, how they are interlinked (Breuer, Janetschek, and Malerba 2019, 4). Initial attempts to make sense of the SDGs included Niestroy's (2016) conceptual framework, which organized the SDGs by dependence: SDGs related to human needs (SDGs 1, 3-5, and 10) depend on SDGs related to production and consumption (SDGs 2, 6-9, and 11-12), which depend on SDGs related to the biosphere (SDGs 13-15); SDGs 16-17 are framed as "underlying goals" (Niestroy 2016, 10). By treating the biosphere as a means to production and consumption, and production and

consumption as a means to human well-being, Niestroy's (2016) model helped to clarify the meaning of sustainable development (while also revealing its anthropocentric assumptions). Conceptual models do not, however, "elucidate the causal relations that link the SDGs," which has been the focus of more recent attempts to *theorize* the SDGs (Breuer, Janetschek, and Malerba 2019, 3–4).

For example, the International Council for Science (ICSU 2017) mapped interactions among the targets for SDGs 2, 3, 7, and 14. This approach was taken up by the United Nations High-level Political Forum on Sustainable Development, which mapped interactions among all SDG targets (Independent Council of Scientists 2019). The map revealed potential co-benefits and trade-offs, but co-benefits vastly outnumbered trade-offs (Independent Council of Scientists 2019). This suggests that the SDGs may be logically consistent. However, progress on the SDGs has been slow, and for some targets, trends are moving in the wrong direction (Independent Council of Scientists 2019). Currently, no country is meeting human needs at a globally sustainable level of resource use (O'Neill et al. 2018).

Doubts have been raised about whether sustainable development, as conceived in the SDGs, is attainable, and whether other concepts of sustainable development ought to be pursued (Quilley and Kish 2019). One thing seems clear: achieving *any* kind of sustainable development (by 2030 or sometime later) will require us to reduce stress on the Earth System – the system of processes that supports all life on Earth. According to the Planetary Boundaries framework, there are nine such processes, and the process that is most stressed is the climate (Steffen et al. 2015). The Intergovernmental Panel on Climate Change (IPCC) has warned that limiting global warming to 1.5^{o}C is necessary in order to reduce climate-related risks to human and natural systems, and

that doing so would require "rapid and far-reaching transitions in energy, land, urban and infrastructure (including transport and buildings), and industrial systems," as well as removal of carbon dioxide from the atmosphere (IPCC 2018).

A recent study examined potential strategies for stabilizing the Earth's climate by 2050. The study combined expert elicitation with a literature review and identified seven "social tipping point interventions," which, the authors suggested, would take no more than ~15 years to trigger and would have observable effects within 30 years: decrease the price of fossil-fuel-free energy; increase demand for fossil-fuel-free technology in cities; decrease the profitability of fossil fuel exploitation; increase the perception of fossil fuels as immoral; raise awareness of climate change impacts; and, increase the number of products and services disclosing their carbon emissions (Otto et al. 2020).

Another recent study looked at the feasibility of achieving "a good life for all within planetary boundaries" (O'Neill et al. 2018). The study defined a "good life" according to the Safe and Just Space framework, which complements the Planetary Boundaries framework with a set of "social boundaries" that correspond to human needs (Raworth 2017). Using a spreadsheet model based on the Planetary Boundaries and the Safe and Just Space frameworks, the study estimated the level of resource use needed to achieve "a sufficient level of performance on each [of 11] social indicators" (i.e., life satisfaction, healthy life expectancy, nutrition, sanitation, income, access to energy, education, social support, democratic quality, and equality) (O'Neill et al. 2018, 92). The study found that while "physical needs" (i.e., nutrition, sanitation, access to energy, and elimination of extreme poverty) could likely be met for 7 billion people without overstressing the Earth System, meeting the other needs would require resource use to become

"two to six times more efficient" (O'Neill et al. 2018, 92). The authors concluded by suggesting two "broad strategies" for achieving a good life for all within planetary boundaries: first, to focus on achieving "sufficiency" in consumption rather than pursuing endless economic growth; and second, to improve "provisioning systems," which transform natural resources into social outcomes (O'Neill et al. 2018). The examples that the authors gave of improving provisioning systems included "switching from fossil fuels to renewable energy, producing products with longer lifetimes, reducing unnecessary waste, shifting from animal to crop products, and investing in new technologies" (O'Neill et al. 2018, 92).

A third study, based on an integrated assessment model, *Earth3*, estimated the number of SDGs that would be achieved and the number of planetary boundaries that would be transgressed under four socioeconomic scenarios: "same" (business as usual), "faster" (accelerating economic growth), "harder" (an intensified but piecemeal approach), and "smarter" (a systemic approach involving transformations) (Randers et al. 2018). The study found that the "same" scenario would result in only 10 out of 17 SDGs being achieved at the cost of transgressing 8 out of 9 planetary boundaries (Randers et al. 2018). Neither the "faster" nor the "harder" scenario would produce outcomes that are good for both people and planet; only the "smarter" scenario would be capable of achieving "near full success of SDGs within PBs [planetary boundaries]" (Randers et al. 2018, 7). Even under this transformative scenario, only 13 of the SDGs would be achieved by 2030 and only 15 by 2050, and the Earth System would only be "moving in the right direction, as if coming back from the brink" (Randers et al. 2018, 30). The "smarter" scenario would rely on five "leverage points" to transform societies and the global system. A leverage point, similar to a "social tipping point intervention," is a place in a system

where a small change has a large effect on the system as a whole (Abson et al. 2017; Meadows 1999). The five leverage points in the "smarter" scenario were: accelerated renewable energy growth sufficient to halve carbon emissions every decade; accelerated productivity in sustainable food chains; new development models in poor countries; unprecedented inequality reduction; and, investment in education for all, gender equality, health, and family planning (Randers et al. 2018).

All three of these studies addressed a mix of "deep" and "shallow" leverage points (Abson et al. 2017). Deep leverage points are things that are harder to change but that could have a relatively large impact, such as the institutions and worldviews that comprise a system. Shallow leverage points are things that are easier to change but that might have a relatively small impact, such as the rates at which things (e.g., money, goods, and energy) move throughout a system. While sustainable development may require a combination of deep and shallow changes, changes in worldviews, institutions, and technologies have played profound roles in transformations throughout history (Nolan and Lenski 2015; Beddoe et al. 2009).

1.2: Societal transformations to sustainability

The words "transition" and "transformation" have been used interchangeably to refer to "radical, non-linear and structural changes in complex adaptive systems" (Hölscher, Wittmayer, and Loorbach 2018, 1). Transitions and transformations are sometimes distinguished by their level of analysis and emphasis: transitions occur in societal sub-systems (e.g., transit) and primarily involve technology, while transformations occur in whole societies and involve a

broader range of mechanisms, including politics, economics, culture, and social or environmental processes (Linnér and Wibeck 2019, 222). While the technological lens has dominated transitions studies in recent years (Geels 2010), other perspectives emphasizing institutions and social-ecological interactions have emerged (Loorbach, Frantzeskaki, and Avelino 2017), drawing the transitions and transformations fields closer together.

Societal transformations have occurred throughout history. Historical examples include the Neolithic Revolution, the Industrial Revolution, the Digital Revolution, and globalization (Linnér and Wibeck 2019). Societal collapses, of which there have been many, are also examples of transformations (Homer-Dixon 2006; Tainter 2008). Similarly, societies that overcame the risk of collapse are examples of transformations to resilience (Butzer 2012). Provisionally, I define a societal transformation to sustainability as a process that leads to a type of society in which everyone's needs are fulfilled at a globally sustainable level of resource use (O'Neill et al. 2018), or a "safe and just" society (Raworth 2017).

At the heart of sustainability transformations is the concept of "need." Wiggins (1987) defined an "absolute need" as something that a person must have in order to avoid being harmed. On this definition, a society in which everyone's needs are fulfilled is a society in which everyone is free from harm. This standard for a 'just' society, which may be too strict to realize in practice, is similar to Galtung's (1969) concept of a 'peaceful' society, which he defined as a society that is free from violence. Galtung defined violence as a situation in which "human beings are being influenced so that their somatic and mental realizations are below their potential realizations" (1969, 168). The word "potential" is a crucial part of Galtung's definition, as it forces us, in judging a situation, to consider whether things could have been different. For example, the

short lifespans of prehistoric hunter-gatherers cannot be cited as evidence that these societies were unjust, since longer life only became possible with the advent of modern medicine and sanitation (Nolan and Lenski 2015). Conversely, gaps in life expectancy today, whether within or between societies, are unjust because the means of achieving long and healthy life exist but are distributed inequitably.

All humans share certain basic needs, such as food, water, air, sleep, and rest – survival needs. Maslow (1943) proposed a hierarchy of five needs, which he suggested are typically satisfied in the following order: physiological, safety, love, esteem, and self-actualization. Building on Maslow, Max-Neef, Elizalde, and Hopenhayn (1991) proposed a matrix of nine needs (i.e., subsistence, protection, affection, understanding, participation, creation, idleness, identity, and freedom) and four ways of experiencing them (i.e., being, having, doing, and interacting). Max-Neef, Elizalde, and Hopenhayn (1991) distinguished between needs, which are universal *ends*, and satisfiers, which are culturally specific *means*. Other theories of human need include Self-Determination Theory (Ryan and Deci 2017), which emphasises autonomy, competence, and relatedness; System Justification Theory (Jost, Federico, and Napier 2013), which emphasises epistemic, existential, and relational needs; and, Terror Management Theory (Solomon, Greenberg, and Pyszczynski 2015), which emphasises the needs for order, permanence, and meaning.

Table 1.1 compares the various theories of need and reveals considerable overlaps. This is interesting in light of the fact that each theory has a different objective. Maslow, who assumed that humans are "perpetually wanting animal[s]" (1943, 18), sought to explain the order in which needs would tend to emerge. Max-Neef, Elizalde, and Hopenhayn (1991) sought to subvert the

Table 1.1: Inventory of needs.

Max-Neef et al. (1991)	Maslow (1943)	Ryan and Deci (2017)	Jost et al. (2013)	Solomon et al. (2015)
Subsistence	Physiological			
Protection	Safety		Existential	Permanence
			Epistemic	Order
Affection	Love	Relatedness	Relational	
	Esteem			
Understanding	Self-actualization	Competence		Meaning
Creation				
Participation		Autonomy		
Identity				
Freedom				
Idleness				

neo-liberal approach to development – with its prescriptions of productivity and profit – with an approach to development that focused on human dignity. Self-Determination Theory (Ryan and Deci 2017) seeks to identify the determinants of psychological well-being. The objectives of System Justification Theory (Jost et al. 2013) and Terror Management Theory (Solomon et al. 2015), while similar to one another, differ radically from the others. The former theory seeks to explain why people sometimes defend the status quo, and the latter theory seeks to explain why people adopt and defend cultural worldviews. According to System Justification Theory, people tend to defend the status quo when their existential needs (e.g., the need to manage fear, threat, and anxiety), epistemic needs (e.g., the need to reduce uncertainty), and relational needs (e.g. the need for social belongingness) are elevated (Jost et al. 2013). In a similar vein, Terror

Management Theory argues that people adopt and defend cultural worldviews as a way of coping with the anxiety that stems from knowing that they will eventually die. If a "need" is something that a person must have in order to avoid being harmed, and anxiety is harmful, then it follows that order, permanence, and meaning, which a cultural worldview provides, are needs.

Drawing on this provisional inventory of needs, and mindful of the distinction between needs and satisfiers (Max-Neef, Elizalde, and Hopenhayn 1991), I redefine a societal transformation to sustainability as a process that leads to a type of society in which everyone's needs are fulfilled in culturally appropriate ways without undermining the integrity of the Earth System. It is perhaps worth nothing that fulfilling "everyone's" needs is an ideal which may never be realized, and here it is helpful to draw on Galtung's (1969) typology of violence, and specifically his concept of "structural" violence, which refers to situations in which the harm that a person experiences is due to unjust institutions. A just society resulting from a sustainability transformation would be one in which institutions are designed so as to minimize to the fullest extent possible the presence of harm/violence, with the ultimate aim of eradicating it.

1.3: Sustainability transformation as guided cultural evolution

Sustainability transformations may be understood as processes of cultural evolution. Culture is "information capable of affecting individuals' behavior that they acquire from other members of their species through teaching, imitation, and other forms of social transmission (Richerson and Boyd 2006, 5). I think of culture in terms of three levels: the micro level (i.e., minds), the meso level (i.e., material products, such as books and the Internet), and the macro

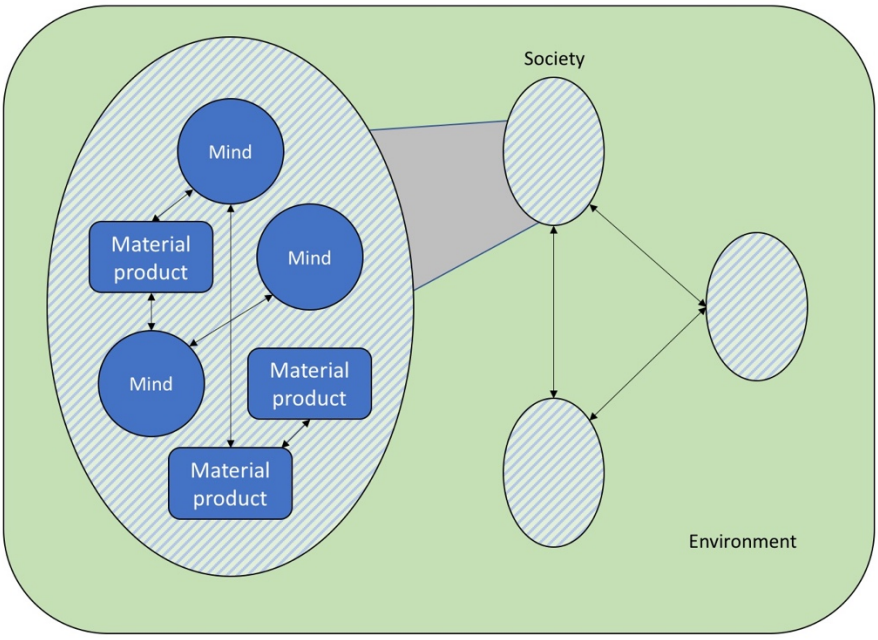

Figure 1.1: Model of culture. Culture as a field of information capable of influencing behaviour, which connects, affects, and is structured by interactions among containers and transmitters of culture (i.e., minds, material products, and societies) and the natural environment. Just as minds are connected through flows of culture, societies are interwoven with the natural environment through flows of matter and energy (as indicated by the diagonal green lines).

level (i.e., societies). Minds, material products, and societies are the containers and transmitters of culture. As such, minds, material products, and societies influence how culture evolves – selecting, (re)combining (i.e., varying), and retaining cultural information in ways that depend on the characteristics of the containers, their past contents, and their interactions with one another and the natural environment. 'Culture' in this unitary sense is a field of information capable of influencing behaviour, which connects, affects, and is given structure by interactions among minds, material products, societies, and the natural environment.

At the level of human societies, culture has been conceptualized as "interdependent sets of worldviews, institutions, and technologies," or "WITs" (Beddoe et al. 2009, 2484). WITs emerge from interactions among individuals (i.e., minds), material products, other WITs, and the

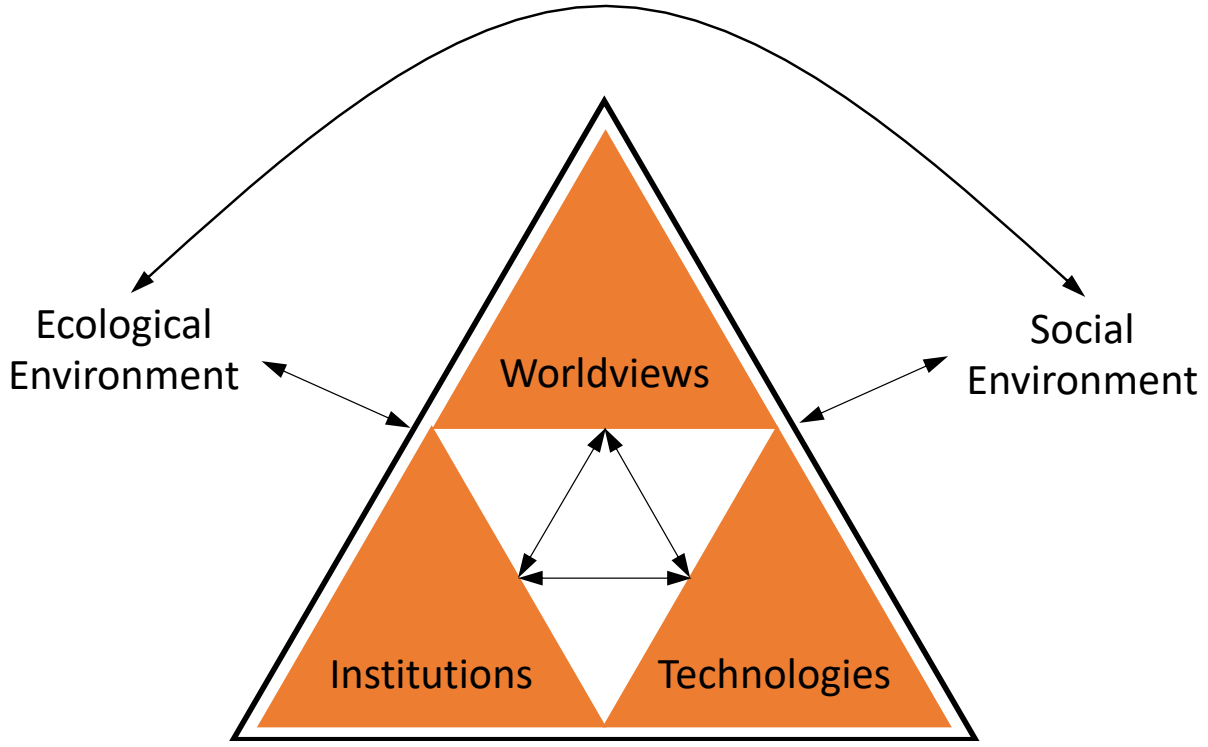

Figure 1.2: Societal cultures as interdependent sets of worldviews, institutions, and technologies (WITs), which co-evolve and interact with their social and ecological environments.

natural environment; in turn, WITs and the natural environment constrain the behaviour of individuals, material products, and other WITs.[1]

WITs are contained by human societies. A human society is "a human population…[that is] politically autonomous and…[that] engages in a broad range of cooperative activities" (Nolan and Lenski 2015, 10). Of course, no society is absolutely politically autonomous. Societies are routinely coerced (Dahl 1957), constrained (Bachrach and Baratz 1962), or manipulated (Lukes 1974), and societies that have shared interests (e.g., security, trade) are dependent on one another to varying degrees (Loyal and Quilley 2013). Nevertheless, it is the *relative* political autonomy of societies that allows them to function as containers and transmitters of culture.

[1] This line of thought is inspired by complex systems theory and structuration theory (Homer-Dixon et al. 2013; Giddens 1984; Blumer 1969).

1.4: Research questions and contributions to knowledge

Beddoe et al. (2009) raised the possibility that societies might be able to steer the evolution of their cultures towards socially just and ecologically sustainable WITs.[2] To do so effectively, policymakers and other societal actors require models that can represent the key features of sustainability transformations, including changes in values and norms. The dominant approaches to modelling sustainability transitions and transformations, such as Integrated Assessment Models (IAMs) and System Dynamics (SD), are weakest at representing this key feature (Köhler et al. 2018). Thus, new approaches are needed. To meet this need, I model sustainability transformations using Cross-Impact Balances (CIB) (Weimer-Jehle 2006). While CIB was developed for scenario analysis, it has the potential to be used for analyzing system dynamics (Schweizer et al. 2013). CIB uses categorical variables to represent state-specific effects, allowing it to represent sustainability transformations as an evolutionary process of recombination (e.g., of types of worldviews, institutions, and technologies). Evolutionary approaches to modelling sustainability transitions and transformations have been rare, although their potential to improve our understanding of such processes has been recognized (Köhler et al. 2018).

[2] In the Galtungian sense, peacefully steering a society's cultural evolution requires refraining from violence, and thus upholding the needs of the members of a society in which change is sought – especially the participation and the freedom needs. Furthermore, as System Justification Theory and Terror Management Theory suggest, efforts to *force* a culture to evolve are likely to be met with resistance and to cause a culture to become more entrenched.

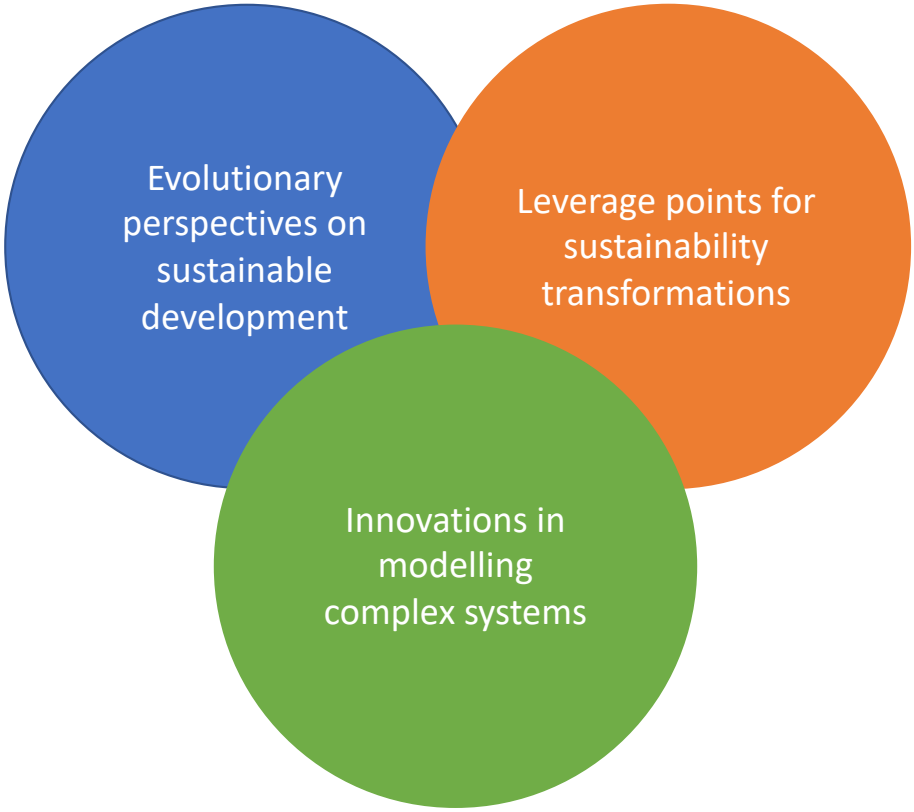

Figure 1.3: The three themes through which this dissertation explores sustainability transformations: evolutionary perspectives on sustainable development (Beddoe et al. 2009); leverage points for sustainability transformations (Abson et al. 2017); and innovations in modelling complex systems (Köhler et al. 2018; Schweizer et al. 2013; Weimer-Jehle 2006).

Thus, my dissertation pushes the frontier of research at the intersection of evolution and sustainability while marking several 'firsts:' the first use of CIB to model evolutionary processes; the first use of CIB to find leverage points for sustainability transformations; and the first computational model based on the WITs framework.[3]

My research is at an exploratory stage and the primary aim of this dissertation is a proof of concept for using CIB to model sustainability transitions and transformations. In particular, I

[3] Costanza et al. (2013) used the WITs framework to develop a narrative of sustainability transformation at the global scale.

aim to demonstrate the value of using CIB to identify leverage points for sustainability transformations. To that end, my dissertation is guided by the following research questions:

1. Which combinations of worldviews, institutions, and technologies (societal cultures, or WITs) are self-reinforcing, and under what environmental selective pressures?
2. Which self-reinforcing societal cultures appear to be most compatible with sustainable development, and why?
3. How might an unsustainable, self-reinforcing societal culture be transformed into a sustainable, self-reinforcing societal culture?

1.5: Plan of the dissertation

My dissertation follows the conventional five-chapter structure. Chapter 2 presents a review of the literature related to societal cultures and their environmental selective pressures. Chapter 3 is the methods chapter and consists of three parts. The first part presents an overview of the dominant approaches to modelling sustainability transitions and transformations and assesses alternative approaches. The second part presents an overview of the model and a detailed description of my analytical approach. The third part presents a detailed description of the model, visualizing and explaining each of its key assumptions. Chapter 4 presents the main results of my research and my answers to the research questions, as well as verification and validation of the model. Chapter 5 discusses the contributions to knowledge and overall significance of the research, directions for future work, and conclusions.

Chapter 2: Literature Review

2.1: Introduction

The WITs framework proposes that societal cultures consist of interdependent sets of worldviews, institutions, and technologies, which co-evolve and interact with their environment (Beddoe et al. 2009). In order to build a model based on this framework, it is necessary to populate each of its four categories – worldviews, institutions, technologies, and environment – with variables.

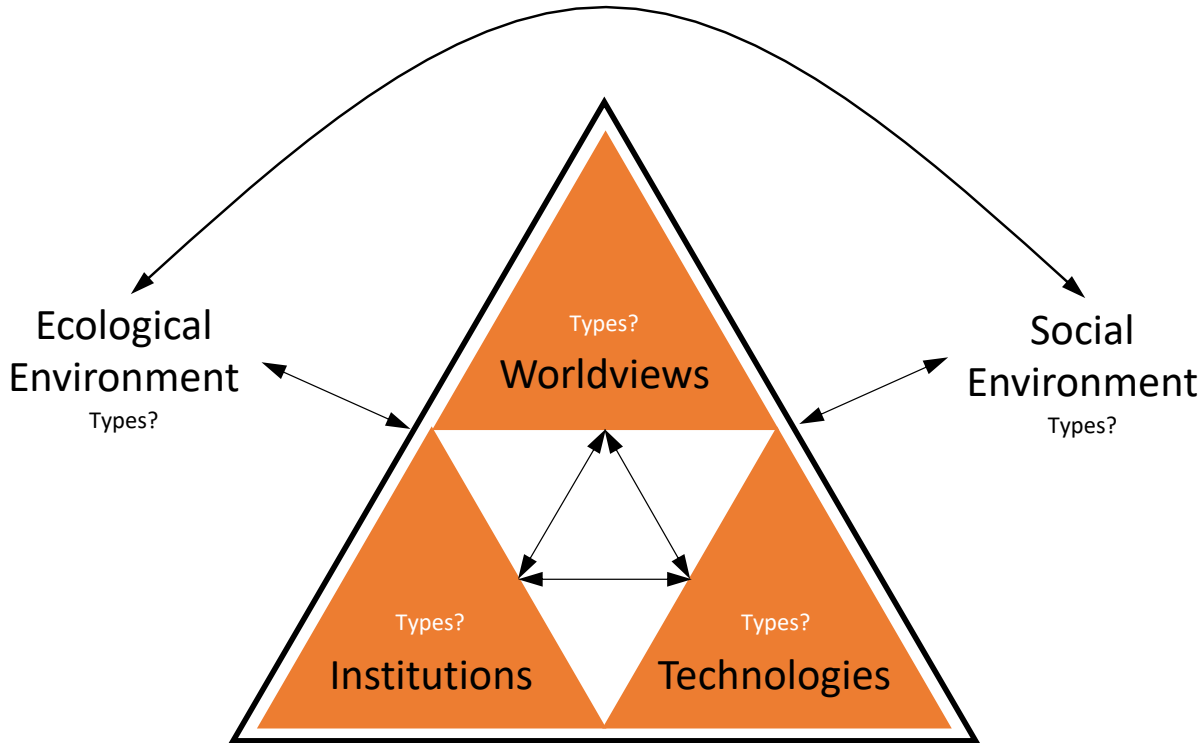

Figure 2.1: Gaps in the WITs framework: what types of worldviews, institutions, technologies, and social and ecological environments describe the evolution of societal cultures?

There are a number of variables that could be included in each of these categories, and different researchers might make different selections. In this chapter, my aim is not to present a definitive list of the most important variables for describing and explaining how societies evolve. Rather, I present exemplars that have strong theoretical and empirical bases and that lend themselves to being interrelated in a model of socio-cultural evolution. This chapter begins with an overview of my process for selecting these variables, followed by a review of the WITs framework. The rest of the chapter discusses the variables.

2.2: Selection of Literature

In order to identify candidate variables for the model, I began by familiarizing myself with the literature on socio-cultural evolution (Pauls 2020). Early works in this literature, the "unilinear theories" (e.g., Hobbes, Voltaire), contended that all societies would progress through a universal and linear sequence of development from less to more "civilized." Later works dismissed these theories as ethnocentric and racist, countering that every culture is "unique in time and place" (Pauls 2020). Adherents of the latter view, the cultural "particularists" (e.g., Boas, Benedict, Mead), amassed a wealth of data on societies, which would inform the next wave of theorizing: multilinear theory. The forerunners of multilinear theory (e.g., White, Steward, Sahlins, Service) rejected the idea of a universal and linear sequence of development, arguing instead that societies share not a single *path* but rather a general *direction* of development: increasing informational complexity and energy consumption.

The state-of-the-art in multilinear theory is Ecological-Evolutionary Theory (EET), which synthesizes theory and data from anthropology, ethnography, and sociology (Nolan and Lenski 2015; Lenski 2005). Its primary data sources are the *Ethnographic Atlas*, which contains coded data on 1,267 societies, and the Standard Cross-Cultural Sample, which contains additional data on a representative sample of 186, relatively autonomous societies. EET is a sophisticated theory that includes a comprehensive conceptual framework and a theoretical account of the mechanisms by which societies evolve. Initially, I was hopeful that EET could serve as the kernel for my model. This proved not to be the case. Through a line-by-line process of extracting the causal arguments in the flagship text of EET, *Human Societies, 12th Edition*, I realized that EET provides only a partial account of how worldviews and institutions influence technologies, how technologies influence worldviews and institutions, and how worldviews and institutions interact. EET does not provide a systematic account of why societies with ideological or institutional options choose one type over another. Moreover, I found that the types of worldviews and institutions that EET discusses lacked strong theoretical and empirical bases.

EET's strength lies in its account of how technology shapes socio-cultural evolution. In particular, EET demonstrates the importance of subsistence technology, i.e., the means by which a society obtains energy, income, and wealth (Nolan and Lenski 2015). The "ecological" component of Ecological-Evolutionary Theory focuses on how environmental conditions in the distant past predisposed a society to one type of subsistence technology or another. For example, societies located on cultivable land suited to plow cultivation (e.g., soil) might transition from horticulture to agriculture, whereas societies located on cultivable land *not* suited to plow cultivation (e.g., clay) might transition from horticulture to herding (Nolan and Lenski 2015). In

recent years, EET has become somewhat dismissive of current environmental factors, such as climate change.

Despite these limitations, I decided to include EET in my model in two ways: by importing some of EET's definitions into the WITs framework; and by incorporating subsistence technology as a variable in the model. For variables related to worldviews and institutions, I turned to other literatures (discussed below).

2.3: The WITs frameworks

The concept of societal cultures as "interdependent sets of worldviews, institutions, and technologies", or "WITs," is widely attributed to Beddoe et al. (2009). However, there is an earlier paper that outlines a similar perspective (Matutinović 2007). In this section, I briefly compare, contrast, and synthesize these two versions of the WITs concept of societal cultures, or "WITs framework"; for simplicity, the WITs-B version (Beddoe et al. 2009), and the WITs-M version (Matutinović 2007).

2.3.1: The containers of WITs

In the WITs-B version, WITs comprise part of "socio-ecological regimes," which Beddoe et al. (2009, 2483) define as "a culture embedded in, and co-evolving with, its ecological context." In the WITs-M version, WITs comprise "socioeconomic systems," which Matutinović (2001, 245) defines as "'tentative solutions' to the problem of local adaptation of the human species…[that] are subject to selective pressures, environmental (biophysical, climatic) and cultural (including

ideologies)." While these definitions are similar, the WITs-M definition says what human systems are *for*, i.e., solving problems related to adapting to the environment. This problem-oriented definition of human systems establishes a linkage between WITs and human needs.

2.3.2: Units of analysis

The two versions of the WITs framework define their units of analysis (i.e., worldviews, institutions, and technologies) in similar terms, although there are some notable differences. First, the WITs-B version defines a worldview as "our perceptions of how the world works and what is possible, encompassing the relationship between society and the rest of nature, as well as what is desirable (the goals we pursue)" (Beddoe et al. 2009, 2484). The WITs-M version defines a worldview as "a set of beliefs, symbols, values, and segments of objective knowledge that are widely shared in a given society over a considerable period of time (for at least the life-span of one generation)" (Matutinović 2007, 3).[4] Elsewhere, Matutinović (2007, 2) clarifies that a worldview is "a society's…general attitude towards life and nature," which "provide[s] a general framework in which alternative visions of preferred futures might arise." So, the definitions are not too far apart.

Second, the WITs-B version defines institutions as "a culture's rules and norms," which "constrain individuals' behaviour, define a recognizable culture, and serve as problem-solving

[4] Matutinovic (2007, 1133) distinguishes 'objective' knowledge, which "can be socially accumulated and independently verified by other persons," from 'subjective' knowledge, "which refers to any kind of idiosyncratic, personal experience." Subjective knowledge would fall under the category of "beliefs." As both forms of knowledge are included under "perceptions of how the world works and what is possible," the WITs-B and the WITs-M versions of "worldview" have more or less the same meaning.

entities that allow societies to adapt to their environments" (Beddoe et al. 2009, 2484).[5] Whereas the WITs-M version assigns the problem-solving trait to socioeconomic systems as a whole, the WITs-B version reserves this trait for institutions specifically. The WITs-M version defines institutions as "a set of habits, rules, and norms that govern a socio-economic system's internal dynamics and regulate its behaviour with respect to the larger metasystem – nature" (Matutinović 2007, 3). Elsewhere, Matutinović (2007, 2) adds that institutions "shape human behaviour." Again, we can see that the definitions are quite similar. I find both definitions somewhat unwieldy, however, and prefer how Nolan and Lenski (2015, 49) define institutions: "durable answers to important and persistent problems." Answers take the form of expectations about behaviour, which typically elicit punishment if violated (Axelrod 1997). Problems include how to make collective decisions, to which different types of political system provide answers (e.g., dictatorship vs. democracy), and how to allocate scarce resources to alternative ends, to which different types of economic system provide answers (e.g., command vs. market).

The two versions of the WITs framework differ substantially in their definitions of technology. The WITs-B version defines technology as "the applied information that we use to create human artifacts…as well as the institutional instruments used to help us meet our goals" (Beddoe et al. 2009, 2484). This is also an unwieldy definition, and simpler ones are available. For example, Arthur (2014) defines technology as "means to human purposes." Although simpler and carrying more or less the same meaning, this definition is too broad, as it overlaps with the meanings of worldview and institutions. For example, worldviews and institutions are means to

[5] Arguably, it is WITs as a whole (i.e., worldviews, institutions, and technologies), and not just institutions, which "define a recognizable culture."

the human purpose of sense-making and problem solving, respectively. Nolan and Lenski (2015, 44) provide a distinct definition of technology: “information about how to use the material resources of the environment to satisfy human needs and desires.” The WITs-M version never supplies a definition of technology, but rather equates it to “patterns of production and consumption” (Matutinović 2007, 2) and “forces of production” (Matutinovic 2007, 1114). These concepts are somewhere between the definition of a technological system and an economic system. Since neither version of the WITs framework contains a clear and distinct definition of technology, I adopt the definition of technology provided by Nolan and Lenski (2015).

2.3.3: Origins

Both versions of the WITs framework reference Norgaard's (1994) co-evolutionary theory, which applies the concept of biological co-evolution to social and environmental systems. “In biology,” Norgaard (1994, 24) explains, “coevolution refers to the pattern of evolutionary change of two closely interacting species where the fitness of the genetic traits within each species is largely governed by the dominant genetic traits of the other.”

While both versions of the WITs framework acknowledge Norgaard (1994), only the WITs-M version explicitly builds on Norgaard’s work. According to Matutinović (2007, 2), the WITs-M version “is based on Norgaard’s (1994) co-evolutionary theory with one major addition – the explicit introduction of worldviews and institutions as units of analysis.” As Matutinović (2007, 1) shows, these units of analysis were already implicit in Norgaard’s theory:

> Social and environmental systems co-evolve such that environmental systems reflect the characteristics of the social systems – **their knowledge, values, social organization, and technologies** – while social systems reflect the characteristics of environmental systems – their mix of species, rates of productivity, spatial and temporal variation, and resilience [emphasis added] (Norgaard 1994, 36–37).

In contrast, the WITs-B version claims that 'worldviews, institutions, and technologies correspond to Meadows' "leverage points"' (Beddoe et al. 2009, 2483). Meadows (1999, 1) defined leverage points as "places within a complex system (a corporation, an economy, a living body, a city, an ecosystem) where a small change in one thing can produce big changes in everything." Meadows (1999) proposed a hierarchy of twelve leverage points, which Abson et al. (2017, 32) have since simplified to a hierarchy of four: parameters, feedbacks, design ("social structures and institutions"), and intent ("values, goals, and worldviews"). Beddoe et al. (2009) do not indicate which of their units of analysis correspond to which set of leverage points. The conceptual overlaps between "worldview" and "intent", and between "institutions" and "design," are straightforward enough. "Technology," "feedbacks," and "parameters," on the other hand, are distinct (albeit related) concepts. Given how Beddoe et al. (2009) define "technology," equating technology with feedbacks and/or parameters requires somewhat of a conceptual stretch (Sartori 1970).[6]

[6] The term "design" might also be taken to refer to technology, and not just, as used by Abson et al. (2018), to refer to social structures and institutions.

2.3.4: Dynamics of co-evolution

In Norgaard's (1994) co-evolutionary theory, social systems consist of four sub-systems: knowledge and values (together: worldviews), social organization (institutions), and technology. Each subsystem consists of various "types." For example, the values sub-system consists of various types of values, such as collectivism vs. individualism. "The dominance, or frequency," Norgaard (1994, 32) explains, "of each particular type in each subsystem is explained by its fitness with respect to the types of things in the other subsystems….With each subsystem applying selective pressure on each of the other subsystems, they all reflect each other." At the same time, the social system co-evolves with the environment, such that environmental types influence the fitness of societal types, and vice versa (Norgaard 1994). In general, Norgaard (1994) argues, neither of these systems, nor any of their sub-systems, is more important than the other; the influence that a change in one (sub)system has on another depends entirely on context.

The context of industrialized societies has been shaped by conquest and later, by the development of fossil fuel technologies, which gave people "the sense of being free from or having control over nature and being able to consciously design their future" (Norgaard 1994, 40). This "apparent freedom" is due to the long delays between human activities (e.g., combustion of fossil fuels) and the appearance of cumulative effects (e.g., climate change) (Norgaard 1994, 42). Over time, fossil fuel technologies have allowed industrialized societies to overcome ecological limits (Ellis 2015), such that industrialized societies now lack "the features needed to interact with and continue to coevolve effectively with ecosystems" (Norgaard 1994,

42). This situation is temporary and may be nearing its end, as industrialized societies overexploit resources locally and abroad (Krausmann et al. 2018). Hence, societies face a choice: proactively re-establish a co-evolutionary relationship with the environment (i.e., transform our cultures towards sustainability) or wait for environmental feedbacks to re-establish that relationship – potentially at much greater cost (i.e., crises).

Norgaard (1994) provides a number of warnings about societal transformations to sustainability. First, since the future is unpredictable (the future depends not only on today's culture and environment but also on a number of unpredictable future factors), sustainability transformations are experiments. As experimentation is risky, sustainability transformations should be undertaken "cautiously on a small scale with as much monitoring of the evolutionary chain of events thereafter as possible" (Norgaard 1994, 42). Second, experiments should be short-term, so that undesirable effects can wear off or be undone quickly (Norgaard 1994). Third, sustainability transformations should preserve cultural diversity, since diversity increases a system's ability to cope with change (i.e., resilience) (Norgaard 1994). Fourth, the introduction of a new worldview, institution, or technology is unlikely to shift how a society functions, as the new feature is likely to be selected against (Norgaard 1994). Thus, new features may require protection while other social subsystems undergo change (Geels and Schot 2007).

Our ability to forecast the co-evolution of cultures and environments is inherently limited. For one, we do not know what new variants of worldviews, institutions, and technologies might emerge, or how they will interrelate. For another, we do not know how the relationships among the *existing* variants of worldviews, institutions, and technologies might respond to events that have never been observed. For example, how might existing WITs respond if the Holocene state

of the Earth System collapses? Since we cannot run randomized, controlled experiments on real societies, we cannot *know* answers to these questions. The best that we can do is to hypothesize about how cultures and environments might co-evolve, and to use these hypotheses – cautiously – to guide our actions.

2.4: Worldviews

2.4.1: Section Introduction

There are two components to the WITs-B definition of worldview: (1) perceptions of how the world works and what is possible, encompassing the relationship between society and the rest of nature, and (2) perceptions of what is desirable (i.e., the goals that we pursue) (Beddoe et al. 2009). In other words, a worldview is a socially shared system of ideas about what *is* and about what *ought* to be. By providing answers to these questions, a worldview helps to integrate a society's various components into a cohesive system (Turner 2014).[7] In this section, I discuss two interrelated perceptions that are central to worldviews: whether the world is seen as progressive, and whether the world is seen as safe vs. dangerous. Second, I discuss three dimensions along which the values of contemporary societies seem to vary: collectivism-individualism, duty-joy, and distrust-trust.

[7] "Values are…used to choose between alternative possible technologies and institutions" (Norgaard 1994, 31).

2.4.2: "Modern" and "pre-modern" worldviews

The ways in which we see the world, and the things which we value, have changed throughout human history. Some scholars distinguish "modern" from "pre-modern" worldviews; the line dividing the "modern" era from the "pre-modern" era varies but is often associated with the Scientific Revolution. For example, Berman (1981) argued that people in pre-modern societies perceive themselves as active participants in the cosmos; their lives, and the 'life' of the cosmos, are intertwined, and this relationship gives life meaning. Berman (1981) called this worldview "participating consciousness." In contrast, people in modern societies perceive themselves as separate from the cosmos; consequently, Berman (1981) contended, they perceive life as lacking meaning. Berman (1981) called this worldview "scientific consciousness." For Berman (1981, 12), "issues of meaning" are "the fundamental issues confronted by any civilization in its history, or by any person in his or her life." While I agree that meaning is *an* important issue for any society or individual (i.e., a need), I believe that Berman (1981) overstates his case.[8] Modern societies are not bereft of meaning. National cultures developed as a source of meaning for early modern societies and have remained important to this day (Anderson 1991). In contemporary societies, a vast diversity of cultural worldviews co-exists alongside national cultures (Solomon, Greenberg, and Pyszczynski 2015). Moreover, a worldview that integrates

[8] While 'meaning' may be 'fundamental' in the sense of being a 'need', I do not see how it can be 'the' fundamental need, if by 'fundamental' Berman (1981) means 'the most important need.' Here I agree with Maslow (1943) in prioritizing survival needs over "issues of meaning."

science with a contemporary form of spirituality may be in the process of emerging (Hedlund-de Witt 2013).[9]

The modern worldview has also been characterized by a belief in the inevitability of progress in the sense of increasing control and material growth (Norgaard 1994). Understood this way, science and progress have gone hand-in-hand (Nolan and Lenski 2015). Knowledge about how the world works and what is possible decreases danger (e.g., by reducing risks and uncertainties, and by increasing control), which, in turn, creates a more stable and predictable environment for the accumulation of more knowledge (Quilley 2010). The sense of progress as increasing control and material growth, however, appears to be limited to societies in which people feel unsafe (Inglehart and Welzel 2005). Drawing on data from the World Values Survey, Welzel (2013) showed that as societies become safer they undergo a shift from "survival values," which emphasize control and material growth, to "emancipative values," which emphasize freedom and development. Of course, the feeling of safety in 'highly developed' societies depends on extensive controls over nature and society (via institutions and technologies) and self (via self-restraint) (Quilley 2010), and a loss of control in any of these areas could cause survival values to resurface (Inglehart and Welzel 2005).

[9] In her dissertation on the "integrated worldview" and its potential to help usher in sustainable societies, Hedlund-de Witt (2013, 33) defines "contemporary spirituality" as "post-traditional, non-dogmatic, frequently non-institutionalized, more individualistic forms of religious, inner-growth, or meaning-oriented practices, beliefs, and experiences." This theme has also been explored by quantum physicists (Bohm 1980), evolutionary biologists (Kauffman 2008), environmental psychologists (Nisbet, Zelenski, and Murphy 2009), political scientists (Ophuls 2011), natural conservationists (Zylstra et al. 2014), sustainability scientists (Ives et al. 2017), and complex systems theorists (Abson et al. 2017).

2.4.3: Cultural dimensions

Welzel's (2013) "Theory of Emancipation" builds on Inglehart and Welzel's (2005) "Revised Theory of Modernization," which is itself inspired by Maslow's (1943) hierarchy of needs. While Welzel (2013) postulated a single value dimension along which societies vary (i.e., survival vs. emancipation), other theories have argued that there are several. For example, Schwartz (2004) proposed three dimensions, while House et al. (2004) proposed nine dimensions.[10] An advantage of Welzel's (2013) theory is that it explains changes in societal values as responses to how people perceive the world, i.e., safe vs. threatening. In doing so, Welzel's (2013) theory captures the two components of the WITs-B definition of worldviews: perceptions of how the world is, and values (i.e., beliefs about how the world should be).[11]

In a recent paper, Beugelsdijk and Welzel (2018) extended Welzel's (2013) theory of emancipation by integrating it with a highly cited theory of societal values: Cultural Dimensions Theory (Hofstede, Hofstede, and Minkov 2010). Hofstede (1980) analyzed data from a survey of

[10] A meta-analysis of the leading theories of societal values found nine factors (Maleki and de Jong 2014). The meta-analysis included most of the dimensions from these theories, excluding only those dimensions for which the availability of data was limited. Several of these theories use samples of questionable national representativeness. For example, Schwartz (2004) relies on data from the European Values Survey for European countries, and student-teacher samples for countries outside of Europe. Similarly, House et al. (2004) rely on samples from managers in domestic organizations. By adopting nearly all of the dimensions from the various theories, the meta-analysis also adopts all of their limitations, including issues of national representativeness. For this reason, I do not use any of these theories in my dissertation.

[11] Research in social psychology confirms a relationship between perceptions of the world and values. Archival research has shown that threatening situations are associated with a shift towards political conservatism (McCann 2008; Willer 2004; Davis and Silver 2004; Doty, Peterson, and Winter 1991), which Jost, Federico, and Napier (2013, 236) define as "resistance to change and acceptance of inequality." According to Jost, Federico, and Napier (2013), people tend to adopt values that cohere with their needs, a process which they call "motivated social cognition." Threatening situations raise the need to manage fear, threat, and anxiety (existential needs) and the need to reduce uncertainty (epistemic needs). When these needs are high, the status quo is more likely to be perceived as a source of safety and certainty (Jost, Federico, and Napier 2013). Thus, threatening situations favour stability rather than change.

Table 2.1: Common basic problems and cultural dimensions.

Common basic problem (Inkeles and Levinson 1969)	Descriptions of factors from IBM survey (Hofstede 1980)	Labels for cultural dimensions (Hofstede 1980)
Relation to authority	Dependence on superiors	Power distance
Concept of self	Balance between individual goals and dependence on company	Collectivism vs. individualism
	Balance between ego values and social values	Masculinity vs. femininity
Dilemmas/conflicts	Need for rules and predictability	Uncertainty avoidance

IBM employees in over 50 countries and found that countries could be distinguished by four value dimensions, which he labelled power distance, collectivism vs. individualism, femininity vs. masculinity, and uncertainty avoidance. [12] Hofstede, Hofstede, and Minkov (2010) later incorporated two additional value dimensions, based on analysis of data from the World Values Survey: long-term vs. short-term orientation, and indulgence vs. restraint.

Cultural Dimensions Theory is based on the idea that values, which Hofstede, Hofstede, and Minkov (2010) defined as "broad tendencies to prefer certain states of affairs over others" (p. 9), comprise the "software of the mind" (p. 22), which provides instructions for handling "common basic problems" (p. 44) faced by all societies.[13] Hofstede (1980) argued that the first four value dimensions empirically confirmed the existence of three common basic problems proposed by Inkeles and Levinson (1969), namely: relation to authority, concept of self, and

[12] Hofstede, Hofstede, and Minkov (2010) reported six studies, carried out between 1990 and 2002, which replicated some or all of the original four dimensions. The replication studies covered various groups (e.g., elites, pilots, consumers) in between 14 and 28 countries.

[13] Hofstede, Hofstede, and Minkov (2010) attribute the idea of different societal answers to common basic problems to Ruth Benedict (1887 – 1948) and Margaret Mead (1901 – 1978). Over the 20th century, various social scientists attempted to identify the "common basic problems."

dilemmas/conflicts.[14] Table 2.1 compares the common basic problems, the descriptions of the factors from the IBM survey, and the labels assigned to the factors.

2.4.3.1: Limitations of Cultural Dimensions Theory

The fit between the common basic problems and the factor descriptions is not so bad. The same cannot be said about the fit between the factor descriptions and their labels. For example, it turns out that the reason why Cultural Dimensions Theory assigns the label "masculinity vs. femininity" to the description "balance between ego values and social values" is that, in the IBM survey, men tended to value "money and careers," while women tended to value "cooperation and a good living environment" (Hofstede 2011, 7).[15] The situation only gets murkier when we consider the *definitions* that Cultural Dimensions Theory assigns to its labels, which seem to be forever changing depending on where one looks. Here are three definitions that Cultural Dimensions Theory offers for "masculinity vs. femininity:"

- "the desirability of assertive behavior against the desirability of modest behavior" (Hofstede, Hofstede, and Minkov 2010, 136);
- "the division of emotional roles between women and men" (Hofstede 2011, 8); and,
- "the extent to which the use of force is endorsed socially" (Hofstede 2020).

[14] According to Hofstede (2011, 5), Inkeles and Levinson (1969) distilled their three common basic problems, which they called "standard analytic issues," from "all available sociological and anthropological studies dealing with what was then called *national character*, which they interpreted as a kind of modal (most common) personality type in a national society [emphasis in original]."
[15] Be that as it may, the label fails to distinguish between male vs. female (sex) and masculine vs. feminine (gender).

Since factors consist of multiple items, it makes sense that masculinity vs. femininity could be described in so many ways. The trouble is that these definitions do not correspond to *any* of the items from the IBM survey that loaded onto the masculinity vs. femininity factor. The items in the IBM survey dealt with the importance attached to earnings potential, job recognition, opportunities for advancement, feeling challenged by one's work, having good working relationships with one's supervisor and colleagues, living in a desirable area, and employment security (Hofstede, Hofstede, and Minkov 2010). With these items in view, it becomes less clear how the misleadingly labelled "masculinity vs. femininity" value dimension relates to the common basic problem "concept of self."[16]

The conceptual and empirical problems in Cultural Dimensions Theory are not limited to the masculinity vs. femininity dimension. Several replication studies have shown that power distance and collectivism vs. individualism comprise a single factor (Beugelsdijk and Welzel 2018; Minkov 2018; Smith, Dugan, and Trompenaars 1996); that long-term vs. short-term orientation and indulgence vs. restraint comprise a single factor (Beugelsdijk and Welzel 2018); and that the uncertainty avoidance and masculinity vs. femininity dimensions are not factors at all (Minkov 2018).

[16] Hofstede, Hofstede, and Minkov (2010, 144) suggested that the label "performance-oriented vs. cooperation-oriented" would be an acceptable alternative for the masculinity vs. femininity factor.

2.4.3.2: Building on Cultural Dimensions Theory

Despite these limitations, Beugelsdijk and Welzel (2018) saw in Cultural Dimensions Theory an opportunity to rectify a weakness in Welzel's (2013) Theory of Emancipation: its reduction of cultural diversity to a single value dimension (i.e., safety vs. emancipation). Beugelsdijk and Welzel (2018, 1471) used nationally representative samples of attitudinal items from the World Values Survey and the European Values Survey to "uncover a better validated set of cultural dimensions inspired by Hofstede."[17] They selected items from the surveys that resonated "on at least some level of intuition with the themes looming in the debate about [cultural dimensions theory]" and that satisfied the following conditions: wide country coverage, coverage in multiple waves of the World Values Survey and the European Values Survey, attitude-based, and significantly correlated with, or previously used to calculate, the country scores of any of the dimensions in Cultural Dimensions Theory (Beugelsdijk and Welzel 2018, 1476–77).[18] Fifteen items met these conditions. Beugelsdijk and Welzel's (2018) analysis uncovered three factors, which the authors labeled "Collectivism – Individualism," "Duty – Joy," and "Distrust – Trust." Together, these factors explained 72% of the variation in the set of 15 items (27%, 26%, and 19%, respectively) (Beugelsdijk and Welzel 2018).

[17] Their dataset covered 495,011 adults ($\geq$ 18 years) in 110 countries over the period 1981 – 2014. The period 1981 to 2014 includes individuals born between 1900 and 1999 and thus covers one century of "formative years" (Beugelsdijk and Welzel 2018, 1477). Inglehart and Welzel (2005) argued that people acquire their values during their formative years.

[18] The country scores for long-term vs. short-term orientation and for indulgence vs. restraint were calculated using data from the World Values Survey (Hofstede, Hofstede, and Minkov 2010).

Beugelsdijk and Welzel (2018, 1481–82) conceptualized Collectivism – Individualism as follows:

> Individualist cultures replace the individual's dependence on particular support groups, especially family and acquaintances, by a more anonymous form of dependence on impartial institutions and universal norms. Impartiality and universalism liberate people from obligations to the extended family. Communal affiliations and commitments continue but are chosen rather than imposed. People set their own goals rather than looking to fulfill the expectations of others… There is a high tolerance of deviation from specific in-group norms, and a low emphasis on conformity and obedience, again especially to expectations from parents or other family…

Beugelsdijk and Welzel (2018) conceptualized Duty – Joy as the extent to which the members of a society feel free to enjoy life and have fun, which is more or less how Hofstede, Hofstede, and Minkov (2010) conceptualized Indulgence vs. Restraint.

Finally, Beugelsdijk and Welzel 2018, (1484) conceptualized Distrust – Trust as "the degree to which members of society are comfortable in unstructured situations [i.e., absence of rules and order], or if such situations create stress and anxiety," which resembles how Cultural Dimensions Theory defines Uncertainty Avoidance.

2.4.4: Section Summary

Beugelsdijk and Welzel's (2018) synthesis of the Theory of Emancipation (Welzel 2013) and Culture Dimensions Theory (Hofstede, Hofstede, and Minkov 2010) is a well-validated and parsimonious model of societal worldviews. Collectivistic and dutiful societies tend to see the world as dangerous, while individualistic and joyful societies tend to see the world as safe (Beugelsdijk and Welzel 2018). There is no clear association between trust and safety, which suggests that the Distrust – Trust dimension may be associated with a different type of perception of the world. Judging from the items that load onto the Distrust – Trust factor, and the items that correlate with it, I would infer that the rise in distrust over the past few decades is attributable to perceived unfairness in political processes and outcomes, as well as rising economic inequality. Worldwide, support for democracy is high (Wike et al. 2017), even among non-democratic societies, while satisfaction with democracy is low (Wike, Silver, and Castillo 2019), perhaps because many democracies have failed to deliver greater economic equality. Taken together with the rising levels of distrust, these trends may suggest that participation and freedom needs are going unmet (perhaps because expectations are rising), and that societies may be ripe for transformations towards (deeper) democracy.

In the next section, I turn to institutional systems. While worldviews help a society to choose among alternative solutions to common basic problems, institutional systems are the solutions. For example, democracy is one possible solution to what I would argue is a common basic problem of organizing collective decision making in a society. In general, solving this problem is the function of a society's political system.

2.5: Institutions

2.5.1: Section Introduction

Contemporary societies consist of a variety of institutional systems, including kinship, religion, education, science, medicine, law, politics, and economy (Beddoe et al. 2009; Turner 2003). Without denying the importance of any of these institutional systems, I focus on the political system and the economic system. By shaping how collective decisions are made and how scarce resources are allocated to alternative ends, these two institutional systems strongly influence individuals' capabilities to fulfill their needs (Deneulin 2008; Sen 1999) and societies' interactions with other societies and their natural environment (Beddoe et al. 2009; Matutinović 2007; Norgaard 1994). The political system and the economic system shape societies' circumstances and, consequently, the perceptions and values of their members (i.e., worldviews). Thus, there are feedbacks between worldviews and institutional systems: through their effects on societies' circumstances, institutional systems influence societies' worldviews, and societies' worldviews influence their choice of institutional systems.

2.5.2: Political system

There are a variety of definitions of "political system," "politics," and "polity." Turner (2003, 78) defined "polity," or political system, as "the consolidation and centralization of power in the hands of leaders who possess the capacity to make binding decisions on members of a

population and, in so doing, coordinate activities, allocate tasks, distribute valued resources, and maintain social control." Lasswell (1936) defined "politics" similarly as the process that determines "who gets what, when, and why." For Nolan and Lenski (2015, 50), "polity" is the system of institutions that "focuses on the distribution of power and the governance of society." In my view, a political system is a system of institutions for organizing collective decision-making in a society, i.e., decisions that are *made by* the collective. The collective is a sub-set of a society's population. Generally speaking, the collective is only a tiny fraction of the population in autocratic societies, and may be as small as a single person in a hereditary monarchy, while the collective is quite large in democratic societies, and may equal the entire adult citizenry in directly democratic societies. The American political scientist Robert Dahl referred to this type of variation in political systems as "inclusiveness" (Dahl 1971). Political systems also vary in the extent to which members of the collective are free to formulate and express preferences and to have their preferences counted equally in decisions. Dahl (1971) referred to this type of variation in political systems as "contestation."

With these two dimensions, Dahl (1971) constructed a typology of political systems (Table 2.2). Political systems with high contestation and high inclusiveness are "polyarchies," which means "many rule." For Dahl (1971), "democracy" was an ideal and unattainable type of political system in which leaders would respond perfectly to the preferences of non-leaders; polyarchy was the best type of political system that Dahl believed was actually attainable. The other three types of political system in Dahl's (1971) typology are: competitive oligarchy (high contestation, low inclusiveness); inclusive hegemony (low contestation, high inclusiveness); and, closed hegemony (low contestation, low inclusiveness).

Table 2.2: Types of political systems in polyarchy theory.

		Inclusiveness	
		Low	High
Contestation	High	Competitive oligarchies	Polyarchies
	Low	Closed hegemonies	Inclusive hegemonies

Empirical research supports the existence of Dahl's two dimensions of political systems. Coppedge, Alvarez, and Maldonado (2008) carried out a principal component analysis of nineteen variables, selected for their relevance to Dahl's (1971) theory. They found that, in the years 1950 to 2000, approximately 75% of the variation in political systems, as measured by these indicators, could be explained by two components (Coppedge, Alvarez, and Maldonado 2008a). They interpreted the first component, which explained roughly 62% of the variation, as representing Contestation, and they interpreted the second component, which explained roughly 12% of the variation, as representing Inclusiveness.

Coppedge, Alvarez, and Maldonado (2008) found that most of the political systems in their dataset were closed hegemonies, inclusive hegemonies, and polyarchies, with relatively few competitive oligarchies. Their study showed that Dahl's (1971) two theoretical dimensions do an exceptional job at representing variation in important features of contemporary political systems (Coppedge, Alvarez, and Maldonado 2008a).

2.5.3: Economic system

The concept of an "economic system" is defined differently in various fields. For example, evolutionary sociologists have defined it as "the gathering of resources, the conversion of resources into usable commodities, and the distribution of these commodities to members of a population" (Turner 2003, 58), or as a system of institutions that "centers on the production and distribution of valued goods" (Nolan and Lenski 2015, 50). Evolutionary economists have defined it as "the production of goods and services, their distribution, and their consumption," (Pryor 2005, 6), or as "the set of arrangements and activities by which a society fulfills its needs" (Arthur 2014, 19). Ecological economists have defined it as "the allocation of scarce resources among alternative ends" (Daly and Farley 2010, 11). These are just a few examples.

Many of the aspects in the above definitions of "economic system" refer to activities that belong to technology, as I see it. These activities include gathering, conversion, and production. The concepts "economy" and "technology" are often intertwined, but in keeping with the WITs framework I think it is important to distinguish them. I follow Daly and Farley (2010) who limit the concept of "economic system" to the allocation of scarce resources to alternative ends. Different economic systems, then, consist of different rules and norms related to the means of allocation, the concept of resources, and the recognition of ends (Table 2.3).

Nolan and Lenski (2015, 256) defined four types of economic system: kinship, command, market, and mixed.[19] At the level of most contemporary societies (i.e., nation-states), only the latter three types of economic system exist. In a command economy,

> Basic choices among economic alternatives are made by a tiny political elite. Sometimes these decision makers claim to act on behalf of the population as a whole, but they are not willing to transfer their enormous decision-making power to the larger population on whose behalf they claim to act (Nolan and Lenski 2015, 256).

In a market economy,

> Producers freely exchange what they produce for goods and services produced by others. Prices are set by the forces of supply and demand, that is, by the relative quantity and quality of the various things that are available and by the relative eagerness of would-be consumers. As this suggests, decision making is considerably more dispersed than in a command economy (Nolan and Lenski 2015, 256).

[19] In hunting and gathering societies, there were no specialized institutional systems, such as the economy. Rather, the kinship system organized politics, economics, etc.

Market economies also have several important limitations. For instance, markets force owners to compete with one another, which, in turn, compels them to prioritize profits over the wellbeing of workers, society, and the environment (Nolan and Lenski 2015; Turner 2014; Marx 1867). Consequently, most contemporary societies have created mixed economies, which temper markets with laws and regulations that protect workers, society, and the environment (Nolan and Lenski 2015; Polanyi 2001).[20] Ecological economists have proposed a new type of mixed economy, which would introduce additional laws and regulations intended to achieve a sustainable scale, just distribution, and efficient allocation (Costanza et al. 2013; Daly and Farley 2010).[21]

These categories may seem quite neat and tidy, but empirical research on economic institutions shows that they are entirely sensible. Pryor (2005) cluster analyzed the economic

Table 2.3: Norms defining contemporary economic systems.

	Means of allocation	Concept of resources	Recognized ends
Command	Government directives	Varies	Varies
Market	Price signals/forces of supply and demand	Built, financial, human, and social capital	Economic growth
Mixed	Government directives & price signals/forces of supply and demand		Economic growth and human well-being
Ecological		Built, human, social, and natural capital	Sustainable scale, just distribution, efficient allocation

[20] For example, health and safety laws, minimum wage laws, unemployment insurance systems, and mandatory employer contributions to retirement savings plans (Nolan and Lenski 2015).
[21] For example, direct regulation, Pigouvian taxes and subsidies, and tradeable permits to achieve sustainable scale; caps on income and wealth, minimum income, employee and community shareholder programs to achieve just distribution; and pricing and valuing nonmarket goods and services to achieve efficient allocation (Daly and Farley 2010).

institutions of developed and developing countries in 1990. His dataset consisted of more than two-dozen indicators drawn from various sources and related to the product market, the labour market, the production and business sector, the government sector, and the finance sector.[22] Pryor's (2005) cluster analysis identified eight clusters: four clusters in developed countries, labelled Anglo-Saxon+, Nordic, Western European, and Southern European; and, four clusters in developing countries, labelled Traditional, Business-oriented, Labour-oriented, and Statist.

Each of Pryor's (2005) clusters closely corresponds to one of Nolan and Lenski's (2015) ideal types, as shown in Table 2.4. The economies in the Anglo-Saxon+ and the Business-oriented

Table 2.4: Correspondence between theorized types of economic system and empirical clusters of economic institutions.

Pryor (2005)	Markets	Government	Nolan & Lenski (2015)
Anglo-Saxon+	Strong	Weak	Market
Business-oriented			
Nordic	Strong	Strong	Mixed
Western European			
Southern European			
Labour-oriented			
Statist	Weak	Strong	Command
Marxist			
Traditional			

[22] 40 indicators for developed countries, 31 indicators for developing countries (Pryor 2005).

clusters correspond to the market type (e.g., strong markets, weak government), while the economies in the Nordic, Western European, and Southern European clusters correspond to the mixed type (e.g., strong markets, strong government). The economies in the Traditional, Labour-oriented, and Statist clusters, as well as Marxist economies, correspond to the command type (e.g., weak markets, strong government).[23]

2.5.4: Section Summary

Coppedge, Alvarez, and Maldonado (2008) provided empirical support for Dahl's (1971) theory of polyarchy, which proposed that political systems vary along the dimensions of contestation and inclusiveness. Pryor (2005) provided empirical evidence of eight types of economic system, which I matched to Nolan and Lenski's (2016) ideal types (i.e., command, market, and mixed).

The political system defines who in society is counted as a member of the collective, and how free members of the collective are to formulate and express their preferences and to have their preferences counted equally in decisions. In essence, the political system determines (formally) who is capable of contesting the status quo, e.g., by raising problems for public consideration, and by proposing and participating in the selection of solutions. The economic system influences these capabilities by shaping the distribution of free time, income, and other resources, which affects whether a *formal* member of the collective can act as an *effective*

[23] Pryor (2005, 225) analyzed Marxist economies separately from other contemporary economies and without cluster analysis due to "a paucity of readily available quantitative information on their institutions and how they actually function (in contrast to how they were supposed to function)."

member of the collective. All else being equal, a person with extensive political rights but limited time away from work and family responsibilities will not be as able to formulate and express preferences as one with ample time. Thus, the distribution of resources among the collective affects the extent to which formal capabilities are effectively realized.

The economic system defines how scarce resources are allocated among alternative ends. Command economies use government directives to allocate resources, market economies use price signals and forces of supply and demand, and mixed economies use a combination of the command and market mechanisms of allocation. Market economies emphasize economic growth, while mixed economies emphasize human well-being alongside economic growth, especially in the form of worker protections. The objectives of command economies vary. Ecological economies are envisioned as emphasizing different ends: sustainable scale, just distribution, and efficient allocation. Just as the economic system affects the political system, so too does the political system affect the economic system. Societies with exclusive political systems, in which the collective is small, are able to exercise greater control over the allocation of resources than societies with inclusive political systems, in which the collective is relatively large. Thus, markets in societies with exclusive political systems may leave individuals with less freedom of choice than markets in societies with inclusive political systems.

The next section focuses on technology. While worldviews influence the choices that societies make about alternative solutions (e.g., alternative political systems) to common basic problems (e.g., collective decision-making), technologies determine which types of solutions are possible, on the one hand, and the extent to which needs can be fulfilled, on the other.

2.6: Technology

2.6.1: Section Introduction

Nolan and Lenski (2015) defined technology as *information* about how to use the environment to meet human needs. They referred to technology in the singular, as they contended that there is an "underlying unity to this store of information" (Nolan and Lenski 2015, 44). This unity is organized around *subsistence* technology, i.e., the information that a society uses to "obtain the energy that its members require" (Nolan and Lenski 2015, 67).[24] All other types of technology, such as communications and transportation, are associated with different levels of subsistence technology. For example, railroads tend to be found in industrial societies, as the simplest trains required the steam engine – an industrial-era invention.

Contemporary societies employ a mix of agricultural, industrial, and 'post-industrial' or 'service-level' technologies. Examples of these technologies include plows, irrigation, and roads (agricultural); fossil fuel energy, factories, and railroads (industrial); and nonbiological energy (e.g., solar, wind), robotics, and the Internet (post-industrial) (Ellis 2015). This section provides an overview of long-term trends in technological development and more recent trends in contemporary societies.

[24] Nolan and Lenski (2015) distinguished seven 'levels' of subsistence technology, with each level producing more energy than the last: hunting and gathering, fishing, horticulture, herding, agriculture, maritime, and industry. Horticulture and agriculture also have "simple" and "advanced" variants, and there are transitional industrial types: industrializing horticultural, and industrializing agricultural.

2.6.2: Technology and economic surplus

Contemporary political systems, whether hegemonic or competitive, exclusive or inclusive, are complex, consisting of countless institutions and specialized occupations. Economic systems are just as complex, if not more so. Sustaining all that complexity requires an *economic surplus*, which Nolan and Lenski (2015, 410) define as "production that exceeds what is needed to keep the producers of essential goods and services alive and productive." With an economic surplus, a society can afford to keep some of its members alive and well while they perform other activities, such as government, trade, and science (Nolan and Lenski 2015). As activity in these areas increases, so too does a society's complexity and, with it, a society's demand for energy and other resources. To some extent, this increasing demand for energy and resources can be offset by technological innovations that unlock new sources of energy and resources or that enhance the efficiency of existing technologies, thereby decreasing the demand for energy and resources per unit consumption – a process referred to as "decoupling." However, increases in efficiency have tended to be offset by increases in consumption – a process referred to as "rebounding" (Jackson and Senker 2011).

2.6.3: Long-term technological development

For thousands of years, human societies had virtually no economic surpluses, as they relied on hunting and gathering technologies (Nolan and Lenski 2015). With the shift to horticultural technologies, human societies began a march of ever-increasing energy and

resource consumption and environmental impacts. Today, most societies use a mix of agricultural and industrial technologies to produce large economic surpluses (Nolan and Lenski 2015). Recognizing the finite capacity of our planet, and the fragility of its ecosystems, ecological economists have called for human societies to change course – away from ever-increasing energy and resource consumption and environmental impacts, and towards a "steady state" in which consumption and impacts are stable or decreasing (Daly and Farley 2010). Such a shift would require the rapid upscaling of sustainable technologies and practices, especially in energy systems.

2.6.4: Technological development in contemporary societies

Since 1990, the share of renewable energy technologies in total final energy consumption worldwide has remained stable around 17% (IEA et al. 2020). Meanwhile, energy consumption has continued to soar. From 1994, the year in which the United Nations adopted the Framework Convention on Climate Change, to 2014, a year before the UN adopted the Sustainable Development Goals, worldwide energy consumption increased by 20%, or 1% per year (World Bank 2020). Alongside this trend in energy consumption is a worldwide decrease in the share of GDP taken up by agricultural and industrial activities. In 1995, agriculture and industry accounted for 45% of worldwide GDP, but by 2018 that amount had shrunk to 35% (The World Bank 2020). Today, many countries, especially those in Europe and North America, produce most of their GDP in the form of services, rather than agriculture and industry. Agriculture and industry remain the

main contributors to GDP in many countries, however, particularly in parts of Asia, Africa, and Latin America.

2.6.5: Section Summary

The worldwide increase in services as a share of GDP is part of a long-term process of increasing societal complexity (e.g., increasing division of labour) and energy and resource consumption.

2.7: Social and Natural Environment

2.7.1: Section Introduction

The interactions that societies have with their social and natural environments are myriad. Societies trade and war with one another, people migrate among societies, and ideas flow across borders (Nolan and Lenski 2015). Ecosystems provide societies with valuable resources and services, while societies maintain, enhance, and sometimes destroy those ecosystems (Ellis 2015). In this section I will briefly discuss two of the most important ways in which societies interact with their environments: inter-societal competition, and exploitation of the Earth's ecosystems. Perhaps more than any of the other ways in which societies interact with their environments, these two types of interactions shape what a society can and cannot do.

2.7.2: Inter-societal competition

Since at least the horticultural era, societies have interacted with one another in ways that have generated global hierarchies, in which some societies are militarily and economically dominant, while others are dependent (Chase-Dunn and Lerro 2015; Wallerstein 1974). Kentor (2000) factor analyzed ten variables, selected for their relevance to military and economic position (e.g., military exports, foreign ownership of capital) and found four factors, which he labelled "economic power," "military power," "economic dependence," and "military dependence." He then carried out a second factor analysis, constraining the number of factors to one. The military and economic variables loaded positively onto the factor, while the dependence variables loaded negatively (Kentor 2000). With this single factor, Kentor (2000) produced country scores for 1990, which indicated a country's relative position in the global hierarchy. To compare country positions over time, Kentor (2000) used three variables (for which the availability of data by country and year was adequate): GDP, GDP per capita, and military expenditures, which correlated strongly with the original country scores (.71, .86, and .91, respectively). Factor analyzing these variables, Kentor (2000) produced country scores for 1900, 1930, 1950, 1970, and 1990. Countries with high scores are referred to as "core" countries: they are, relative to the other countries, militarily and economically dominant. Countries with low scores are referred to as "peripheral" countries: they are, relative to the other countries, militarily and economically dependent. The results of Kentor's (2000) analysis are unsurprising. In 1990, at the end of the Cold War, the country at the top of the global hierarchy was the United

States, followed by the USSR, Japan, China, and Germany. At the bottom of the hierarchy were Chad, Mali, Ethiopia, and the Congo (then, “Zaire”).

Kentor's (2000) analysis quantifies inequalities of military and economic power in the global system of societies. All else being equal, societies with more military and economic power are better able to fulfill the needs and desires of their members than societies with less military and economic power. Moreover, just as owners of capital have to compete with one another in order to maintain their status as owners, so too do societies in the core have to compete with one another in order to maintain their status as core countries; often this comes at the expense of other societies and the environment (Wils, Kamiya, and Choucri 1998; Choucri and North 1975).

Competition over position in the global hierarchy diverts resources from the fulfillment of human needs. Ecological economists refer to the resources that are spent on competition for position as “regrettably necessary defensive expenditures” (Daly and Farley 2010). These defensive expenditures are regrettably necessary because the only way to lessen them is to change the institutions that compel societies to compete with one another for position, i.e., the international system. In the international system that exists today, competing societies identify negatively with each other’s security, inferring intentions from capabilities and worrying about relative gains and losses (Wendt 1992). In a more cooperative international system, societies would identify positively with one another, perceiving “the security of each…as the responsibility of all” (Wendt 1992, 400).

According to Wendt (1992), getting from a competitive to a cooperative international system would require the existence of a shared problem, which competition cannot solve, and

for which the perceived benefits of cooperation outweigh the perceived costs. While climate change should qualify as such a problem, the slow progress towards decarbonization of energy systems and the consistently high military expenditures in many core countries suggests that competition for position remains a higher priority than mitigation of climate change. Raskin (2016, 32) has suggested that societal transformations towards sustainability may depend on the emergence of a global citizens' movement that can "redirect policy, tame corporations, and unify civil society." If Raskin is right, then hope for transformation lies not in persuading the leaders of competitive countries to identify positively with one another, but in replacing them with citizens who already harbour a global identity.

2.7.3: Exploitation of the Earth's ecosystems

Societies draw on a variety of land types for natural resources and services, including cropland for agriculture, grassland for livestock, lakes and oceans for aquaculture, and forests for timber products and carbon sequestration (Borucke et al. 2013). The productive land and sea area that human societies rely on for natural resources and services is referred to as "biocapacity," while the amount of resources and services that human societies demand from ecosystems is referred to as "ecological footprint" (Borucke et al. 2013). Countries with a surplus of biocapacity over ecological footprint are referred to as "ecological creditors," while those with a deficit are referred to as "ecological debtors." Until the 1970s, most societies consumed less in a year than the Earth's ecosystems could provide. Since then, however, most societies have been accruing an ecological debt (Borucke et al. 2013).

2.7.4: Section Summary

Societies that are militarily and economically dominant are in a better position to secure their interests than societies that are militarily and economically dependent. A society's position in the global hierarchy depends, to some degree, on the extent to which the society exploits its biophysical environment. Although these two aspects of a society's environment have obvious interlinkages, a society's position in the global hierarchy and the extent to which it exploits its biophysical environment may also be causes and consequences of other societal characteristics (i.e., its worldviews, institutions, and technologies).

2.8 Summary

In this chapter, I reviewed the WITs framework, which proposes that societal cultures consist of interdependent sets of worldviews, institutions, and technologies that co-evolve and interact with their environment (Beddoe et al. 2009). I argued that the WITs framework could be clarified and enhanced by importing the definitions of institutions and technologies from Nolan and Lenski (2015). Next, I reviewed literature related to the four categories of the WITs framework (i.e., worldviews, institutions, technologies, and environment). This literature centred on exemplar variables that have strong theoretical and empirical bases, and which lend themselves to being interrelated in a model of societal evolution. These variables are not a definitive list of the most important variables for describing and explaining how societies evolve,

but rather a defensible starting point for building a model of societal evolution, on which future work can build.

Chapter 3: Materials and Methods

3.1: Introduction

This chapter consists of three parts. Section 3.2 provides an overview of the dominant approaches to modelling sustainability transitions and transformations and assesses alternative approaches. Section 3.3 presents a brief overview of the model and a detailed description of my analytical approach. Section 3.4 provides a detailed description of the model, visualizing and explaining each of its key assumptions.

3.2: Methods of modelling sustainability transitions and transformations

3.2.1 Dominant approaches

Through a review of six literatures[25] related to modelling sustainability transitions, Köhler et al. (2018) identified four categories of methods[26] and assessed them in terms of their capabilities to represent six key features of sustainability transitions (which also apply to transformations). Table 3.1 summarizes their assessment. Köhler et al. (2018) concluded that the four categories of methods have moderate to strong capabilities to represent non-linear behaviours; moderate capabilities to represent dynamics at and across different scales, as well

[25] Computational social science (ABMs); eco-innovation (IAMs); complex systems (complexity models); system dynamics; evolutionary economics (IAMs and complexity models); and social-ecological systems (ABMs and IAMs).
[26] Complexity models include NK models, complexity networks, and percolation models.

as to represent open processes and uncertainties or contingencies; weak to strong capabilities to represent diversity and heterogeneity; and weak to moderate capabilities to represent qualitatively different system states, as well as to represent changes in social values and norms.[27]

Although not covered by Köhler et al. (2018), there are other methods for modeling sustainability transitions and transformations. Examples of these methods include Boolean

Table 3.1: Capabilities of different methods to represent key features of sustainability transitions, adapted from Köhler et al. (2018)

		Method			
		Agent-based Models (ABMs)	Integrated Assessment Models (IAMs)	Complexity Models (CM)	System Dynamics (SD)
Key feature	Non-linear Behaviours	**Strong**	Moderate/ Strong	**Strong**	**Strong**
	Dynamics at and across different scales	Moderate	Moderate	Moderate	Moderate
	Open processes and uncertainties or contingencies	Moderate	Moderate	Moderate	Moderate
	Qualitatively different system states	Moderate	Weak/ Moderate	Moderate	Moderate
	Diversity and heterogeneity	**Strong**	Moderate/ Strong	Moderate/ Strong	Moderate
	Changes in social values and norms	Moderate	Weak/ Moderate	Moderate	Moderate

[27] Köhler et al. (2018) scored the methods by literature (e.g., the social-ecological systems literature uses IAMs and ABMs) on a scale from 0 to 1. For scores below .25, I used the term "weak;" for scores between .25 and .75, I used the term "moderate;" and for scores above .75, I used the term "strong." For methods that are used by multiple literatures, I reported the lowest and highest ratings. For example, Köhler et al. (2018) gave IAMs in the eco-innovation literature a low score for representing qualitatively different system states but gave IAMs in the evolutionary economics and social-ecological systems literatures a moderate score for this key feature. Thus, I report the score as "weak/moderate."

Networks (BN), Fuzzy Cognitive Mapping (FCM), and Cross-Impact Balances (CIB). Through each of these methods, it is possible to identify self-reinforcing system states and to explore the dynamics of contradictory system states.

3.2.2: Alternative approaches

BN, FCM, and CIB represent systems as directed, cyclical networks. A network consists of a set of variables and connections among them. In a directed network, the connections among variables have a direction (e.g., A→ B). In a cyclical network, variables may be involved in cycles (e.g., A → B → A). Directed, cyclical networks are necessary for representing non-linear behaviours, such as feedbacks.

In BN, the variables are Boolean variables, which may represent any concept, and which have two states: true, or false.[28] The connections among variables are if-then rules, which may contain Boolean operators (i.e., AND, OR, and NOT). The states of endogenous variables are controlled by if-then rules.

Table 3.2: Distinguishing features of alternative methods

Method	Variable type	Variable states	Connection type
Boolean Networks (BN)	Boolean	True/false	If-then rules
Fuzzy Cognitive Mapping (FCM)	Continuous	Degree of activity as a fraction in the range [0,1]	Weighted impacts as fractions in the range [-1,1]
Cross-impact Balances (CIB)	Categorical	Mutually exclusive qualitative states Impact balance as a positive or negative integer	Weighted impacts as integers in the range [-3,3]

[28] Fuzzy BN is under development. For example, see Poret, Monteiro Sousa, and Boissel (2019).

In FCM, the variables are continuous variables, which may represent any concept, and which may have any state in the range [0,1], where a value closer to 1 means "more on than off" and a value closer to 0 means "more off than on." The connections among variables are weighted impacts, typically in the range [-1,1] (fractions allowed). The states of endogenous variables are controlled by mathematical functions, which take weighted impacts from other variables as inputs.

In CIB, the variables are categorical variables, which may represent any category of concepts, and which may have multiple, mutually exclusive qualitative states (e.g., Political System: Democracy, Anocracy, Dictatorship). The connections among variables are weighted impacts, typically in the range [-3,3] (integers only). In contrast to FCM, the connections among variables in CIB are state-specific. For example, each state of Political System may have different effects on other variables. The states of endogenous variables are controlled by a simple rule, discussed in section 3.3.[29]

3.2.3: Capabilities of alternative methods to represent key features of sustainability transitions and transformations

Table 3.3 presents my assessment of BN, FCM, and CIB in terms of their capabilities to represent the six key features of sustainability transitions identified by Köhler et al. (2018).

[29] CIB combines Cross-Impact Analysis (CIA) with Morphological Analysis (MA). Weimer-Jehle (2006) discusses advantages of CIB over CIA. For example, CIB does not require the estimation of conditional, joint, or marginal probabilities of events, whose estimation requires prior knowledge of the system as a whole. Rather, knowledge of the system as a whole is an intended outcome of CIB analysis (Weimer-Jehle 2006). The main advantage of CIB over MA is that the connections among variables in CIB are directed and state-specific.

Table 3.3: Capabilities of alternative methods to represent key features of sustainability transitions, adapted from Köhler et al. (2018); comparison of model features

		Method		
		Boolean Networks (BN)	Fuzzy Cognitive Mapping (FCM)	Cross-impact Balances (CIB)
Key feature	Non-linear behaviours	**Strong**	**Strong**	**Strong**
	Dynamics at and across different scales	Moderate	Moderate	Moderate
	Open processes and uncertainties or contingencies	Moderate	Weak/ Moderate	**Strong**
	Qualitatively different system states	**Strong**	Moderate	**Strong**
	Diversity and heterogeneity	Moderate	Moderate	Moderate
	Changes in social values and norms	**Strong**	Moderate	**Strong**

The three methods have equally strong capabilities to represent three of the six key features. Since they model systems as directed, cyclical graphs, BN, FCM, and CIB have strong capabilities to represent non-linear behaviours (e.g., feedbacks). They also have moderate capabilities to represent dynamics at and across different scales,[30] as well as to represent diversity and heterogeneity.[31] The limiting factor for the latter two features is the trade-off between model detailedness and model completeness (Holtz et al. 2015). As scales and actors are added, the complexity of a model increases exponentially. Either the model must be simplified, or the computational resources must be increased; additionally, more complex

[30] Multi-scale CIB is actively under development. Kurniawan's (2020) dissertation analyzes scenario consistency across scales, and Schweizer & Kurniawan (2016) demonstrate a multi-scale approach to CIB.

[31] As Köhler et al. (2018) note, sustainability modellers may benefit from combining different methods (e.g., combining CIB, which excels at representing qualitatively different system states and changes in values and norms, with ABM, which excels at representing diversity and heterogeneity).

models require more information (Ritchey 2018). This limiting factor also applies to the methods discussed by Köhler et al. (2018).

BN, FCM, and CIB are capable of representing qualitatively different system states and changes in values and norms, although they do so differently. BN and CIB allow for state-specific effects, while FCM does not. This has important implications for nominal variables.[32] For example, consider a model of the effects of an energy infrastructure investment on employment. Suppose that there are three options for the energy infrastructure investment (Coal Plant, Hydroelectric Dam, and Wind Farm), only one of which will be chosen (e.g., due to budgetary constraints, demand requirements, availability of land, etc.), and three effects on employment (Low, Medium, High). Only one investment option will be selected. Suppose also that there are other variables in the model that represent contextual factors affecting the choice of energy infrastructure investment (e.g., local attitudes towards non-renewable energy; national greenhouse gas reduction targets, etc.). In BN, a binary variable must be used to represent each option for the energy infrastructure investment. To ensure internal consistency, if-then rules must be used to ensure that only one option is true at any time. In CIB, a single categorical variable with mutually exclusive states is used to represent the options for the energy infrastructure investment. In FCM, a continuous variable must be used to represent each option for the energy infrastructure investment, but it is possible that each option will have a non-zero state, depending on the states of the contextual factors. Thus, each option for the energy infrastructure investment may exert some influence on employment, which is internally

[32] All three methods are equally capable of representing binary and ordinal variables with monotonic effects. For binary and ordinal variables with non-monotonic effects, a state-specific method, such as BN or CIB, is required.

inconsistent, as only one project will be selected. To ensure internal consistency, a model of the energy infrastructure investment situation must use if-then rules or categorical variables with mutually exclusive states. In summary, BN and CIB have strong capabilities to represent qualitatively different system states and changes in values and norms, while FCM has moderate capabilities to represent these key features of sustainability transitions and transformations (since it is limited in dealing with nominal variables).

BN, FCM, and CIB are capable of representing open processes and uncertainties or contingencies. As a scenario-based method, CIB excels at representing this key feature of sustainability transitions and transformations. CIB requires experts to identify key uncertainties and to judge their interrelationships in order to assemble (with the aid of a computer) a variety of internally consistent scenarios (Weimer-Jehle 2006). The use of categorical variables facilitates thinking about alternative states (uncertainties) for each variable. In principle, BN and FCM are also capable of representing alternative states for variables and may be used for scenario analysis, although with FCM there are limitations related to nominal variables (discussed above). All three methods have deterministic and probabilistic implementations.[33] In summary, CIB has strong capabilities to represent open processes and uncertainties; BN has moderate capabilities to represent this key feature; and FCM has weak to moderate capabilities to represent this key feature.

[33] For example, Schweizer et al. (2013) extended classical CIB by introducing stochastic "succession rules," which govern how contradictory system states evolve.

3.2.4: Appropriateness of the methods to the study of guided cultural evolution

The state-specific nature of BN and CIB allows these methods to represent system change as an evolutionary process of recombination (e.g., of types of worldviews, institutions, and technologies). Köhler et al. (2018, 14-15) describe evolutionary models with recombination as "promising approaches for exploring structural change…[that] have only rarely been applied in sustainability transitions modelling."

Although both methods are capable of representing evolution through recombination, CIB has a couple of advantages over BN. First, CIB can represent the degree to which a variable state is promoted or opposed (the state's "impact balance"), whereas BN can only represent whether a state is true or false.[34] This feature of CIB is essential for comparing the sensitivity of multiple leverage points – information which may be relevant to decision-making. For example, sensitive leverage points may be prioritized because they represent risks or opportunities for system change. Second, the informational requirements for CIB are lower than for BN.[35] BN requires identifying if-then rules for each endogenous variable – rules that may refer to the states

[34] The impact balance in CIB is akin to the degree of activation in FCM; the quantities are calculated differently, however. Additionally, for each internally consistent scenario, CIB reports the degree to which all of the variable state are promoted or opposed. This feature facilitates thinking about counterfactuals. By quantifying (with impact balances) the degree to which *alternative* variable states are promoted or opposed, CIB provides insight into the relative ease or difficulty of realizing counterfactual scenarios. Such insights appear to be harder to come by through FCM.

[35] CIB also has lower informational requirements than the methods discussed by Köhler et al. (2018). For example, SD requires understanding a system's structure well enough to express that structure as a system of equations, which requires knowing the location of thresholds and rates of change. CIB is ideal for modelling systems "for which the available knowledge about the interactions of the system is partly or wholly too qualitative to be expressed trustworthily by a mathematical formula" (Weimer-Jehle 2006, 336).

of multiple variables, thus requiring a sophisticated understanding of a system's structure. In contrast, CIB requires judging how pairs of variable states interact.[36]

In light of these advantages and disadvantages of the alternative methods, I chose to model the evolutionary dynamics of sustainability transformations using CIB.[37]

3.3: Model Overview and Analytical Approach

3.3.1: Overview of the Model

The model synthesizes the literatures reviewed in chapter two and consists of **eight variables**, each with between two and four states (see Table 3.4). Three variables, drawn from the literature on national cultures, describe societies in terms of their worldviews: **individualism vs. collectivism**, **duty vs. joy**, and **distrust. vs. trust** (Beugelsdijk & Welzel 2018; Hofstede et al. 2010; Inglehart 2005). Two variables, drawn from the literature on institutional systems, describe societies in terms of their **political system** (democracy, anocracy, dictatorship) (Coppedge et al. 2008; Dahl 1971) and **economic system** (command, market, mixed) (Nolan & Lenski 2015; Pryor 2005). One variable, drawn from the literature on sociocultural evolution, describes societies in terms of their **primary subsistence technology** (post-industry, industry, agriculture, or diversified) (Nolan & Lenski 2015; Lenski 2005). One variable, drawn from the literature on

[36] Boolean operators and complex causes, such as INUS causes (Mackie 1980), may be included in CIB via procedures demonstrated by Weimer-Jehle (2008).

[37] CIB has weak capabilities to represent quantitatively different system states. Continuous variables must be converted into ordinal variables in order to be included in a CIB model, incurring a loss of information.

Table 3.4: Variables and states for the model.

Category	Variable	States	Source
Worldviews	Collectivism-Individualism	Collectivist Individualist	Beugelsdijk & Welzel (2018); Hofstede (1980); Inglehart (1971)
	Duty-Joy	Dutiful Joyful	
	Distrust-Trust	Distrusting Trusting	
Institutions	Political System	Democracy Anocracy Dictatorship	Coppedge, Alvarez, and Maldonado (2008); Dahl (1971)
	Economic System	Market Mixed Command	Nolan and Lenski (2015); Pryor (2005)
Technologies	Subsistence Technology	Post-Industry Diversified Industry Agriculture	Nolan and Lenski (2015); Lenski (2005)
Environment	International System	Competitive Cooperative	Chase-Dunn and Lerro (2015); Wendt (1992); Choucri and North (1975)

international relations, describes the **international system** (competitive, cooperative) (Wendt 1992). The eighth variable is a control variable, which modulates the effect of the international system on societies' primary subsistence technologies.

The matrix in Figure 3.1 presents my judgments of how the variable states interact (these judgments are discussed further in section 3.4). The rows of the matrix show the impacts that each variable state has on the others. For example, the "Individualist" row shows the impacts that the individualism worldview has on the states of Political System, Economic System, and Subsistence Technology. Impacts are recorded on a Likert scale ranging from -3 (strongly restricting) to +3 (strongly promoting).

	CI		DJ		DT		Pol			Econ			Tech				Int		IS & ST		
	Ind	Col	Joy	Dut	Tru	Dis	Dem	Ano	Dic	Mar	Mix	Cmd	Pos	Div	Ind	Agr	Comp	Coop	Comp	Comp & Agr	Coop
Collectivism-Individualism																					
Individualist			0	0	0	0	3	-2	-3	3	2	-3	2	1	1	-2	0	0	0	0	0
Collectivist			0	0	0	0	-3	2	3	-3	-2	3	-2	-1	-1	2	0	0	0	0	0
Duty-Joy																					
Joyful	0	0			0	0	3	-2	-3	-2	2	-2	2	1	1	-2	0	0	0	0	0
Dutiful	0	0			0	0	-3	2	3	2	-2	2	-2	-1	-1	2	0	0	0	0	0
Distrust-Trust																					
Trusting	0	0	0	0			3	-3	-3	2	3	-3	0	0	0	0	0	0	0	0	0
Distrusting	0	0	0	0			-3	3	3	-2	-3	3	0	0	0	0	0	0	0	0	0
Political System																					
Democracy	3	-3	3	-3	3	-3				0	0	0	0	0	0	0	0	0	0	0	0
Anocracy	2	-2	2	-2	-3	3				0	0	0	0	0	0	0	0	0	0	0	0
Dictatorship	-3	3	-3	3	-3	3				0	0	0	0	0	0	0	0	0	0	0	0
Economic System																					
Market	3	-3	-2	2	2	-2	0	0	0				0	0	0	0	0	0	0	0	0
Mixed	2	-2	2	-2	3	-3	0	0	0				0	0	0	0	0	0	0	0	0
Command	-3	3	-2	2	-3	3	0	0	0				0	0	0	0	0	0	0	0	0
Subsistence Technology																					
Post-Industry	2	-2	2	-2	0	0	0	0	0	0	0	0					0	0	0	-2	0
Diversified	1	-1	1	-1	0	0	0	0	0	0	0	0					0	0	0	-2	0
Industry	1	-1	1	-1	0	0	0	0	0	0	0	0					0	0	0	-2	0
Agriculture	-2	2	-2	2	0	0	0	0	0	0	0	0					0	0	-2	1	0
International System																					
Competitive	-1	1	-1	1	-2	2	0	0	0	0	0	0	0	0	0	0			1	1	-2
Cooperative	1	-1	1	-1	2	-2	0	0	0	0	0	0	0	0	0	0			-2	-2	1
IS & ST																					
Competitive	0	0	0	0	0	0	0	0	0	0	0	0	3	-3	3	-3	0	0			
Competitive & Agriculture	0	0	0	0	0	0	0	0	0	0	0	0	-3	-3	3	0	0	0			
Cooperative	0	0	0	0	0	0	0	0	0	0	0	0	-3	3	-3	-3	0	0			

Figure 3.1: Matrix of cross-impact judgments. The rows show the impacts that each variable state has on the others. For example, the Individualism row shows the impact of the individualism worldview on the states of Political System, Economic System, and Subsistence Technology. Impacts are recorded on a Likert scale ranging from -3 (strongly restricting) to +3 (strongly promoting).

In addition to the model shown in Figure 3.1, which represents my judgments of how the variable states interact, I considered fourteen alternative versions of the model. In each version, I kept the basic structure of the model intact (i.e., variables, variable states, connections, and their directions did not change).[38] Rather, I applied a multiplier to one or more of the four categories of the WITs framework, i.e., worldviews, institutions, technologies, and environment. These alternative versions of the model incorporate the influence of archetypes of social ontologies.[39] For example, the version of the model in which the impacts of the environment are doubled, while the impacts of the other categories are kept the same, incorporates the influence of World Systems Theory (Wallerstein 1974). A list of the models, their multipliers, and corresponding social ontologies is available in Appendix A.

3.3.2: Analytical approach

3.3.2.1: Analytical approach for research question 1

Research question 1 asks which combinations of worldviews, institutions, and technologies (societal cultures) are self-reinforcing, and under what environmental selective pressures.

When a societal culture is self-reinforcing, the culture may be thought of as a ball resting at the bottom of a valley, as depicted in Figure 3.2. In CIB, system states are called "scenarios," and scenarios that are self-reinforcing are referred to as "internally consistent."

[38] Future research could involve other experts in suggesting alternative variables, variable states, connections, directions, and specific weightings.
[39] Social ontologies, such as Marxism, are broad categories that include a diversity of perspectives.

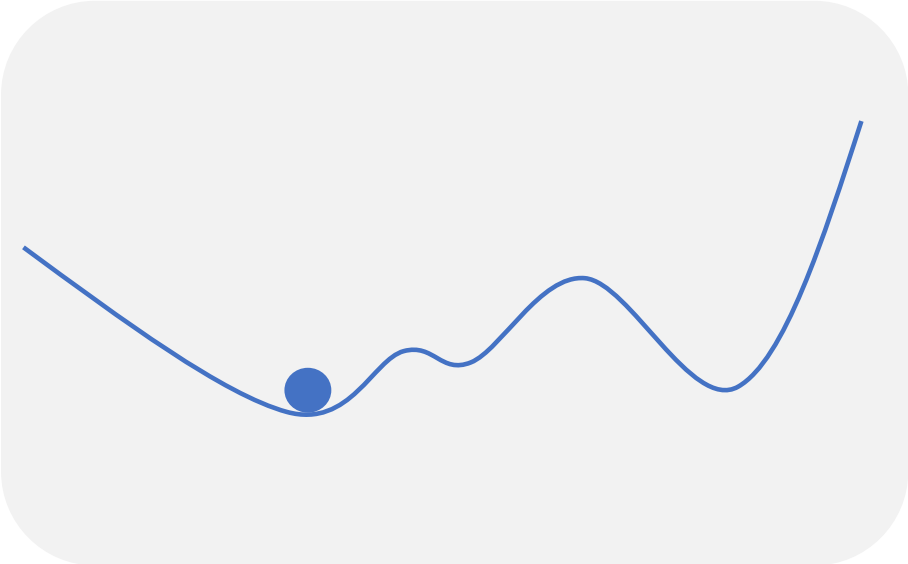

Figure 3.2: Hill-and-valley diagram of an internally consistent scenario, visualized as a ball resting at the bottom of a valley. In *ScenarioWizard*, the "strong" consistency rule is used to identify perfectly internally consistent scenarios.

Internal consistency is assessed by calculating and comparing impact balances. Figure 3.3 illustrates this concept using three of the variables in the model.

The scenario shown in Figure 3.3 consists of the states {Individualist, Market, Post-Industry}. Each variable state in the scenario has a balance, which is the sum of the impacts of the other variable states in the scenario. For example, the balance of the Collectivist state is -5, which is the sum of the impact of the Market state (-3) and the impact of the Post-Industry state (-2). Similarly, the balance of the Individualist state is +5, which is the sum of the impact of the Market state (+3) and the impact of the Post-Industry state (+2).

The balances show that the variable states in the scenario are promoting one another (see also Figure 3.4). Thus, the scenario is internally consistent. Since each of the variable states has the highest balance for its variable, this scenario is said to be "perfectly" internally consistent. For example, the Market state of Economic System has a balance of +3, while the Mixed state of Economic System has a balance of +2. The scenario {Individualist, Mixed, Post-Industry} would be internally consistent, but not perfectly so, since the Individualist state and

Selection:		X			X			X			
Variables		**Collectivism -Individualism**			**Economic System**			**Subsistence Technology**			
		I	**C**		**M**	**Mx**	**C**	**P**	**D**	**I**	**A**
Collectivism-Individualism:											
Individualist		0	0		3	2	-3	2	1	1	-2
Collectivist		0	0		-3	-2	3	-2	-1	-1	2
Economic System:											
Market:		3	-3		0	0	0	0	0	0	0
Mixed:		2	-2		0	0	0	0	0	0	0
Command:		-3	3		0	0	0	0	0	0	0
Subsistence Technology:											
Post-Industry		2	-2		0	0	0	0	0	0	0
Diversified		1	-1		0	0	0	0	0	0	0
Industry		1	-1		0	0	0	0	0	0	0
Agriculture		-2	2		0	0	0	0	0	0	0
Balances		**+5**	**-5**		**+3**	**+2**	**-3**	**+2**	**+1**	**+1**	**-2**

Figure 3.3: Matrix of an internally consistent scenario, consisting of the states {Individualist, Market, Post-Industry}, as indicated by the highlighted rows.

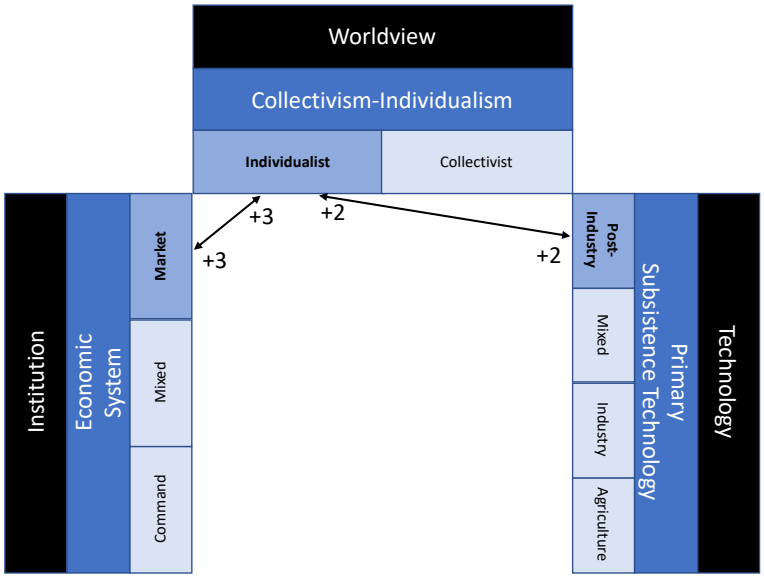

Figure 3.4: Influence diagram of variable states judged to be consistent. In this combination, the individualist worldview, the market type of economic system, and post-industry type of subsistence technology are favoured. Thus, all variables are in a consistent state. For details on the judgments underlying these relationships, see section 3.4.

the Post-Industry state slightly favour the Market state. We may think of an *imperfectly* internally consistent scenario as a ball resting at an indentation along a hillside, as depicted

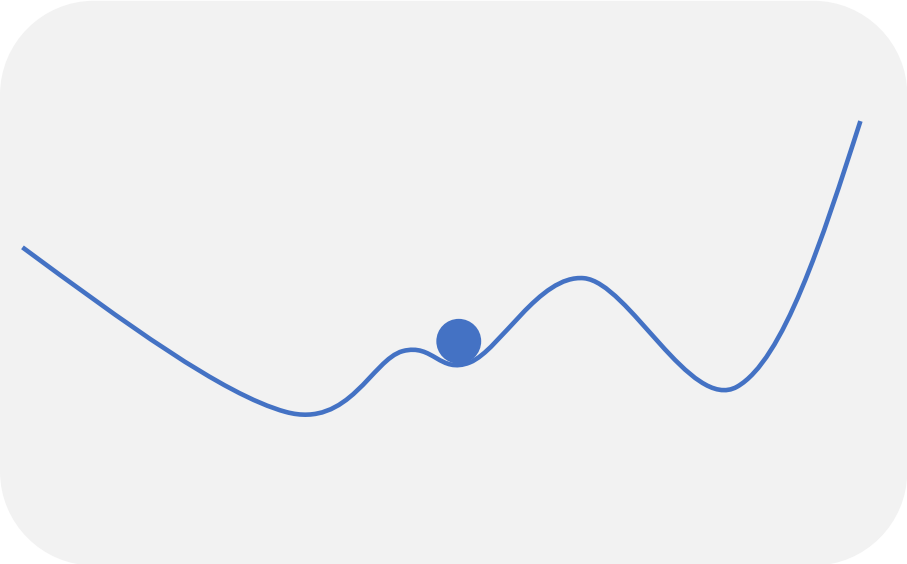

Figure 3.5: Hill-and-valley diagram of an (imperfectly) internally consistent scenario, visualized as a ball resting at an indentation along a hillside. In *ScenarioWizard*, the "weak" consistency rule is used to identify perfectly as well as imperfectly internally consistent scenarios.

in Figure 3.5. With a little force, it would be possible to nudge the system further downhill to a deeper resting state.

The process of assessing combinations of variable states for internal consistency is automated by the software package, *ScenarioWizard* (Weimer-Jehle 2021), which is freely available for download and use at www.cross-impact.de.[40] *ScenarioWizard* allows the analyst to configure the degree of internal consistency required to count a scenario as a solution. Three options are available. The "strong" consistency rule sets the highest threshold for internal consistency: all of the variables must be in the states with the highest balances. The "weak" consistency rule sets a lower threshold for internal consistency: all of the variables must be in states with non-negative balances (or if all balances for a variable are negative,

[40] The current software implementation is only available for the Windows operating system. A virtual machine, such as Parallels, may be used to access *ScenarioWizard* on computers running other operating systems.

then in the state with the balance closest to zero). A third option allows the analyst to set a custom threshold.[41]

To answer research question 1, I used *ScenarioWizard* to assess all possible scenarios for internal consistency. I used the strong consistency rule.[42] Since the model consists of four variables with two states, three variables with three states, and one variable with one state, this assessment involved checking 2^4 x 3^3 x 4 = 1,728 scenarios for internal consistency. I repeated this analysis for all fifteen versions of the model.

3.3.2.2: Analytical approach for validating the model

Validation is an important step in the modelling process and refers to "an evaluation of the credibility of the model as a representation of the subject modelled" (David, Fachada, and Rosa 2017, 174). My model aims to represent the cultural evolution of contemporary societies, in order to develop hypotheses about how we might steer the evolution of our societal cultures towards sustainability. As discussed in chapter two, our ability to predict cultural evolution is limited by our uncertainty about what new cultural variants might emerge and how they might interrelate, and by our uncertainty about how existing cultural variants might behave in new contexts.

One way to validate the model is to test its relevance and legitimacy to stakeholders (van Voorn et al. 2016). Participatory research is beyond the scope of my dissertation but is

[41] We may think of the custom threshold as allowing the system to rest somewhere along the hillside. A higher threshold allows the system to be at rest farther up the hillside.

[42] In future research, it would be worthwhile to use the weak consistency rule, as well. The weak consistency rule implies that societies settle for satisfactory, rather optimal, combinations of worldviews, institutions, and technologies. This line of thinking applies the theory of bounded rationality (Simon 1972) to societies. Whether societies 'satisfice' or optimize is an empirical question worth addressing (e.g., through a validation exercise like the one described below).

an area for future work (see chapter five). Another way to validate the model is to check whether it can reproduce the past. Although future behaviour may depart from past behaviour (Holtz et al. 2015), the ability of the model to reproduce the past can establish a baseline of scientific credibility (van Voorn et al. 2016).

To validate my model, I traced the recent evolutionary histories of a sample of contemporary societies and compared their most recent states to the internally consistent scenarios identified through research question 1.

We may think of a society whose culture is evolving as a ball sitting atop a hill (or somewhere alongside a hillside), as depicted in Figure 3.6. Contradictions among cultural characteristics will push the society downhill towards one of the valleys.

In CIB, a society with contradictory cultural characteristics is represented as an internally inconsistent scenario. Figure 3.7. shows an example, the combination {Individualist, Command, Post-Industry}. The balances show that two of the variable states are not

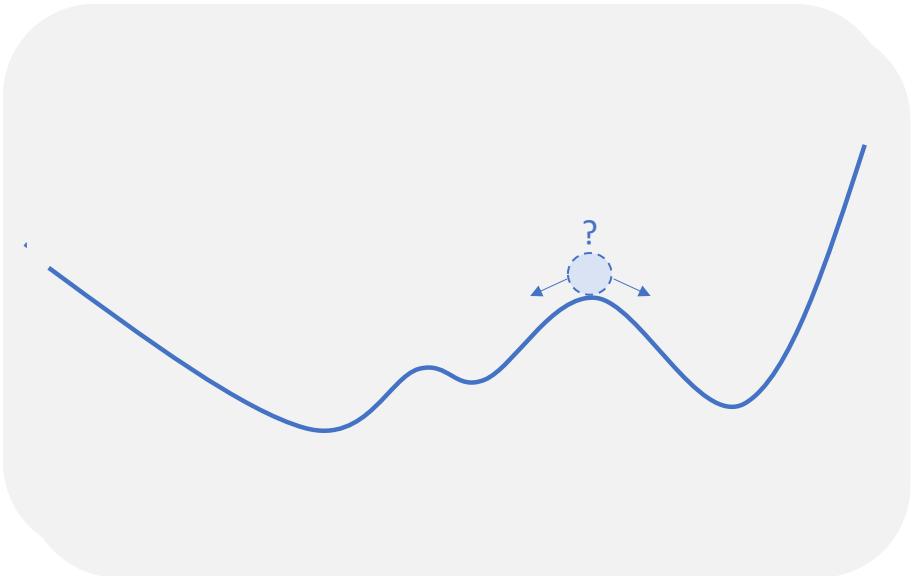

Figure 3.6: Hill-and-valley diagram of an internally inconsistent scenario, visualized as a ball resting atop a hill.

supported by the scenario (see also Figure 3.8). The scenario favours the Collectivist state (balance = +1) and the Market state (balance = +3).

The process of resolving inconsistencies in scenarios is referred to as "succession analysis" and is semi-automated by *ScenarioWizard*. The software allows the analyst to configure a rule for the succession analysis. Four options are available. The “global” succession rule updates all of the variable states simultaneously. The “local” succession rule updates variable states one at a time, starting with the variable that has the largest negative balance. The “incremental” succession rule is the same as the global succession rule, except that a variable can only move to an adjacent state; this rule limits the dynamics of the system to gradual rather than radical change. The incremental succession rule is only an appropriate choice when all the variables have ordinal states (e.g., high, medium, low). The “adiabatic”

Selection:		X				X			X			
Variables		Collectivism -Individualism			Economic System				Subsistence Technology			
		I	C		M	Mx	C		P	D	I	A
Collectivism-Individualism:												
Individualist		0	0		3	2	-3		2	1	1	-2
Collectivist		0	0		-3	-2	3		-2	-1	-1	2
Economic System:												
Market:		3	-3		0	0	0		0	0	0	0
Mixed:		2	-2		0	0	0		0	0	0	0
Command:		-3	3		0	0	0		0	0	0	0
Subsistence Technology:												
Post-Industry		2	-2		0	0	0		0	0	0	0
Diversified		1	-1		0	0	0		0	0	0	0
Industry		1	-1		0	0	0		0	0	0	0
Agriculture		-2	2		0	0	0		0	0	0	0
Balances		-1	+1		+3	+2	-3		+2	+1	+1	-2

Figure 3.7: Matrix of an internally inconsistent combination of variable states, consisting of the states {Individualist, Command, Post-Industry}, as indicated by the highlighted rows.

rule is the same as the local succession rule, except that variables are updated by column from left to right in the matrix; this rule is meant to introduce time into the model, such that faster-moving variables (left-side) are updated before slower-moving variables (right-side). The adiabatic succession rule is an appropriate choice when the variables have distinct rates of change.

As mentioned, succession analysis is only semi-automated. The analyst must load an initial scenario and then apply the chosen succession rule step by step until the system reaches an internally consistent scenario (as defined by the chosen consistency rule).

For example, using the strong consistency rule and the global succession rule, the inconsistent scenario shown in Figures 3.7 and 3.8, {Individualist, Command, Post-Industry}, would update to the scenario {Collectivist, Market, Post-Industry}, which is internally inconsistent. Over several steps, the system returns to the initial scenario, {Individualist, Command, Post-Industry}. Thus, the system becomes trapped in a loop.

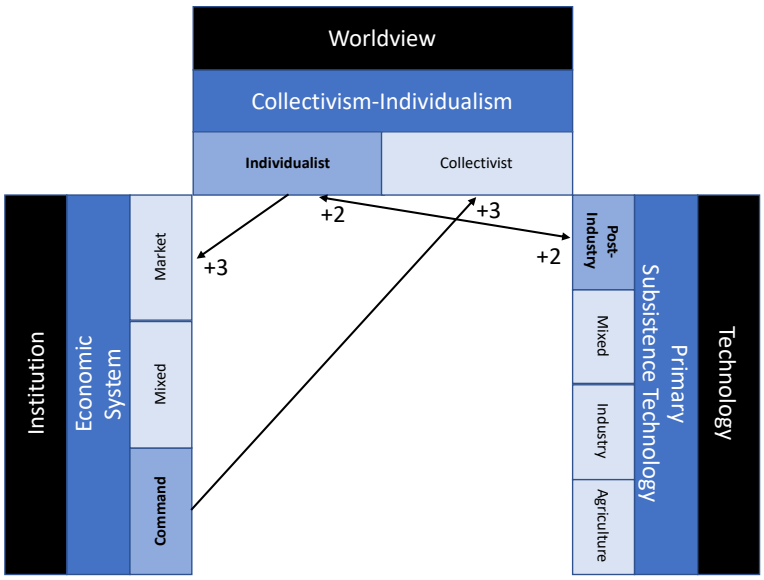

Figure 3.8: Influence diagram of variable states judged to be inconsistent. In this scenario, the collectivist worldview, the market type of economic system, and post-industry type of subsistence technology are favoured. Thus, two variables are in an inconsistent state: Collectivism-Individualism, which should be in the collectivist state, and Economic System, which should be in the market state. For details on the judgments underlying these relationships, see section 3.3.

The local succession rule produces a different outcome. In the first step, the Economic System variable updates first, since it senses the greatest inconsistency. The highest balance for the Economic System variable is the balance of the Market state, which is +3. Meanwhile, the balance of the state that is in the scenario, the Command state, is -3. The difference between these balances is 6. By contrast, the difference between the highest balance for the Collectivism-Individualism variable and the balance of the state that is in the scenario is 2. Thus, the Economic System variable senses the greatest inconsistency.

When the Economic System variable updates to the Market state, the scenario becomes perfectly internally consistent.

Hence, the choice of succession rule has an important effect on the way that an internally inconsistent scenario is updated. We may think of the different succession rules as representing different theories of change, each of which may be appropriate for certain models and not others.[43]

For my model, I used the global and the local succession rules. The incremental succession rule would not allow abrupt changes in variable states, such as a shift from democracy to dictatorship (e.g., a coup) or the reverse (e.g., a revolution). Additionally, the incremental rule would not allow technological leapfrogging (e.g., shifting from agriculture to post-industry).[44] I did not use the adiabatic rule, as I did not make any assumptions about the relative rates at which worldviews, institutions, and technologies change.[45]

[43] Each of these 'theories of change' is based on a deterministic succession rule. Schweizer et al. (2013) have developed probabilistic succession rules. Testing the probabilistic succession rules is an area for future research.
[44] Since the world contains societies with post-industry, industry, and agriculture types of subsistence technology, and since the world is globalized through politics, trade, and communications (e.g., the Internet), it makes sense to allow technological leapfrogging (i.e., diffusion of culture). This view is consistent with multilinear theory (Nolan & Lenski 2015).
[45] This could be explored through future research.

To validate the model, I tested the ability of all fifteen versions to reproduce the recent evolutionary histories of eighteen countries (for the list of countries, see Table 3.5).[46] I selected countries as follows. First, I randomly selected twenty-five countries that had been surveyed by the World Values Survey at least twice. I excluded any country for which there had been fewer than ten years between the first time and the most recent time that it had been surveyed. This left me with sixteen countries. Next, I added China and India, which I thought were highly salient due to their large populations, territories, and economies, and rapid rates of population and economic growth.

Next, I gathered data for each of the variables. For each country, I gathered data for the year in which the country was first surveyed by the World Values Survey and for every subsequent year in which the country was surveyed. For example, Brazil was first surveyed by

Table 3.5: Countries included in and excluded (due to data limitations) from the validation tests.

	Included	**Excluded**
Randomly selected	Argentina Brazil Chile Germany Japan Jordan Mexico Nigeria Norway Peru Russia South Africa Spain Switzerland United States Uruguay	Albania Bulgaria Egypt Ghana Pakistan Poland Tunisia United Kingdom Zimbabwe
Selected for salience	China India	

[46] It may strike some readers as odd to compare countries such as Switzerland and China, which have vastly different populations and geographical sizes. Future work may incorporate these and other variables that distinguish countries. For now, my model tests whether it is sensible to compare countries along the dimensions prioritized by the WITs framework.

the World Values Survey in 1991 and was surveyed again in 1997, 2006, 2014, and 2018. Thus, I collected data about Brazil in each of these years.

For the Collectivism-Individualism, Duty-Joy, and Distrust-Trust variables, I calculated country scores using data from the World Values Survey (World Values Survey Association 2020) and regression equations from Beugelsdijk and Welzel (2018). For the Economic System variable, I used data from Pryor (2005) for the year 1990. For other years, I used the Heritage Foundation's *Economic Freedom* indicator (Heritage Foundation 2020), which I found correlated reasonably well with the market, mixed, and command types of economic system. For the Political System variable, I used data from Coppedge, Alvarez, and Maldonado (2008) up to the year 2000. For other years, I used the country ratings from Freedom House's *Freedom in the World* report (free, partly free, and not free), which have similar, albeit not identical, meanings as the states of Political System (Freedom House 2020). For the Subsistence Technology variable, I used three indicators from the World Bank's *World Development Indicators* database: Agriculture, forestry, and fishing, value added (% GDP); Industry (including construction), value added (% GDP); and, Services, value added (% GDP) (World Bank 2020). I did not collect any data for the International System variable, as the international system has not changed from competitive to cooperative.

Next, I categorized the quantitative data in order to match country characteristics to variable states. My coding criteria are reported in Appendix B.

I carried out thirty tests per country: two for each version of the model (one with the global succession rule, and another with the local succession rule). In total, I carried out 540 tests. For each test, I began by loading an initial scenario corresponding to the cultural characteristics of the country in the first year for which I had data. Next, I ran the succession

analysis and recorded the resulting internally consistent scenario (I refer to this as the "successor").

For each country, I looked for two things in the results of the validation tests: first, which of the internally consistent scenarios (self-reinforcing societal cultures) had the country become most like (if any); and second, did the succession analysis output the internally consistent scenario that the country had, in fact, become most like? Ideally, the answers to these two questions would agree.

3.3.2.3: Analytical approach for research question 2

Research question 2 asks which self-reinforcing societal cultures appear to be most compatible with the Sustainable Development Goals (SDGs), and why. Compatibility refers to the presence of conditions that *enable*, but that do not guarantee, achieving the SDGs. To answer this question, I compared each of the variable states in my model to each of the 169 SDG sub-goals, or "targets."

For example, consider the variable Economic System, which has three states: Command, Market, and Mixed. Recall that in a command economy, the government makes most important decisions about economic allocation (i.e., production and consumption, supply and demand). In a market economy, decisions about economic allocation are highly decentralized among individuals, firms, governments, etc. In a mixed economy, governments make important decisions about economic allocation (e.g., minimum wage laws), but economic decision-making remains highly decentralized.

Alongside the Economic System variable, consider SDG 12 (Responsible Consumption and Production), which has eight targets. In particular, consider target 12.2, which calls for

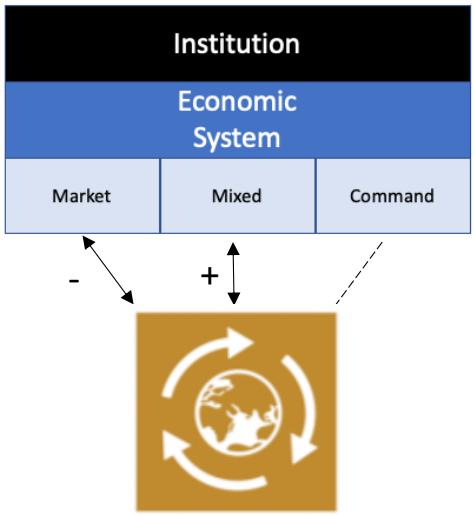

Figure 3.9: Compatibility of the states of the Economic System variable with SDG target 12.2.

achieving “the sustainable management and efficient use of natural resources” by 2030 (UN 2015).

I assessed the compatibility of each of the states of Economic System with SDG target 12.2 (see Figure 3.9). I made the following assessments. First, I judged the Market state of Economic System as being incompatible with SDG target 12.2 My rationale for this judgment is as follows. In a market type of economic system, firms compete with one another to increase their share of the market, which allows them to obtain higher profits. Competition for market share and profits places tremendous pressure on firms to lower costs (Marx 1867). Ways of lowering costs include externalizing costs onto workers, society, and the environment (Costanza et al. 2013). For example, firms may forego providing health insurance to their workers; firms may allow unsafe products to enter the market; and firms may allow pollutants to enter the environment untreated. Since increasing market share and profits are the dominant motives in a market type of economic system, I concluded that the market type

of economy is incompatible with the goal of achieving the sustainable use and management of natural resources. This goal will, in a market type of economic system, at best be secondary to the goals of increasing market share and profits.

Second, I judged the Mixed type of economic system as being compatible with SDG target 12.2. My rationale for this judgment is that, in a mixed type of economic system, the government influences economic allocation so as to protect workers, society, and the environment from the impacts of economic competition (Nolan and Lenski 2015; Polanyi 2001). Since unsustainable use and management of natural resources endangers the well-being of workers, society, and the environment, societies with the mixed type of economic system might be more inclined to address these impacts.

Third, I judged the Command type of economic system as being neither compatible nor incompatible with SDG target 12.2 My rationale for this judgment is that, when the government makes most of the important decisions about economic allocation, how the economy affects workers, the society, and the environment depends heavily on the ideology of the government.

I repeated this process for the eighteen variable states in my model (excluding the states for the control variable) and the 169 SDG sub-targets. In my judgment, 85 of the 169 SDG targets were relevant to one or more of the variable states in my model (for full details, see Appendix C). Most of these targets relate to the Economic System variable (52 targets) and the International System variable (27 targets). A few other targets relate to the Political System variable (5 targets) and the Subsistence Technology variable (1 target + 2 targets that overlap with the International System variable).

Many of the SDG targets require increased international cooperation, to ensure inclusive and sustainable development. I judged the competitive international system as

incompatible with SDG targets that require international cooperation, and the cooperative international system as compatible with SDG targets that require international cooperation.

Several of the SDG targets require reforms to political institutions, to ensure individual political rights and freedoms. I judged the dictatorship type of political system as incompatible with these SDG targets, the anocracy type of political system as neither compatible nor incompatible with these SDG targets, and the democracy type of political system as compatible with these SDG targets.

Finally, one of the SDG targets encourages the development of the tertiary sector of the economy (i.e., services). I judged the diversified and post-industry types of subsistence technology as compatible with this SDG target, and the industry and agriculture types of subsistence technology as incompatible with this SDG target.

After assessing the compatibility of the variable states with the SDG targets, I calculated a "SDG compatibility" score for each of the internally consistent societal cultures. For each target and compatible variable state, I assessed one positive point; for each target and incompatible variable state, one negative point. I assessed no points for relationships between SDG targets and variable states that I judged as neither compatible nor incompatible.[47]

[47] Some of the SDGs have many targets (e.g., SDG 17), while others have few (e.g., SDG 13). By weighting the SDG compatibility score by target, I have assumed that goals with more targets have a larger impact on sustainability. I made this assumption for the sake of simplicity, and other weightings should be investigated in future work. For example, the SDG compatibility score could be adjusted by drawing on research by the Independent Council of Scientists (2019), who assessed interactions among the SDGs. Using network analysis, Pham-Truffert et al. (2020) built on this assessment of SDG interactions and calculated the weighted out-degree centrality for each SDG target. Thus, the SDG compatibility score would be re-weighted using the weighted out-degree centrality scores from Pham-Truffert et al. (2020).

3.3.2.4: Analytical approach for research question 3

Research question three asks how an unsustainable, self-reinforcing societal culture might be transformed into a sustainable, self-reinforcing societal culture. The purpose of this question is to identify leverage points for sustainability transformations. To answer this question, I developed a procedure for analyzing the sensitivity of the self-reinforcing societal cultures.

To illustrate this procedure, consider the internally consistent scenario shown in Figures 3.3 and 3.4 on page 66: {Individualist, Market, Post-Industry}. The balances of this scenario are shown in Figure 3.10. First, we record the states with the highest balances. The state of the Collectivism-Individualism variable with the highest balance is the Individualist state, which has a balance of +5; for the Economic System variable, the state with the highest balance is the Market state, which has a balance of +3; and for the Subsistence Technology variable, the state with the highest balance is the Post-Industry state, which has a balance of +2.

Second, we find the states with the second-highest balances. The state of the Collectivism-Individualism variable with the second-highest balance is the Collectivist state, which has a balance of -5; for the Economic System variable, the state with the second-highest balance is the Mixed state, which has a balance of +2; and for the Subsistence Technology variable, the states with the second-highest balances are the Diversified state and the Industry state, which have balances of +1.

Third, we find the differences between the highest and the second-highest balances. The difference for the Collectivism-Individualism variable is 10; for the Economic System variable, the difference is 1; and for the Subsistence Technology variable, the differences are

Selection:		X			X			X			
Variables		Collectivism -Individualism			Economic System			Subsistence Technology			
		I	C		M	Mx	C	P	D	I	A
Balances		+5	-5		+3	+2	-3	+2	+1	+1	-2

Figure 3.10: Balances for the internally consistent scenario, {Individualist, Market, Post-Industry}.

each 1. We may think of these differences as representing the least-effort options for perturbing the scenario, {Individualist, Market, Post-Industry}. Of the three options, perturbing the Collectivism-Individualism variable would require the most effort, since its difference is 10, while perturbing the Economic System and the Subsistence Technology variables would require the least effort, since their difference are 1.

Fourth, we perturb one of the variables by shifting it to the state with the second-highest balance, carry out a succession analysis, and trace the evolution of the system until it reaches an internally consistent scenario. If the system returns to the initial scenario (pre-perturbation), then we have not identified a leverage point; the scenario is resilient against the perturbation. If, however, the system arrives at a different internally consistent scenario, then we have discovered a leverage point (see Figure 3.11).

For example, for the scenario {Individualist, Market, Post-Industry}, perturbing the Economic System variable by shifting it to the Mixed state results in a scenario that does not meet the "strong" threshold for internal consistency, since the Market states remains more favoured (see Figures 3.3 and 3.4 on page 66). Consequently, the system evolves, and in one step the system returns to the initial scenario.

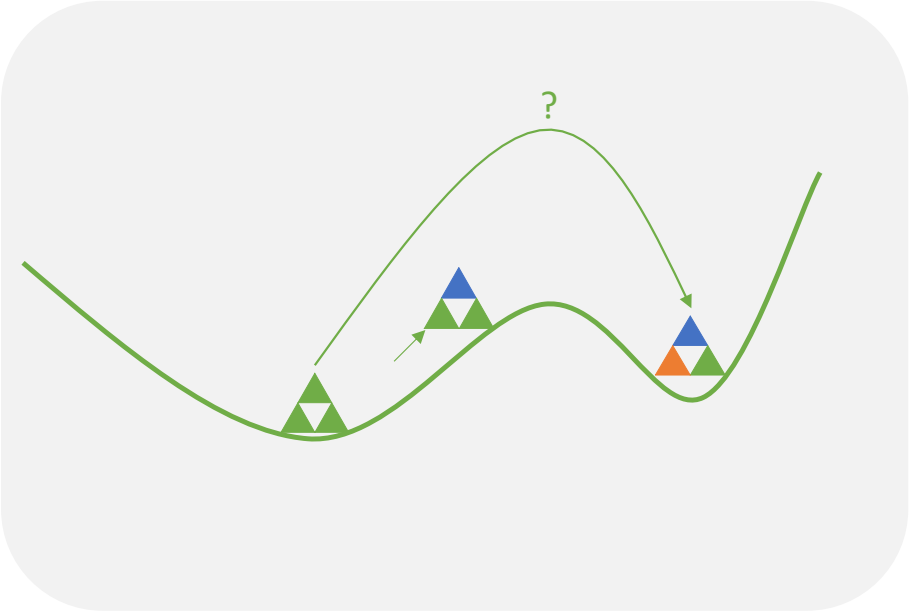

Figure 3.11: Perturbation of an internally consistent scenario, in order to identify leverage points for societal transformations (towards or away from sustainability).

In the full model, there are seven variables that can be perturbed (excluding the control variable). Since this procedure is not automated in *ScenarioWizard*, and to keep things manageable, I applied the procedure as follows. First, for each self-reinforcing societal culture, I identified the three variables with the smallest differences between highest and second-highest balances. Second, I perturbed these variables individually (Var 1, Var 2, or Var 3), in pairs (Var 1 & Var 2, Var 1 & Var 3, and Var 2 & Var3), and in triplets (Var 1 & Var 2 & Var 3). After each perturbation, I ran a succession analysis: once using the global succession rule, and again using the local succession rule. Thus, I ran fourteen tests on self-reinforcing societal culture. For each test, I recorded the perturbation and the resulting self-reinforcing societal culture. With this information, I was able to map pathways among self-reinforcing societal cultures.

To visualize these results, it is necessary to use an alternative to the hill-and-valley diagrams, which become difficult to interpret when there are multiple scenarios and pathways. Instead, I use Circos plots (Krzywinski et al. 2009). Figure 3.12 compares a hill-and-

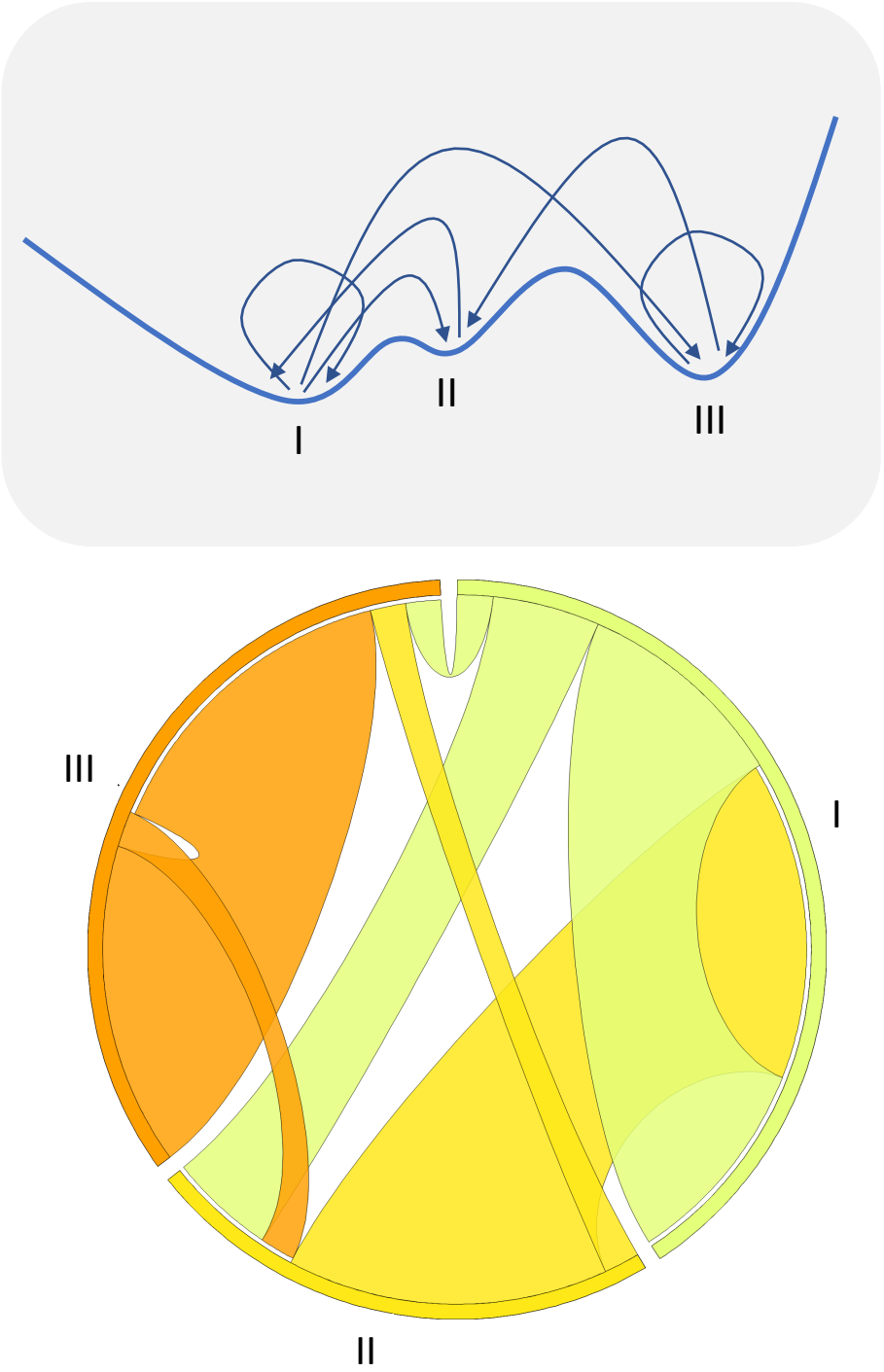

Figure 3.12: From hill-and-valley diagrams to Circos plots. Valleys represent internally consistent scenarios and correspond to segments, and arrows represent pathways and correspond to ribbons. Ribbon thickness indicates the number of pathways between scenarios.

valley diagram to a Circos plot, which consist of segments and ribbons. Valleys represent internally consistent scenarios and correspond to segments, and arrows represent pathways

and correspond to ribbons. Ribbon thickness indicates the number of pathways between scenarios. The value of Circos plots becomes clear when we try to interpret the pathways.

Consider a system with three internally consistent scenarios, I, II, and III. Suppose that we tested ten potential leverage points per scenario and obtained the results as shown in Table 3.6. The row for scenario I tells us that six perturbations result in the system returning to scenario I, three perturbations result in the system arriving at scenario II, and one perturbation results in the system arriving at scenario III.

The row for scenario II tells us that nine perturbations result in the system arriving at scenario I, none of the perturbations result in the system returning to scenario II, and one perturbation results in the system arriving at scenario III.

Finally, the row for scenario III tells us that none of the perturbations result in the system arriving at scenario I, one of the perturbations results in the system arriving at scenario II, and nine of the perturbations result in the system returning to scenario III.

These results suggest several conclusions. First, scenario III is highly resilient, scenario I is moderately resilient, and scenario II is highly sensitive. Second, it would be possible to go from scenario I to scenario III in two ways: directly, and indirectly via scenario II. Thus, the system exhibits equifinality (multiple paths to outcomes). Third, while it would be possible to go directly from scenario I to scenario III, it would not be possible to go directly from scenario III to scenario I. Thus, the system exhibits hysteresis (irreversibility).

Table 3.6: Pathways among internally consistent scenarios.

	I	**II**	**III**
I	6	3	1
II	9	0	1
III	0	1	9

These results are much easier to illustrate using a Circos plot. In Figure 3.12, the thick ribbon starting at scenario III and returning to scenario III tells us that scenario III is highly resilient. The thin ribbon starting at scenario III and stretching out to scenario II shows that there is at least one leverage point for going directly from scenario III to scenario II. The thickness of the ribbons corresponds to the number of pathways listed in Table 3.6.

3.3.3: Section Summary

The analytical approach is cumulative: the identification of self-reinforcing societal cultures (research question 1) was necessary in order to validate the model. Validating the model was necessary in order to justify proceeding with research questions 2 and 3. Assessing the self-reinforcing societal cultures in terms of their compatibility with sustainable development (research question 2) was necessary, in combination with the results of sensitivity analysis, for identifying pathways from unsustainable, self-reinforcing societal cultures to sustainable, self-reinforcing societal cultures (research question 3).

3.4: Detailed Description of the Model

In this section, I present my judgments of how the variable states are interrelated. CIB is based on pairwise judgments (e.g., how does a state of variable X affect a state of variable Y?) and uses numerical scores, typically in the range of -3 to +3, to represent the direction (i.e., promoting or restricting) and strength (i.e., weakly, moderately, or strongly) of impacts.

Section 3.4.1 describes the variables and states. The remaining sub-sections describe and visualize my judgment of how pairs of variables interact. Additional supporting details for my judgments (e.g., justifying strong vs. moderate vs. weak impacts) may be found in the footnotes.

3.4.1: Variables and states

3.4.1.1: Collectivism-Individualism

The Collectivism-Individualism variable describes "the relationship between the individual and the collectivity" (Hofstede 2001, 209). In particular, it describes "the extent to which people are autonomous individuals or embedded in their groups" (Triandis and Gelfand 2012, 499). According to Beugelsdijk and Welzel (2018), people in collectivist societies tend to be more embedded in their groups, while people in individualist societies tend to be more autonomous. A key distinction between collectivist and individualist societies relates to deference to authority (e.g., parents, religion, the state). Collectivist societies tend to be more, and individualist societies tend to be less, deferential to authority (Beugelsdijk and Welzel 2018).

3.4.1.2: Duty-Joy

The Duty-Joy variable refers to a society's "tendency to allow relatively free gratification of basic and human desires related to enjoying life and having fun…[versus] a conviction that such gratification needs to be curbed and regulated by strict social norms"

(Hofstede 2001, 281). According to Beugelsdijk and Welzel (2018), people in dutiful societies tend to be more restrained, while people in joyful societies tend to be more indulgent. A key distinction between dutiful and joyful societies relates to freedom of choice and control over how life turns. Dutiful societies tend to feel less, and joyful societies tend to feel more, free to choose and in control over how life turns out (Beugelsdijk and Welzel 2018).

3.4.1.3: Distrust-Trust

The Distrust-Trust variable reflects "the degree to which members of society are comfortable in unstructured situations, or if such situations create stress and anxiety" (Beugelsdijk and Welzel 2018, 1484). According to Beugelsdijk and Welzel (2018), people in distrusting societies tend to feel stressed and anxious in unstructured situations, while people in trusting societies tend to feel comfortable in such situations. A key distinction between distrusting and trusting societies relates to confidence in institutions (e.g., justice, democracy). Distrusting societies tend to have less, and trusting societies tend to have more, confidence in institutions (Beugelsdijk and Welzel 2018).

3.4.1.4: Political System

The Political System variable describes the organization of collective decision-making in a society (i.e., decisions that are *made by* the collective). I follow Dahl (1971) in differentiating political systems by their degree of contestation (i.e., freedom to formulate and signify preferences, and to have those preferences counted equally in the conduct of government) and inclusiveness (i.e., the proportion of the population that is free to take part

in collective decision-making – the size of the collective). Polyarchy refers to a political system in which contestation and inclusiveness are high, while closed hegemony refers to a political system in which contestation and inclusiveness are low. Dahl (1971) distinguished two other types of political system, which I combine into a single intermediate type: competitive oligarchy (high contestation, low inclusiveness) and inclusive hegemony (low contestation, high inclusiveness). In the model, I use the more familiar terms "democracy," "anocracy," and "dictatorship" to refer to "polyarchy," "competitive oligarchy" / "inclusive hegemony", and "closed hegemony," respectively.

3.4.1.5: Economic System

The Economic System variable describes the mechanisms by which a society allocates scarce resources among alternative ends (Daly and Farley, 11). I follow Nolan and Lenski (2015) in differentiating economics systems by the roles that markets and government play in allocation. In the market economy, markets play a strong role in allocation, while government plays a weak role. In the command economy, markets play a weak role in allocation, while government plays a strong role. In the mixed economy, markets and government both play a strong role. While the market, command, and mixed economies are theoretical constructs, I showed in chapter 2 that they are compatible with empirically-derived clusters of economic institutions (Pryor 2005).

3.4.1.6: Subsistence Technology

The Subsistence Technology variable refers to the primary technology that a society uses to obtain energy, income, and wealth (Nolan and Lenski 2015). The agriculture type of subsistence technology involves the cultivation of fields using the plow and is associated with a large primary sector (e.g., farming, fishing, mining, and forestry) (Nolan and Lenski 2015). The industry type of subsistence technology involves the manufacture of goods using renewable and non-renewable energy sources and is associated with a large secondary sector (e.g., mills, factories) (Nolan and Lenski 2015). The post-industry type of subsistence technology involves the provision of services and is associated with a large tertiary sector (e.g., education, health care, trade) (Nolan and Lenski 2015). The diversified type of subsistence technology refers to a society that does not rely primarily on any one of these forms of subsistence technology, but rather combines them.

3.4.1.7: International System

The International System variable refers to the system of identities and institutions that shapes interactions among societies (Wendt 1992). I include two of Wendt's (1992) three types of international system: competitive, and cooperative. Under the competitive system, (groups of) societies regard one another as rivals for power, prestige, and wealth (e.g., the North-Atlantic Treaty Organization (NATO) vs. the Shanghai Cooperation Organization (SCO)). Under the cooperative system, all or most societies regard one another as allies and pursue collective gains; this is a hypothetical system. I do not include Wendt's (1992) individualistic system, which refers to a system in which societies are indifferent to one another. This type

of system does not seem plausible in our highly interconnected world, in which societies are always affecting one another directly or indirectly.

3.4.2: Judgments of how the variable states are interrelated

In CIB, judgments of how variable states are interrelated are guided by the following question (Weimer-Jehle 2006):

> If the only piece of information you have is that variable X has the state x, would you evaluate the direct influence of X on Y as a hint that variable Y has the state y (promoting influence, positive points assessed) or as a hint that variable Y does not have the state y (restricting influence, negative points assessed)?

In the following sub-sections, I judge how each variable state impacts the others based on the variable definitions in section 3.3 and the literature review in chapter two. Since my judgments are based on definitions, they should be regarded as hypotheses. Thus, one of the purposes of my model is to develop possible *explanations* of how societal cultures evolve by testing these hypotheses (Edmonds et al. 2019).

3.4.2.1: Collectivism-Individualism and Political System

If a society has the collectivist worldview (more deferential to authority), then the worldview strongly promotes (+3) the dictatorship type of political system (low contestation and low inclusiveness), moderately promotes (+2) the anocracy type of political system (high

contestation and low inclusiveness, or low contestation and high inclusiveness), and strongly restricts (-3) the democracy type of political system (high contestation and high inclusiveness). Conversely, if a society has the individualist worldview (less deferential to authority), then the worldview strongly restricts (-3) the dictatorship type of political system, moderately restricts (-2) the anocracy type of political system, and strongly promotes (+3) the democracy type of political system.[48] These judgments are pictured in Figure 3.13.

I also assume that a society's type of political system reciprocates the promoting or restricting impacts of its Collectivism-Individualism worldview. The reason for this assumption is that while worldviews help a society to decide among alternative institutional systems, institutional systems provide a stable context in which individuals acquire their worldviews (Nolan and Lenski 2015; Hofstede, Hofstede, and Minkov 2010; Richerson and Boyd 2006).

Exception: I assume that the anocracy type of political system promotes, rather than restricts, the individualist worldview. The reason for this assumption is that I regard the anocracy type of political system as partially satisfying certain human needs (i.e., participation, freedom) (Max-Neef, Elizalde, and Hopenhayn 1991). I assume that once a person has experience one of their needs being indulged, they become less willing to go without that need being indulged. Thus, I assume that some experience of democracy (i.e., having some freedom of choice and control over how life turns out) creates demand for more experiences of democracy.

[48] I judge the anocracy type of political system as being moderately consistent with the collectivist worldview (rather than the individualist worldview) because I regard the anocracy type of political system as more similar to the dictatorship type of political system than to the democracy type of political system. As power remains highly concentrated in anocratic political systems, individuals in a society with an anocracy type of political system remain highly dependent on government elites.

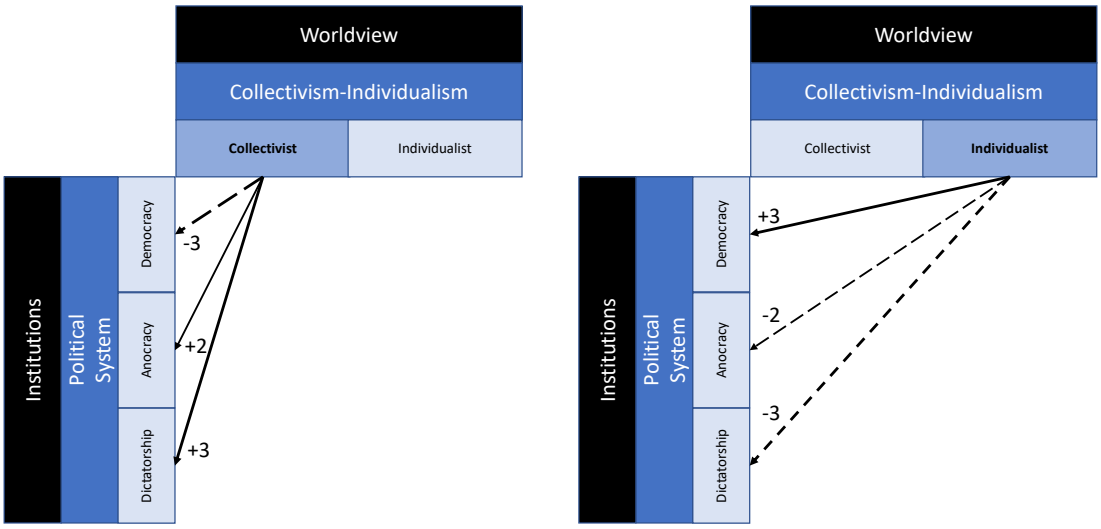

Figure 3.13: Impacts of Collectivism-Individualism on Political System. Solid lines indicate promoting impacts. Dashed lines indicate restricting impacts.

3.4.2.2: Collectivism-Individualism and Economic System

If a society has the collectivist worldview (more deferential to authority), then the worldview strongly promotes (+3) the command type of economic system (weak markets and strong government), moderately restricts (-2) the mixed type of economic system (strong markets and strong government), and strongly restricts (-3) the market type of economic system (strong markets and weak government). Conversely, if a society has the individualist worldview (less deferential to authority), then the worldview strongly restricts (-3) the command type of economic system, moderately promotes (+2) the mixed type of economic system, and strongly promotes (+3) the market type of economic system.[49] These judgments are pictured in Figure 3.14.

[49] I judge the mixed type of economic system as being moderately consistent with the individualist worldview (rather than the collectivist worldview) because I regard the mixed type of economic system as more similar to the market type of economic system than to the command type of economic system. As markets play a strong

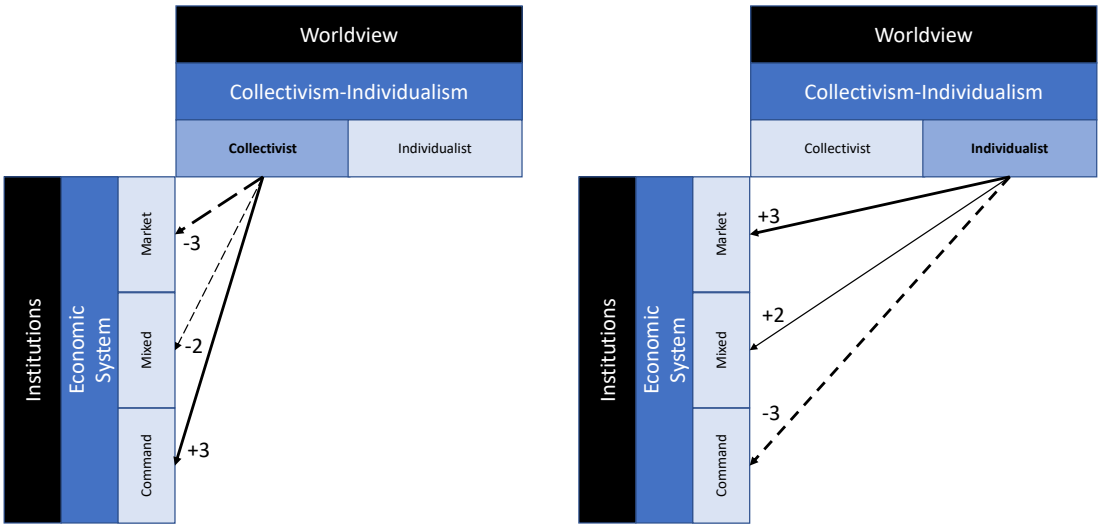

Figure 3.14: Impacts of Collectivism-Individualism on Economic System. Solid lines indicate promoting impacts. Dashed lines indicate restricting impacts.

I also assume that a society's economic system reciprocates the promoting or restricting impacts of its Collectivism-Individualism worldview. The reason for this assumption is that while worldviews help a society to decide among alternative institutional systems, institutional systems provide a stable context in which individuals acquire their worldviews (Nolan and Lenski 2015; Hofstede, Hofstede, and Minkov 2010; Richerson and Boyd 2006).

3.4.2.3: Distrust-Trust and Political System

If a society has the distrusting worldview (less confidence in institutions, such as the justice system and democracy), then the worldview strongly promotes (+3) the dictatorship type of political system (low contestation and low inclusiveness) and the anocracy type of

role in mixed economies, individuals in a society with a mixed type of economy retain a high degree of autonomy in economic decision-making.

political system (high contestation and low inclusiveness, or low contestation and high inclusiveness), and strongly restricts (-3) the democracy type of political system (high contestation and high inclusiveness). Conversely, if a society has the trusting worldview (more confidence in institutions, such as the justice system and democracy), then the worldview strongly restricts (-3) the dictatorship and anocracy types of political system, and strongly promotes (+3) the democracy type of political system.[50] These judgments are pictured in Figure 3.15.

I also assume that a society's type of political system reciprocates the promoting or restricting impacts of its Distrust-Trust worldview. The reason for this assumption is that while worldviews help a society to decide among alternative institutional systems, institutional systems provide a stable context in which individuals acquire their worldviews (Nolan and Lenski 2015; Hofstede, Hofstede, and Minkov 2010; Richerson and Boyd 2006).

[50] I judge the anocracy type of political system as being strongly consistent with the distrusting worldview (rather than the trusting worldview) because I regard the anocracy type of political system as more similar to the dictatorship type of political system than to the democracy type of political system. Experience with aspects of democracy (i.e., the anocracy type of political system) may create expectations that cannot be realized without a wider sharing of power. Consequently, the anocracy type of political system may fail to raise trust.

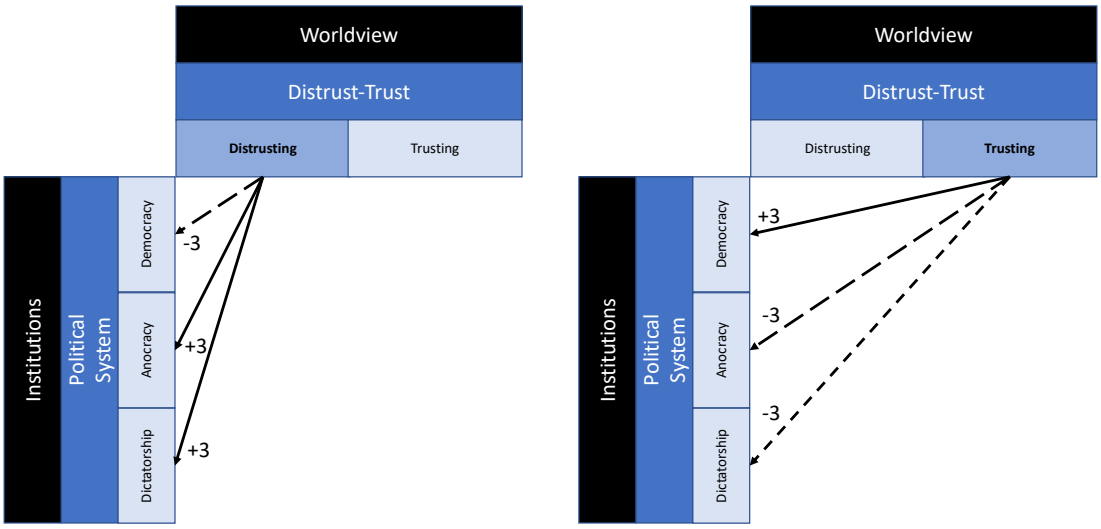

Figure 3.15: Impacts of Distrust-Trust on Political System. Solid lines indicate promoting impacts. Dashed lines indicate restricting impacts.

3.4.2.4: Distrust-Trust and Economic System

If a society has the distrusting worldview (less confidence in institutions, such as the justice system and democracy), then the worldview strongly promotes (+3) the command type of economic system (weak markets and strong government), strongly restricts (-3) the mixed type of economic system (strong markets and strong government), and moderately restricts (-2) the market type of economic system (strong markets and weak government).[51] Conversely, if a society has the trusting worldview (more confidence in institutions, such as the justice system and democracy), then the worldview strongly restricts (-3) the command type of economic system, strongly promotes the mixed type of economic system, and

[51] I judge the market type of economy as being strongly inconsistent with the distrusting worldview, since market economies depend on trust among buyers and sellers and on courts to adjudicate and enforce contracts. Without trust in the justice system, I assume that markets cannot function properly.

moderately promotes the market type of economic system.[52] These judgments are pictured in Figure 3.16.

I also assume that a society's type of economic system reciprocates the promoting or restricting impacts of its Distrust-Trust worldview. The reason for this assumption is that while worldviews help a society to decide among alternative institutional systems, institutional systems provide a stable context in which individuals acquire their worldviews (Nolan and Lenski 2015; Hofstede, Hofstede, and Minkov 2010; Richerson and Boyd 2006).

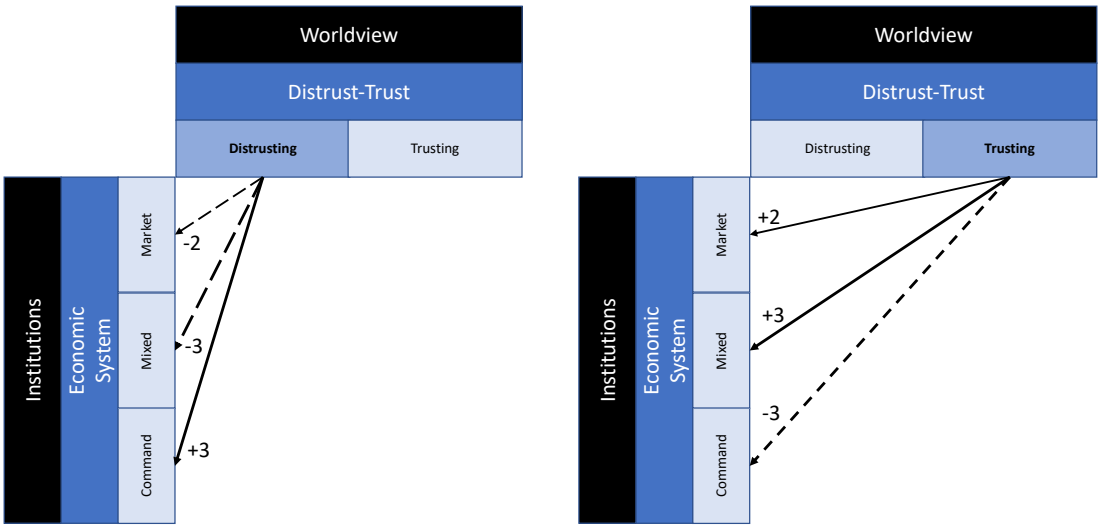

Figure 3.16: Impacts of Distrust-Trust on Economic System. Solid lines indicate promoting impacts. Dashed lines indicate restricting impacts.

[52] I judge the mixed type of economic system as being more strongly consistent with the trusting worldview (compared to the market type of economy) because in societies with the trusting worldview, not only do people tend to have greater confidence in institutions, but also people tend to feel a stronger sense of obligation to others (Beugelsdijk and Welzel 2018). I assume that this sense of obligation favours the mixed type of economy, in which laws and regulations exist to protect workers, society, and the environment (Nolan and Lenski 2015).

3.4.2.5: Political System and Duty-Joy

If a society has the dictatorship type of political system (low contestation and low inclusiveness), then the political system strongly promotes (+3) the dutiful worldview (lesser sense of freedom of choice and control over how life turns out) and strongly restricts (-3) the joyful worldview (greater sense of freedom of choice and control over how life turns out). If a society has the anocracy type of political system (high contestation and low inclusiveness, or low contestation and high inclusiveness), then the political system moderately restricts (-2) the dutiful worldview and moderately promotes (+2) the joyful worldview.[53] If a society has the democracy type of political system (high contestation and high inclusiveness), then the political system strongly restricts (-3) the dutiful worldview and strongly promotes (+3) the joyful worldview. These judgments are pictured in Figure 3.17.

I also assume that a society's Duty-Joy worldview reciprocates the promoting or restricting impacts of its political system. The reason for this assumption is that while institutional systems provide a stable context in which individuals acquire their worldviews, worldviews help a society to decide among alternative institutional systems (Nolan and Lenski 2015; Hofstede, Hofstede, and Minkov 2010; Richerson and Boyd 2006).

Exception: I assume that the Joyful worldview restricts, rather than promotes, the anocracy type of political system. The reason for this assumption is that regard the anocracy type of political system as partially satisfying certain human needs (i.e., participation,

[53] I judge the mixed type of political system as being moderately consistent with the joyful worldview (rather than the dutiful worldview) because I regard the mixed type of political system as partially satisfying certain human needs (i.e., participation, freedom) (Max-Neef, Elizalde, and Hopenhayn 1991). I assume that once a person has experience one of their needs being indulged, they become less willing to go without that need being indulged. Thus, I assume that some experience of democracy (i.e., having some freedom of choice and control over how life turns out) creates demand for more experiences of democracy.

freedom) (Max-Neef, Elizalde, and Hopenhayn 1991). I assume that once a person has experience one of their needs being indulged, they become less willing to go without that need being indulged. Thus, I assume that some experience of democracy (i.e., having some freedom of choice and control over how life turns out) creates demand for more experiences of democracy, which prevents a backslide to the anocracy type of political system.

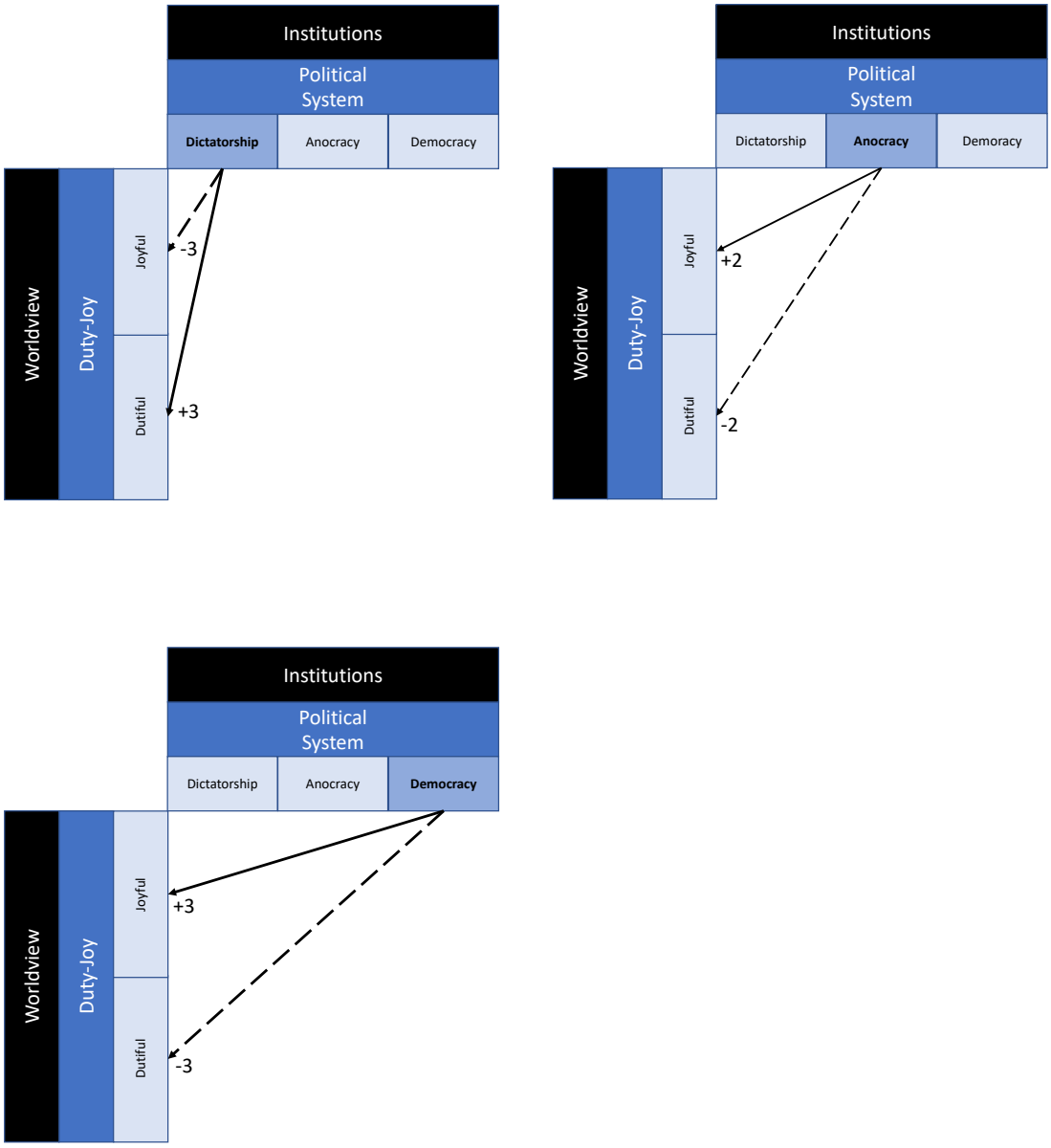

Figure 3.17: Impacts of Political System on Duty-Joy. Solid lines indicate promoting impacts. Dashed lines indicate restricting impacts.

3.4.2.6: Economic System and Duty-Joy

If a society has the command type of economic system (weak markets and strong government), then the economic system moderately promotes (+2) the dutiful worldview (lesser sense of freedom of choice and control over how life turns out) and moderately restricts (-2) the joyful worldview (greater sense of freedom of choice and control over how life turns out). If a society has the mixed type of economic system (strong markets and strong government), then the economic system moderately restricts (-2) the dutiful worldview and moderately promotes (+2) the joyful worldview. If a society has the market type of economic system (strong markets and weak government), then the economic system moderately promotes (+2) the dutiful worldview and moderately restricts (-2) the joyful worldview.[54] These judgments are pictured in Figure 3.18.

I also assume that a society's Duty-Joy worldview reciprocates the promoting or restricting impacts of its economic system. The reason for this assumption is that while institutional systems provide a stable context in which individuals acquire their worldviews, worldviews help a society to decide among alternative institutional systems (Nolan and Lenski 2015; Hofstede, Hofstede, and Minkov 2010; Richerson and Boyd 2006).

[54] I judge the market type of economic system as being moderately consistent with the dutiful worldview (rather than the joyful worldview) because I regard the market type of economic system as partially thwarting certain human needs (i.e., idleness, freedom) (Max-Neef, Elizalde, and Hopenhayn 1991). The competitive logic of market economies compels owners of firms to prioritize profits over people (e.g., seeking monopoly prices and minimizing wages), which limits the freedom of choice and control that workers have over how their lives turn out (e.g., sacrificing more leisure time, since wages are low) (Nolan and Lenski 2015; Turner 2014; Marx 1867). By contrast, mixed economies, which temper markets with protections for workers (e.g., health and safety laws, minimum wage laws, unemployment insurance systems, and mandatory employer contributions to retirement savings plans), allow workers to have more choice and control over how their lives turn out (e.g., retaining more leisure time, since wages are more equitable) (Nolan and Lenski 2015; Polanyi 2001).

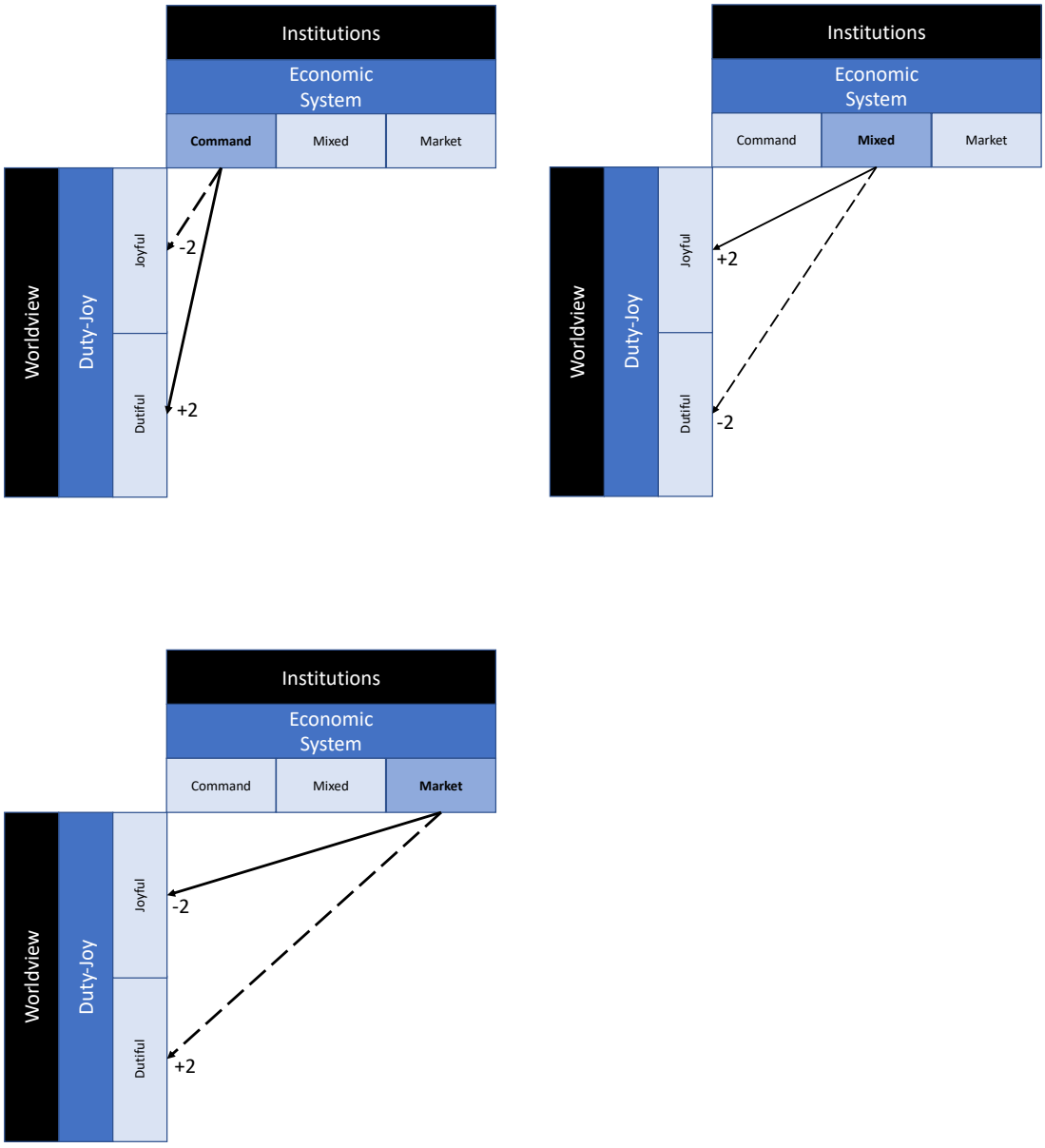

Figure 3.18: Impacts of Economic System on Duty-Joy. Solid lines indicate promoting impacts. Dashed lines indicate restricting impacts.

3.4.2.7: Subsistence Technology and Collectivism-Individualism

If a society has the agriculture type of subsistence technology, then the subsistence technology moderately promotes (+2) the collectivist worldview (more deferential to authority) and moderately restricts (-2) the individualist worldview (less deferential to

authority). If a society has the industry or diversified type of subsistence technology, then the society weakly restricts (-1) the collectivist worldview and weakly promotes (+1) the individualist worldview. If a society has the post-industry type of subsistence technology, then the subsistence technology moderately restricts (-2) the collectivist worldview and moderately promotes (+2) the individualist worldview. These judgments are pictured in Figures 3.19.

I also assume that a society's Collectivism-Individualism worldview reciprocates the promoting or restricting impacts of its subsistence technology. The reason for this assumption is that while subsistence technologies (as socio-technical systems) provide a stable context in which individuals acquire their worldviews, worldviews help a society to decide among alternative subsistence technologies (Nolan and Lenski 2015; Hofstede, Hofstede, and Minkov 2010; Richerson and Boyd 2006).[55]

[55] As discussed in chapter 2, subsistence technologies are the core technologies of whole socio-technical systems (Nolan and Lenski 2015; Geels and Schot 2007). These systems include associated technologies (e.g., communications, transportation), and aspects of social organization (e.g., degree of occupational specialization) (Nolan and Lenski 2015; Ellis 2015).

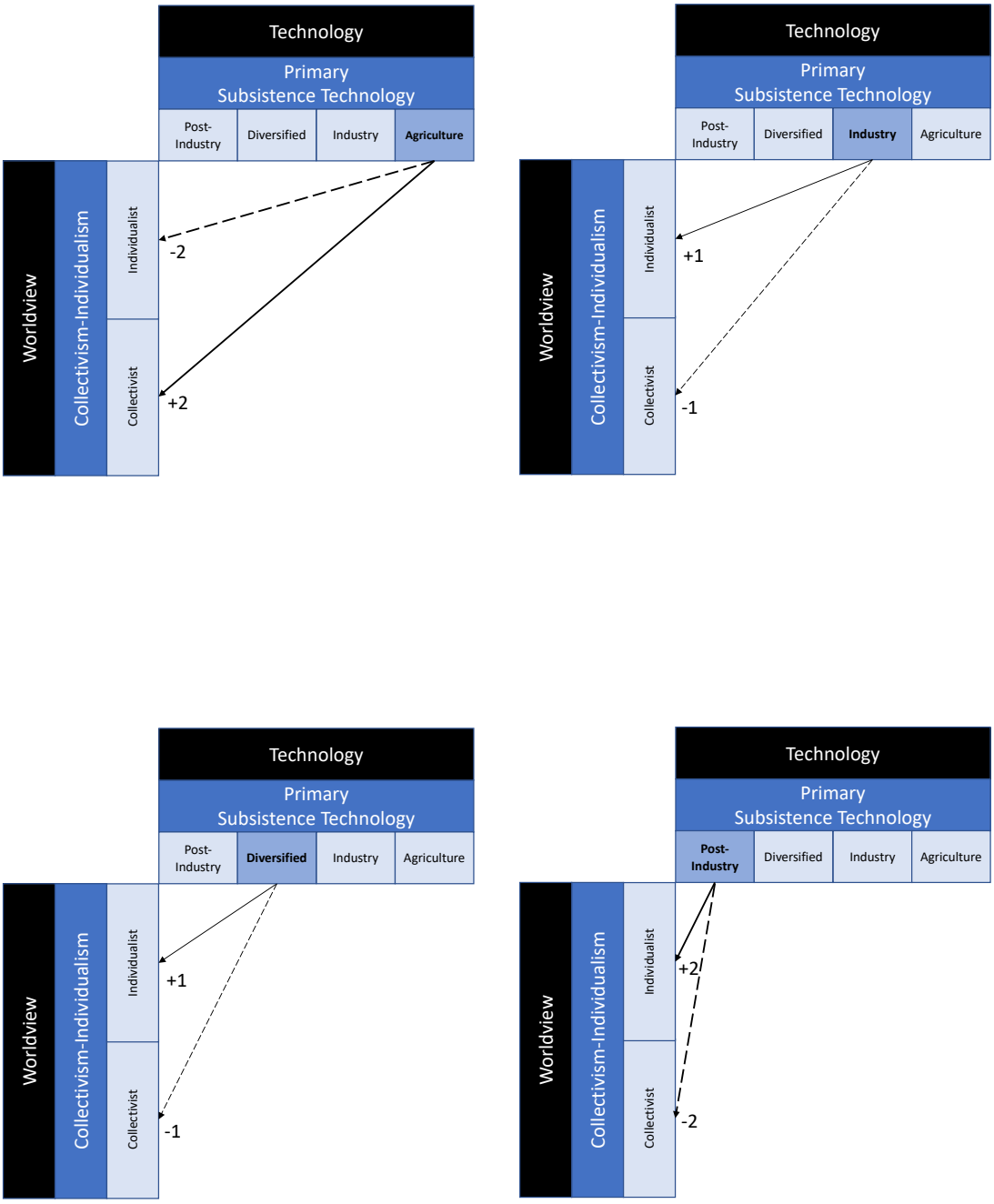

Figure 3.19: Impacts of Subsistence Technology on Collectivism-Individualism. Solid lines indicate promoting impacts. Dashed lines indicate restricting impacts.

3.4.2.8: Subsistence Technology and Duty-Joy

If a society has the agriculture type of subsistence technology, then the subsistence technology moderately promotes (+2) the dutiful worldview (lesser sense of freedom of choice and control over how life turns out) and moderately restricts (-2) the joyful worldview (greater sense of freedom of choice and control over how life turns out). If a society has the industry or diversified type of subsistence technology, then the subsistence technology weakly restricts (-1) the dutiful worldview and weakly promotes (+1) the joyful worldview. If a society has the post-industry type of subsistence technology, then the subsistence technology moderately restricts (-2) the dutiful worldview and moderately promotes (+2) the joyful worldview.[56] These judgments are pictured in Figures 3.20.

I also assume that a society's Duty-Joy worldview reciprocates the promoting or restricting impacts of its subsistence technology. The reason for this assumption is that while subsistence technologies (as socio-technical systems) provide a stable context in which individuals acquire their worldviews, worldviews help a society to decide among alternative subsistence technologies (Nolan and Lenski 2015; Hofstede, Hofstede, and Minkov 2010; Richerson and Boyd 2006).

[56] I judge the agriculture type of subsistence technology as being moderately consistent with the dutiful worldview because agricultural societies involve a complex division of labour and depend on a disciplined workforce in order to ensure a stable food supply (e.g., diligently planting, growing, harvesting, and storing food) (Nolan and Lenski 2015; Hofstede, Hofstede, and Minkov 2010). While the industry, post-industry, and diversified types of subsistence technology also involve a complex division of labour, they also produce substantially larger economic surpluses, allowing a greater proportion of the population to take on economic activities that are not directly related to ensuring the population's survival (Nolan and Lenski 2015; Hofstede, Hofstede, and Minkov 2010). Thus, individuals in these latter societies tend to have greater freedom of choice and control over how they lead their lives.

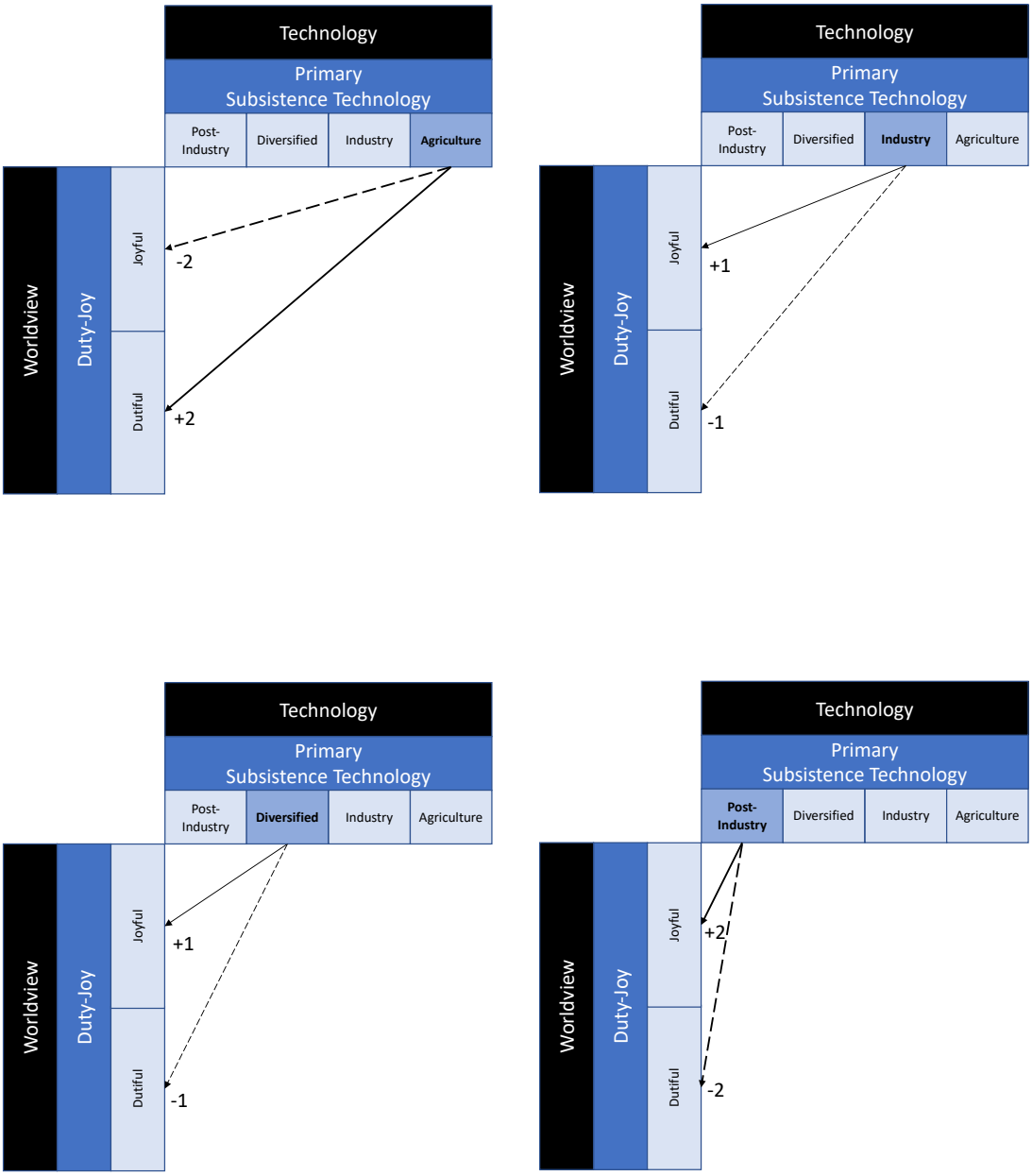

Figure 3.20: Impacts of Subsistence Technology on Duty-Joy. Solid lines indicate promoting impacts. Dashed lines indicate restricting impacts.

3.4.2.9: International System and Collectivism-Individualism

If the international system is competitive, then the international system weakly promotes (+1) the collectivist worldview (more deferential to authority) and weakly restricts (-1) the individualist worldview (less deferential to authority). Conversely, if the international system is cooperative, then the international system weakly restricts (-1) the collectivist worldview and weakly promotes (+1) the individualist worldview.[57] These judgments are pictured in Figure 3.21.

I assume that Collectivism-Individualism does not reciprocate the effects of the international system, since the structure of the international system is determined by the interactions of multiple societies.

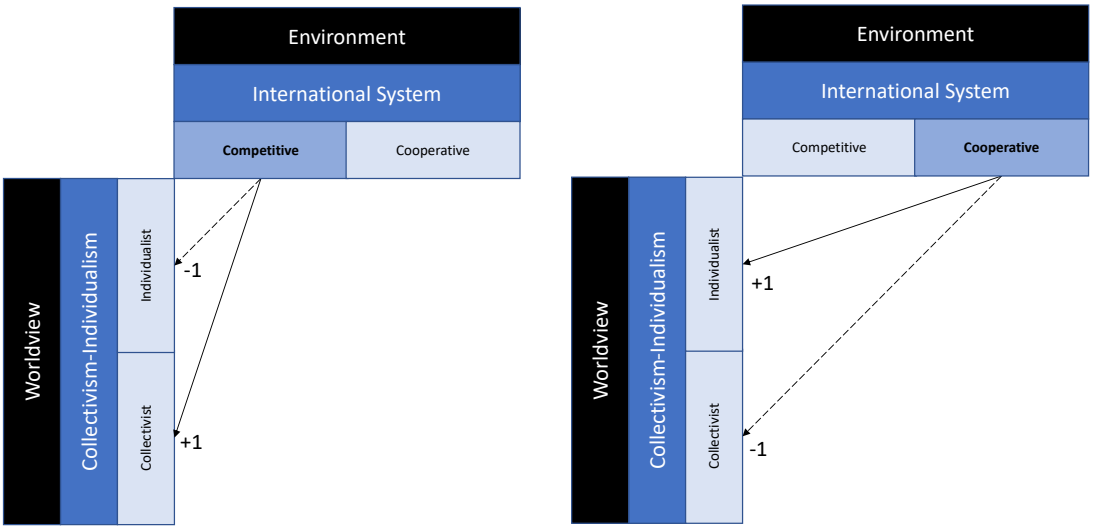

Figure 3.21: Impacts of International System on Collectivism-Individualism. Solid lines indicate promoting impacts. Dashed lines indicate restricting impacts.

[57] I judge the competitive type of international system as weakly consistent with the collectivist worldview (rather than the individualist worldview) because I assume that inter-societal competition requires societies to align individuals' actions with the collective interest (e.g., security) (Hofstede, Hofstede, and Minkov 2010). Conversely, I assume that inter-societal cooperation allows societies to relax restrictions on individual behaviour, since the situation is less threatening.

3.4.2.10: International System and Duty-Joy

If the international system is competitive, then the international system weakly promotes (+1) the dutiful worldview (lesser sense of freedom of choice and control over how life turns out) and weakly restricts (-1) the joyful worldview (greater sense of freedom of choice and control over how life turns out). Conversely, if the international system is cooperative, then the international system weakly restricts (-1) the dutiful worldview and weakly promotes (+1) the joyful worldview.[58] These judgments are pictured in Figure 3.22.

I assume that Duty-Joy does not reciprocate the effects of the international system, since the structure of the international system is determined by the interactions of multiple societies.

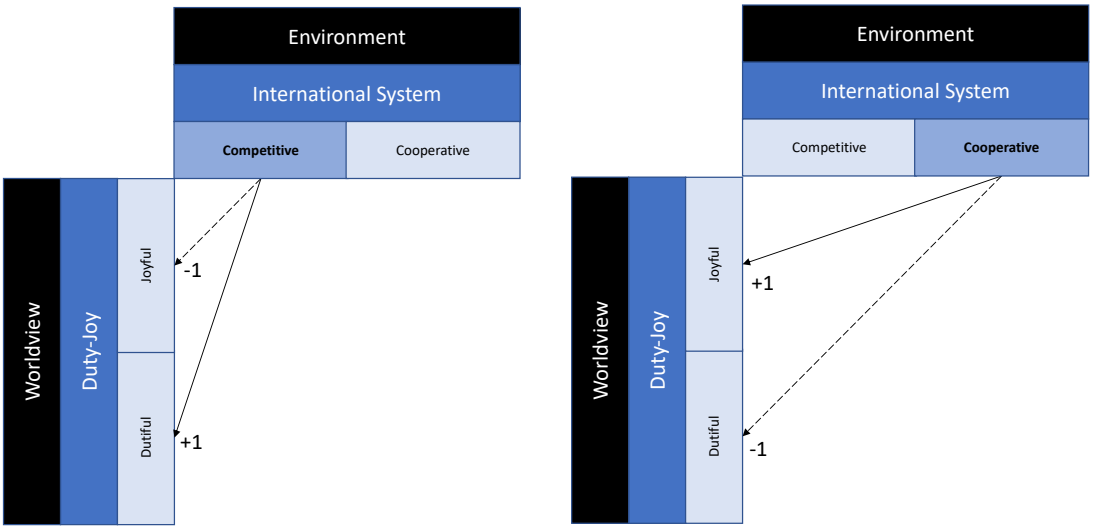

Figure 3.22: Impacts of International System on Duty-Joy. Solid lines indicate promoting impacts. Dashed lines indicate restricting impacts.

[58] I judge the competitive type of international system as weakly consistent with the dutiful worldview (rather than the joyful worldview) because I assume that inter-societal competition motivates a society to be thrifty (in order to provide for the collective interest). In turn, thrift is an element of the dutiful worldview worldview (Beugelsdijk and Welzel 2018).

3.4.2.11: International System and Distrust-Trust

If the international system is competitive, then the international system moderately promotes (+2) the distrusting worldview and moderately restricts (-2) the trusting worldview. Conversely, if the international system is cooperative, then the international system moderately restricts (-2) the distrusting worldview and moderately promotes (+2) the trusting worldview.[59] These judgments are pictured in Figure 3.23.

I assume that Distrust-Trust does not reciprocate the effects of the international system, since the structure of the international system is determined by the interactions of multiple societies.

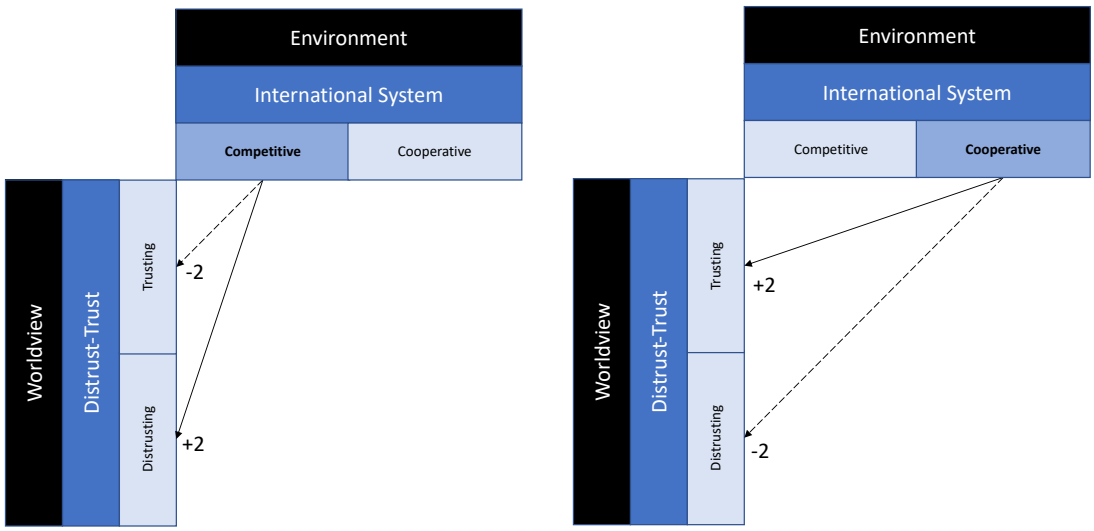

Figure 3.23: Impacts of International System on Distrust-Trust. Solid lines indicate promoting impacts. Dashed lines indicate restricting impacts.

[59] I judge the competitive type of international system as moderately consistent with the distrusting worldview (rather than the trusting worldview) because I assume that inter-societal competition is perceived as threatening, and the presence of a threatening environment is associated with right-wing ideology (Jost, Federico, and Napier 2013). In turn, right-wing ideology is an element of the distrusting worldview (Beugelsdijk and Welzel 2018).

3.4.2.12: International System and Subsistence Technology

If the international system is competitive, then the international system strongly restricts (-3) the agriculture and diversified types of subsistence technology, and strongly promotes (+3) the industry and post-industry types of subsistence technology. Conversely, if the international system is cooperative, then the international system strongly restricts (-3) the agriculture, industry, and post-industry types of subsistence technology and strongly promotes (+3) the diversified type of subsistence technology.[60] These judgments are pictured in Figure 3.24.

Exception: If a society has the agriculture type of subsistence technology and the international system is competitive, then the international system strongly promotes (+3) the industry type of subsistence technology and strongly restricts (-3) the diversified and post-industry types of subsistence technology.[61] This judgment requires an additional variable, which makes the state of Subsistence Technology conditional on the states of International System and Subsistence Technology.[62]

I assume that Subsistence Technology does not reciprocate the effects of the international system, since the structure of the international system is determined by the interactions of multiple societies.

[60] I judge the competitive international system as strongly promoting the post-industry and industry types of subsistence technology because inter-societal competition promotes a division of labour among countries (Chase-Dunn and Lerro 2015). Rich and powerful countries tend to specialize in services and outsource industrial and agricultural activities to poorer and less powerful countries, where labour and capital costs tend to be lower (Chase-Dunn and Lerro 2015). This makes a more balanced mix of technologies (i.e., the diversified type) difficult to achieve in any country.

[61] I assume, following World Systems Theory (Chase-Dunn and Lerro 2015), that rich and powerful countries prevent poorer and less powerful countries from entering the 'club' of countries that specialize in services, in order to maintain an international division of labour that favours the already rich and powerful countries .

[62] The use of Boolean logic in CIB is discussed in Weimer-Jehle (2008).

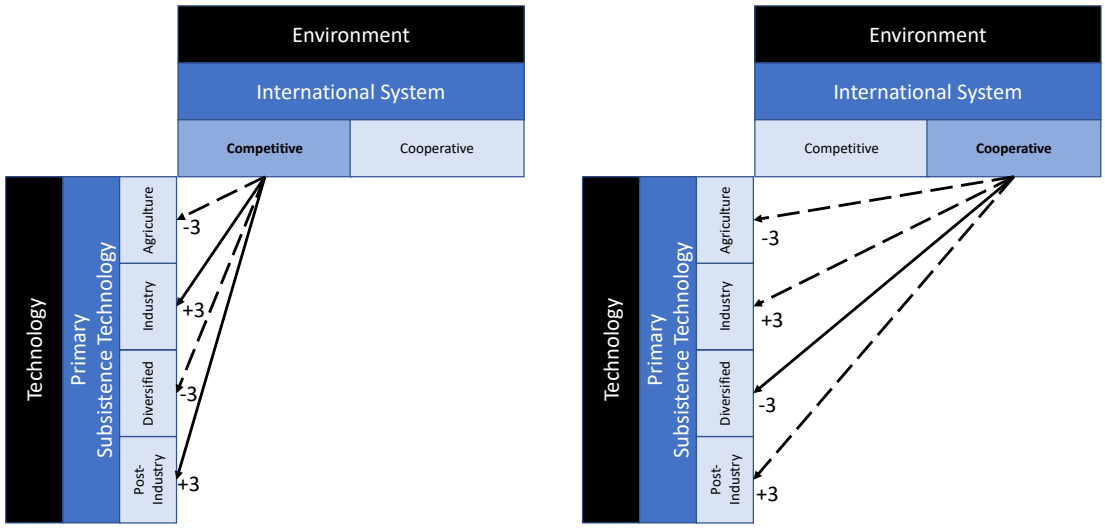

Figure 3.24: Impacts of International System on Subsistence Technology. Solid lines indicate promoting impacts. Dashed lines indicate restricting impacts.

3.4.2.13: Compatible Variable States

In CIB, pairs of variable states that are judged as neither promoting nor restricting one another imply that the variable states can coexist. There are several pairs of variable states that I judged as being compatible with one another:

- All states of Political System and Economic System;
- All states of Distrust-Trust and Subsistence Technology;
- All states of Political System and Subsistence Technology;
- All states of Political System and International System;
- All states of Economic System and Subsistence Technology; and,
- All states of Economic System and International System;

These variable states may interact with one another indirectly, but only direct interactions are recorded in CIB. Consider, for example, the states of Political System and Economic System. The political and economic systems shape the extent to which individuals are free to make political and economic decisions, respectively. Under the democracy type of political system, political freedoms are maximized, while under the dictatorship type of political system, these freedoms are minimized. Under the anocracy type of political system (i.e., competitive oligarchy and inclusive hegemony), political freedoms are at an intermediate level. Similarly, economic freedom is *in a formal sense* maximized under the market type of economic system, but at the cost of economic inequality, which limits individuals' opportunities. Thus, *effectively*, the market type of economic system may be no freer than the mixed type of economic system, which limits inequality and thereby provide more equitable opportunities. Certainly, economic freedom is minimized under the command type of economic system. Despite these parallels, I do not see anything directly incompatible about any combination of political and economic system. A society could have a democracy type of political system and a command type of economic system, or a dictatorship type of political system and a market type of economic system. While such combinations may not be *directly* incompatible, they may be *indirectly* incompatible through their interactions with worldviews. For example, I judged the democracy type of political system as promoting the individualist worldview, and the command type of economic system as promoting the collectivist worldview.

3.4.3: Section Summary

Figure 3.25 presents a high-level overview of the connective structure of the model. In my judgment, worldviews, institutions, and technologies interact directly, and each of these things is influenced by the social environment. My model does not include a variable for the natural environment, as I follow Norgaard (1994) in assuming that contemporary societies have been able to evolve independently from the natural environment, due to the tremendous productive power of fossil fuel and other industrial technologies.[63] In future work, I plan to include biophysical variables, since we can expect their states to change as the adverse effects of contemporary societies continue to accumulate.[64] For now, I focus on the human aspects of cultural evolution.

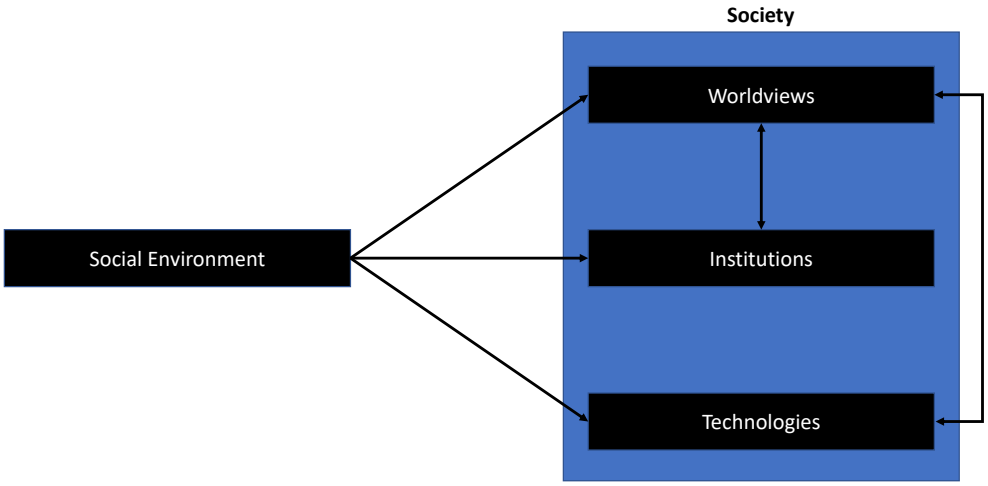

Figure 3.25: High-level overview of the connective structure of the model.

[63] Biophysical variables have, of course, played an important role in shaping cultural evolution (Dartnell 2018; Nolan and Lenski 2015). It has only been during the relatively brief (and unsustainable) Industrial period (or "Anthropocene") that human societies have been able to escape the constraints of the biosphere (Norgaard 1994; Crutzen 2002).

[64] For example, the collapse of the Holocene state of the Earth System, which has supported life for the past ten thousand years, could make the Earth System less stable and hospitable (Steffen et al. 2015).

3.5: Summary

In this chapter, I provided a brief introduction to CIB, a description of my analytical approach, and a detailed description of the model. CIB is a judgment-based, computational method for identifying internally consistent scenarios (self-reinforcing system states) and pathways (sequences of contradictory system states between pairs of self-reinforcing system states) (Weimer-Jehle 2006). CIB uses categorical variables to represent state-specific effects, allowing it to represent system change as an evolutionary process of recombination (e.g., of types of worldviews, institutions, and technologies).

The model synthesizes the literatures reviewed in chapter two and consists of eight variables, each with between two and four states. The variables are drawn from a variety of social science literatures and describe societies in terms of worldviews, institutions, technologies, and environmental selective pressures. In addition to the main model, I considered fourteen alternative versions of the model, which incorporate the influence of archetypes of social ontologies.

The analytical approach consists of standard CIB procedures for identifying internally consistent scenarios and novel procedures developed for the purpose of identifying leverage points and pathways.

Chapter 4: Results and Analysis

4.1 Introduction

In this chapter, I present the main results of my research and provide answers to the research questions: which combinations of worldviews, institutions, and technologies (societal cultures, or WITs) appear to be self-reinforcing, and under what environmental selective pressures (research question 1); which self-reinforcing societal cultures appear to be most compatible with sustainable development, and why (research question 2); and, how might an unsustainable, self-reinforcing societal culture be transformed into a sustainable, self-reinforcing societal culture (research question 3)? In support of answering these questions, I begin by verifying and validating the model.

4.2 Bias Statistics

Verification refers to "evaluating the computational implementation of a model in terms of the researchers' intentions" (David, Fachada, and Rosa 2017, 174). In CIB, verification of the model is done by checking the bias statistics.

Bias statistics are frequencies, and they tell us how often, out of all possible scenarios, a variable state reaches its highest degree of support. When a variable state reaches its highest degree of support often, this means that the model assumptions *favour* this variable state. The purpose of bias statistics is to detect the presence of model assumptions (impact judgments) that *unduly* favour or disfavour a variable state.

Table 4.1 presents the bias statistics for versions 6 and 8 of the model, the versions that performed best in the validation tests (see Section 4.4). The bias statistics of both

Table 4.1: Bias statistics for versions 6 and 8 of the model.

Collectivism-Individualism	Ind 66.7%	Col 38.9% – 40.3%		
Duty-Joy	Joy 59.7%	Dut 45.8% – 52.8%		
Distrust-Trust	Tru 50.0%	Dis 50.0%		
Political System	Dem 50.0%	Ano 25.0%	Dic 50.0%	
Economic System	Mar 25.0%	Mix 37.5%	Cmd 37.5%	
Subsistence Technology	Pos 25.0%	Div 33.3%	Ind 58.3%	Agr 8.3%
International System	Comp 100.0%	Coop 100.0%		
IS & ST	Comp 37.5%	Comp & Agr 12.5%	Coop 50.0%	

versions of the model are almost identical; only the bias statistics for the Collectivist state and the Dutiful state differ, and only slightly.

None of the bias statistics suggest the presence of model assumptions that unduly favour or disfavour a variable state. Although the bias statistics of the Competitive and Cooperative states are 100%, this is not surprising. These variable states exert influences on, but do not sense influences from, other variables. As such, they always reach their highest degree of support.

4.3 Internally consistent scenarios

Of the 1,728 scenarios, between eight and fifteen are internally consistent, depending on the version of the model. Since versions 6 and 8 of the model performed best in the

Table 4.2: Tableau-style summary of internally consistent scenarios that emerged from versions 6 and 8 of the model. Each column represents a scenario. The top row specifies a name for the scenario. The first term in the name refers to the subsistence technology of the scenario. The second term refers to the type of political system of the scenario. To distinguish scenarios with the same subsistence technology and political system, the economic system is included in brackets. The subsequent rows indicate the variable states that comprise the scenario.

	Diversified Democracy	**Diversified Dictatorship**	**Post-Industrial Democracy**	**Post-Industrial Anocracy (Command)**	**Industrial Democracy***	**Industrial Anocracy**	**Post-Industrial Anocracy (Market)**	**Post-Industrial Dictatorship**	**Agricultural Dictatorship**	**Industrial Dictatorship**
International System	Cooperative		Competitive							
Duty-Joy	Joyful	Dutiful	Joyful		Dutiful					
Collectivism-Individualism	Individualist	Collectivist	Individualist	Collectivist	Individualist				Collectivist	
Distrust-Trust	Trusting	Distrusting	Trusting	Distrusting	Trusting	Distrusting				
Political System	Democracy	Dictatorship	Democracy	Anocracy	Democracy	Anocracy		Dictatorship		
Economic System	Mixed	Command	Mixed	Command	Market				Command	
Subsistence Technology	Diversified		Post-Industry		Industry		Post-Industry		Agriculture	Industry

* Emerged from version 8, but not from version 6.

validation tests, I focus on their internally consistent scenarios.

Versions 6 and 8 produced the same nine system internally consistent scenarios; version 8 also produced a tenth. Table 4.2 presents the characteristics of the internally consistent scenarios that were produced by versions 6 and 8 of the model.

4.4 Validation

Before we can interpret the outputs of the model, we have to have some confidence in the model's representation of reality (David, Fachada, and Rosa 2017). To that end, I tested the ability of each of the fifteen versions of the model to correctly reproduce the recent evolutionary histories of a sample of contemporary societies.

Overall, several versions of the model perform well (for full details, see Appendix D). The versions of the model that performed best are versions 6 and 8, which correctly reproduce the recent evolutionary histories of fourteen out of eighteen countries.[65]

The model gets two countries wrong in all versions. Jordan has become most like ***Post-Industrial Anocracy (Command)***, but the model incorrectly predicts ***Post-Industrial Democracy***.[66] Nigeria has also become most like ***Post-Industrial Anocracy (Command)***, but the model incorrectly produces ***Agricultural Dictatorship*** and ***Industrial Dictatorship***.[67] In the case of Peru, the model predicts ***Post-Industrial Democracy*** and ***Post-Industrial Anocracy***

[65] It is noteworthy that the model performs so well, even without incorporating variables such as population and geographical size. These results provide tentative support for the WITs framework, which prioritizes worldviews, institutions, and technologies as the drivers of sociocultural evolution. Nevertheless, future work will also examine the impact of demographic and geographical variables.

[66] It may be necessary to include 'neighbour effect' variables (e.g., the presence of dictatorships or democracies) to explain the cultural evolution of countries such as Jordan.

[67] This is not a catastrophically wrong prediction, as perturbing any of ***Post-Industrial Anocracy (Command)'s*** sensitive variables causes the system to evolve towards ***Industrial Dictatorship***.

Table 4.3: Correct and incorrect predictions of versions 6 and 8 of the model.

	Countries becoming like Post-Industrial Democracy	Countries becoming like Post-Industrial Anocracy (Command)
Correctly predicted by versions 6 and 8	Chile Germany Japan Norway South Africa Spain Switzerland United States Uruguay	Brazil China India Russia
	Peru	
Incorrectly predicted by versions 6 and 8		Argentina Mexico
Incorrectly predicted by all versions		Jordan Nigeria

(Command). These results are correct, as Peru has, over a period of twenty-two years (1996-2018), remained unchanged and most like ***Post-Industrial Democracy*** and ***Post-Industrial Anocracy (Command)***.

Versions 6 and 8 get two countries wrong: Argentina and Mexico. Both of these countries have become most like ***Post-Industrial Anocracy (Command)***, but the model predicts ***Post-Industrial Democracy***. While versions 4 and 12 of the model make correct predictions for Argentina and Mexico, these versions get only ten out of eighteen countries right.[68]

As shown in Table 4.4, versions 6 and 8 of the model have three multipliers in common: Environment has a multiplier of 2, and worldviews and technologies have a multiplier of 1.

[68] While it is perhaps possible that the rules for how worldviews, institutions, technologies, and environments interact vary by country, I assume that the rules are universal and rather that the rules are incompletely and imperfectly represented by the model.

Table 4.4: Multipliers of impacts for versions 6 and 8 of the model.

Model Version	Environment	Worldviews	Institutions	Technologies
6	2	1	2	1
8	2	1	1	1

The difference in the multiplier of institutions accounts for all the differences in the results of versions 6 and 8. These differences are the existence of ***Industrial Democracy***, which exists in version 8 but not in version 6; and the existence of links from ***Agricultural Dictatorship*** and ***Industrial Dictatorship*** to ***Industrial Anocracy***, which exist in version 6 but not in version 8.

4.5 Answers to the Research Questions

The results of the validation tests allow us to have some confidence in the model as a representation of reality. I now turn to analyzing the main results and answering the research questions.

4.5.1 Research question 1: Which combinations of worldviews, institutions, and technologies (societal cultures, or WITs) are self-reinforcing, and under what environmental selective pressures?

According to versions 6 and 8 of the model – the versions that performed best in the validation tests – there appear to be between nine and ten self-reinforcing societal cultures, as shown in Table 4.2. Seven to eight of these societal cultures describe countries that exist under a competitive international system, while the other two societal cultures describe countries that exist under a cooperative international system.

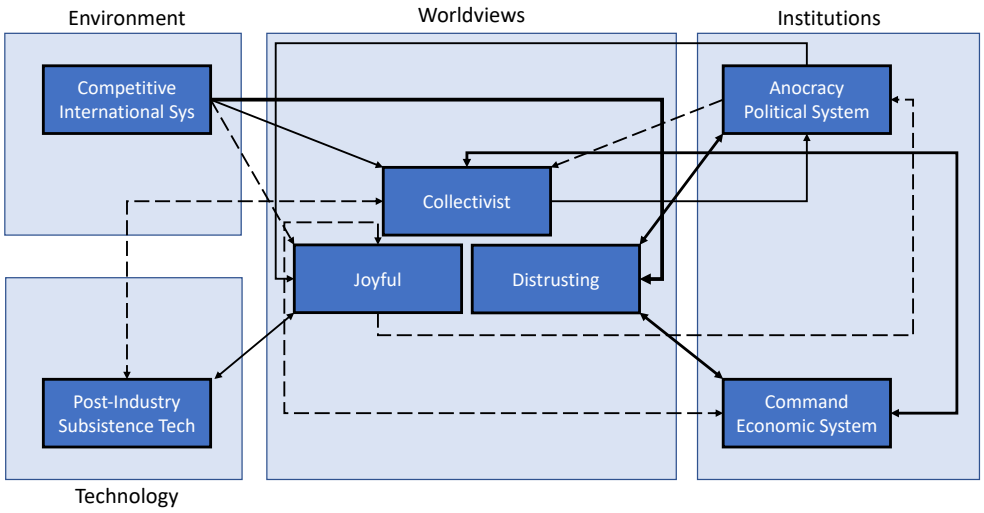

Figure 4.1: ***Post-Industrial Anocracy (Command)*** in version 8 of the model. Solid lines indicate promoting impacts. Dashed lines indicate restricting impacts. Line thickness indicates magnitude of impact.

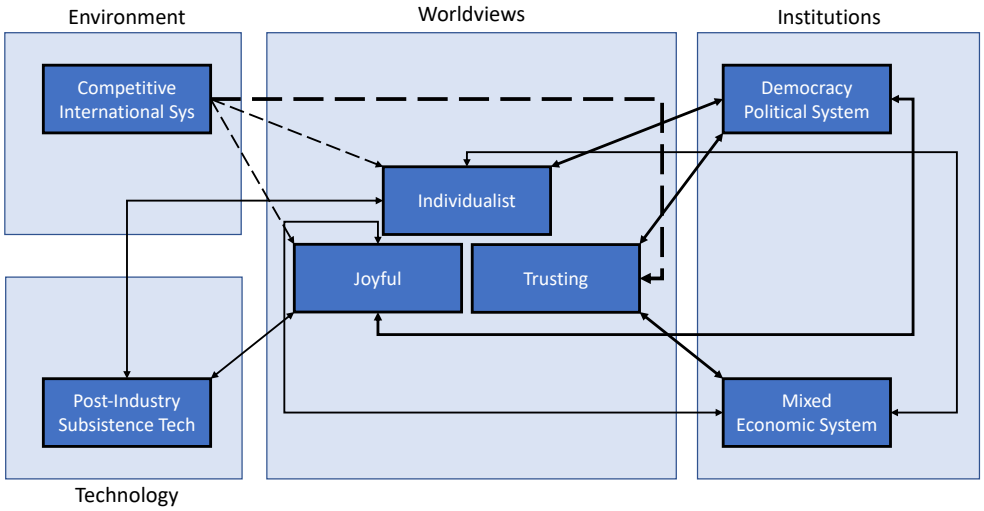

Figure 4.2: ***Post-Industrial Democracy*** in version 8 of the model. Solid lines indicate promoting impacts. Dashed lines indicate restricting impacts. Line thickness indicates magnitude of impact.

The validation tests provide evidence for the existence of two of these self-reinforcing societal cultures: ***Post-Industrial Democracy*** and ***Post-Industrial Anocracy (Command)***. As

such, we are limited to regarding the other seven to eight self-reinforcing societal cultures as *hypothetically* self-reinforcing societal cultures.

From Figure 4.1 we can see that ***Post-Industrial Anocracy (Command)*** has several internal contradictions. For example, the collectivist worldview and the post-industry subsistence technology are mutually restricting. Similarly, the joyful worldview and the command economic system are mutually restricting. There are also two asymmetric interactions: first, the joyful worldview restricts the anocracy political system, but the anocracy political system promotes the joyful worldview. Second, the collectivist worldview promotes the anocracy political system, but the anocracy political system restricts the collectivist worldview. Finally, the competitive international system restricts the joyful worldview.

Post-Industrial Anocracy (Command) is self-reinforcing despite these contradictions because of several stabilizing influences. First, the collectivist worldview is promoted by the command economic system (+3) and by the competitive international system (+2), which outweigh the restricting impacts of the post-industry subsistence technology (-2) and the anocracy political system (-2) (balance = +1). Second, the post-industry subsistence technology is promoted by the joyful worldview (+2), which is equal to the restricting impact of the collectivist worldview (-2) (balance = 0). Third, the joyful worldview is promoted by the post-industry subsistence technology (+2) and by the anocracy political system (+2), which are equal to the restricting impacts of the command economic system (-2) and the competitive international system (-2) (balance = 0). Fourth, the command economic system is promoted by the collectivist worldview (+2) and by the distrusting worldview (+2), which outweigh the restricting impact of the joyful worldview (-2) (balance = +2). Fifth, the anocracy political system is promoted by the collectivist worldview (+2) and by the distrusting worldview (+2),

which outweigh the restricting impact of the joyful worldview (-2) (balance = +2). The distrusting worldview is the only variable state that receives only promoting impacts.

The balances of 0 for the post-industry subsistence technology and the joyful worldview suggest that ***Post-Industrial Anocracy (Command)*** might be easy to destabilize. Indeed, this is what the sensitivity analysis revealed (discussed below).

In contrast, ***Post-Industrial Democracy*** has a very different structure (see Figure 4.2) The strong internal consistency at the societal level (i.e., among worldviews, institutions, and technologies) outweighs the restricting impacts from the social environment (i.e., the Competitive international system).

4.5.2 Which self-reinforcing societal cultures appear to be most compatible with sustainable development, and why?

Table 4.5 lists the self-reinforcing societal cultures in order from most to least compatible with 85 of the 169 targets of the Sustainable Development Goals (SDG), which I selected for their relevance to the variables in the model. For a breakdown of the scores, see Appendix C.

Of the two self-reinforcing societal cultures towards which the contemporary societies in my sample appeared to be evolving, one has a positive SDG Compatibility Score – ***Post-Industrial Democracy*** – while the other has a negative SDG Compatibility Score – ***Post-Industrial Anocracy (Command)***.

Post-Industrial Democracy describes a society with the post-industry type of subsistence technology, the democracy type of political system, the mixed type of economic

Table 4.5: Compatibility of the self-reinforcing societal cultures with the Sustainable Development Goals (SDGs), based on my assessment of 85 targets, selected for their relevance to the variables in the model. SDGs: **1** (No Poverty), **2** (Zero Hunger), **3** (Good Health & Well-Being), **4** (Quality Education), **5** (Gender Equality), **6** (Clean Water & Sanitation), **7** (Affordable & Clean Energy), **8** (Decent Work & Economic Growth), **9** (Industry, Innovation, & Infrastructure), **10** (Reduced Inequalities), **11** (Sustainable Cities & Communities), **12** (Responsible Consumption & Production), **13** (Climate Action), **14** (Life Below Water), **15** (Life On Land), **16** (Peace, Justice, & Strong Institutions), and **17** (Partnerships for the Goals).

Self-Reinforcing Societal Culture	Fully Compatible	Partially Compatible	Fully Incompatible	SDG Compatibility Score
Diversified Democracy	1-17	None	None	85
Post-Industrial Democracy	1-5, 7-8, 11	6, 10, 12-16	9, 17	31
Diversified Dictatorship	1-10, 12-15, 17	None	11, 16	23
Post-Industrial Anocracy (Command)	1-5, 7-8, 11	6, 10, 12-16	9, 17	-26
Agricultural Dictatorship	1-5, 7	6, 8, 10-16	9, 17	-33
Industrial Dictatorship	1-5, 7	6, 8, 10-16	9, 17	-33
Industrial Democracy	None	11, 16	1-10, 12-15, 17	-74
Post-Industrial Anocracy (Market)	None	8, 11, 16	1-7, 9-10, 12-15, 17	-77
Industrial Anocracy	None	11, 16	1-10, 12-15, 17	-79
Post-Industrial Dictatorship	None	8	1-7, 9-17	-82

system, and the competitive international system. Based on the 85 targets that I assessed, ***Post-Industrial Democracy*** is fully compatible with eight of the SDGs: SDGs 1 (No Poverty), 2 (Zero Hunger), 3 (Good Health & Well-Being), 4 (Quality Education), 5 (Gender Equality), 7 (Affordable & Clean Energy), 8 (Decent Work & Economic Growth), and 11 (Sustainable Cities & Communities). Most of these compatibilities are due to the mixed type of economic system, which includes regulations that protect people and planet from economic impacts (e.g., extreme inequality, environmental degradation). The compatibility of ***Post-***

Industrial Democracy with SDG 8 (Decent Work & Economic Growth) is due to the post-industry type of subsistence technology, which emphasizes value-added, labour-intensive production (e.g., services).

Post-Industrial Democracy is only partially compatible with seven of the SDGs, based on the 85 targets that I assessed: SDGs 6 (Clean Water & Sanitation), 10 (Reduced Inequalities), 12 (Responsible Consumption & Production), 13 (Climate Action), 14 (Life Below Water), 15 (Life On Land), and 16 (Peace, Justice, & Strong Institutions). Where ***Post-Industrial Democracy*** is partially compatible with these SDGs, it is mostly because of the mixed type of economic system, or in the case of SDG 16 (Peace, Justice, & Strong Institutions), because of the democracy type of political system. All of the incompatibilities are due to the competitive international system.

Post-Industrial Democracy is fully incompatible with two of the SDGs, based on the 85 targets that I assessed: SDGs 9 (Industry, Innovation, & Infrastructure), and 17 (Partnerships for the Goals). Once again, all of the incompatibilities are due to the competitive international system.

Post-Industrial Anocracy (Command) has the same compatibilities with the 85 targets of the SDGs as ***Post-Industrial Democracy***, but it has a lower SDG Compatibility Score because of its Command type of economic system, which I judged as neither compatible nor incompatible with the targets that required new economic regulations (no points assessed). In contrast, I judged the Mixed type of economic system as compatible with those targets (positive points assessed).

In other work, my colleagues and I used CIB to study systemic interactions among the SDGs (Lazurko et al. Forthcoming). In our study, we identified six "keystone" SDGs: SDGs 3 (Good Health & Well-Being), 5 (Gender Equality), 7 (Affordable & Clean Energy), 8 (Decent

Work & Economic Growth), 12 (Responsible Consumption & Production), and 13 (Climate Action). We found that progress on these six SDGs appeared to be necessary and sufficient for achieving all seventeen SDGs, due to the systemic nature of the SDGs. Specifically, we found that at least two of SDGs 3, 5, and 8 needed to be progressing, and that all of SDGs 7, 12, and 13 needed to be progressing. Comparing these conclusions to Table 4.5, it would appear that only ***Diversified Democracy*** and ***Diversified Dictatorship*** meet the conditions for achieving all seventeen SDGs. These are the self-reinforcing societal cultures that exist under the cooperative international system. Four other self-reinforcing societal cultures nearly meet the conditions that we identified in our study for achieving all seventeen SDGs: ***Post-Industrial Democracy, Post-Industrial Anocracy (Command), Agricultural Dictatorship,*** and ***Industrial Dictatorship.*** These four self-reinforcing societal cultures are only partially compatible with SDGs 12 (Responsible Consumption & Production) and 13 (Climate Action), due to the effects of the competitive international system. ***Agricultural Dictatorship*** and ***Industrial Dictatorship*** are also only partially compatible with SDG 8 (Decent Work & Economic Growth), due to the effects of their industry type of subsistence technology.

It is interesting how often the dictatorship type of political system appears in this list of self-reinforcing societal cultures that meet or nearly meet the conditions for achieving all seventeen of the SDGs. This may be the result of how I judged the compatibilities among the 85 targets and the states of the Political System variable. Another interpretation is that dictatorships might be in a position to catalyze sustainability transformations that later lead to transitions to democracy.

4.5.3 How might an unsustainable, self-reinforcing societal culture be transformed into a sustainable, self-reinforcing societal culture?

To answer this question, I systematically subjected each self-reinforcing societal culture to a sensitivity analysis, perturbing its sensitive variables individually, in pairs, and in triplets. Figures 4.3 and 4.4 present a visual summary of the sensitivity analysis in the form of Circos plots. Each self-reinforcing societal culture is represented by a segment. The ribbons indicate how the culture evolved after being perturbed. The initial culture is indicated by a ribbon end that is joined to a segment. The culture after being perturbed is indicated by a ribbon end that is detached from a segment.

The Circos plots for versions 6 and 8 of the model are almost identical. There are only a couple of noteworthy differences. First, version 8 includes the self-reinforcing societal culture ***Industrial Democracy***. Second, there are links from ***Agricultural Dictatorship*** and ***Industrial Dictatorship*** to ***Industrial Anocracy*** in version 6 of the model; these links do not exist in version 8.

From the results of the validation tests, we know that the contemporary societies in my sample appeared to be evolving towards ***Post-Industrial Democracy*** and ***Post-Industrial Anocracy (Command)***. From the answers to research question 2, we know that ***Post-Industrial Democracy*** appears to be more compatible with sustainable development than ***Post-Industrial Anocracy (Command)***, but that ***Diversified Democracy*** appears to be more compatible with sustainable development than ***Post-Industrial Democracy***.

Are there any leverage points (i.e., small perturbations) for getting from ***Post-Industrial Anocracy (Command)*** (the self-reinforcing societal culture with the fourth-highest prospects for sustainable development) to ***Post-Industrial Democracy*** (the self-reinforcing societal

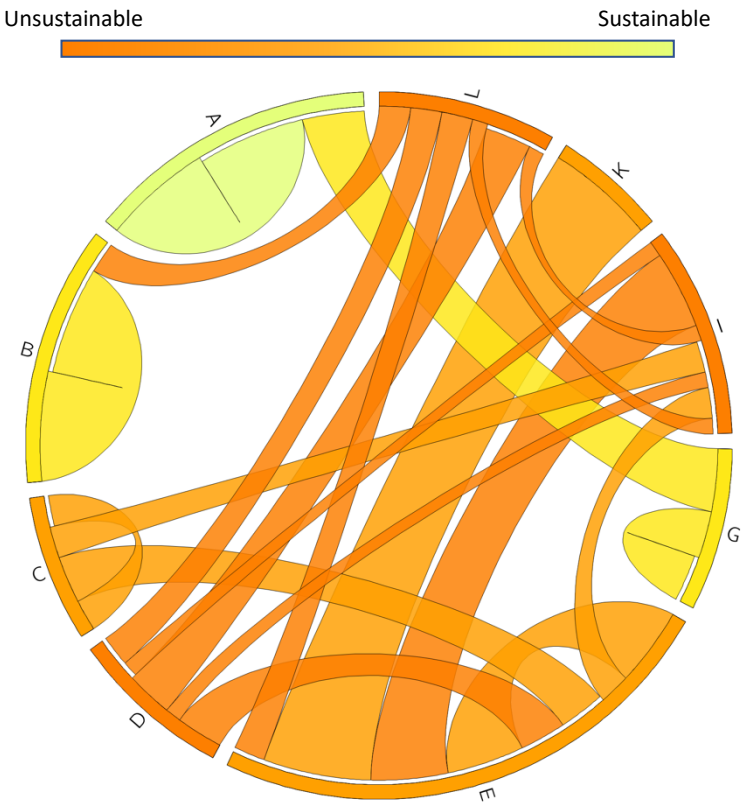

Figure 4.3: Version 6, evolution of self-reinforcing societal cultures following perturbations to sensitive variables.

Legend:

A: Diversified Democracy
B: Post-Industrial Democracy
C: Agricultural Dictatorship
D: Post-Industrial Dictatorship
E: Industrial Dictatorship
G: Diversified Dictatorship
I: Industrial Anocracy
K: Post-Industrial Anocracy (Command)
L: Post-Industrial Anocracy (Market)
N: Industrial Democracy

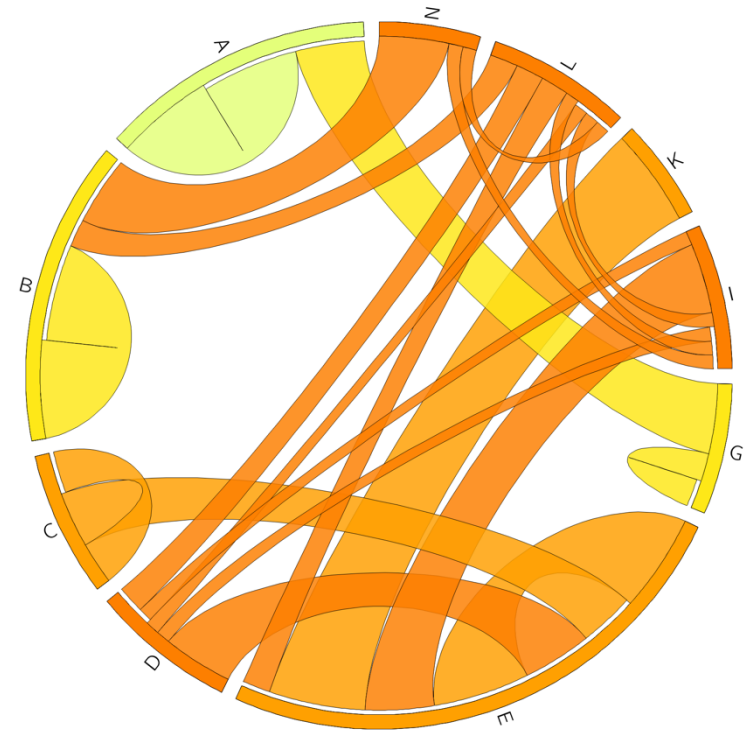

Figure 4.4: Version 8, evolution of internally consistent societal cultures following perturbations to sensitive variables.

culture with the second-highest prospects for sustainable development) or to ***Diversified Democracy*** (the self-reinforcing societal culture with the highest prospects for sustainable development)? Are there any leverage points for getting from ***Post-Industrial Democracy*** (the self-reinforcing societal culture with the second-highest prospects for sustainable development) to ***Diversified Democracy*** (the self-reinforcing societal culture with the highest prospects for sustainable development)? To answer these questions, we turn to Figures 4.3 and 4.4.

Figure 4.3 shows that, in version 6 of the model, there is a single direct pathway from ***Post-Industrial Anocracy (Command)*** (the self-reinforcing societal culture with the fourth-highest prospects sustainable development) to ***Post-Industrial Democracy*** (the self-reinforcing societal culture with the second-highest prospects for sustainable development), as shown in Figure 4.5.

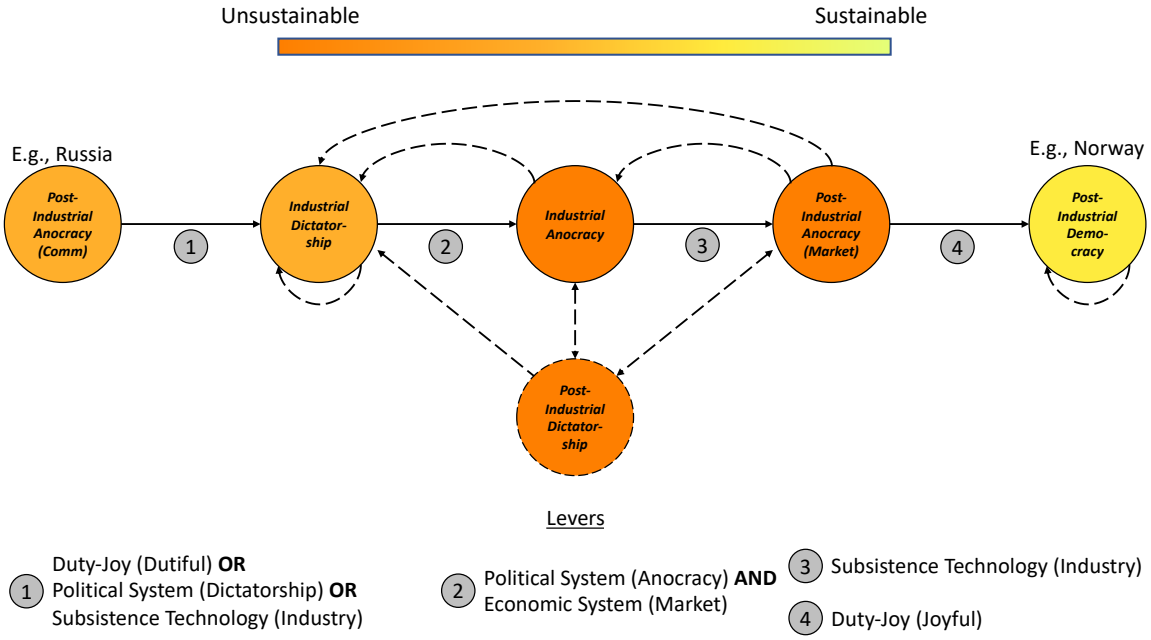

Figure 4.5: Pathway from ***Post-Industrial Anocracy (Command)*** to ***Post-Industrial Democracy***. Solid lines indicate the intended pathway. Dashed lines indicate other possible pathways. Levers are variable states that, if promoted, destabilize the self-reinforcing societal culture, causing it to evolve into another. For example, promoting the Dutiful worldview causes ***Post-Industrial Anocracy (Command)*** to evolve into ***Industrial Dictatorship***.

This pathway exists in version 6 of the model, but not in version 8, which suggests that in order to get from ***Post-Industrial Anocracy (Command)*** to ***Post-Industrial Democracy***, the impacts of institutions have to be relatively stronger than the impacts of worldviews and technologies. Otherwise, getting from the former to the latter self-reinforcing societal culture might require a relatively large perturbation to one or more of the less sensitive variables (e.g., a crisis, collapse, revolution).

The pathway from ***Post-Industrial Anocracy (Command)*** to ***Post-Industrial Democracy*** is interesting in that it involves transiting through the Industry type of subsistence technology. Historically, the shift from industrial to post-industrial subsistence technologies has tended to involve an increase in societal complexity and energy and resource consumption (Nolan and Lenski 2015). While it is not necessarily the case that a shift from post-industrial to industrial subsistence technologies would entail a decrease in societal complexity and energy and resource consumption, this is one possible implication.[69]

Another thing that is noteworthy about this pathway is that it involves substantially *worsening* a society's prospects for sustainable development in order to eventually improve them. For example, the SDG Compatibility Score along this pathway, which starts at -26, reaches a local minimum of -79 at ***Industrial Anocracy*** before eventually reaching a local maximum of +31 at ***Post-Industrial Democracy*** (see Table 4.5).

Figures 4.3 and 4.4 show that there are no pathways from ***Post-Industrial Anocracy (Command)*** (the self-reinforcing societal culture with the fourth-highest prospects for sustainable development) or ***Post-Industrial Democracy*** (the self-reinforcing societal culture with the second-highest prospects for sustainable development) to ***Diversified Democracy***

[69] This oscillation between post-industrial and industrial subsistence technologies appears to be due to the impacts of the Collectivist worldview and the Joyful worldview, which cancel each other out, causing the balance for all states of Subsistence Technology to be 0 (see the matrix of the model in chapter 3).

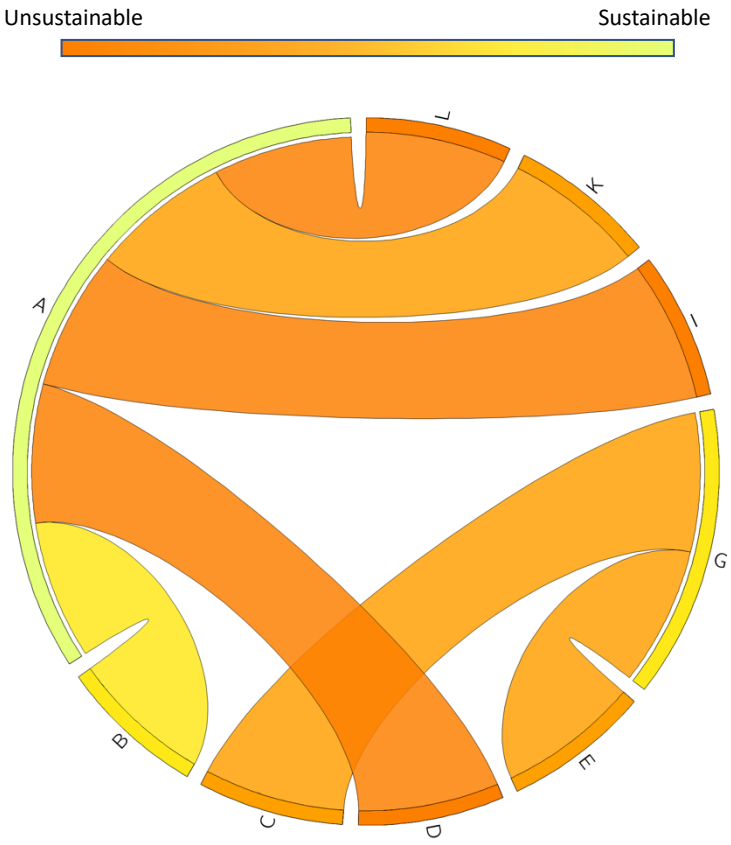

Figure 4.6: Versions 6 and 8, evolution of self-reinforcing societal cultures following a shift in the international system from competition to cooperation.

Legend:

A: Diversified Democracy
B: Post-Industrial Democracy
C: Agricultural Dictatorship
D: Post-Industrial Dictatorship
E: Industrial Dictatorship
G: Diversified Dictatorship
I: Industrial Anocracy
K: Post-Industrial Anocracy (Command)
L: Post-Industrial Anocracy (Market)
N: Industrial Democracy

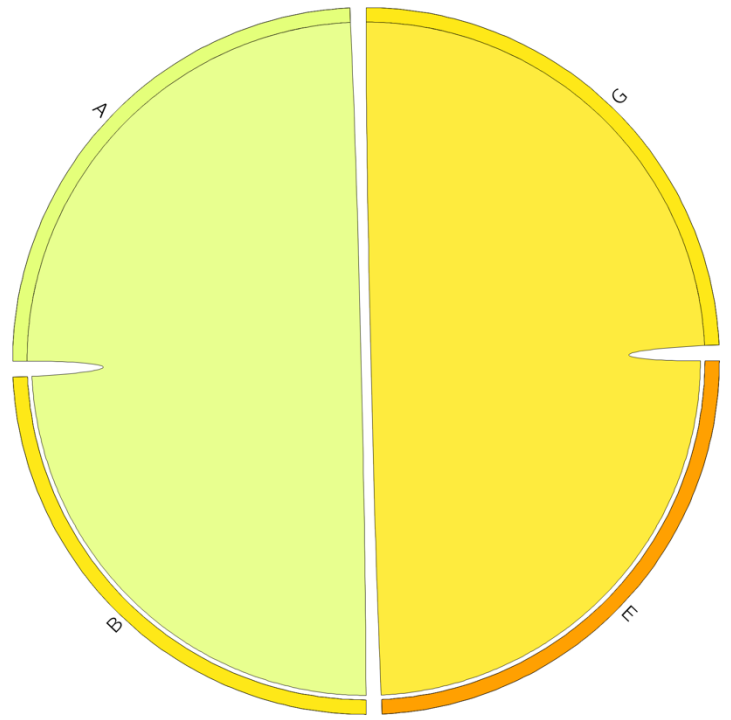

Figure 4.7: Versions 6 and 8, evolution of self-reinforcing societal cultures following a shift in the international system from cooperation to competition.

(the self-reinforcing societal culture with the highest prospects for sustainable development). To get to ***Diversified Democracy***, it is necessary for the International System variable to shift from the Competition state to the Cooperation state. The outcomes of such a shift are shown in Figure 4.6, while the outcomes of the reverse shift are shown in Figure 4.7. These figures reveal hysteresis in the model: while several self-reinforcing societal cultures evolve into ***Diversified Democracy*** or ***Diversified Dictatorship*** following a shift in the international system from competition to cooperation, ***Diversified Democracy*** and ***Diversified Dictatorship*** only evolve into ***Post-Industrial Democracy*** and ***Industrial Dictatorship***, respectively.

The evolution of ***Post-Industrial Anocracy (Command)*** into other self-reinforcing societal cultures, as well as the outcomes of shifts in the international system, have to be interpreted with caution, since we do not have observations against which to validate these results. In chapter 5, I discuss ways in which future work could build on the current model in order to increase confidence in hypothetical outcomes.

4.6 Interpretation

Out of the 1,728 combinations of worldviews, institutions, technologies, and environmental selective pressures that are described by my model, contemporary societies appeared to be evolving towards one or the other of only two very different self-reinforcing societal cultures: ***Post-Industrial Democracy*** and ***Post-Industrial Anocracy (Command)***. And so, rather than the end of history (Fukuyama 1992), in which all societies converge towards one type (i.e., ***Post-Industrial Democracy***), we seem to face a potential clash of civilizations (Huntington

1996), in which societies converge towards a small number of highly contrasting and potentially conflicting types (i.e., ***Post-Industrial Democracy*** and ***Post-Industrial Anocracy (Command)***).

Based on my assessment of 85 SDG targets, ***Post-Industrial Anocracy (Command)*** appears to have worse prospects for sustainable development than ***Post-Industrial Democracy***. The possibility of getting from the former to the latter self-reinforcing societal culture in an incremental way (i.e., via perturbations to sensitive variables) appears to depend on the relative strength of influence of institutions. If the influence of institutions is relatively stronger than the influence of worldviews and technologies (version 6 of the model), then an incremental pathway from ***Post-Industrial Anocracy (Command)*** to ***Post-Industrial Democracy*** may be possible. If, on the other hand, the influences of worldviews, institutions, and technologies are relatively equal (version 8 of the model), then getting from ***Industrial Anocracy (Command)*** to ***Post-Industrial Democracy*** may not be possible without a large perturbation (e.g., a crisis, collapse, revolution, etc.). This uncertainty has important implications for how we imagine and work towards change.

Suppose that the pathway from ***Industrial Anocracy (Command)*** to ***Post-Industrial Democracy*** exists. The most efficient pathway from ***Industrial Anocracy (Command)*** to ***Post-Industrial Democracy*** involves going through ***Industrial Dictatorship***, which has slightly worse prospects for sustainable development than ***Post-Industrial Anocracy (Command)***.

Suppose instead that the incremental pathway from ***Industrial Anocracy (Command)*** to ***Post-Industrial Democracy*** does not exist, in which case it might be possible for a country to get stuck at ***Industrial Dictatorship***. In this case, the best strategy for promoting sustainable development in societies like ***Post-Industrial Anocracy (Command)*** may involve *preventing* those societies from becoming like ***Industrial Dictatorship***, while at the same time promoting a shift in

the international system from competition to cooperation. Of course, we cannot be sure how a shift to a cooperative international system would affect how countries evolve, as there are no observations against which to validate this aspect of the model. If my model is correct, however, then societies like ***Post-Industrial Anocracy (Command)*** would evolve towards ***Diversified Democracy*** (the self-reinforcing societal culture with the highest prospects for sustainable development), while societies like ***Industrial Dictatorship*** would evolve towards *Diversified Dictatorship* (the self-reinforcing societal culture with the third-highest prospects for sustainable development).

For my part, the incremental pathway from ***Industrial Anocracy (Command)*** to ***Post-Industrial Democracy***, insofar as it requires going through ***Industrial Dictatorship***, is morally indefensible. The only moral justification that can be offered for *decreasing* political freedoms on the road to sustainability is "the ends justify the means," which I find inadequate, to say the least. Moreover, so long as it remains uncertain whether it is possible to move beyond ***Industrial Dictatorship*** (i.e., whether version 6 or 8 of the model best represents reality), I find the risk of trapping a country at ***Industrial Dictatorship*** unacceptable.

Rather than as a policy option, we might think of the incremental pathway from ***Industrial Anocracy (Command)*** to ***Post-Industrial Democracy*** as a back-up. If a society like ***Industrial Anocracy (Command)*** experiences a perturbation that causes it to become like ***Industrial Dictatorship***, then the incremental pathway to ***Post-Industrial Democracy*** may offer a way *out* of political and economic repression.

Overall, the better strategy – on moral grounds – for promoting the sustainable development of societies like ***Post-Industrial Anocracy (Command)*** or ***Industrial Dictatorship***

may be to promote a shift in the international system from competition to cooperation. This strategy, though, is not without its challenges. Countries with the characteristics of ***Post-Industrial Anocracy (Command)*** and ***Post-Industrial Democracy*** are, in most ways, *cultural opposites*. Research in social psychology has shown that sharp cultural differences among groups can lead to conflict and distrust (Solomon, Greenberg, and Pyszczynski 2015; Berreby 2005). Wendt (1992), drawing on social identity theory (Tajfel and Turner 1979) and realistic conflict theory (Sherif 1966), has suggested that the need to solve a common problem may foster self-interested cooperation among rival groups and that, over time, a pattern of self-interested cooperation may eventually develop into friendship. It remains to be seen whether the Sustainable Development Goals, which define a set of globally shared problems, will function as a platform for the emergence of a cooperative international system. So far, there are many reasons to remain skeptical: Russia's interference with the US elections; the trade conflict between China and the US; border disputes between India and China; etc. Alternatively, Crisp and Hewstone (2006) have suggested that, by appealing to cultural commonalities, rival groups may be able to construct a wider, more inclusive social identity. Societies like ***Post-Industrial Anocracy (Command)*** and ***Post-Industrial Democracy*** have two cultural characteristics in common: the joyful worldview, and the post-industry type of subsistence technology. Emphasizing those commonalities may help to foster a wider, more inclusive social identity among otherwise culturally quite different countries.

4.7: Summary

In this chapter, I presented the main results of my research and answered the research questions. By testing the validity of all fifteen versions of the model against a sample of eighteen countries, I identified versions 6 and 8 as the best versions of the model. These versions have three multipliers in common: Environment has a multiplier of 2, and worldviews and technologies have a multiplier of 1. The difference in the multiplier of institutions accounted for the few differences in the results of versions 6 and 8.

In answer to research question 1, I found between nine and ten self-reinforcing societal cultures (see Table 4.2). Seven to eight of these societal cultures described countries under a competitive international system, while the other described countries under a cooperative international system.

In answer to research question 2, I found that the self-reinforcing societal cultures that appeared to be most compatible with sustainable development were ***Diversified Democracy***, ***Post-Industrial Democracy***, ***Diversified Dictatorship***, and ***Post-Industrial Anocracy (Command)*** (see Table 4.5).

In answer to research question 3, I found that it appeared to be possible to transform an unsustainable, self-reinforcing societal culture, such as ***Post-Industrial Anocracy (Command)***, into a more sustainable, self-reinforcing societal culture, such as ***Post-Industrial Democracy*** (see Figure 4.5). However, the existence of an incremental pathway from the former to the latter societal culture appeared to depend on which of versions 6 and 8 of the model best represents reality. If the influence of institutions is relatively stronger than the influence of worldviews and

technologies (version 6 of the model), then an incremental pathway from ***Post-Industrial Anocracy (Command)*** to ***Post-Industrial Democracy*** might exist. However, this pathway would involve going through ***Industrial Dictatorship***, which would entail a reduction in political freedoms. If, on the other hand, the influences of worldviews, institutions, and technologies are relatively equal (version 8 of the model), then getting from ***Post-Industrial Anocracy (Command)*** to ***Post-Industrial Democracy*** might not be possible without a large perturbation (e.g., a crisis, collapse, revolution, etc.). In either case, I concluded that the incremental pathway from ***Post-Industrial Anocracy (Command)*** to ***Post-Industrial Democracy*** has moral implications that cannot be defended. An alternative pathway, which involves promoting a shift in the international system from competition to cooperation, appeared to be more defensible on moral grounds, but faced different difficulties related to sharp cultural differences and potentially conflicting social identities.

Chapter 5: Discussion and Conclusions

5.1: Discussion

5.1.1: Contributions to knowledge and overall significance of the research

My dissertation makes theoretical, applied, and methodological contributions to knowledge that are significant and original.

5.1.1.1: Theoretical contributions

My dissertation clarifies definitions in the WITs framework of societal cultures and populates its categories with exemplary variables drawn from a variety of social science literatures. My dissertation synthesizes these variables into a Cross-Impact Balances (CIB) model of sociocultural evolution. In so doing, my dissertation marks several firsts: the first use of CIB to model evolutionary processes, and the first computational model based on the WITs framework. As a proof of concept, my dissertation demonstrates how cultural evolutionists as well as other interdisciplinary researchers may use CIB to analyze and extend theory.

5.1.1.2: Applied contributions

My dissertation produces several exploratory results. It identifies self-reinforcing societal cultures, evaluates these cultures in terms of their compatibility with the Sustainable Development Goals, and identifies leverage points for societal transformations (towards or away from sustainability). In so doing, my dissertation marks an additional first: the first use of CIB to find leverage points for sustainability transformations. My use of CIB to study sustainability transformations directly addresses needs in sustainability modelling: representing qualitatively different system states and changes in values and norms (Köhler et al. 2018) and identifying leverage points (Abson et al. 2017).

5.1.1.3: Methodological contributions

In terms of methodological contributions, my dissertation develops procedures for using CIB to identify leverage points for sustainability transformations. These procedures will be valuable not only to sustainability modellers, but also to modellers of complex systems generally. The demonstrated procedures enable analysts to gain powerful new insights into systems for which some or all of the available knowledge is qualitative (Weimer-Jehle 2006). Thus, these procedures will benefit researchers as well as non-academic stakeholders, such as policymakers, who often have to make decisions in spite of limited quantitative data. Such decisions may now become more rigorous and systematic, enabling stakeholders to anticipate and develop contingency plans for not only alternative futures, but also alternative processes of change.

5.1.2: Directions for future work

My dissertation breaks new ground in the study of guided cultural evolution and sustainability transformations. I aim to revisit and extend this work in the future in a number of ways: participatory modelling, more extensive validation, testing probabilistic succession rules, automating procedures, and exploring additional hypotheses. Researchers considering building on the present work should review Appendix E for lessons learned.

5.1.2.1: Participatory modelling

Including other perspectives through participatory modelling (e.g., interviews, questionnaires, and workshops) will serve several purposes. Academic and non-academic stakeholders could suggest different specifications of the model: different variables, states, interactions, weights, etc. Additionally, stakeholders could help to assess the compatibility of variable states with the SDG targets. Stakeholders could also help to validate the model. Through stakeholder input, the relevance, credibility, and legitimacy of the model may be increased, thereby enhancing the scientific and policy impact of the research (van Voorn et al. 2016).

5.2.2.2: Extended validation

In this dissertation, I validated the model by testing whether the model could reproduce the recent evolutionary histories of a sample of contemporary societies. I focused on whether

the countries in the sample had become more like the internally consistent societal culture predicted by the model. While the model performed well, future work could test and refine the coding of countries and examine causal mechanisms (e.g., by checking whether changes in the model unfold in the same or similar sequence as changes in real societies). The validation tests at this detailed level of analysis will be highly sensitive to the choice of succession rule. Thus, a wide range of succession rules should be tested, including probabilistic succession rules.

5.2.2.3: Probabilistic succession

My analytical approach involved the use of deterministic succession rules. This means that each time a particular internally inconsistent scenario was updated, the resulting scenario was always the same (e.g., scenario X always becomes scenario Y). While the local succession rule produced reasonably good results, probabilistic succession rules may do even better. The reason for this is that, even if the dynamics of real systems obey an underlying logic, real systems are always being impacted by their environments, and these impacts introduce an element of randomness or chaos into the system's dynamics (B. Walker et al. 2004). Schweizer et al. (2013) developed software for conducting CIB analysis using probabilistic succession rules, and future work may take advantage of these rules.

5.2.2.4: Automating procedures

The CIB software, *ScenarioWizard*, could be improved by incorporating probabilistic succession rules. An additional improvement to *ScenarioWizard* would involve strengthening its capabilities for succession and sensitivity analysis. Currently, succession and sensitivity analyses require a lot of manual input from the researcher. This can result in hours of tedious labour, which could introduce human error. Enhancements to *ScenarioWizard* could include the option to identify a pair of internally consistent scenarios and ask the software to compute pathways between the two scenarios, conforming to a set of constraints. For example, one might want to identify all the pathways between a pair of scenarios that involve perturbing only the three most sensitive variables, individually, in pairs, and in triplets, and that use the local succession rule (the constraints that I used in my analysis). More advanced capabilities might include the option to introduce an element of randomness in the successions. For example, what might happen if, at a random point along a succession pathway, one of the less sensitive variables were suddenly perturbed? This type of analysis might help researchers and users prepare for unexpected events that could arise during a process of change. Since CIB is a judgment-based method, and decisions about strategy often have to be made amid a paucity of quantitative data, these more advanced capabilities for succession and sensitivity analyses could become powerful tools for decision-makers, bringing added discipline and rigour to time-sensitive decisions.

5.2.2.5: Additional hypotheses

Finally, future research should incorporate (e.g., through participatory modelling and/or desk research) variables for ecosystems and the biosphere, in order to represent the dynamics of social-ecological co-evolution. Additionally, neighbour effects should be considered (e.g., being in the presence of dictatorships vs. democracy), along with geographical variables (e.g., large vs. small territory).

5.2: Conclusions

My exploratory results suggest that societies have been converging towards a small number of highly contrasting types, and that this polarization may be expected to continue. The results also suggest that achieving sustainable development may require a transformation in the international system from competition to cooperation. Achieving such a transformation might require societies to foster an inclusive social identity, in order to overcome potential sources of conflict that can stem from sharp cultural differences. Future work will revisit and extend these preliminary findings.

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Appendix A: Versions of the Model

Since my judgments of how the variable states interact are hypotheses, the purpose of the multiple versions of the model is to cast a wider net.

Versions of the model. Each version applies a different set of multipliers to the variables in each category of the WITs framework.

Version	Environment	Worldviews	Institutions	Technologies	Social Ontology Archetype
1	1	1	1	1	
2	2	2	2	1	
3	2	2	1	2	
4	2	2	1	1	
5	2	1	2	2	Classical Marxism (Marx and Engels 1846
6	2	1	2	1	
7	2	1	1	2	Ecological-Evolutionary Theory (Lenski 2005)
8	2	1	1	1	World Systems Theory (Wallerstein 1974)
9	1	2	2	2	
10	1	2	2	1	Weber (1905)
11	1	2	1	2	
12	1	2	1	1	Idealist Evolutionism (Parsons 1966)
13	1	1	2	2	
14	1	1	2	1	
15	1	1	1	2	

The fifteen versions of the model incorporate the influence of archetypes of social ontologies. Some versions of the model correspond to a well-recognized literature (e.g., World Systems Theory), while others do not. The versions of the model without an associated social ontology may correspond to a literature not listed, or they may represent novel perspectives.

Version 1 is the base model; it represents my judgments of how the variable states interact. Versions 2 to 15 apply a multiplier of two to one or more of the categories in the WITs framework. By doubling the impacts of a category of variables, the influence of that category is emphasized. I limited the number of model versions to 15 for practical reasons (e.g., time constraints). In future research, other 'weighting profiles' (e.g., 3, 5, 2, 1) could be tested as part of a more expansive hypothesis testing.

Appendix B: Coding criteria for matching country characteristics to variable states

Coding criteria for the worldview variables

Data are from the World Values Survey (World Values Survey Association 2020), with coverage by year varying by country. Country scores were calculated using regression equations from the online appendix to Beugelsdijk and Welzel (2018).

Variable	State	Threshold	Maximum	Minimum
Collectivism-Individualism	Collectivist	≤ 70.61	158.60	-17.38
	Individualist	> 70.61		
Dutiful-Joyful	Dutiful	≤ 6.93	190.49	-176.61
	Joyful	> 6.93		
Distrusting-Trusting	Distrusting	≤ 47.28	135.11	-40.56
	Trusting	> 47.28		

The thresholds are the midpoints of the factor ranges. Each factor is based on a number of items. For example, one of the items for the Collectivism-Individualism factor is the attitude towards property ownership, where a score of 1 means a strong preference for state ownership

of property, and a score of 10 means a strong preference for private ownership of property. The threshold for Collectivism-Individualism corresponds to a middle score for all of the factor items.

Coding criteria for the Political System variable

Data are from Coppedge, Alvarez, and Maldonado (2008) and are available until 2000. For later years, I used the Freedom in the World ratings from Freedom House (2020).

Variable	State	Coppedge, Alvarez, and Maldonado (2008) principal component scores	Freedom in the World rating
Political System	Democracy	Contestation and Inclusiveness > 0	Free
	Anocracy	Either Contestation or Inclusiveness > 0, but not both	Partly Free
	Dictatorship	Contestation and Inclusiveness < 0	Unfree

Coding criteria for the Economic System variable (data from Pryor 2005; Heritage Foundation 2020)

Data are from Pryor (2005) and are available for 1990 only. For other years, I used the Heritage Foundation's Economic Freedom indicator (Heritage Foundation 2020). To map the variable states to the Economic Freedom scores, I correlated my country classifications in 1990

with the Economic Freedom scores in 1995, the closet year with data. I found the maximum for each category and used that as the cut-off. For example, of the eighteen countries in my sample, Pryor classified six of them (in 1990) as a type of economy that I have grouped into the "Command" type. The maximum Economic Freedom score for these six countries in 1995 was 52.

Variable	State	Pryor Cluster	Economic Freedom Score
Economic System	Command	Statist Marxist Traditional	$\leq$ 52
	Mixed	Nordic Western European Southern European Labour-oriented	> 52 and $\leq$ 63
	Market	Anglo-Saxon + Business-oriented	$\geq$ 63

Coding criteria for the Subsistence Technology variable

Data are from the World Bank (World Bank 2020), with coverage by year varying by country. Although services, industry, and agriculture are the main national accounts, values do not always sum to 100%. As such, I coded countries according to whether any one of the three sectors accounted for a larger share of %GDP than the other two combined. When no single sector was dominant, I coded the country as "diversified."

Variable	State	Rule
Subsistence Technology	Post-Industry	%GDP from services > (%GDP from industry + %GDP from agriculture)
	Industry	%GDP from industry > (%GDP from industry + %GDP from agriculture)
	Agriculture	%GDP from agriculture > (%GDP from services + %GDP from industry)
	Mixed	Other

Appendix C: Breakdown of SDG compatibility scores

This table is read as follows. Consider the column for SDG 1 (No Poverty). In my judgment, the Economic System variable is relevant to three of the targets for this SDG: targets 1.3, 1.4, and 1.5. I judged the Market state as incompatible (-1 point per target), the Mixed state as compatible (+1 point per target), and the Command state as neither compatible nor incompatible (0 points per target) with these targets. Since Diversified Democracy contains the Mixed state, it receives +3 points. Diversified Dictatorship receives 0 points, because it contains the Command state. Industrial Democracy receives -3 points, since it contains the Market state. And so on. "Eco" stands for Economic System; "Pol" stands for Political System; "Tec" stands for Subsistence Technology; and "Int" stands for "International System."

SDG:	1	2	3	4	5	6	6	7	8	8	9	10	10	11	11
Variable	Eco	Eco	Eco	Eco	Eco	Eco	Int	Eco	Tec	Eco	Int	Eco	Int	Pol	Eco
SDG targets:	1.3,1.4,1.5	2.1,2.2,2.3, 2.4,2.5	3.7,3.8,3.9	4.1,4.2,4.3	5.4	6.1,6.2,6.3, 6.4,6.6	6.5	7.1,7.3	8.2	8.3,8.4,8.5, 8.8,	9.1,9.2	10.1,10.2,10.3, 10.4	10.5,10.6,10.7	11.3	11.1,11.2,11.4, 11.5,11.6,11.7
Diversified Democracy	3	5	3	3	1	5	1	2	1	4	2	4	3	1	6
Diversified Dictatorship	0	0	0	0	0	0	1	0	1	0	2	0	3	-1	0
Post-Industrial Democracy	3	5	3	3	1	5	-1	2	1	4	-2	4	-3	1	6
Post-Industrial Anocracy (Command)	0	0	0	0	0	0	-1	0	1	0	-2	0	-3	0	0
Industrial Democracy	-3	-5	-3	-3	-1	-5	-1	-2	-1	-3	-2	-4	-3	1	-6
Industrial Anocracy	-3	-5	-3	-3	-1	-5	-1	-2	-1	-3	-2	-4	-3	0	-6
Post-Industrial Anocracy (Market)	-3	-5	-3	-3	-1	-5	-1	-2	1	-3	-2	-4	-3	0	-6
Post-Industrial Dictatorship	-3	-5	-3	-3	-1	-5	-1	-2	1	-3	-2	-4	-3	-1	-6
Agricultural Dictatorship	0	0	0	0	0	0	-1	0	-1	0	-2	0	-3	-1	0
Industrial Dictatorship	0	0	0	0	0	0	-1	0	-1	0	-2	0	-3	-1	0

SDG:	12	12	13	13	14	14	15	15	16	16	17
Variable	Int	Eco	Int	Eco	Eco	Int	Eco	Int	Pol	Int	Int
SDG targets:	12.1,12.2	12.2,12.3,12.4, 12.5,12.6	13.1	13.2	14.1,14.2,14.3, 14.4,14.5	14.3,14.5, 14.6,14.7	15.1,15.2,15.3, 15.4,15.5	15.6	16.3,16.6, 16.7,16.10	16.8	17.1,17.2,17.3,17.6,17.7,17.9,17.10, 17.11,17.12,17.13,17.15,17.16
Diversified Democracy	2	5	1	1	5	4	5	1	4	1	12
Diversified Dictatorship	2	0	1	0	0	4	0	1	-4	1	12
Post-Industrial Democracy	-2	5	-1	1	5	-4	5	-1	4	-1	-12
Post-Industrial Anocracy (Command)	-2	0	-1	0	0	-4	0	-1	0	-1	-12
Industrial Democracy	-2	-5	-1	-1	-5	-4	-5	-1	4	-1	-12
Industrial Anocracy	-2	-5	-1	-1	-5	-4	-5	-1	0	-1	-12
Post-Industrial Anocracy (Market)	-2	-5	-1	-1	-5	-4	-5	-1	0	-1	-12
Post-Industrial Dictatorship	-2	-5	-1	-1	-5	-4	-5	-1	-4	-1	-12
Agricultural Dictatorship	-2	0	-1	0	0	-4	0	-1	-4	-1	-12
Industrial Dictatorship	-2	0	-1	0	0	-4	0	-1	-4	-1	-12

Appendix D: Results of the validation tests for all fifteen versions of the model

K = Post-Industrial Anocracy (Command), B = Post-Industrial Democracy, C = Agricultural Dictatorship, and E = Industrial Dictatorship.

Country	Years	Initial Year	Final Year	Best Match in Final Year	Successor	Similarity to Successor (final year)	% Change in Similarity (final – initial year)
Argentina	22	1995	2017	K	K	83.3	+33.3
Brazil	21	1997	2018	K	K	83.3	0.0
Chile*	28	1990	2018	B	B	66.7	+33.3
China	28	1990	2018	K	K	66.7	0.0
Germany	21	1997	2018	B	B	83.3	+16.7
India	22	1990	2012	K	K	83.3	+33.3
Japan*	24	1995	2019	B	B	83.3	+33.3
Jordan	17	2001	2018	K	B	33.3	-16.7
Mexico	28	1990	2018	K	K	83.3	+16.7
Nigeria I	28	1990	2018	K	C	50	0.0
Nigeria II	28	1990	2018	K	E	50	0.0
Norway	11	1996	2007	B	B	100	0.0
Peru I	22	1996	2018	B	B	66.7	0.0
Peru II	22	1996	2018	K	K	66.7	0.0
Russia	27	1990	2017	K	K	83.3	0.0
South Africa*	23	1990	2013	B	B	83.3	+33.3
Spain*	21	1990	2011	B	B	83.3	+16.7
Switzerland	11	1996	2007	B	B	83.3	+16.7
United States*	22	1995	2017	B	B	83.3	+16.7
Uruguay*	15	1996	2011	B	B	83.3	+16.7

	Succession by Version of the Model (local succession rule)														
Country	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Argentina	B	B	B	K	B	B	B	B	B	B	B	K	B	B	B
Brazil	K	K	B	K	K	K	B	K	B	K	B	K	B	K	B
Chile*	B	B	B	K	B	B	B	B	B	B	B	K	B	B	B
China	K	K	B	K	K	K	B	K	B	K	B	K	B	K	B
Germany	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B
India	B	B	B	B	B	K	B	K	B	B	B	B	B	B	B
Japan*	B	B	B	K	B	B	B	B	B	B	B	K	B	B	B
Jordan	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B
Mexico	B	B	B	K	B	B	B	B	B	B	B	K	B	B	B
Nigeria I	E	E	E	E	E	E	E	E	C	C	C	C	E	E	E
Nigeria II	E	E	E	E	E	E	E	E	C	C	C	C	E	E	E
Norway	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B
Peru I	B	B	B	K	B	B	B	B	B	B	B	K	B	B	B
Peru II	B	B	B	K	B	B	B	B	B	B	B	K	B	B	B
Russia	K	K	B	K	K	K	B	K	B	K	B	K	B	K	B
South Africa*	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B
Spain*	B	B	B	K	B	B	B	B	B	B	B	K	B	B	B
Switzerland	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B
United States*	B	B	B	K	B	B	B	B	B	B	B	K	B	B	B
Uruguay*	B	B	B	K	B	B	B	B	B	B	B	K	B	B	B
Correct successor:	13	13	10	10	13	14	10	14	10	13	10	10	10	13	10

* These countries have been rapidly and consistently becoming more individualist, but their scores have yet to cross the theoretical midpoint of Collectivism-Individualism. In the final year of the test, I classify these countries as individualist. Re-classifying these countries in their final year does not affect the succession analysis, since I rigidly applied the coding rules to the initial conditions. For all other countries, linearly projecting their trends in Collectivism-Individualism does not alter their classification in the final year. Thus, I believe that the decision to re-classify these countries more faithfully represents the recent evolutionary trends in these countries.

Appendix E: Learning journey

This dissertation took several unexpected turns and encountered dead ends. In this appendix, I share some of my lessons learned, which I hope will be of benefit to other CIB analysts and researchers.

Initially, the aim of my dissertation was to investigate ecological identity as a potential leverage point for sustainability transformations (see the addendum to this appendix). The plan was to develop and validate an evolutionary model of societies based on the WITs framework, and then incorporate one or more variables for the ecological identity hypothesis. We never got past the first task.

We had planned to populate the categories of the WITs framework using Ecological-Evolutionary Theory (Nolan and Lenski 2015). Through a line-by-line analysis of the theory's flagship text, *Human Societies, 12th Edition*, I extracted every proposition that I could find. Although I amassed a substantial list, when it came time to model these propositions using CIB, I found thousands of perfectly internally consistent scenarios. The model had too many degrees of freedom! An interesting thing that I learned from this exercise was that CIB could be used to diagnose text-based theories. Although Ecological-Evolutionary Theory uses an extensive conceptual framework to describe societies, its theoretical framework (i.e., causal argumentation) is quite thin. While time-consuming, extracting causal arguments from text and modelling them using CIB proved to be an effective way of evaluating the sophistication of a text-based theory!

Faced with the need for new sources of variables and causal relationships, I turned to some of the leading theories in sociology and political science. Many of these theories were supported by time-series datasets. Gaps in the coverage meant that I was not able to model the dynamics of sociocultural evolution using quantitative methods, such as System Dynamics. However, the variables that I settled on would have allowed me to model sociocultural evolution using Boolean Networks or Fuzzy Cognitive Mapping, since all of the variables could be thought of as ordinal variables. For example, the states of Subsistence Technology could be thought of in terms of increasing energy and informational complexity (e.g., agriculture < industry < diversified < post-industry). The list of variables that I included in the model was provisional, and I expect that future work will include nominal variables. For this reason, and because I wanted to demonstrate the power of CIB to model sustainability transformations, I stuck with the CIB method.

A reaction to one of the earlier iterations of my model (there were several) briefly sent me off course. An advisory committee member described the cross-impact judgments as "heroic" and insisted that I parameterize the model with data. Looking back, I do not see my judgements as heroic; rather, I see them as hypotheses, which I was able to test through validation. In any case, I briefly tried to specify the cross-impact judgments using statistical methods. I started by fitting regression equations with cross-sectional data for 1990 – the only year in which the datasets of the various theories that I was using overlapped. I was, at the time, not aware of the problem of endogeneity bias, so I was regressing all of the variables on one another. I used the statistically significant, standardized correlation coefficients to specify the cross-impact balances. This, of course, was in error. When x affects y, and y affects x, the effect of x cannot be isolated

from the effect of y. To solve this problem, one has to use Structural Equation Modelling (SEM), which requires identifying additional variables that are not endogenous and that can 'step in' for the endogenous variables. Since SEM required adding another research activity, and I was short on time, I decided to pursue another avenue.

I turned to Qualitative Comparative Analysis (QCA), which is a Boolean logic-based method for identifying necessary and sufficient conditions for outcomes. After several weeks of experimenting with QCA, I concluded that it was not suitable for my needs, either. While it is little mentioned in the literature, QCA, when used to model a system, suffers from the same endogeneity problem as statistics. Additionally, I found that by using the outputs of QCA as the inputs to CIB, I ended up with what was essentially a Boolean network. This defeated one of the principal benefits of CIB, namely the ability to represent the degree to which a variable state is promoted or opposed. In my QCA-CIB model, a variable state could only be on or off, just as in a Boolean Network.

This brought me back to my original approach: judgment. By this point, I had come to the belief that my judgments should be thought of as hypotheses, and that it was perfectly valid to produce a model of hypotheses, especially if I was going to validate it against data. Moreover, the principal purpose of the dissertation as to prove the concept of using CIB to study sustainability transformations. To my knowledge, CIB had never been used to identify leverage points, and it had been little used to study system dynamics. Thus, I reframed the judgments in terms of hypotheses, defined the purpose of the model in terms of explanation, and described the results as exploratory, allowing me to emphasize the methodological contribution of the dissertation.

My advice for CIB analysts hoping to combine CIB with statistical approaches, QCA, or other methods is to be cautious and to think carefully about the requirements of the various methods. Purely statistical approaches to parameterizing an evolutionary model have an important limitation. If we build a model based on what we have observed, then we are not taking into account the potential impacts of emergent cultural variants, such as new worldviews, institutions, or technologies. Additionally, sustainability transformations are imagined processes, which may involve variables interacting in novel contexts that have not been observed. Methods such as CIB allow us to incorporate different types of data, such as inferences from observations and judgment-based hypotheses about the future. However, combining SEM with CIB seems to be a promising avenue for methodological development.

My thoughts on CIB and QCA are that rather than use QCA to generate inputs for CIB, one might use QCA to analyze the outputs of CIB, i.e., to identify sets of jointly sufficient conditions ("INUS" sets).[70] While it is certainly the case that the ability to include Boolean operators in CIB is beneficial (I did so in my model, combining the states of Subsistence Technology and International System), I think that there is little benefit to specifying a CIB model purely with the outputs of QCA. However, analyzing CIB outputs with QCA to identify INUS sets seems like a promising avenue for methodological development.

[70] In QCA, as in any method of empirical analysis, there is the problem of "limited diversity" of cases. Many combinations of conditions may not have been observed, and thus, the analyst has to make decisions about whether to treat the un-observed combinations of conditions as jointly sufficient for the outcome, or not. In many analyses, the number of un-observed combinations of conditions may greatly exceed the number of observed combinations of conditions, and thus, the analyst may be forced to make a large number of judgments (unless automated, somewhat arbitrary, and so-called "simplifying assumptions" are used). Doing so can be mentally taxing, since it requires judging not just individual conditions or small sets of conditions (e.g., 2-3), but large sets of conditions (e.g., 4-10). In CIB, one has to judge interactions between pairs of variable states (although additional states may also be considered, see Weimer-Jehle 2008), and the CIB algorithm finds internally consistent scenarios. These outputs of CIB, the internally consistent scenarios, might then be used to help identify sets of jointly sufficient conditions for outcomes.

Addendum on ecological identity

I plan to revisit this hypothesis in future work. Briefly, the hypothesis combines ideas from Terror Management Theory (Solomon, Greenberg, and Pyszczynski 2015; Becker 1973) and social identity theory (Crompton and Kasser 2009; Tajfel and Turner 1979). Humans sort themselves into social groups and tend to favour their own group (Tajfel and Turner 1979); in situations of inter-group conflict, humans may also derogate out-groups (Mummendey and Otten 1998). Humans also experience anxiety when faced with reminders of their mortality and adopt cultural worldviews in order to imbue life with a sense of order, permanance, and meaning (Solomon Greenberg, and Pyszczynski 2015; Becker 1973). Threats to one's cultural worldview trigger existential anxiety, which is typically dealt with by enacting one's cultural worldview (Solomon, Greenerg, and Pyszczynski 2015). Enacting one's cultural worldview bolsters self-esteem, which helps to cope with existential anxiety (Solomon, Greenerg, and Pyszczynski 2015). However, groups with rival cultural worldviews can spark conflict by enacting their worldviews, as each particular worldview may be interpreted as an implicit denial of the significance of others (thereby disrupting equanimity) (Solomon, Greenerg, and Pyszczynski 2015).

Contemporary cultural worldviews are often associated with nations and other social groups, and conflict among these groups (e.g., for markers of self-esteem, such as status, wealth, and power) can drive material growth and environmental impacts (Hirsch 1978; Choucri and North 1975). Meanwhile, the discourse of environmental limits implicitly threatens the cultural worldviews of many contemporary groups who envision progress as increasing material abundance and control over nature (Jackson and Senker 2011; Norgaard 1994). Insofar as nature

is perceived as an out-group, the limits discourse may activate psychological defence mechanisms tied to existential anxiety and reinforce domination over and exploitation of nature (Dickinson 2009).

Recent research has found that humility may function as an alternative to self-esteem for coping with existential anxiety (Kesebir 2014). Combined with the notion that humans favour their in-group, I saw in ecological identity the potential for a powerful leverage point for sustainability transformations.

First, identifying with nature may activate in-group loyalty, thereby increasing concern for non-human nature (Crompton and Kasser 2009). In turn, this may promote the emergence of new norms of respect for nature (Leopold 1949).

Second, identifying with nature may foster humility, since if one identifies with nature one is forced to recognize and accept one's small place in the greater web of life. However, identifying with nature may also help to satisfy the innate need to feel part of something ordered, permanent, and meaningful. New worldviews, which integrate a reverence for the universe with a scientific worldview, may support this type of connection (Kauffman 2008).

Third, identifying with nature may lower the salience of other social identities, such as nations, and thereby allow individuals and groups relatively greater freedom to disengage from and support transformation of the unsustainable worldviews, institutions, and technologies with which they are associated. These include not only unsustainable consumption and production, but also excessive forms of economic and geopolitical competition, which divert resources from the well-being of people and planet towards economic and military arms races (i.e., driving

structural deepening (Arthur 1993) and upping regrettably necessary defensive expenditures (Daly and Farley 2010)).

Fourth, identifying with nature may help to heal humanity psychologically and physically (i.e., from the alienating and polluting impacts of the scientific and industrial revolutions, respectively (Berman 1981)), as the health benefits of engagement with nature are increasingly well documented (Keniger et al. 2013).